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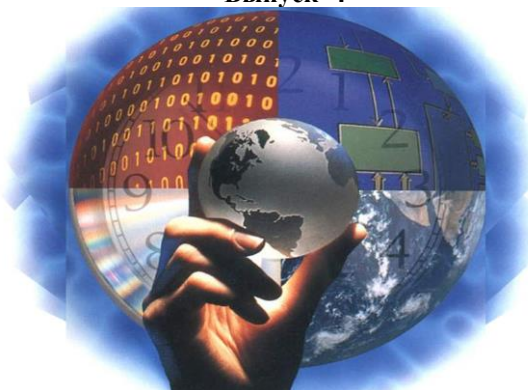
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**Recent Achievements and Prospects
of Innovations and Technologies
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В сборнике содержатся материалы докладов, рассматривающих теоретические и практические вопросы инновационных технологий, проблемы сохранения культурной памяти, истории, экологии, филологии, педагогики, психологии и др.

Материал предназначен для студентов, аспирантов и ученых в области технических, естественных, гуманитарно-экономических наук.

Тексты материалов конференций представлены в авторской редакции.

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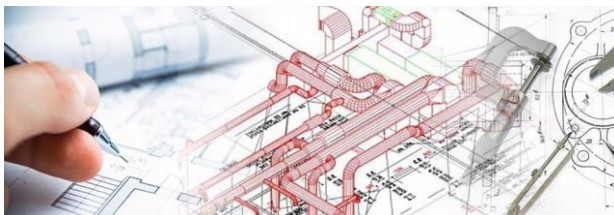
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SECTION 1. ENGINEERING INNOVATION PROCESSES



UDC 66.041

MATHEMATICAL MODELLING OF REACTION FURNACE COIL WEAR RESISTANCE

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Аннотация. В данной статье представлены результаты моделирования износостойкости печных труб в ходе пиролиза бензина. Алгоритм, реализованный на языке Python, основан на решении модифицированного линейного закона суммирования напряжений, учитывающего динамику отложений кокса, и запас по пределу длительной прочности в различных условиях работы. Кроме того, в работе используются графические интерпретации изменения давления в ходе пиролиза бензина, полученные при математическом моделировании соответствующего процесса, а также рассматриваются причины износа печных труб и методы оценки их поврежденности при эксплуатации.

Annotation. This article presents the results of modelling the wear resistance of furnace coils during gasoline pyrolysis. The algorithm, implemented using the Python language, is based on the solution of the modified linear cumulative stress rule, which takes into account the dynamics of coke deposits and the reserve on the long-term strength at different operating conditions. In addition, the paper uses graphical interpretations of pressure drops during gasoline pyrolysis, obtained by mathematical modelling

of the corresponding process, and also considers the causes of furnace tube deterioration and methods for assessing their damage during operation.

Keywords: pyrolysis, coke formation, wear resistance, temperature optimization, steel grades, mathematical modeling, operational efficiency

Pyrolysis is the main process for the production of lower olefins. For example, in 2022, the total capacity of Russian producers for ethylene was 4.77 million tonnes and for propylene 2.46 million tonnes [2]. However, pyrolysis is complicated by the fact that coke accumulates on the inner walls of the coils during the process. Coke formation is caused by petrochemical processes at thermodynamically unstable state of hydrocarbons. Coke penetrates into the coils and it leads to metal embrittlement, thermal conductivity reduction and heat stress increase, which results in burnouts. To prevent emergencies, the most damaged part of the coil is cut out and replaced with a new one.

Unfortunately, there is no publicly available information on the software existence capable of estimating safe operation coil life. This underlines the importance and relevance of research in the field of mathematical modelling of tube wear resistance, as the need for reliable methods of predicting their condition and durability remains an unsolved problem in industry.

The lifetime of furnace tubes depends on the damage accumulation during the operating cycle, and can change depending on the operating conditions. High temperatures and stresses have a significant role in this process. The temperature and stress condition are related to the non-uniform coke deposition along the inner diameter of the coil tubes. This process has clearly non-linear dynamics, and the intensity of coke deposition increases sharply at the end of the cycle, when a critical value is reached, requiring furnace shutdown for coke removal. The cycle duration (run life) varies from three months to one year depending on the operating conditions, type of heated product and other factors. Such conclusions are confirmed both experimentally and theoretically practically

In the study by Kuzeev I.R., Bayazitov M.I., Kulikov D.V., Chirkova A.G. [6] it is proposed to estimate the furnace tube metal damage at constant loads within one cycle on the basis of the linear cumulative stress rule expressed through the corresponding equation:

$$\Pi = \sum_{i=1}^k \left(\frac{t_i}{T_{pi}} \right) \leq 1, \quad (1)$$

where t_i – run life duration (cycle);

T_{pi} – time to pipe breakage at current loads and temperature;

k – number of operation cycles.

Moreover, the values of parameters t_i and T_{Pi} are specified in the relevant standards.

However, it can be noticed that this equation does not take into account the influence of temperature loads and dynamics of coke deposits, so equation (1) will take a modified form:

$$\Pi = \sum_{i=1}^k \left(\frac{t_i}{T_{Pi}} \right) * n_t * n_\sigma \leq 1, \quad (2)$$

where n_t – coefficient taking into account the influence of the type and dynamics of coke deposits;

n_σ – coefficient, taking into account the margin for the limit of long-term strength at the considered moment of tube operation.

This rule is the basis for the mathematical model developed in Python. The model itself is a web page (Figure 1), where the user enters his data and receives the result as a corresponding graph and table of values.

Figure 1. Calculation module interface

Using the unsteady mathematical model of gasoline pyrolysis described in [1], data on the pressure change at the inlet and outlet of the coil with time were obtained (Table 1).

Table 1. Pressure change in the coil over time

Number of completed cycle hours	Inlet pressure, MPa	Outlet pressure, MPa
24	0.4	0.1
48	0.402	0.099
72	0.406	0.099
96	0.41	0.099
120	0.413	0.099
144	0.416	0.098
168	0.419	0.098
192	0.422	0.098
216	0.424	0.097
240	0.426	0.097

480	0.454	0.095
720	0.53	0.093
960	0.75	0.09

Dependence of pressure change on the time of coil coking, shown in Figure 2. The process is carried out at a temperature of 835 °C.

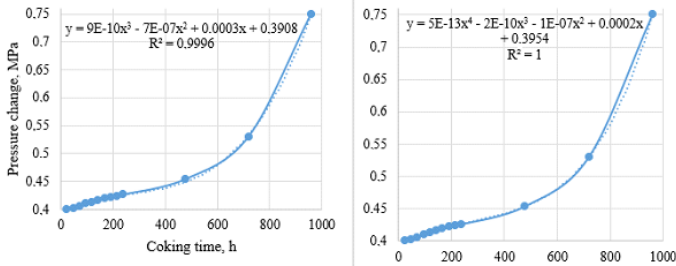


Figure 2. Coil fouling dynamics

The approximation of the values showed that the greatest convergence in terms of R^2 error is with a 4th order polynomial described by the following regression equation:

$$\Delta P = 5 * 10^{-13}t^4 - 2 * 10^{-10}t^3 - 1 * 10^{-7}t^2 + 0.0002t + 0.3954 \quad (3)$$

The maximum pressure difference at the end of the cycle was 0.66 MPa.

The outer diameter and wall thickness according to [5] are 159 mm and 10 mm, respectively.

Estimated operating time of pyrolysis furnace according to SSM 93 «Instruction on technical supervision, methods of revision and rejection of tube furnaces, tanks, vessels and apparatuses of oil refining and petrochemical industries» [3] is about 100 000 hours.

Meanwhile, 1 cycle of gasoline pyrolysis lasts 1,000 hours. When data are entered into the form, they are processed and output in the form of a graph (Figure 3) and a table.

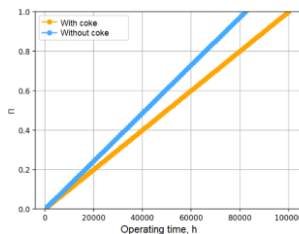


Figure 3. Determination of wear resistance of furnace tubes made of «XH32T» steel

It is also worth noting that it is assumed that during steam combustion of coke between working cycles, complete cleaning of tubes surface from accumulations is achieved. In Figure 3, the parameter « Π » describes the damage of the furnace tubes, where 1 represents the total damage of the coil, i.e. the time at which the tube should be replaced due to accumulated damage, among which there may be flexure of tubes, the presence of burnouts, blisters and dark spots on the surface of the tubes, as well as faulty doublers that have a product skip [4]. The graph shows that the operating time of the coil with coke accumulation included is less than without it. The damage with and without taking into account coke accumulation is equal to 0.9967 and 0.8200 respectively by the time of 82 000 h, i.e. the end of 82 cycle. The residual time to $\Pi = 1$ can be estimated by the equation [4]:

$$t_{res} = t_{cur} * (1 - \Pi_i)$$

where t_{cur} – time limit corresponding to the current operating time;

Π_i – coil damage corresponding to the current operating time.

Thus, the time to complete coil damage ($\Pi = 1$) taking into account coke accumulation will be 270 hours after 82 cycles.

Nevertheless, it is important to note that $\Pi = 1$ means that the cracks visible to the naked eye, and experimentally determined damage threshold values, which it is desirable not to exceed $\Pi = 0.6...0.7$. They correspond to the association of micropores into microcracks and a decrease in the strength characteristics of the material [6]. For steel grade «XH32T» the threshold operating time at which $P < 0.7$ is 57 cycles. For steels of other grades regulated by MD 26-02-80-2004 [5] (Figure 4), this time is different.

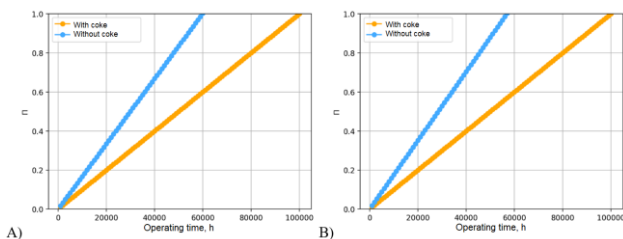


Figure 4. Determination of wear resistance of furnace tubes made of «10X23H18» (A) and «12X18H12T» steel (B)

The graphical comparison of «XH32T», «10X23H18» and «12X18H12T» steel grades is shown in Figure 5. For 10X23N18 steel the threshold operating time is 46 cycles and 44 cycles for «12X18H12T» steel. This is primarily due to the chemical composition of the steel. It is necessary

to take into account the grade of steel, because the composition of the alloy determines its properties and corrosion rate. In most of the steels used, the main defence against corrosion and oxidation is chromium, while nickel is needed to make the austenitic structure. At high temperatures carbon, being in atomic state, interacts with chromium, forming chromium carbide, while for protection against corrosion it must be in the crystal grid of iron, to avoid this, titanium is added to alloys, and thus carbon begins to produce compounds with titanium, first of all, titanium carbide. In case of a strong excess of carbon in the medium, carbon also reacts with chromium over time, then the steel ceases to be corrosion and scale resistant or becomes less scale resistant, as the degree of scale resistance depends on the chromium content in the composition.

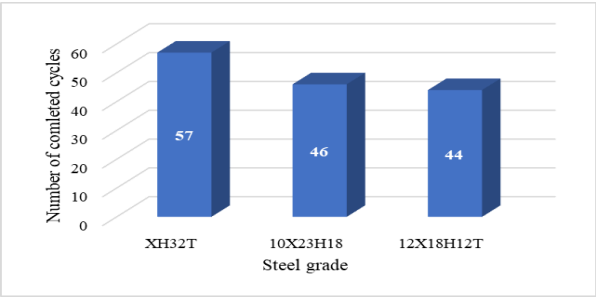


Figure 5. Comparison of steel grades by duration of safe operation

Therefore, for the model obtained with the given initial data, the optimal choice of material is «XH32T» steel. In order to optimise the process within the framework of the module for calculating the wear resistance of furnace tubes, it is possible to vary the process temperature, cycle duration or pipeline parameters, selecting the most suitable ones.

The process temperature was varied in steps of 25 °C. The results of temperature variation are presented in Table 2, where t – temperature; Π – damage; k – number of completed cycles.

Table 2. Change in coil operating time with varying process temperature

t	735 °C	760 °C	785 °C	810 °C	835 °C	860 °C	885 °C	910 °C	935 °C	960 °C
Π	0.596	0.693	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.695
	9	6	36	52	52	52	52	52	52	2
k	100	88	88	57	57	57	57	24	24	24

According to Table 2, it can be concluded that increase in the temperature above 885 °C is inappropriate due to a sharp reduction in the number of

interrepair runs more than 2.5 times from 57 completed cycles to 24 completed cycles, which indicates how the temperature increase affects the embrittlement of «XH32T» steel in the process of gasoline pyrolysis.

At the same time, reducing the temperature to less than 810 °C leads to an increase in the duration of safe operation of the coil 1.5 times and more from 57 completed inter-repair runs to 88, the duration of one inter-repair run is 1000 h. In the temperature range of 760...785 °C, the coil can be safely operated for 83 cycles, and reducing the temperature by another 25 °C to 735 °C, the damage of the coil was only 0.5969 during the whole estimated operation period of the pyrolysis furnace of about 100,000 h. By increasing the estimated time, it was found that the maximum permissible damage for the safe operation of the coil was 117 cycles, and the damage reached the value of 0.6983. At the same time, reducing the temperature by 100 °C from the operating temperature will significantly reduce the olefin yield, because the maximum yield of olefins is at higher temperatures.

After consideration of the above, it can be said that it is reasonable to maintain the reactor temperature in the range of 785...885 °C for normal process flow.

In conclusion, mathematical modelling of the pyrolysis process of hydrocarbon feedstocks is a complex task requiring the consideration of various interrelated parameters such as kinetic regularities and coke formation processes. The main difficulties consist in the large volume of calculations, the difficulty of analysing the results and establishing the presence of all components in the feedstock. Coke formation significantly affects the performance of the coils by increasing pressure drops and causing thermal stresses, which can lead to emergencies.

The developed model, implemented in Python, allows estimating the wear resistance of coil tubes taking into account the temperature influence and optimising the operation modes of the plant. The approximation of the data showed that maximum convergence (RI) is provided by a 4th order polynomial. The results showed that the use of «XH32T» steel in the temperature range of 785-885 °C is recommended for the best operation of the coil. This approach allows increasing the reliability and efficiency of the equipment during pyrolysis of gasoline fraction.

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OPTIMIZATION OF ENERGY CONSUMPTION IN SMART HOMES USING ARTIFICIAL INTELLIGENCE

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Аннотация. Описана концепция умных домов. Изложены основные подходы к снижению энергопотребления в жилых зданиях. Отмечено, что применение ИИ в управлении энергопотреблением открывает новые возможности для повышения эффективности. Представлены методы глубокого обучения с подкреплением и градиента политики. Проанализирована система оптимизации энергоснабжения. В заключение подчеркивается, что интеграция искусственного интеллекта в системы управления энергоснабжением умного дома позволяет добиться значительной экономии энергии.

Ключевые слова: искусственный интеллект, умный дом, гибкость, система HVAC, метод глубокого обучения с подкреплением, система оптимизации энергоснабжения.

Annotation. The concept of smart homes is described. The main approaches to reducing energy consumption in residential buildings are stated. It is noted that the application of AI in energy consumption management opens new possibilities for improving efficiency. The deep reinforcement learning and policy gradient methods are presented. The energy supply optimization system is analyzed. In conclusion it is emphasized the integration of artificial intelligence into smart home energy management systems enables significant energy savings.

Keywords: artificial intelligence, smart home, flexibility, HVAC system, method of deep reinforcement learning, energy supply optimization system.

In the context of global growth in energy consumption and the pursuit of sustainable development, the issue of energy efficiency is becoming particularly relevant. Modern buildings consume a significant portion of the world's energy, making them a key target for the implementation of energy-saving technologies [3, p. 623]. In this regard, the concept of smart homes is gaining increasing importance, offering the integration of modern technologies to optimize resource use and improve living comfort. This article examines the methodology for training artificial intelligence and aims to explain how it can enable the optimization of energy consumption in smart homes.

Smart homes are residential spaces equipped with automation systems that allow efficient management of various aspects of household operations, including lighting, heating, ventilation, and security. The integration of artificial intelligence (AI) into these systems opens new horizons for improving energy efficiency by enabling real-time adaptation of energy consumption based on residents' needs and external conditions [6, p. 31].

Currently, there are widely used solutions. Traditional approaches to reducing energy consumption in residential buildings include the use of energy-efficient materials, improved thermal insulation, and heat recovery systems.

However, these methods have limitations related to fixed parameters and insufficient flexibility in adapting to changing conditions.

With the development of smart home technologies, automation systems have become available, allowing for the monitoring and control of energy consumption. For example, smart thermostats can adjust room temperature based on occupants' presence and time of day, contributing to reduced energy costs [3, p. 625]. However, such systems often operate based on predefined scenarios and do not account for dynamic changes in user behavior and the external environment.

The application of AI in energy consumption management opens new possibilities for improving efficiency. AI can analyze large volumes of data, including information on weather conditions, residents' habits, and electricity tariffs, to optimize the operation of heating, ventilation, and air conditioning systems [6, p. 31]. For instance, the use of AI for managing HVAC systems can reduce energy consumption and carbon emissions by 8–19% [3, p. 627]. Moreover, AI can predict energy needs and adapt device operation in real time, ensuring more flexible and efficient resource management [2].

Examples of successful AI applications in smart homes include projects where machine learning-based systems analyze residents' behavior and automatically adjust the operation of household appliances to optimize energy consumption [6, p. 31]. Such approaches demonstrate the potential of AI in creating more sustainable and economical living spaces.

Based on the above, the integration of AI into smart home systems represents a promising direction for optimizing energy consumption, offering adaptive and intelligent solutions capable of accounting for multiple factors and ensuring efficient resource use.

To optimize energy consumption in a smart home, the proposed method is deep reinforcement learning (DRL).

Reinforcement learning mimics the learning process of living beings interacting with their environment through trial and error.

The method works as follows: an agent (algorithm) interacts with a dynamic environment, performing actions and receiving rewards or penalties for them. The agent's goal is to develop a behavior strategy (policy) that maximizes cumulative long-term reward [4, p. 134].

DRL enables the agent to learn an optimal energy consumption management strategy by interacting with the environment (smart home) and receiving rewards for achieving target metrics. In this case, the agent will learn to control various smart home devices (lighting, heating, air conditioning, household appliances) to minimize energy consumption while maintaining comfortable conditions for residents.

Policy gradient method. The chosen DRL algorithm is Proximal Policy Optimization (PPO), known for its stability and effectiveness in control tasks. PPO uses a stochastic policy that allows the agent to explore various action options and find optimal solutions. Thanks to various stochastic gradient ascent options over policy parameters, these methods were developed, with the goal of finding a policy parameterized by a neural network to maximize the expected cumulative reward. Like all other policy-based methods, this variant typically requires evaluating the utility function for the current policy, and an effective approach would involve using an actor-critic architecture that can work with off-policy data. The deep deterministic policy gradient algorithm is a representative of this type of method [7, p. 119].

The system architecture includes:

1. Agent: a neural network implementing the PPO algorithm. The agent receives input data about the environment's state (temperature, lighting, occupancy sensor readings, current energy consumption) and selects actions (turning devices on/off, adjusting their operating parameters).

2. Environment: a smart home model simulating the interaction of various devices and changes in environmental parameters based on the agent's actions. The model accounts for external factors such as weather and time of day.

3. Reward function: determines how well the agent performs the optimization task. The reward considers reduced energy consumption and maintaining comfortable conditions for residents (temperature, lighting). Penalties are imposed for exceeding permissible parameter limits.

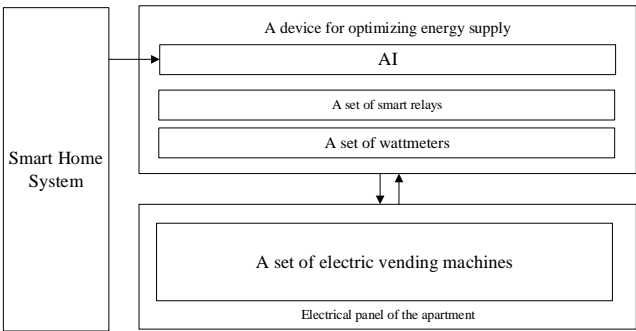
Deep reinforcement learning (DRL) represents a promising approach to optimizing energy consumption in smart homes, offering several significant advantages. DRL ensures system adaptability to dynamically changing environmental conditions, such as weather and residents' habits, enabling the identification of optimal energy management strategies in real time [1, p. 60]. Built-in automation allows the agent, after training, to independently manage smart home devices without human intervention. An important aspect is personalization: the system can account for residents' individual comfort preferences (temperature, lighting) and optimize energy consumption based on these parameters. DRL has the potential for significant energy savings by identifying patterns in consumption that are not obvious to humans and proposing more efficient management strategies. Additionally, the system considers multiple factors affecting energy consumption, including weather, time of day, and electricity tariffs, enabling their comprehensive optimization [5, p. 30].

DRL implementation comes with certain challenges despite these advantages. Developing and training a DRL agent requires computational resources as well highly qualified specialists in machine learning.

The effectiveness of DRL agent training directly depends on the quality and volume of training data, and insufficient or noisy data may reduce system performance. The “curse of dimensionality” arises, complicating agent training as the number of managed devices and environmental parameters increases. It can be difficult to interpret the agent’s decisions, complicate system analysis and debug. Safety is a critical concern. For instance, incorrect training or external interference may result to undesirable agent actions, causing equipment damage.

Finally, training a DRL agent directly in a real smart home is costly and risky, necessitating the use of simulations, which may not fully reflect real-world conditions and require careful validation of results.

The system of energy supply optimization is founded on interconnected components operating as a single mechanism (pic. 1.1). AI is the central element. It serves as the analytical hub and processes real-time energy consumption data from a network of wattmeters that is installed on each electrical line.



Picture 1.1 — Energy consumption optimization implementation scheme

The sensors accurately record the operating parameters of all consumers—from lighting fixtures to socket groups. The system uses a set of smart relays for direct load management — actuators. These modern switching devices turn circuits on or off based on AI commands. It enables dynamic load redistribution. For example, the system can temporarily cut power to them to reduce overall load upon detecting unused socket groups in certain rooms.

A key systems component is its integration with smart home elements that allows controlling energy-intensive household appliances—water heaters, air conditioners, heating systems. The AI can temporarily limit their power or shift their operation to off-peak periods without compromising resident comfort.

All system components are physically connected through the apartment's standard electrical panel, making the solution scalable and convenient for

upgrading existing electrical networks. Manual control by means of traditional circuit breakers remains possible.

In conclusion, compared to traditional methods, the integration of AI into smart home energy management systems enables significant energy savings. AI provides dynamic adaptation to changing conditions, including occupant behavior, weather factors, and fluctuations in electricity tariffs, unlike passive energy-saving technologies (e.g., airtight windows).

AI can regulate energy consumption according to user needs while automating routine processes, enhancing living comfort. AI-based control surpasses these approaches through machine learning and real-time data analysis.

The prospects for applying AI with deep reinforcement learning (DRL) are vast. This system can be integrated not only into smart homes but also used to create entire smart microdistricts, distributing grid load. Once the AI is trained for specific tasks, energy savings can be achieved even in large-scale industrial facilities. Another crucial application is using DRL to train anomaly detection in consumption patterns, identifying sudden equipment failures or cyberattacks. The AI will coordinate devices to prevent conflicting objectives. A promising direction is developing pre-trained models in simulations or on a single home, which can then be fine-tuned for specific residences with minimal additional data.

Thus, AI-driven energy management represents a significant step in the evolution of smart homes, combining technological innovation with practical benefits for users and the environment. The DRL approach to energy management in smart homes is only beginning to reveal its potential. As algorithms advance, new opportunities will emerge—from fully autonomous homes to "smart districts" with adaptive power grids.

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REVIEW OF THE FEATURES OF THE SPECTRAL DENSITIES OF COLORED TYPES NOISE

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Аннотация. В статье представлены результаты обзора особенностей спектральных плотностей основных цветных шумов. Рассмотрены белый, розовый, красный, синий и фиолетовый шумы и построены их спектрограммы. Проведен сравнительный обзор рассматриваемых цветовых шумов. Выделены их основные характеристики, распределение мощности по спектральному составу и их основные области применения. Рассмотрены примеры использования каждого типа шума в технических задачах, а также их значение в моделировании реальных сигналов и тестировании оборудования.

Ключевые слова: шум, цветные типы шумов, спектральная плотность, спектральная плотность мощности, спектрограмма.

Annotation. The article presents the results of a review of the features of the spectral densities of the main types of colored noise. White, pink, red, blue, and violet noises are considered, and their spectrograms are constructed. A comparative analysis of the reviewed types of colored noise is conducted. Their main characteristics, power distribution across the spectral composition, and key areas of application are highlighted. Examples of the use of each type

of noise in technical tasks, as well as their importance in modeling real signals and testing equipment, are examined.

Keywords: Noise, colored types of noise, spectral density, power spectral density, spectrogram.

Introduction

Currently, colored noise is widely present in communication systems and affects their performance quality. Colored noises, such as white, pink, and brown, have unique spectral characteristics, making them important subjects of study to improve the reliability of signal transmission. The development of methods for processing and suppressing colored noise is a pressing task, especially in the context of increasing data transmission volumes and the need to ensure stable communication channels.

Main part

Electrical noise refers to random fluctuations of current and voltage in electrical devices. The color of noise is determined by how its energy is distributed across frequencies [1]. The names of colored noises draw an analogy to the light spectrum. White noise has energy evenly distributed across all frequencies, similar to the spectrum of white light, meaning its power remains constant at all frequencies. Pink noise has a power spectral density that decreases with increasing frequency, being inversely proportional to frequency, which makes it more intense at lower frequencies. Red (or Brownian) noise has a power spectral density that declines even faster than pink noise, with power proportional to the square of the inverse frequency. Blue noise has a power spectral density that increases with frequency, meaning higher power at higher frequencies. Violet noise exhibits a power spectral density that grows proportional to the square of the frequency, making it most intense at the highest frequencies.

White noise is a random signal with a uniform power spectral density. Since its energy is evenly distributed across the entire frequency range, no specific region is emphasized. Figure 1 shows the spectrogram of white noise.

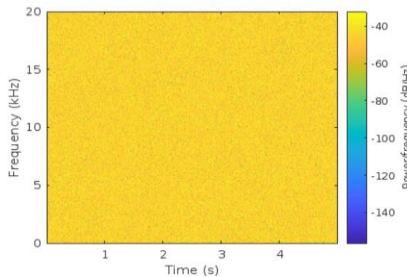


Figure 1 — Spectrogram of white noise

Thanks to its uniform distribution, white noise is used as a reference signal to evaluate system responses to various inputs. White noise has found wide application. It is employed for testing equipment, such as amplifiers or filters, to determine their parameters and noise resistance. It serves as the basis for random number generation algorithms needed in statistics and cryptography. Additionally, it is used to mask other noises, for instance, in devices designed to improve sleep.

Pink noise is a random signal whose power spectral density is inversely proportional to frequency.

$$S(f) = \frac{K}{f}$$

где $K > 0$ — proportionality coefficient determining the scale of spectral density.

$S(f)$ — power spectral density

Pink noise has its energy evenly distributed across a logarithmic frequency scale. This means that each frequency range, where the upper limit is twice the lower limit, contains the same amount of energy. Figure 2 illustrates the spectrogram of pink noise.

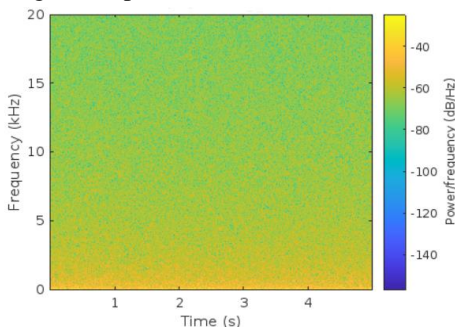


Figure 2 — Spectrogram of pink noise

Pink noise can be generated by filtering white noise and reducing the signal amplitude as the frequency increases. It is used to test amplifiers and filters. Its power density is evenly distributed across octaves, allowing effective evaluation of devices over the entire frequency range. Unlike white noise, which has equal power across all frequencies, pink noise reduces power by 3 dB per octave. This makes it more natural for human perception and closer to real signals, which is crucial for calibrating equipment, taking into account the characteristics of actual audio and radio signals.

Red or brown noise is a type of noise in which the signal power decreases by 6 dB per octave. It is also called Brownian noise, drawing an analogy with Brownian motion. Figure 3 shows the spectrogram of red noise.

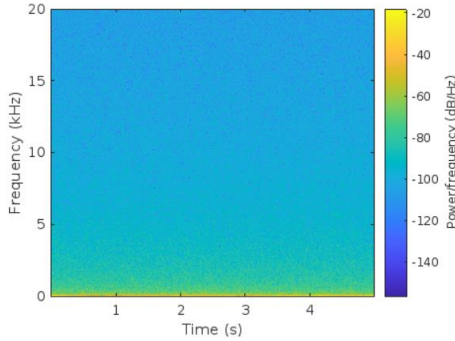


Figure 3 — Spectrogram of red noise

The spectral density of red noise is inversely proportional to the square of the frequency.

$$S(f) = \frac{K}{f^2}$$

That is, it has higher power at low frequencies and lower power at high frequencies compared to white or pink noise.

Red noise (or Brownian noise) is often used in radio electronics and related fields due to its characteristics, which make it valuable for modeling and filtering [2]. Red noise is utilized to simulate low-frequency signals during the calibration and testing of audio equipment, such as amplifiers, speakers, and equalizers. It helps evaluate how devices respond to low frequencies while attenuating high-frequency noise. In radio electronics, where suppressing high-frequency interference and ensuring stable performance at low frequencies are critical, red noise can serve as a reference for filtering and eliminating unwanted high-frequency noise. In some cases, red noise is applied to model biological processes, such as movements in biological systems (e.g., blood flow or air currents), which often predominantly contain low-frequency components. In radio electronic devices operating in the low-frequency range, red noise assists in analyzing the characteristics of filters and amplifiers at low frequencies, where precise calibration is essential.

Blue noise is a type of noise where energy increases with frequency. Blue noise is analogous to pink noise but operates in the opposite manner. The power spectral density of blue noise is proportional to frequency. With each

octave, the power increases by 3 dB. Figure 4 shows the spectrogram of blue noise.

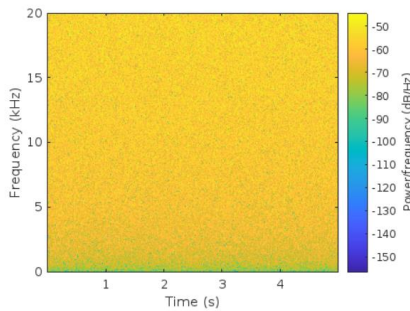


Figure 4 — Spectrogram of blue noise.

Blue noise can be obtained by passing white noise through a first-order high-pass filter, which suppresses low frequencies, or by taking the derivative of white noise, where the spectra are mirrored. Blue noise is used as a source of high-frequency load to test the stability and quality of high-frequency circuits. It is applied for testing the noise immunity of radio receivers. Since blue noise is poorly perceived by the human ear, it is often used for testing microphones without operator perception. Another application of blue noise is dithering. This audio process adds a small amount of productive noise to an audio signal whose bit depth has been reduced to limit quantization distortions.

Violet noise is a type of noise where the power spectral density is proportional to the square of the frequency. Violet noise has almost no energy at low frequencies; all its energy is concentrated in the high-frequency range. With each octave, its power increases by 6 dB. Violet noise does not occur naturally. It can be obtained by passing white noise through a second-order differentiating filter or by taking the derivative of blue noise. Figure 5 shows the spectrogram of violet noise.

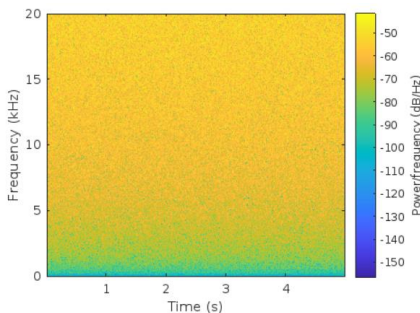


Figure 5 — Spectrogram of violet noise

In electronics, violet noise is useful for testing a circuit's response to rapid signal changes—for example, in high-frequency amplifiers and digital inputs. It effectively identifies overload and poor stability. It is not directly used in radio transmission or communication, as it is too noisy and unnatural. However, as a testing tool, it is highly effective.

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SECURITY SYSTEM BASED ON THE Z-WAVE NETWORK

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Аннотация. Разработана структурная схема системы сенсорной сети умного дома для безопасности участка на основе радио-модуля и мобильного модуля. Преимуществом такой системы безопасности на основе умного дома, является то, что при обнаружении каких-либо нарушителей система сразу информирует клиента с помощью мобильной связи по смс. В основу этой системы входит два датчика, которые производят мониторинг территории, а также радио-модуль куда будут поступать информация с датчиков.

Ключевые слова: сеть, радиомодуль, умный дом, безопасность, датчик.

Annotation. A block diagram of a smart home sensor network system for site security based on a radio module and a mobile module has been developed. The advantage of such a smart home-based security system is that

if any intruders are detected, the system immediately informs the client using mobile communications via SMS.

The basis of this system includes two sensors that monitor the territory, as well as a radio module where information from the sensors will be received, based on which it will already give commands to the mobile module.

Keywords: network, radio module, smart home, security, sensor.

In the modern world, people at home even use a huge number of different electronic devices at home, ranging from a kettle to a plasma TV, and managing these devices would become much easier if they were combined into one single home system, which would be controlled from a central device. Companies such as Yandex, Google, and Xiaomi have solved this problem by installing the so-called smart home system. In such systems, digital sensors are installed on home electronic devices that control and monitor the status of these devices, as well as transmit this information to the central unit or to each other. Z-Wave is a widespread radio data transmission protocol designed for home automation. A characteristic feature of Z-Wave is standardization from the physical layer to the application layer. That is, the protocol covers all levels of the OSI classification, which makes it possible to ensure compatibility of devices from different manufacturers when creating heterogeneous networks. The Z-Wave protocol was developed for apartments and small houses. Typically, such systems contain from 5 to 100 devices. The main feature of Z-Wave is that it belongs to the do-it-yourself format, i.e. the homeowner can install and configure the system himself. Data transmission is carried out at a frequency of 869.0 MHz. FSK modulation (frequency manipulation). Transfer rate: 42 kbit/s, 100 kbit/s and 9.6 kbit/s (for compatibility with older devices). The borehole is not more than 1%. The maximum transmission capacity is 1 MW. Our security system will include: Z-Uno ZM5101 radio module, SIM900D GSM module, Zipato VS-ZP3102 motion sensor, Zipato VS-ZD2012 door/window opening sensor. The block diagram of a security system based on its own sensor network is shown in Fig. 1.1.

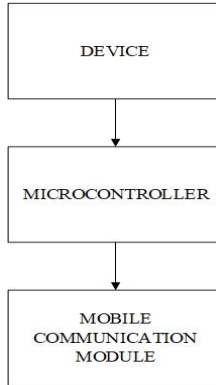


Fig. 1.1 is a block diagram of a security system based on its own sensor network

The motion and temperature sensor monitors the area. There are several devices for this purpose. We will select the Zipato VS-ZP3102+ sensor as the most suitable for our technical specification.



Figure 1.2 — *Zipato VS-ZP3102+*

In case of motion detection, the sensor will send the "On" status to all connected network nodes, with 1 indicator blinking. If there is no movement within three minutes from the moment the "On" status is sent, the sensor will send the "Off" status to all connected nodes [4]. There is no indication during normal operation. VS-ZP3102+ is equipped with an autopsy sensor. If the back cover is removed, the sensor will send an alert signal to the Z-Wave™ controller and the display will be continuous. The sensor will be activated until the lid is closed. The sensor is equipped with one Panasonic CR123A battery. Technical characteristics of the VS-ZP3102+ sensor: — protocol: Z-Wave™ (ZM3102N); — frequency range: 869 MHz; — Range of action: up to 30 m line of sight; — Operating temperature: -15°C - 40°C (5°F - 104°F); — Battery:

Panasonic CR123A * 1 pc. A door and window opening sensor is also needed. We proceeded from the fact that installing motion sensors throughout the protected area was, firstly, expensive and, secondly— impractical. We will use the Zipato VS-ZD2012 wireless magnetic contact door/window opening sensor. The sensor is controlled via the Z-Wave™ protocol (wireless two-way network data exchange protocol) and is fully compatible with any Z-Wave network.



Figure 1.3 — *Zipato VS-ZD2012.*

Devices connected to the power grid are Z-Wave repeaters and are designed to repeat the Z-Wave signal. They are used to overcome obstacles with a radio signal and eliminate dead zones. The device is designed to transmit information about entry into the room, the condition of doors and windows (open/closed) via the Z-Wave channel. Opening the door/window and separating the magnet from the sensor will send the "On" status to all connected network nodes, with 1 indicator blinking [2]. Closing the door/window and connecting to the magnet will send the "Off" status to all connected network nodes, with 1 indicator blinking. There is no indication during normal operation. VS-ZD2012 is equipped with an autopsy sensor. If the back cover is removed, the sensor will send an alert signal to the Z-Wave™ controller and the display will be continuous. The sensor will remain active until the lid is closed. The sensor is equipped with a Camelion CR123A battery. The characteristics of which will be given below.

Zipato VS-ZD2012 Specifications:

- Z-Wave™ protocol;
- frequency range 869 MHz (vs-zd2102.ru);
- operating temperature -15°C - 60°C (5°F -140°F);
- CR123a battery pack – 1 pc.

The radio module receives signals from sensors, and also performs further manipulations with it. For these purposes, let's choose the —Z-Uno module. The Z-Uno ZMEXZUNOM module is a Z—Wave module that works with the Z-Wave protocol, which allows you to approach home automation creatively. It is an ideal solution for monitoring devices such as smart appliances, heating sensor, security sensor, AV control, building automation, smart sockets, lighting. Wireless communication and network management

are supported by the internal firmware of the Z-Uno module. It works with gateways and directly with other Z-Wave devices.

Protocols:

— *ITU G.9959*;

— *Z-Wave Plus*

Technical specifications:

— Built-in *Z-Wave RF* antenna;

— совместима с протоколом *ITU G.9959*;

— *26 GPIO 4 ADC 12 bits*;

— *4 PWM*;

— *2 UART*;

— *1 USB*;

— *1 SPI (master or slave)*;

— *4 IR controllers, 1 IR learn capability*;

— *8X6 Keypad scanner*;

— *1 GPT*;

— *3 Interrupts*;

— *1 I2C (software on GPIO)*;

— *1 1-Wire (software on GPIO)*;

— *256 kB EEPROM*;

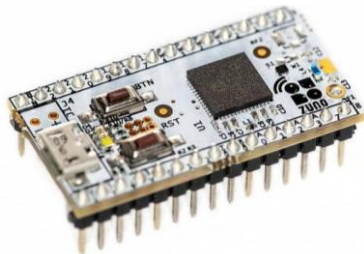


Fig. 1.4 — Appearance of the radio module

The mobile communication module is controlled directly by the primary controller, which is programmed for its further use. In turn, the primary controller to which the mobile communication module is connected receives the signal and controls the mobile module, as well as When an unauthorized

entry into the territory is detected, the motion sensor sends an analog signal, which is subsequently converted to digital and transmitted by secondary controllers to the primary one. The primary controller, in turn, is programmed so that when a penetration is detected, it sends a command to the mobile communication module [1, 3]. The mobile communication module sends a mobile message to the user's phone. The SIM900D mobile communication module is suitable for our technical task. Designed for the global market, the SIM900D is a four-band GSM/GPRS module operating at GSM 850 MHz, EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz. The SIM900D has a multi-channel GPRS Class 10 and Class 8 (optional), and also supports GPRS CS-1, CS encoding schemes.-2, CS-3 and CS-4. With a 33x33x3 mm configuration, the SIM900D can meet almost all user size requirements such as M2M, smartphone, PDA, FWP and other mobile devices. The SIM900D has 48 SMT contact pads and provides all hardware interfaces between the module and customer boards.

- Serial port and debugging port can help the user to easily develop custom applications;

- an audio channel that includes two microphone inputs and two receiver outputs;

- programmable general purpose inputs and outputs;

- the SPI display interface will provide users with the flexibility to develop custom applications.

The SIM900D is designed using energy-saving technology, so the current consumption is only 1.0mA in sleep mode. The SIM900D integrates TCP/IP protocol and extended TCP/IP AT commands, which are very useful for data transmission.



Fig. 1.5 — GSM module appearance

The use of a radio module in conjunction with a mobile communication module and two "smart" sensors is considered. Namely, motion sensors and window openings. For the network we have chosen, sensors and a radio module have been selected that can work together inside this network.

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UDC 62/61

THEORETICAL MODEL OF IMPROVEMENT OF HAND PROSTHESIS TECHNOLOGY

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Аннотация: Человечество всегда стремилось постигать новое и совершенствовать старое. Путем изучения многих процессов созданных нашей природой, и постоянно прогрессировавших на протяжении исторических эпох, ученые смогли создать сложный механизм – протез, явившийся симбиозом точных, гуманитарных и естественных наук, а также психологии. Именно благодаря протезам люди, страдавшие от дисфункций или вовсе утраты конечностей, могли снова чувствовать себя уверенно, как с точки зрения выполняемых ими функций, так и с точки зрения психологического комфорта.

Ключевые слова: теоретическая модель, протез, протезирование, технологии протезирования, протез конечности.

Annotation. Mankind has always tried to understand the new and improve the old. Through the study of many processes created by our nature, and constantly progressing throughout historical epochs, scientists have been able to create a complex mechanism a prosthesis, which is a symbiosis of exact, humanities and natural sciences, as well as psychology. It was thanks to

prosthesis that people who suffered from dysfunction or loss of limbs could feel confident again, both in terms of the functions they performed and in terms of psychological comfort.

Keywords: theoretical model, prosthesis, prosthetic care, prosthetic technologies, limb prosthesis.

The step-by-step development of mankind, the benefits of scientific research constantly gifted people with new problems. The more intelligent people became, the more frequent were small skirmishes, local conflicts and world wars, with the consequent bloodshed, dysfunction, serious injuries, up to the irrecoverable loss of limbs and deaths of the people. Moreover, about 50 million people a year “move” from the category of healthy to disabled [5] as a result of road and industrial injuries, natural and man-made disasters, diseases such as vascular obliterative lesions, atherosclerosis and diabetes mellitus [1]. It is also worth taking into account situations when a child is born with pathologies: lack of limbs, hearing, vision, curvature or incorrectly formed and functioning organs or skeleton [1]. The total proportion of such people is approximately 12% - 15% of the world population [4, 7]. Of these, an average of 300,000 people lose their lower limbs [3] and 390,000 people lose their upper limbs [6]. Due to congenital or acquired impairments of body functions or structures that impede a person's physical activity and professional activity, a certain psychological barrier is created between healthy individuals and people with disabilities [1]. Rehabilitation of people with disabilities in terms of physical, psychological health, social comfort occurs by replacing lost or irreversibly damaged body parts with artificial analogues - prostheses.

Extremely unstable relations in the world, the desire of some states to dominate in politics and general selfish unwillingness of people to find non-conflict solutions to problems give birth to wars in modern society, as a consequence of wars people are seriously injured, wounded and maimed, which raises the issue of prosthetics as very relevant issue at present. This paper discusses the creation of prosthetic limbs, current aspects of bioengineering.

Over a long period of human history, there have been many stages of development in one field or another. Intensive intellectual and physical achievements have influenced the formation of new, previously unseen views and ideas in terms of scientific and psychological cognition of the surrounding reality. The symbiosis of many studies in such fields as: mathematics, physics, mechanics, chemistry, electrical engineering, computer science, cybernetics, economics, biology and psychology has led to the creation of prosthetic technologies, thanks to which people with physical disabilities can to a certain extent regain lost opportunities.

Over the course of step-by-step improvement, prostheses fulfil certain functions: the function of support (of the patient on the prosthesis), the function of attachment (of the prosthesis to the patient's body), stability during standing (static stability) and during movement (dynamic stability), adequate dynamism (mobility of its constituent parts relative to each other), structural (mechanical) strength, reliability and durability, aesthetics (making up for cosmetic effect due to amputation and psychological rehabilitation) [1]. To date, there are different types of prostheses that have their own characteristics.

Depending on the task, particular prosthetic methods and approaches are used. Each person requires different dimensions, sometimes materials, as well as types of limb prosthesis, because all people have individual characteristics of body. Moreover, designing, manufacturing, implementation and rehabilitation are extremely time-consuming, complex and financially costly processes, and not everyone is able to afford a new and most perfect prosthesis.

But despite the high development of science and technology in our time, the prostheses themselves still have a number of problems and disadvantages, such as low battery capacity, inaccurate operation of sensors and gyroscopes, large weight and dimensions of prostheses, small range of capabilities and functions of the artificial limb, poor moisture protection, insufficient strength of the materials used, long and labour-intensive production of parts, unnatural outer shell, and most importantly expensive development and manufacture, i.e. high cost of the artificial limb [1].

Apart from technical and economic problems, which are currently being worked on to find the “golden mean”, the efforts of psychologists and rehabilitators helping people who have survived serious injuries to return to their usual life are very important. Besides the ‘Uncanny Valley’ phenomenon is also a cause for concern [8], which implies that a person can calmly treat artificial intelligence that does not aspire to be similar to humans, such as mechanised puppies, but if this robot resembles or copies human appearance, behaviour, facial expressions and gestures, the human brain becomes afraid of it [1; 9].

Using the information, we have received about bionic and neural prostheses, let us try to create our own theoretical model of the prosthesis that will be able to solve all the problems that have arisen. All parts, technologies, as well as machines that are assumed to be used to create the model of artificial limb are manufactured and sold in the Russian Federation.

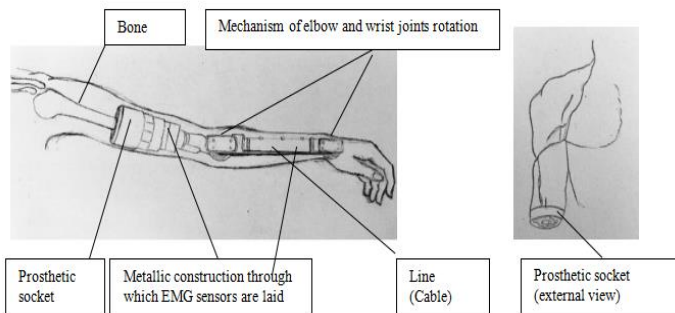
The prosthesis consists of an electromechanically driven hand, prosthetic socket, support structure, hand rotation mechanism, EMG sensors, battery, charger, electrical cables and cosmetic shell (sheath).

1.1 The prosthetic arm functions by bending at the wrist or elbow joints. There are special gears in the elbow and wrist rotation mechanism, which

tension the embedded cables (special threads), which in turn lead to flexion of the elbow and wrist joints, as well as the fingers on the artificial limb.

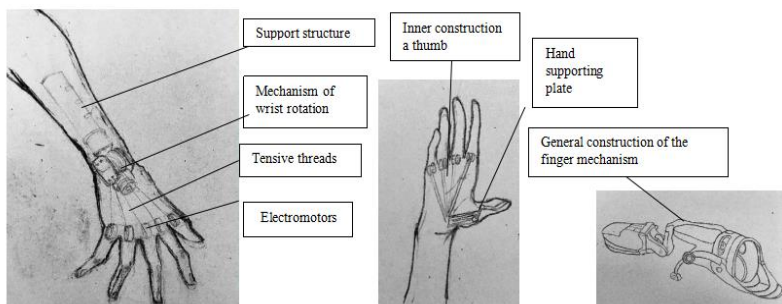
1.2 The prosthesis is held on the arm by a prosthetic socket (an interface between a residual limb (stump) and a prosthetic device), which connects the prosthesis and the arm. The socket fits snugly over the arm and is located inside the prosthesis, into which the existing part of the limb is inserted.

1.3 The prosthetic socket contains EMG sensors for muscle activity, which enable the prosthesis to be controlled. EMG sensors consist of sensitive electrodes. They read the electrical potential from the muscles at the moment of contraction [13].



Picture 1. Figures to paragraphs 1.1, 1.2, 1.3.

1.4. The artificial limb will be multi-grip, which means that motors for each finger of the hand will be installed in the prosthesis, which will allow it to perform many different grips (gestures) and types of closing and opening of the hand. Moreover, it will be possible to squeeze or unclench the hand so that at a certain moment it can be stopped and fixed. Since the prosthesis must be compact and free of protruding parts that can cause inconvenience to the patient, the motor must be sufficiently powerful and small. Stepper motors meet the requirements of the technical specification most fully. A stepper motor is a mechanical device that converts electrical impulses into mechanical, and, unlike other motors, “controlled” motion, i.e. the angle of rotation of the rotor depends on the number of pulses received by the motor [8].



Picture 2. Figures to paragraph 1.4.

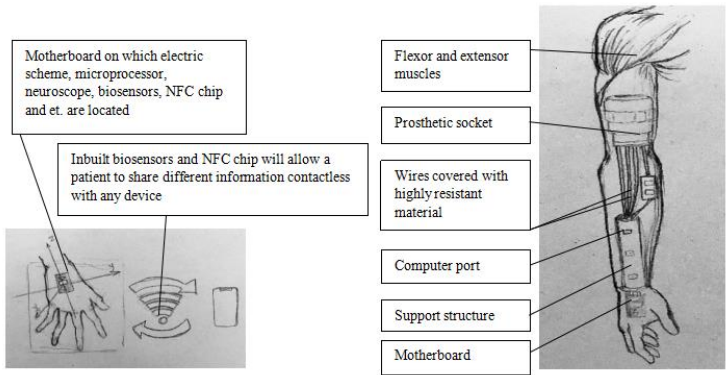
1.5. A microprocessor will be installed in the prosthesis. A microprocessor located in the prosthetic hand will allow reading information from EMG sensors and converting it into motor commands using computer algorithms, after which the prosthesis will perform a specific gesture or grip. Artificial intelligence will be integrated into the microprocessor, which will be able to correct errors in the program code. Also, the system with artificial intelligence will allow you to instantly check the patient's tolerance of prescribed medications and their compatibility with medications that a person is already taking. Moreover, thanks to artificial intelligence, the prosthesis will become self-controlled, which means it will begin to remember the user's movements. Artificial intelligence will be based on an operating system, which will give the user the opportunity, if necessary, to directly give it commands. For feedback from the microprocessor, computer ports and wireless communication modules must be installed in the artificial limb. Magnetic cable connection technology will be used for greater security.

1.6. Our prosthesis will have a neuroscope that detects the position in space; sensors read the load, determine the center of gravity of the patient, react to his speed and change. This ensures stable operation of the human-prosthetic interface so that a person can move more freely and feel better in space [2].

1.7. Biosensors will be installed in the prosthesis with the purpose of operational monitoring of individual body parameters and are especially in demand among patients with chronic diseases who need to constantly monitor several physiological parameters at once (blood glucose levels, blood pressure). These devices can send health information to a doctor or to a phone, and even call an ambulance if necessary. Thus, the patient will always be able to monitor his health status and take timely measures to eliminate any ailments.

1.8. There is also a possibility of installation an NFC chip in the prosthesis. The NFC device operates at a frequency of 13.56 MHz and consists of a reader and an antenna, or a tag and an antenna. The reader generates a radio frequency field that can interact with the tag or with another reader. A reader is an NFC device that operates in active communication mode. With its help, the user will be able to connect additional accessories to the prosthesis and use the contactless payment function.

1.9. The artificial limb has a built-in passive cooling system, that is, it lacks an active part (fan), which is responsible for heat dissipation. Thus, the prosthesis will not make any sounds.

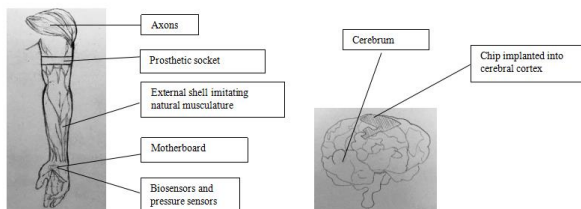


Picture 3. Figures to paragraphs 1.5, 1.6, 1.7, 1.8, 1.9.

1.10. The prosthesis will also have a set of myosensors for each individual finger and have an ultrasonic reading of muscle tension, due to which the speed of signal transmission from the residual muscles to a particular finger will be clear, moreover, thanks to them, a person will be able to feel what they touch, as well as feel the temperature of these objects. Sensors will be installed on flexor and extensor muscles, and will also be attached to motor neurons (axons) that did not die after amputation, but remained on the edge of the damaged stump, and which can be monitored using myosensors, in addition, chips will be implanted in the cerebral cortex, from where a signal is sent to compress or unclench the hand; a channel is formed that allows the axon to exchange information with the electronic system of the prosthesis. Amputees will not have to rely solely on their eyesight, instead they will be able to rely on a natural sense of proprioception in assessing exactly how to operate their prosthesis. In this way, a “neuro-

mechanical bridge” will be created, thanks to which the prosthesis will be controlled and felt by our brain like a real hand [10]

1.11. Pressure sensors will be installed in the hand, which will determine the degree of compression of the object in the hand by the prosthesis, and if the object starts to fall out, the prosthesis will automatically compress it [2].



Picture 4. Figures to paragraphs 1.10, 1.11.

1.12. Each wire built into the prosthesis will be covered with a highly resistant insulating material to ensure the durability of sensors and electromechanisms.

1.13. The prosthesis will be protected from the aquatic environment according to the IP68 standard. The IP68 water and dust protection standard includes absolute tightness against the ingress of small particles inside the structure, and also eliminates the penetration of moisture under the panel. The prosthesis with IP68 protection class can be used at a depth of 1.5 meters for up to 30 minutes without fear for its integrity. This protection is characterized by a high degree of tightness, since according to this standard, an additional waterproof film is laid at the joints, seals and between small gaps in the prosthesis structure, so that the artificial limb will not be affected by moisture [11].

1.14. The internal component of the prosthesis will be made of titanium, carbon fiber and high-alloy steels. These materials are quite durable and lightweight. They will be able to ensure the durability of the artificial limb. Thanks to these materials, our prosthesis will weigh no more than 500 grams. Moreover, the design and capabilities of the prosthesis will allow people with disabilities equipped with an artificial limb to lift loads weighing up to 10 kilograms and with a diameter of up to 10 centimeters.

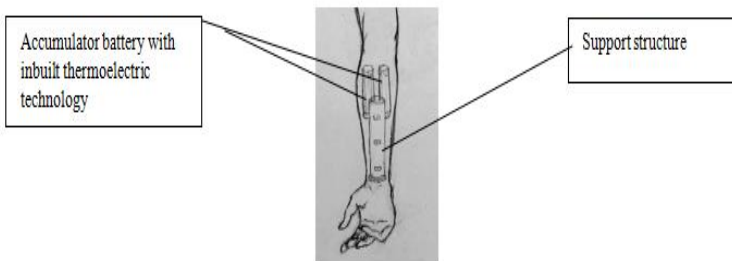
1.15. Thermoelectric technology will be installed in the prosthesis, which works on the basis of the Seebeck effect, discovered in 1821. This effect considers the occurrence of an electromotive force in a closed circuit consisting of dissimilar conductors connected in series, the contacts between which are at different temperatures. Thus, the prosthesis will partially charge

itself during compression and decompression cycles, which will significantly prolong its working time.

2.1. A lithium polymer battery will be built into the prosthesis, which provides it with a fast charge. A lithium polymer battery with a capacity of 200 Watts per hour is capable of providing up to 18 hours of battery life, and this is exactly what will be installed in the proposed model of prosthesis. It also has a compact size and low weight by itself. These batteries are very good at providing low power for a long time. They have a high specific charge density, so batteries can store a significant amount of electrical energy in a small volume. This battery is durable, which will allow a person not to think about replacing it for a long time. Lithium polymer batteries can be manufactured in any size and shape, as they are very flexible. These batteries behave better at high temperature fluctuations, charge quickly (charge time is about two hours), can provide up to 5,000 charging cycles, are characterized by one of the lowest self-discharge rates and the highest service life. Batteries are low toxic [12].

2.2. A special insulating fiber will be laid between the battery and the rest of the inner part of the prosthesis to better protect and seal the lithium polymer battery.

The outer shell of the prosthesis will be made of silicone, medical nylon and nanofiber. These are quite durable, wear-resistant, and most importantly, pleasant to touch materials. They will provide additional protection of the entire prosthesis structure from the environment, as well as make the prosthesis as anthropomorphic and realistic as possible. These materials easily stretch and take the desired shape of the object they are applied to. Silicone and nylon do not require high labor costs in production. These materials imitate human skin well, moreover, they are dyed well and keep the color. It is very important that the patient feels comfortable with prosthesis and does not experience a feeling of alienation of the artificial limb from the rest of the body.



Picture 5. Figures to paragraphs 1.15, 2.1, 2.2.

A plastic frame on which all the components of the outer shell are attached will be constructed. The frame is attached using magnetic fastening technology. The frame imitates the shape of a human hand, and together with silicone and nylon inserts, the appearance of the artificial limb will be as similar as possible to an ordinary hand.

The proposed model will allow a person to independently design and decorate their own prosthesis. Prosthesis can look futuristic if the patient likes an unusual and memorable design, or on the contrary anthropomorphic. In the second case, there will be no external differences between prosthesis and a human hand. Accordingly, there will be no factor that externally shows the foreignness of the prosthesis from the rest of the human body, which will allow the person with a disability to be more relaxed in society. A person can add LEDs to the shell design, color the silicone coating, add tattoos to it, engrave the surface, cutting out various patterns and symbols. The proposed prosthesis will help a person to cope with complexes, internal contradictions and self-rejection after the loss of limbs.

Details for our prosthesis, such as supporting metal structures, gears, rotation mechanisms, lever mechanisms, nylon shells, plastic fingers and forearm will be printed on a 3D printer using Laser Engineered Net Shaping technology. Such printers, in addition to plastic, silicone and nylon objects, can print titanium and steel objects. The powder-shaped material is blown out of the nozzle and hits the focused laser beam. Part of the powder flies past, and the part that gets into the laser's focus instantly is sintered and layer by layer forms a three-dimensional detail. Powders of various materials can be mixed and alloys can be obtained in this way, and if a special dye is added to them, they can be immediately produced in the desired color. First, we need to create a project of all the details, take the individual measurements of each prosthesis component, because all people have different sizes, after which we generate 3D models and print. This will greatly simplify the production and manufacture of a prosthesis, since most of them, unlike the proposed model, are created on machines in which the parts are turned separately on a lathe, after which they are processed, and only after these operations the prostheses begin to be assembled. A 3D printer with this technology will produce ready-to-use parts that do not require special refinement, and in case of replacement of an artificial limb part, it will be possible to re-print this part.

The proposed concept of designing and creating prostheses will make it possible to solve the issues that have been ignored, but are no less significant for a person without limbs: aesthetics (a beautiful, realistic, elegant prosthesis that makes person with disabilities a full-fledged member of a healthy society

again) and working capacity (reliable, moderately heavy, modern artificial limb).

The task was to ensure that the theoretical technology of the prosthesis could completely recreate the missing body functions of the patient. To make a person without a limb the same as a healthy one. People with such prosthesis reach a completely new level, previously unprecedented. More advanced, physically resilient, always quickly replaceable in case of breakdown, functionally differentiated, changing a person with disabilities greatly.

Humanity is gradually approaching an incredibly interesting chapter of its own history. The rapid development of science is transforming our society into something completely new and unprecedented. The eternal desire of people to create an ideal system, a world without flaws and conflicts may become more realistic in future. Proper promotion of the scientific technologies will make it possible to achieve well-being in society and further better worldview. And perhaps it is at this time that people will stop being afraid of the boundlessness of human thought, because from now on we will increase the beauty of the world around us, get rid of selfishness and bitterness, and become truly happy.

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DEVELOPMENT OF THE TOPOLOGY OF THE ZERO CORRECTOR FOR THE DIGITAL ADC CODE

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Аннотация. В данной работе рассматривается процесс разработки и топология нулевого корректора цифрового кода АЦП последовательного приближения. Исследование направлено на решение актуальной проблемы систематических ошибок, возникающих в выходном коде преобразователя из-за влияния паразитных параметров интегральных проводников и технологического разброса параметров элементов микросхемы. Разработанная топология реализована с использованием отечественной КМОП-технологии HCMOS8D с техпроцессом 180 нм. Проектирование выполнено в профессиональной САПР Cadence Virtuoso IC Design. Архитектура корректора включает три основных функциональных блока: 12-разрядные регистры для хранения исходного кода АЦП и кода ошибки, 12-разрядные КМОП-сумматоры с возможностью работы в режиме вычитателя и специализированный блок управления процессом коррекции.

Ключевые слова: проектирование интегральных схем, нулевой корректор, КМОП, 180 нм, АЦП.

Annotation. This paper discusses the development process and topology of a zero corrector for a digital code of a successive approximation ADC. The study is aimed at solving the current problem of systematic errors that occur in the output code of the converter due to the influence of parasitic parameters of integrated conductors and technological spread of parameters of microcircuit elements. The developed topology is implemented using domestic CMOS technology HCMOS8D with a 180 nm process technology. The design was performed in the professional CAD Cadence Virtuoso IC Design. The corrector architecture includes three main functional blocks: 12-bit registers for storing the ADC source code and error code, 12-bit CMOS adders with the ability to operate in the subtractor mode, and a specialized correction process control block.

Keywords: integrated circuit design, zero corrector, CMOS, 180 nm, ADC.

Introduction

The design of ADC integrated circuits faces a critical challenge of output code offset caused by parasitic parameters of integrated interconnects. This offset manifests both as a DC component in the output code and as a variable

component that varies with different output codes. To minimize the DC offset component, zero-correction circuits are employed at the ADC output, which subtract the constant offset from the ADC code.

This paper presents the development results of a 12-bit zero-corrector for successive-approximation ADCs, implemented using domestic 180 nm CMOS technology and designed in Cadence Virtuoso IC Design environment.

Main part

Figure 1 shows the block diagram of the 12-bit ADC zero-corrector.

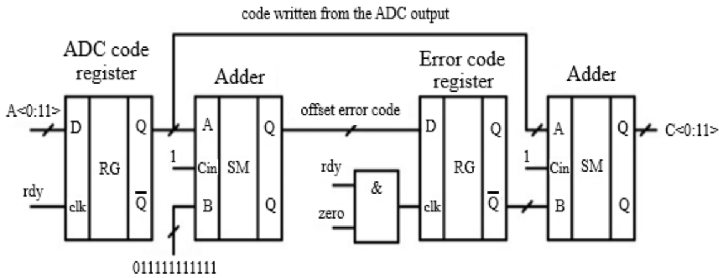


Figure 1. - Block diagram of the 12-bit ADC zero corrector

The presented block diagram of the zero corrector consists of the following blocks:

- 12-bit ADC code and error code registers;
- 12-bit CMOS adders;
- error register control unit.

The zero corrector operates according to the following operating principle. An analog signal corresponding to zero volts is fed to the ADC input, and as a result of the conversion, a code corresponding to zero volts (D_0) and an error code (ΔD) are obtained. The obtained code is written to the ADC code register by the rdy signal (ADC conversion ready signal). To obtain the value of ΔD , it is necessary to subtract D_0 from the mixture $D_0 + \Delta D$. To do this, the adders in the corrector act as subtractors and implement binary subtraction $(D_0 + \Delta D) - D_0$. As a result, the code ΔD is formed at their output, which is written to the error code register by the active level of the rdy and zero signals (the ADC error recording signal). As a result, the second adder, also operating in the subtractor mode, implements the following binary subtraction $(D_0 + \Delta D) - \Delta D$. As a result, the code D_0 is formed at the corrector output. Subsequently, ΔD is stored in the zero corrector and subtracted from the mixture $D + \Delta D$, resulting in the corrected ADC code D . The ADC code and error registers are implemented on the basis of the simplest memory cells, which are

implemented using 12 D-triggers, implemented according to the scheme of two switched pass-through keys [1]. The basic diagram of the D-trigger is shown in Fig. 2. The adders are implemented on the basis of a series connection of 12 traditional CMOS full adders (TCFA) [2, p. 28].

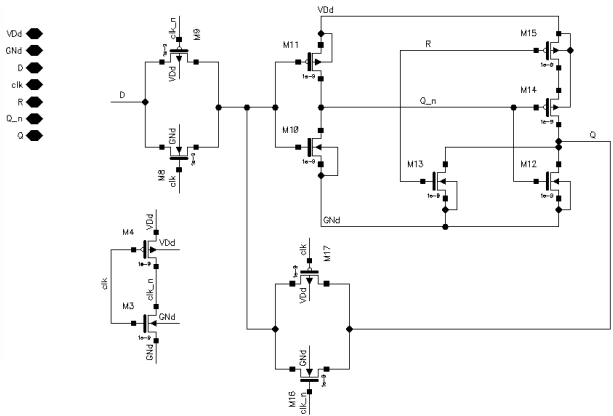


Figure 2. - Schematic diagram of a D-trigger

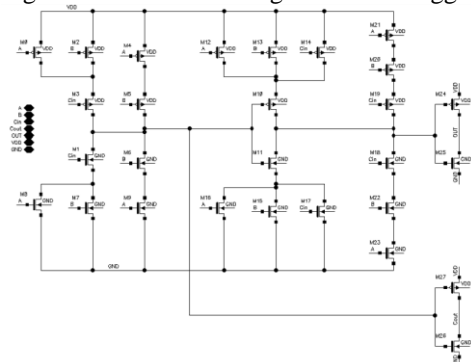


Figure 3. - Schematic diagram of the TKPS

Fig. 4 shows the topology of the 12-bit ADC zero corrector.

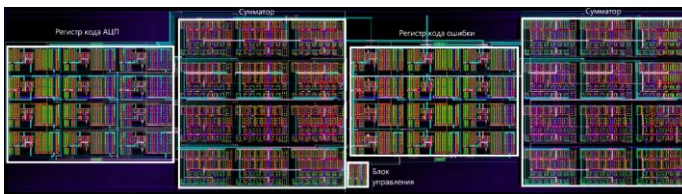


Figure 4. - Topology of the 12-bit ADC zero corrector

Results.

Figures 5, 6, 7 show graphs where D_x is the code at the ADC output, D_x_COR is the signal at the corrector output, Rdy and $ZERO$ are the ADC error recording signals. Moderation was performed at ADC input voltage values of 0 mV, -50 mV and 50 mV, respectively, and an offset voltage of 100 mV [1].

Let's analyze Figure 5, when a signal with an amplitude of 0 mV is fed to the ADC input. The logical zero of the ADC corresponds to the code 2048, which corresponds to 2.048 V at the output of the circuit under test. After the ADC has completed the conversion, the voltage at its output is 1.62 V. At the moment when single signals rdy and $zero$ arrive at the inputs of the control unit, the offset error value $\Delta D = 428$ mV is calculated and subsequently taken into account at the output of the zero corrector.

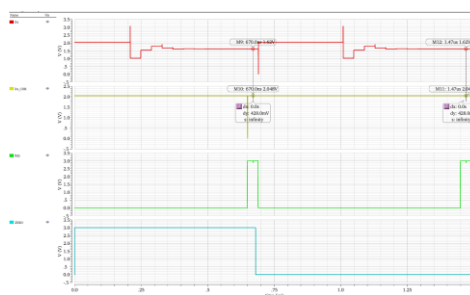


Figure 5. - Simulation results

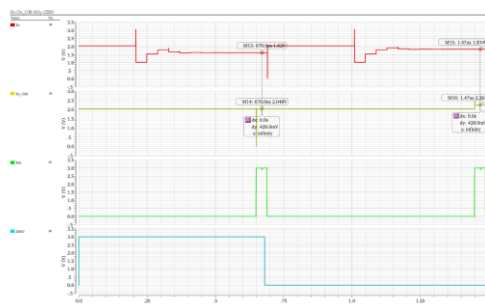


Figure 6. - Simulation results

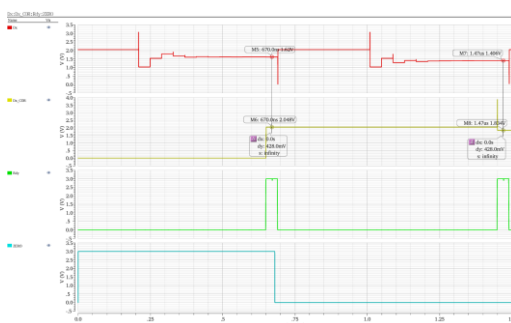


Figure 7. - Simulation results

Conclusion

Thus, the result of developing the topology of a 12-bit zero corrector for a successive approximation ADC based on domestic 180 nm CMOS technology in the Cadence Virtuoso IC Design CAD system was presented.

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MAIN DIRECTIONS OF DEVELOPMENT OF MARITIME TRANSPORT IN THE ARCTIC

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Аннотация. В статье представлены результаты анализа литературы, связанной с развитием ледокольного флота Российской Федерации, благодаря которым осуществляется движение по Северному морскому пути. Также в работе раскрываются особенности проектирования и построения ледоколов, использование которых улучшают качества судовождения в сложных северных условиях. Кроме этого, в статье представлены направления развития специализированных судов в суровых ледовых условиях, а также развития инфраструктуры Арктической зоны.

Ключевые слова: Северный морской путь, судовождение, ледовые условия, ледокол, арктическая зона.

Annotation. The article presents the results of the analysis of literature related to the development of the icebreaker fleet of the Russian Federation, thanks to which movement along the Northern Sea Route is carried out. The work also reveals the features of designing and building icebreakers, the use of which improves the quality of navigation in difficult northern conditions. In addition, the article presents the directions for the development of specialized vessels in severe ice conditions, as well as the development of infrastructure in the Arctic zone.

Keywords: Northern Sea Route, navigation, ice conditions, icebreaker, Arctic zone.

Introduction.

In today's realities, it can be reasonably stated that one of the shortest sea routes from the European part of Russia and the Far East is the Northern Sea Route [6, p.12]. The development of the Northern Sea Route is associated with a number of reasons:

1. First of all, with the warming of the Arctic. Thus, recently global warming of the Earth and its surface has begun to occur, which leads to the melting of Arctic glaciers, including those at the North Pole [4, p.92]. Every

year the ice cover becomes thinner, the area of northern sea waters increases, and the navigation zones and periods also grow.

2. Development of the Northern Transport Corridor, as well as improvement of the infrastructure of the Arctic zone adjacent to the Russian Federation [6, p.39].

3. Search and use of mineral deposits that were previously hidden under thick ice [5, p.96]. This is due to the fact that the Arctic territories of Russia geographically extend from Franz Josef Land to the Wrangel and Herald Islands, which constitutes a fairly large area of the Arctic territory. As a result, Russia is interested in the economic development of both the Arctic zone, the Northern Transport Corridor, and the Northern Sea Route (Fig. 1) [6, p.14].

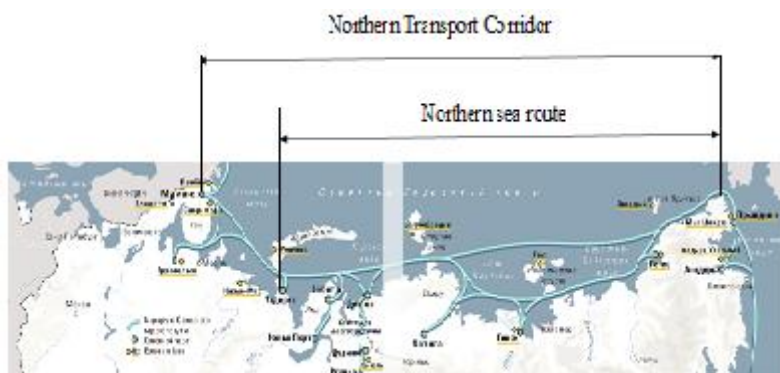


Fig. 1. – Schematic representation of the Northern Sea Route and the Northern Transport Corridor

The peculiarity of using the Northern Transport Corridor is the possibility of passing through it. So usually, navigation along this route begins at the end of June (beginning of July) and ends at the end of September (beginning of November) [4, p.95]. This is due to the fact that the cold climate has a strong influence on the state of the northern seas and their waters.

An analysis of literary sources [2, 5, 6] showed that due to a milder climate and warmer weather conditions, as well as the use of modern icebreakers, the navigation season along the Northern Sea Route could increase from four months to year-round [2, p.131]. At the same time, it is assumed [5, p.112] that by 2035 the Arctic shelf will be completely free of ice in the summer, which will allow for the Northern Transport Corridor to be loaded to its full capacity. Thus, an increase in cargo flow along the Northern Sea Route is already being observed today. For example: in 2021, the cargo

flow was 34.85 million tons, in 2022 about 34 million tons, and since 2023, the cargo turnover has been growing (in 2023 - up to 36.25 million tons, in 2024 up to 37.89 million tons). It is planned that in 2025 the cargo flow could reach more than 40 million tons [5, p.104-107].

Statement of the problem. Today, difficult weather conditions and freezing of the northern seas reduce the intensity of cargo transportation and delivery of goods to the destination. This leads to the fact that during the passage along the route, specialized Arctic-class vessels – icebreakers are used. Icebreakers are specialized vessels designed to navigate frozen sea areas during various icebreaking operations in order to maintain navigation. Therefore, **the purpose of this article** is to consider the features of the development of the icebreaker fleet of the Russian Federation.

Presentation of the main material.

To navigate the Northern Sea Route through freezing seas and their waters, specialized vessels are used – icebreakers, which perform various icebreaking operations, which depend on the technical characteristics and their design capabilities. Icebreakers are classified according to their ability to navigate through ice, depending on the navigation conditions and ice conditions in the seas. The most operational is the project 10520 of the «Arktika» and «Taimyr» types and their improved projects. These projects have increased power due to nuclear reactors and belong to an ice class of not lower than Icebreaker8, which allows year-round operation along the Northern Sea Route due to the use of propellers with a capacity of at least 45 MW during operation.

Currently, Russia's icebreaker fleet is one of the largest. Thus, at the beginning of 2025, it includes 42 specialized icebreakers of the Icebreaker6 class and above, 22 of which are domestically produced. Table 1 presents data on operating nuclear icebreakers, as well as on diesel icebreakers of various capacities performing tasks in northern sea areas [1, p. 1-2].

Table 1. Number of icebreakers of the Russian Federation

Number of icebreakers with power							Ice class
up to 7 MW	up to 10 MW	up to 22 MW	more than 22 MW	up to 40 MW	up to 55 MW	60 MW	
Nuclear icebreakers							
-	-	-	-	2	2	4	Icebreaker8, Icebreaker9
Diesel icebreakers							
7	5	17	5	-	-	-	Icebreaker6, Icebreaker7

On July 31, 2022, the Maritime Doctrine of the Russian Federation was approved (Decree of the President of the Russian Federation No. 512), which presents the tasks related to the development of the Northern Sea Route as a national transport communication of the Russian Federation, taking into account the possibility of its international use to ensure competitiveness in the world market (in terms of the quality of transport services and safety of navigation) [3]. One of these directions is the development of the icebreaker fleet, as well as auxiliary marine transport vehicles.

The implementation of this direction is connected with the construction of nuclear icebreakers in accordance with Project 22220 of the «Arktika» type. Icebreakers of Project 22220 are the largest and most powerful icebreakers in the world today. Icebreakers of Project 22220 are to replace old icebreakers built during the Soviet era, such as: «Vaigach», «Taimyr», «Yamal» and «50 Let Pobedy». As of December 2024, 4 icebreakers have been built and are in operation: «Arktika», «Sibir», «Ural», and «Yakutia». In addition, the launch of the icebreaker «Chukotka» is planned for 2026. At the same time, it is necessary to solve a number of problems aimed at:

- creation of a universal class of icebreakers for use in various water areas and river beds;
- increase in ice breaking and penetration from 2.25 m to 3.0 m and more;
- possibility of expanding the passage channel;
- assessment of hydrometeorological conditions and ice conditions;
- automation of ship systems and the ship control system as a whole;
- increasing the reliability of marine nuclear power plants and the safety of operation of ship systems and devices;
- the use of artificial intelligence systems to take into account external influences and internal factors;
- reduction of vessel operating costs;
- increasing the operational life of the vessel to 40 years.

In addition, it is necessary to mention one of the promising areas – the development, construction and operation of floating nuclear power plants of Project 20870 (the vessel «Akademik Lomonosov») [8]. The use of floating nuclear thermal power plants makes it possible to solve a number of problems related to the provision of both electricity and heat to socio-economic facilities in the Arctic region in the conditions of the northern climate and permafrost. This direction is also promising and is aimed at the development of shipbuilding and nuclear energy.

Another promising direction of marine transport systems is the development of unmanned vessels [7, p.74]. Currently, many countries have been working for a long time on the creation and full implementation of

autonomous vessels into the maritime transport system. This direction is extremely promising, as it assumes the absence of people on board, which allows minimizing life support systems and additional devices necessary for the crew in critical conditions, thereby increasing the useful volume of the vessel and significantly reducing the influence of the human factor [7, p75-76]. This is due to the fact that unmanned vessels can have different degrees of automation, such as [7, p75-76]:

- ship automation of control processes for devices and units, informatization of control systems and decision-making support, control and stabilization of energy systems with the crew;
- the vessel is controlled remotely (control of the vessel systems and operating parameters is carried out from shore control systems) with the crew present;
- remote control of ship systems without a crew on board;
- fully autonomous vessel: the vessel's control system makes decisions and independently determines the required actions based on: prescribed algorithms or intelligent control systems.

The control and management of the vessels in the convoy will be carried out by operators located on board the icebreaker or at coastal stations.

To ensure year-round navigation in the waters of the northern seas, it is necessary to use high-power nuclear icebreakers (engine power must be more than 110 MW). This will make it possible to solve transport problems related to the transportation of various goods in various climatic conditions. Therefore, at the current stage of shipbuilding, active construction of icebreaker fleet vessels with nuclear reactors is underway.

Conclusions on the work.

The development of the Arctic region is directly linked to the expansion of the possibilities of using the Northern Sea Route, its infrastructure, as well as the commissioning of new generation icebreakers. Taking into account the harsh conditions of shipping, as well as the influence of various hydrometeorological and ice factors, put forward a number of modern requirements for the construction of nuclear icebreakers with the ability to solve multifunctional tasks to ensure the uninterrupted operation of ships in the seas of the Arctic zone, including energy supply.

The development of the Arctic zone can only be achieved by increasing the intensity of the flow through the year-round operation of both nuclear and diesel icebreaker fleets. At the same time, the main task of the Russian shipbuilding industry is the creation of specialized vessels with increased capacity (more than 110 MW).

To increase the efficiency of operation along the Northern Sea Route and reduce the influence of the “human” factor, it is necessary to develop

autonomous vessels and remote-control systems taking into account the influence of the Arctic climate.

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DEVICE OF USER IDENTIFICATION IN ACCESS CONTROL AND MANAGEMENT SYSTEM

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Аннотация. Проведен анализ существующих вариантов идентификации в системах контроля и управления доступом. Разработанные структурная и функциональная схемы, а также программа для обработки и отображения данных от модуля считывания QR кодов. Выбраны требуемые считыватели, а также плата микроконтроллера. Представлен результат работы сегментов системы, а также тока потребления датчиков.

Проведена доработка программного обеспечения и базы данных (БД) с целью оптимизации взаимодействия между устройством идентификации и программной частью, расположенной на компьютере пользователя. Обозначены варианты доработки корпуса устройства идентификации с целью уменьшения компактности.

Ключевые слова: система контроля и управления доступом, QR коды, RFID-карты, база данных, программное обеспечение.

Annotation. The article provides an analysis of identification types in access control and management systems. Structural and functional schemes, as well as the program for processing and displaying data from the module of QR codes reading are developed. The required readers and the microcontroller board are chosen. The result of operation of segments of the system, as well as the current consumption of the sensors is presented.

Improvement of software and database has been carried out (DB) in order to optimize the interaction between the identification device and the software part located on the user's computer part located on the computer. The variants of modification of the identification device housing in order to reduce its compactness are considered.

Keywords: QR codes, access control and management system, RFID cards, database, software.

Introduction

The current systems are dominated by systems using RFID cards. Access control and management systems are an integral part of all modern institutions. In addition to access control systems, RFID cards or their analogues are used in banks and stores. That's why the card user runs the risk of losing one or all of one's cards at the same time, or the user may forget the card he needs at the moment. In such situations, a smartphone application can be appropriate as additional or primary measure for user identification. Based on this, it will be relevant to improve the previously created device at the software level, as well as identify possible enhancements aimed at reducing the area occupied by the device.

The subjective of the study is to analyze identification types in access control and management systems.

The main part

Due to the fact that the hardware of the device is actually completed and ready for use, the main focus of the work is aimed at processing certain segments of the software (software), as well as the database in order to optimize operation.

The original version used a single database consisting of a single table. In the current version, there are two tables that are not directly connected to each other, however, there are fields that allow you to link the rows of the two tables with certain manipulations. The menu file has been redesigned to optimize the software. Previously, launching the menu simultaneously loaded all windows at once, which took up extra time and resources. At the moment, this is implemented through separate files. Also, all program elements have been adapted to the current database implementation.

The os library was used to open multiple windows [2].

The Arduino IDE integrated development environment was used to create a program for the identification device [1].

To optimize the space occupied by the device at this stage, it is planned to increase the height of the housing and dismantle the connection contacts by performing standard soldering of the necessary contacts with each other.

With this housing option, the MFRC522 RFID tag scanning module will be located above the Barcode Scanner Module, which will simplify the identification process. Additionally, the device will have a more compact form factor, which will allow it to be comfortably placed in most cases.

The device will be powered using USB version 3.0. This will provide the identification device with the necessary power parameters.

Here are the electrical parameters for the USB 3.0 port:

- the maximum voltage 5 V;
- the maximum current is 0.9 A.

A case has been created for the developed device to simplify operation. The device body is shown in Fig. 1.

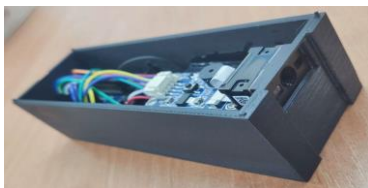


Fig. 1. - The device body

Conclusion

Thus, the article provided an analysis of identification types in access control and management systems. The software part of the device was finalized. Solutions that would reduce the current size of the device have also been described.

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UDC 681.5

MODEL OF A SEA BUOY FOR MONITORING ENVIRONMENTS IN THE ARCTIC REGION

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Аннотация. Рассмотрена техническая система, реализующая обнаружение и определение расстояния до границы раздела сред воздух-снег-лед-вода. Разработана модель морского буя, осуществляющего контроль за изменениями в среде. Создан и испытан экспериментальный образец такого буя. Проведена разработка, сборка и прошивка модели буя. Проведены экспериментальные исследования, показавшие эффективность и возможность реализации данного технического решения. Результаты исследования можно использовать при создании морских буёв для проведения работ в области исследования Арктики и Антарктики.

Ключевые слова: граница раздела сред, измерение толщины льда, измерение толщины снега, ультразвуковые датчики, Арктические буи, Arduino Uno

Annotation. A technical system for detecting and determining the distance to the interface boundaries of air-snow-ice-water is considered. A model of a marine buoy monitoring environmental changes has been developed. An experimental prototype of such a buoy has been created and

tested. The development, assembly, and firmware programming of the buoy model have been carried out. Experimental studies have been conducted, demonstrating the effectiveness and feasibility of this technical solution. The research results can be used in the creation of marine buoys for conducting work in the Arctic and Antarctic research fields.

Keywords: interface boundary, ice thickness measurement, snow thickness measurement, ultrasonic sensors, Arctic buoys, Arduino Uno

INTRODUCTION

Our civilization, at the beginning of the third millennium, has encountered numerous global challenges, including global warming [1, 2]. While the consequences may not yet be visible to the average person, we may soon face them. To be able to respond quickly to climate change, it is necessary to monitor glacier melting.

The problem of glacier and ice melt is global in scope. For several years, debates have been ongoing, and various hypotheses have been proposed. However, the fact that changing environmental conditions are affecting the reduction and thinning of ice cover in polar regions is undeniable [3, 4]. Under these circumstances, it is crucial [5, 6] to track the rate and locations of ice melting to document changes and respond appropriately.

The objective of this work is to develop a model of a marine buoy designed to monitor environmental changes.

A technical system capable of detecting the interface boundaries between air-snow-ice-water is under consideration. This task holds significant importance in science and technology, particularly in fields such as hydrology, climatology, glaciology, and navigation. Methods for detecting interface boundaries can be categorized into several groups:

1. Optical methods (LiDAR, spectrometry, thermal imaging) – analysis of light reflection and temperature.

2. Acoustic methods (sonar, ultrasound) – differences in sound speed and medium density.

3. Electromagnetic methods (ground-penetrating radar, radar) – changes in dielectric permittivity.

4. Mechanical methods (drilling, tactile sensors) – direct assessment of density and structure.

5. Chemical methods (isotope analysis) – differences in composition.

6. Satellite methods (radar, optical sensors) – monitoring of large areas.

The acoustic method is the most suitable for solving the given problem because media such as air, snow, ice, and water have different densities, and the speed of sound in them varies significantly. This method is simple to implement and requires relatively inexpensive equipment.

Acoustic instruments for detecting interface boundaries between air, snow, ice, and water utilize the properties of sound waves (speed, reflection, refraction) in different media. These instruments are sensitive to material density and acoustic characteristics.

Types of Acoustic Instruments:

- Echosounders (e.g., Teledyne Odom Hydrographic Echosrac) – ice thickness measurement.
- Sonars (e.g., Kongsberg MS1000) – analysis of the ice-water boundary.
- Ultrasonic probes (e.g., Olympus Epoch 650) – study of ice and snow structure.
- Underwater systems (e.g., Sub-ICE AUV) – monitoring of subglacial layers.
- Sound velocity profilers (e.g., Applied Acoustics AcouStar) – laboratory and field research.

Equipment Design

To assemble the marine buoy model, components, sensors, and equipment compatible with the Arduino Uno platform were used (Fig. 1).

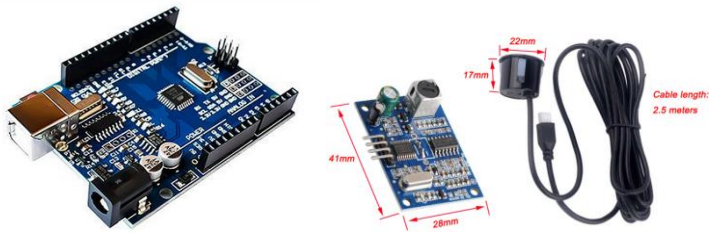


Fig. 1. - Arduino board and JSN-SR04T ultrasonic sensor

Arduino Uno is a popular development board for electronic projects based on the ATmega328P microcontroller. It is equipped with 14 digital input/output pins (6 of which support PWM), 6 analog inputs, a 16 MHz quartz crystal, a USB port for connecting to a computer, and a power jack. Power can be supplied via USB (5V) or an external source (7–12V). The Uno supports simple programming in C++ through the Arduino IDE.

JSN-SR04T Sensor. The JSN-SR04T is a waterproof ultrasonic distance sensor designed for operation in harsh conditions (humidity, rain, submersion in water). It measures distances in the range of 25–450 cm (in air) and up to 5 meters in water using ultrasonic pulses. The sensor operates at 5V, has two connection modes (analog and digital), and features a sealed housing, making it suitable for automation projects, robotics, or liquid level monitoring.

Key features include a wide detection zone ($\sim 25^\circ$ angle), interference protection, and easy integration with Arduino via digital pins. However,

accuracy decreases in water due to differences in sound speed, and calibration requires accounting for ambient temperature. Nevertheless, the sensor is a powerful tool for distance measurement at depth, in challenging weather conditions, and in high-humidity environments where a standard sensor would fail.

A buoy housing model has been developed, illustrating the general concept of the device's operation. It is schematically shown in Fig. 2.

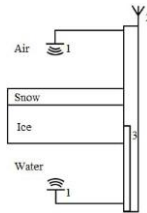


Fig. 2. Conventional diagram of the buoy.

In the diagram shown in Figure 2:

1 – Ultrasonic sensors used to measure distance. The upper sensor will measure the distance to the snow, while the lower one, mounted on the rail, will move toward the ice and take measurements.

2 – Communication antenna.

3 – Rail on which the lower sensor moves. When the rail makes contact with the ice, we will determine the length of the water layer and, consequently, the water–ice boundary.

The design is a long pipe buried in the ice, located in multiple environments, with two sensors - upper and lower. The lower sensor (located in water) will be mounted on a movable rail. Before taking measurements, the rail and ultrasonic sensors will be preheated using a heater. Then, the lower sensor is raised until it makes contact with the ice. By knowing the distance traveled by the rail, the first boundary (water-ice) can be measured. Next, the ice thickness is measured using the ultrasonic sensor.

After that, the upper sensor measures the distance to the snow. By subtracting the air, water, and ice measurements from the total length, the remaining value gives the snow depth. This is how the boundaries between the different environments are determined. The collected data is then transmitted to a server via an antenna for processing.

Since most of the structure will remain unused, it is planned to place lithium-ion batteries inside the support pipe in a spiral arrangement down to the rail. A motor will be installed in front of the rail to raise and lower the

lower ultrasonic sensor. The rail will be equipped with a motion sensor; once the rail stops moving, it will record the water-ice boundary.

The connection method between the "Arduino Uno" board and the JSN-SR04T sensor is shown in Fig. 3.

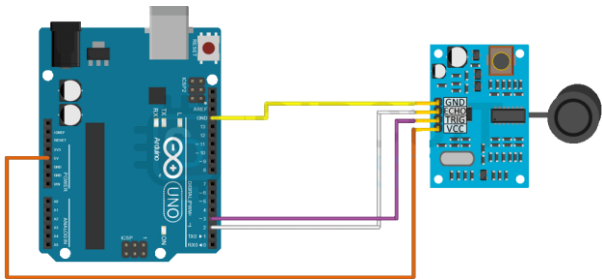


Fig. 3. Connection method of the "Arduino Uno" board to the JSN-SR04T sensor.

The SR04T ultrasonic sensor emits a 40 kHz ultrasonic wave into the surrounding space. After receiving the signal reflected from an obstacle, it is amplified by the operational amplifier within the sensor module and then processed by the built-in STM8 microcontroller, which generates the resulting pulse at the sensor's output (echo pin). The duration of this pulse equals the time taken for the ultrasonic wave to travel to the obstacle and back.

The layout of the main components on the "JSN-SR04T" board is shown in Fig. 4.

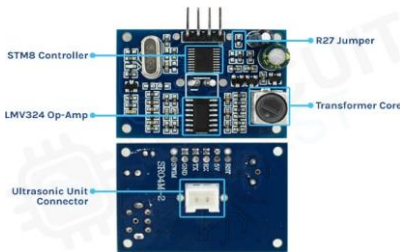


Fig. 4. The "JSN-SR04T" diagram showing the arrangement of the main components.

Controller STM8 – a microcontroller that processes signals.

OP LMV324 – an operational amplifier that amplifies the signal received after its reflection from an obstacle, as it is very weak.

Transformer Core – used to convert a 40 kHz square wave to the voltage level at which the ultrasonic sensor module operates. Can be adjusted by the user to improve the accuracy of the readings.

Ultrasonic Unit Connector – a two-pin connector used to connect to the ultrasonic unit.

Jumper R27 – by placing different resistors here, the operating mode can be changed.

We will use the "JSN-SR04T" in standard mode.

After applying a trigger pulse to the sensor's trigger contact, the sensor emits an ultrasonic wave into space, and after its reflection from an obstacle, it generates a pulse at its output contact, the duration of which is equal to the time it takes for the ultrasonic wave to travel to the obstacle and back.

Firmware has been developed for the JSN-SR04T sensor, which measures the boundary between two media.

Experimental Studies

Testing of the sensors, their functionality, and the accuracy of the theory of ultrasonic wave reflection from the boundary between media was carried out. The reflection of the ultrasonic wave from the following boundaries was tested: air–water, water–air. Measurements were taken to verify the correct operation of the ultrasonic sensor in aquatic and air environments.

Before starting the tests, a preliminary experiment was conducted to ensure the sensor was working correctly in an air environment. After confirming that the sensor provided accurate readings, it was decided to proceed with measuring the air-water boundary (Fig. 5).

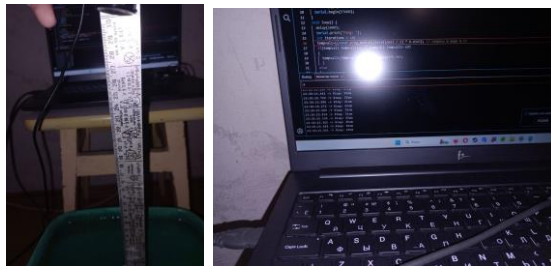


Fig. 5. Measurement of the air-water boundary.

As shown in the figure, the sensor correctly displays the boundary between the media. This proves that the wave is capable of reflecting from the boundary. Then we proceeded to testing in water. First, it was decided to verify the accuracy of the measurements in water (Fig. 6).

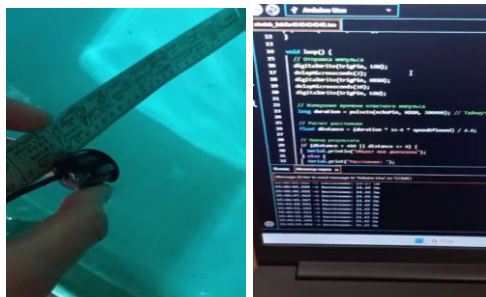


Figure 6. Verification of correct operation underwater.

Having confirmed the correct operation underwater, we can proceed to the final experiment: whether ultrasound reflects from the water-air boundary (Fig. 7).

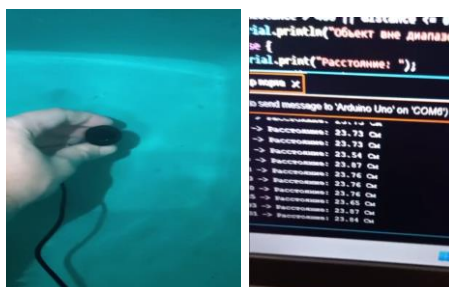


Figure 7. Measurement of the water-air boundary.

Thus, it can be concluded that the ultrasonic wave is capable of reflecting from the boundary between media, and therefore, we will obtain the same result from the "air-snow" boundary. Also, knowing that ultrasound can propagate in water and reflect from the "water-air" boundary, we can conclude that ultrasound is capable of passing through ice and reflecting from the "ice-snow" boundary, which proves the functionality of the device's operating principle.

Conclusion

The topic of this research has practical significance, and its results can be used in the creation of marine buoys for work in the following areas: exploration of the Arctic and Antarctica, studying the impact of environmental changes on their wildlife, navigation in northern regions, and so on.

In the process of intensive and efficient research and development of the North and South Poles, not only scientific vessels are used but also various devices (buoys) that collect data for predicting environmental changes. These

devices can eliminate the need for direct human presence in hazardous data collection zones while also simplifying and systematizing the process.

Thus, the development, assembly, and firmware programming of a buoy model have been carried out, along with experiments to study the possibility of its practical application. The prospects for using such buoys to ensure the safe study of Arctic ice and the processes occurring there, as well as for data collection and further processing, have been identified.

The result of the work was a preliminary test of measurements and the functionality of the marine buoy's sensors at the boundaries of different media.

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FEATURES OF NUMBER REPRESENTATION IN COMPUTER MEMORY

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Аннотация. В статье представлены результаты анализа особенностей представления чисел в памяти электронных вычислительных машин. Рассмотрены наиболее распространенные способы представления чисел, к которым относятся десятичная система счисления, удобная для человека, и двоичная система счисления, удобная для ЭВМ. Приведена взаимосвязь между десятичной и двоичной системами счисления. Рассмотрены особенности всех видов представления двоичных знаковых чисел и выделены их основные достоинства и недостатки. Также рассмотрены особенности экспоненциальной формы записи двоичных чисел для представления чисел с плавающей запятой.

Ключевые слова: ЭВМ, система счисления, двоичные числа, дополнительный код, числа с плавающей запятой.

Annotation. The article presents results of analysis of the features of representation of numbers in memory of electronic computers. The most common ways of representing numbers are considered, which include a human-friendly decimal system and a computer-friendly binary system. The relationship between decimal and binary systems of counting is shown. The features of all types of representation of binary symbolic numbers are considered and their main advantages and disadvantages are highlighted. The features of exponential form of binary number writing for floating point number representation are also considered.

Keywords: computer, numbering system, binary numbers, two's complement, floating point numbers.

Introduction

One of the key tasks in the training of students in technical universities is to understand how to work with different counting systems. Understanding the features of working with the main modern counting systems allows to fully master modern information technologies. The key system of counting for understanding the principle of operation of modern

electronic computers is a binary counting system. The study of binary representation techniques used in modern computers requires an understanding of the presentation of integer and real numbers, including fixed- and floating-point formats.

Main part

Information — the content of a message or signal, information considered during its transmission or reception. With the help of electronic computers information can be transmitted in various forms: number, text, audio, video and others. Computers, in turn, do not deal with information, but with data.

The decimal system is considered to be the most convenient for human perception. It uses a set of numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. In this system, the numbers are formed by degrees: units, tens, hundreds, thousands, tens of thousands, hundreds of thousands, millions and so on. As a rule, any integer in the decimal system can be represented as follows:

$$3297 = 3 \cdot 10^3 + 2 \cdot 10^2 + 9 \cdot 10^1 + 7 \cdot 10^0.$$

In such a record, the degree 10 indicates what number corresponds to a particular order. The decimal numbers are also written in the same way

$$132.56 = 1 \cdot 10^2 + 3 \cdot 10^1 + 2 \cdot 10^0 + 5 \cdot 10^{-1} + 6 \cdot 10^{-2}.$$

Unlike humans, computers process data presented as a series of zeroes and units. This method of number recording is called binary counting system and is the basis for all modern computers. To represent numbers in computers usually use bit sets — sequences of zeros and units of fixed length. It is technically easier to process sets of fixed length than sets of variable length. The position in a bit set is called a spread. Also, in the context of computers, a burst can be called the part of a register or memory cell where one bit is stored.

As in the decimal system, in the binary system numbers are also divided into ranks, with the ranks will be divided already by degree 2. Each digit in the binary representation is called a bit (or order bit). The numbering of bits is carried out from right to left, starting from zero - this is different from the usual decimal system. A bit in the extreme right-hand position and having the least significance has a sequence number of 0. An example representing a binary number is shown in the figure. 1.

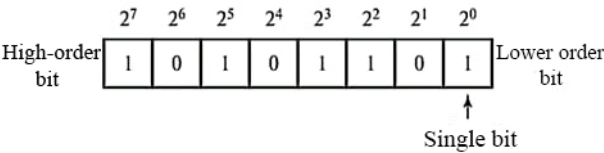


Fig. 1 - Representation of a binary number

Thus, the usual counting system is different from that used by modern computing devices. Therefore, there is a certain relationship between the decimal and binary systems of counting.

To convert a decimal number into a binary, you need to divide this number by 2. For each division you should fix the balance, which will always be either 0 or 1. Then the partial is again divided by 2 and the next balance is also written. The process continues until the private becomes equal to one. After all divisions have been completed, the remainder are written in reverse order - from the last one equal to 1 and ending first.

An example of converting the number 16110 from a decimal system to a binary. In binary system the number will be 10100001_2 .

$$161/2 = 80 \text{ (remainder 1)}$$

$$80/2 = 40 \text{ (remainder 0)}$$

$$40/2 = 20 \text{ (remainder 0)}$$

$$20/2 = 10 \text{ (remainder 0)}$$

$$10/2 = 5 \text{ (remainder 0)}$$

$$5/2 = 2 \text{ (remainder 1)}$$

$$2/2 = 1 \text{ (remainder 0)}$$

$$1/2 = 0 \text{ (remainder 1)}$$

To convert an integer from binary system to decimal system it is necessary to divide it into individual bits (ranks) and multiply each bit by 2, raised to the appropriate degree. The count of the degree starts from zero and runs from right to left - from the youngest (right) bat to the oldest. After that, all the resulting works are added together and the result will be a number in the decimal system.

An example of converting the number 10100001_2 from binary to decimal. In the decimal system, the number will be 161_{10} .

$$\begin{aligned} 10100001_2 &= 1 \cdot 2^7 + 0 \cdot 2^6 + 1 \cdot 2^5 + 0 \cdot 2^4 + 0 \cdot 2^3 + 0 \cdot 2^2 + 0 \cdot 2^1 \\ &\quad + 1 \cdot 2^0 = 161_{10} \end{aligned}$$

Real numbers in computer science are called numbers having fractional part. In many programming languages they are represented with a period instead of a comma, for example 5.1.

In order to convert the decimal fraction into a binary counting system, it is necessary to convert the whole fraction into a binary system, then multiply the fraction of the fraction by 2, write down the result obtained until only the fraction of the result obtained is multiplied again by 2, Write down the resulting result number to the decimal point (0 or 1) and so on until the fraction of the multiplication result is equal to 0 or to the required number of digits after the decimal point. Then you need to write the sequence of zeros and units in order after the point separating the whole and fractional part of the real number.

An example of converting the number 1.25 from a decimal system to a binary, where the whole part in the binary system will be equal to 1. In the binary system the fraction will be equal to 1.01.

Number	Number multiplied by 2	Binary
0.25	0.5	0
0.5	1	1

Another important factor in describing binary numbers is the representation of binary negative numbers. For the description of negative numbers in binary counting system three kinds of representation are used: sign and magnitude method, ones' complement code and two's complement code [1]. In each of the types of representation, the leading degree of the binary number is a sign of the binary number, and if the character bit is zero, the number is positive, and if the character bit is one, the number is negative. This view allows to strictly separate positive and negative binary numbers.

The method of representing negative binary numbers as a sign and magnitude method is based only on the fact that the older bit of the binary number shows the number sign, and the remaining steps show the magnitude of the number by module. The key drawback of this representation of negative binary numbers is the existence of two codes for zeroes ($-0 - 100...000$ and $+0 - 000...000$), which complicates operations on numbers. An example of the representation of a positive and negative binary number in sign and magnitude method is shown in the figure. 2.

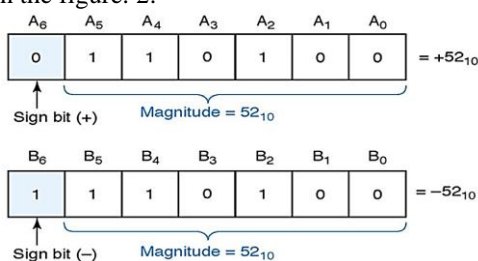


Fig. 2 - Representation of positive and negative numbers in sign and magnitude method

The method of representing negative binary numbers as ones' complement code on formation of negative binary number by inversion of positive binary number code. Similarly to the sign and magnitude method of representation of negative binary number in the form of ones' complement, it has a disadvantage expressed as having two zeros ($-0 - 111...111$ and $+0 -$

000...000). The example of the representation of a positive and negative binary number in ones' complement is shown in Figure 3.

00000010 = +2
00000001 = +1
00000000 = +0
11111111 = -0
11111110 = -1
11111101 = -2

Fig. 3 - Representation of positive and negative numbers in ones' complement

The method of representing negative binary numbers as two's complement is based on forming a previously considered ones' complement and adding a unit to its lower order bit. This method has no disadvantage in the presence of two zeros, but arithmetic operations on numbers in two's complement code. An example of the representation of a positive and negative binary number in a two's complement is shown in Figure 4.

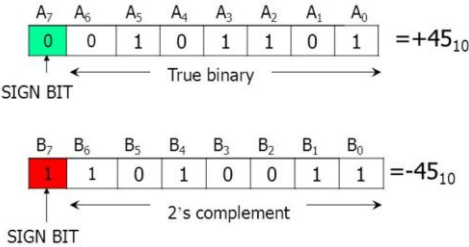


Fig. 4 - Representation of positive and negative numbers in two's complement

Another important factor when considering working with numbers in computers is to consider the features of floating-point numbers [2]. Such numbers are represented in an exponential form of notation, which is a way of expressing real numbers through mantis and order. This format is particularly useful when working with very large or extremely small numbers, and also helps to standardize their representation. Any number N in a system with a base p can be written as

$$N = M \cdot p^n,$$

where M — mantis; n — порядок.

According to the recording method, the exponential form of the number is divided into normal and normalized forms of the record. The key difference

between these forms of recording is the different representation of number mantis.

The normal form of recording is characterized by a mantis $M \in [0, 1)$, $0 \leq M < 1$. If the decimal number has a nonzero integer, then the order value will be positive. If the whole part is zero, the order takes a negative value. For example, the number 0.0000000000000000012 in normal exponential form is written as. The disadvantage of this form of writing is the ambiguity of the representation of numbers. This is expressed in different representation of the same numbers. For example, the number 0.0001 in an exponential normal form of a record can be represented as $0.12 \cdot 10^{-20}$, $0.000001 \cdot 10^2$, $0.00001 \cdot 10^1$, $0.0001 \cdot 10^0$, $0.001 \cdot 10^{-1}$

The normalized form of recording is characterized by a mantis, that is for a decimal number or a mantis, that is for a binary number. In other words, the mantis is a fractional number characterized only by a single value of the whole part and an unlimited value of the fractional part. For example, the number 1015000 in the normalized exponential form of writing is written as, or 1.015E6 (E6 is a decimal number at 6). This way of recording is characterized by uniqueness, because any number can be written down only in a single way, but the disadvantage of such a form of representation is that it is impossible to represent 0, therefore, when applying this form, a special bit for the number 0 is used. $M \in [1, 10)$ $1 \leq M < 10$ $M \in [1, 2)$ $1 \leq M < 2$ $0.15 \cdot 10^6$

Modern computers use two basic float and double data types to work with floating point numbers. The only difference between these types of data is the amount of memory they use. The float data type occupies 32 bits of computer memory, when the double data type occupies twice as much memory - 64 bits. Depending on the amount of memory occupied, the data types considered can accept modules of decimal values (without taking into account the sign) in the following intervals: float data type accepts modules of decimal values in interval $[3.4E-38; 3.4E+38)$; The double data type accepts modules of decimal values in the interval $[1.7E-308; 1.7E+308)$.

On the computer, the real number of types of floats and double kept as a normalized exponential record where the degree is 2 instead of 10. This is due to the fact that all information on the computer is coded in binary format, ie using bits. Therefore, the values for float and double will be in the ranges and respectively. For storage of numerical values in memory a strictly defined volume is allocated, which also affects the features of representation. $[3.4 \cdot 2^{-127}; 3.4 \cdot 2^{127})$ and $[1.7 \cdot 2^{-1023}; 1.7 \cdot 2^{1023})$.

As already mentioned before, when using float type each numerical value takes 32 bits of memory. For each bit in the float type, a separate task is selected.

An example of the distribution of bits in float type is shown in Fig. 5.

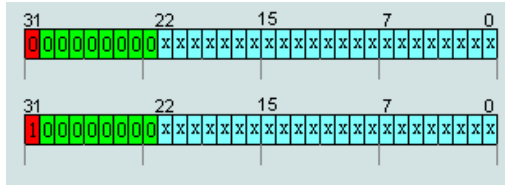


Fig. 5 - A schematic representation of the selection of memory for the number type float size in 32 bits

The first bit (red in Fig. 5) serves as a symbolic bit. Depending on its value, a float number can be positive (the character bit is 0) or negative (the character bit is 1).

The next 8 bits (green in Fig. 5) are responsible for the value of the exponent of the number. Since the exponent of a number can be both positive and negative, to define the degree sign you need to set one bit for the degree sign, however, in order not to spend one bit per sign in the exponent degree of a float number type enter a half-byte mix +127 (01111111). Thus, in the memory of the computer is stored a range of degrees not from -127 to 127, but from 0 to 254, that is all exponent values are positive and to allocate one bit under sign is not required. To reverse the actual degree of exposure from the computer's stored computer degree of exposure, it is necessary to subtract the previously set offset by half a byte.

The remaining 23 bits are responsible for the value of the number's mantis. Since float numbers are stored in computer memory in normalized form, the number mantis is within range $1 \leq M < 2$. It follows that the higher bit (whole part) of a mantis is always equal to 1. This unit is called an implicit unit, and it is not stored in the assigned 23 bits of computer memory. Therefore, only the rest of the mantis is stored in the computer memory without an implicit unit in the available 23 bits, and when processing such numbers of the mantis the number equals 24 bits taking into account the implicit unit.

As an example, let's consider how the number -4.25_{10} of type float is represented in computer memory. To begin with, we will translate the number into a binary system of counting the number module. The integer part of the number is 4, which in a binary system would be 100, and the fractional part of the number is 0.25, which in a binary system would be 0.01. Thus, the number in the binary system of enumeration will be -100.01_2 . Next, convert the number obtained in the binary system to an exponential normalized form

$$-100.01_2 = -1.0001 \cdot 2^2.$$

Based on the obtained number, the bit in the computer memory is equal to 1, since the number is negative. The exponent in computer memory will be defined by expression. From the mantis we throw an implicit unit, fill the remaining minor bits with zeros and get 000100000000000000000000. Thus, the number -4.25_{10} type float in computer memory will be stored as follows $2 + 127 = 129_{10} = 10000001_2$

1 10000001 000100000000000000000000

The storage of double-precision floating-point numbers in computer memory is carried out in the same way as for float numbers, with some differences in characteristics. A double-precision number occupies 64 bits in memory. These bits are distributed as follows (from left to right): a sign bit; the exponent, which is allocated 11 bits for double numbers. An exponent bias is also applied, which for double numbers is +1023; and the mantissa (the significant part), which is allocated 52 bits. As with float numbers, the integer part of the mantissa (the implicit leading one) is not stored in memory.

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2. Real numbers in computer memory. Explanation. [Electronic resource]/ JAVARUSH. — URL: <https://javarush.com/groups/posts/3997-vejshestvennihe-chisla-v-pamjati-kompjuteru>

UDC 511.11

SUM OPERATION OF FLOATING-POINT NUMBERS IN DIGITAL CIRCUITS

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Аннотация. The article discusses the operation of summing floating-point numbers and a scheme for its implementation in processor systems. Unlike floating-point integers, represented in the IEEE 754 standard, they consist of three parts: a sign, an exponent, and a mantissa. Operations are divided into work with all components, which complicates this operation.

Ключевые слова: ПЛИС, система счисления, двоичные числа, System Verilog, числа с плавающей точкой.

Annotation. In this article results of overview methods for increasing the bandwidth of microstrip patch antennas are presented. The multi-resonator, multi-layer and slots methods are considered. It is shown that using the multi-resonator method of increasing the bandwidth of a microstrip patch antenna allows to achieved a bandwidth of up to 9 % of the resonant frequency, however, it's a significant increase the dimensions of the structure. Using the multi-layer method allows to achieved a bandwidth of up to 8,5 % of the resonant frequency with a significant complication of the structure. Using the slots method allows to achieved a bandwidth of up to 8 % of the resonant frequency, however, it's reducing the efficiency of the patch.

Keywords: FPGA, numeral system, binary numbers, SystemVerilog, floating point numbers.

Introduction

Floating-point adders are key components in the arithmetic logic units (ALUs) of processors, graphics accelerators, and other computing systems. Unlike integer adders, working with floating-point numbers requires accounting for the exponent and mantissa, which significantly complicates the device architecture.

Adding such numbers involves several stages: aligning the exponents, adding the mantissas, normalizing the result, and rounding. Each of these stages requires specialized hardware solutions, making the design of efficient adders a complex engineering task.

This paper examines the fundamental principles of constructing floating-point adders, including methods for handling exponents, adding mantissas, and optimizations aimed at improving speed and reducing hardware costs. Special attention is given to modern approaches such as pipelining and overflow prediction, which accelerate operations in high-performance computing systems.

The relevance of the topic is driven by the increasing demands for precision and speed in calculations, machine learning, and computer graphics, where floating-point operations are particularly intensive.

Main Part

Unlike integers, floating-point numbers, as defined in the IEEE 754 standard, consist of three parts: the sign, the exponent, and the mantissa.

The development of modern processor systems is implemented using hardware description languages such as System Verilog/VHDL. These languages allow the description of the behavior of a circuit. They allow the use of text to show which components system should include and how they should be connected.

Synthesizers have been created for hardware description languages, allowing them to be automatically converted into bitstreams that are loaded onto FPGAs and define their corresponding structure.

To demonstrate working with floating-point numbers in Verilog, consider an adder for two 32-bit floating-point numbers.

Figure 1 shows the representation of a 32-bit floating-point number.

sign	exponent	mantissa
0	10001111	01100010100110011000000

Figure 1 — Representation of a 32-bit floating-point number in the IEEE-754 standard

The 1st bit indicates the sign of the number, the next 8 bits represent the exponent (the power of two by which the mantissa will be multiplied +127 to support negative exponents), and the remaining 23 bits represent the mantissa.

To obtain the real number, consider the example from Fig. 1:

a) Add a one to the left of the mantissa, place the entire mantissa in the fractional part, and convert the number from binary to decimal.

$$1.01100010100110011000000 = 1.385154724121$$

b) Multiply the resulting number by $2^{\text{exponent}-127}$

$$1.385154724121 * 2^{142-127} = 12620.75$$

c) The sign bit is 0, so the result is 12620.75.

Adding such numbers is not as simple as summing the bits, as is done with integer operations.

The task is divided into adding numbers with the same sign and numbers with different signs. The initial data for the first case is shown in Fig. 2.

	sign	exponent	mantissa
1st number	0	10011111	11100010100110011000000
2nd number	0	10011100	11010110000100010100011

Figure 2 — Data for adding two numbers with the same sign

The algorithm for adding numbers with the same sign is as follows:

a) A 1 is appended to the mantissas, and the mantissa size is 24 bits.

1.01100010100110011000000

1.11010110000100010100011

b) The exponents of both numbers are compared, and the mantissa of the number with the smaller exponent is shifted right by the difference in exponents.

10011111 = 159

10011100 = 156

0.00101010110000100010100011

c) The mantissas are added as ordinary unsigned integers, considering overflow.

+ 1.11100010100110011000000

0.00101010110000100010100011

10.10001101010110111010100011

d) The larger of the operands' exponents is taken as the result's exponent.

10011111 = 159

e) Normalization of the number (necessary to maintain precision over time). If the resulting mantissa has a 1 in the 25th position (carry from addition), the mantissa is shifted right by 1, and the result's exponent is incremented by 1. If the resulting mantissa starts with 0, it is shifted left until the 24th position becomes 1. With each shift, the result's exponent is decremented by 1.

1.010001101010110111010100011

159 + 1 = 160

f) The result's sign is taken from either operand, the exponent from step D, and the 23 least significant bits are taken from the mantissa obtained in step D.

Result: 0_10100000_01000110101011011101010.

For adding numbers with different signs, in step B, the smaller mantissa should be subtracted from the larger one. If the mantissas had to be swapped for correct subtraction, the result's sign, initially equal to the sign of the first number, should also be changed to the opposite.

The flowchart of the operation is shown in Figure 3.

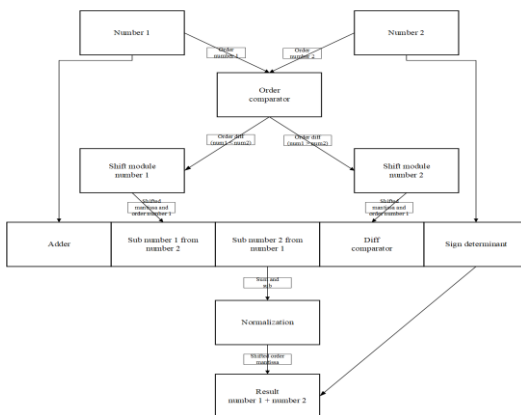


Figure 3 — Flowchart of the floating-point addition operation

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2. Представление числе в ЭВМ [Электронный ресурс] / MSU. — Режим доступа: <https://al.cs.msu.ru/static/classes/NumberRepresent.pdf>

UDC 621.391

DEVELOPMENT AND IMPLEMENTATION OF A BAND-PASS FILTER FOR THE FREQUENCY RANGE OF 268—298 MHz

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Аннотация: В этой статье представлена разработка и реализация полосно-пропускающего фильтра (ППФ), состоящего из последовательно-соединенных фильтров высоких (ФВЧ) и низких частот (ФНЧ) в диапазоне рабочих частот 268 — 298 МГц. Была разработана принципиальная схема и топология печатной платы фильтра, а также изготовлена печатная плата

Ключевые слова: полосно-пропускающий фильтр, системы связи, системы автоматизированного проектирования (САПР).

Annotation. This report represents the development and implementation of a band-pass filter composed of a series-connected high-pass filter (HPF) and low-pass filter (LPF) in the frequency range of 268—298 MHz. The schematic diagram and PCB layout of the filter were designed, and the printed circuit board was fabricated.

Keywords: band-pass filter, communication systems, computer-aided design (CAD).

Introduction

In terrestrial communication systems, there is a need to improve the quality of radio communication in environments with high interference. One solution is the use of a band-pass filter, which reduces interference from adjacent radiation sources by suppressing unwanted signals in communication channels.

This report describes the calculation, synthesis, and implementation of a band-pass filter realized through the series connection of HPF and LPF.

Main section

A seventh-order band-pass filter for the 268–298 MHz range was designed under the order of "Uranis-Radiosystems." The filter circuit was synthesized using the Filter Solutions software. The seventh-order design ensures a steep roll-off of the frequency response at the passband edges and the required suppression in the stopband [2]. The filter was implemented as two series-connected HPF and LPF. The calculation results are shown in Fig. 1 (a – HPF, b – LPF).

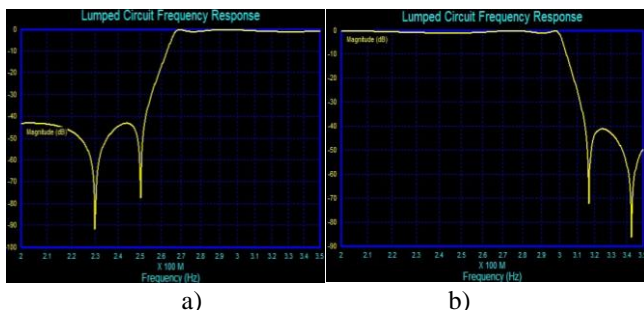


Fig. 1 — Frequency response of the filters: a) HPF; b) LPF

Based on the obtained data, the schematic diagram (Fig. 2) and PCB layout of the filter (Fig. 3) were created in Altium Designer CAD software. In the schematic diagram, to improve electrical parameters, some capacitors were replaced with two parallel-connected capacitors [2]. Various design solutions were implemented in the PCB layout. The inductors were positioned perpendicular to each other to minimize their mutual interaction. Vias were drilled to connect the layers [3]. To reduce conductive interference, a non-conductive area was created on the bottom layer. The trace width was set to 1 mm.

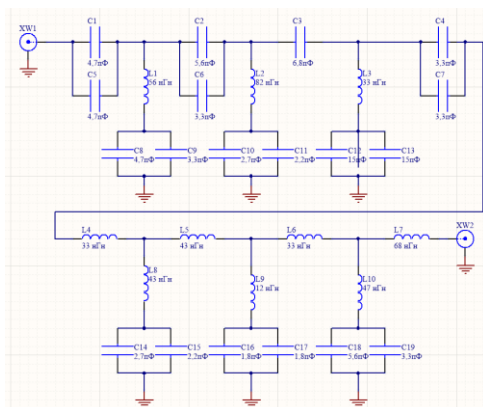


Fig. 2 — Schematic diagram of the filter

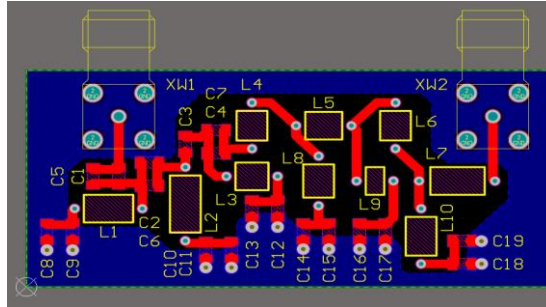


Fig. 3 — PCB layout of the filter

For fabrication, GERBER and DRILL files (layers and vias files, respectively) were generated and sent to the PCB manufacturer "Rezonit" [2]. The board was made of two-layer fiberglass with a thickness of 1.5 mm. Capacitors with the required values and 0805 package size were selected, and the parameters of the inductors (winding length, wire length, and number of turns) were calculated using the Coil64 application. Fig. 3 and 4 show screenshots from the software for inductors of 12 nH and 82 nH as an example.

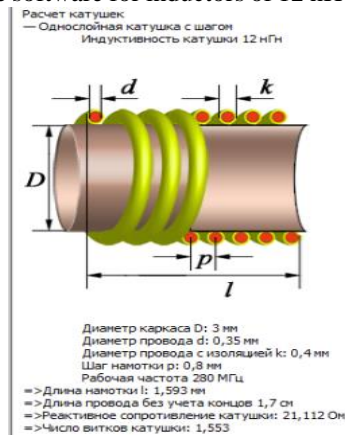


Fig. 4 — Calculation of a 12 nH inductor

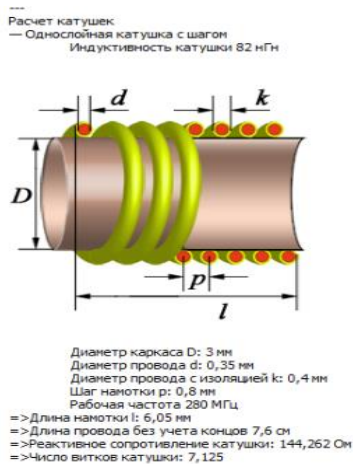


Fig. 5 — Calculation of a 81 nH inductor

The inductors were wound according to the calculated parameters using 0.4 mm diameter copper wire [1]. SMA connectors were implemented for the board's input and output. The capacitors were selected in 0805 package size. After receiving the fabricated PCB and components, the assembly process was completed [3]. The fully assembled filter PCB is shown in Fig. 5.

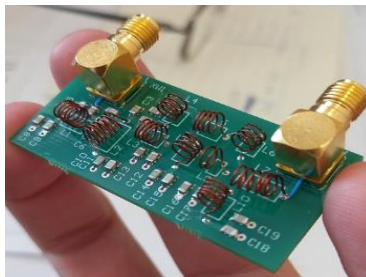


Рис. 6 — Assembled filter

Initial measurements (Fig. 6) revealed performance discrepancies from expected results, prompting a tuning procedure. This involved:

- Adjusting the inter-turn spacing of inductors
- Modifying the number of winding turns
- Optimizing capacitor values
- Separate tuning of HPF and LPF sections by isolating their circuits.

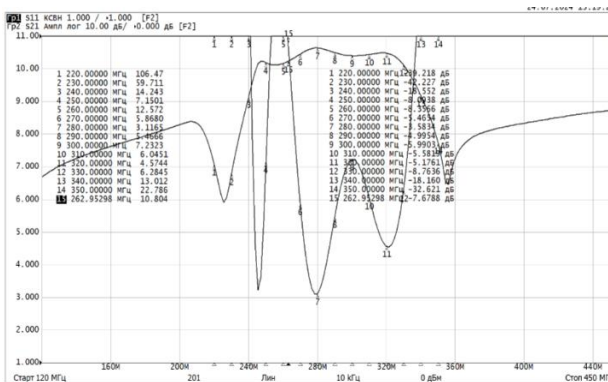


Fig. 7 — Initial output data

The post-tuning measurement results are presented in Fig. 7.

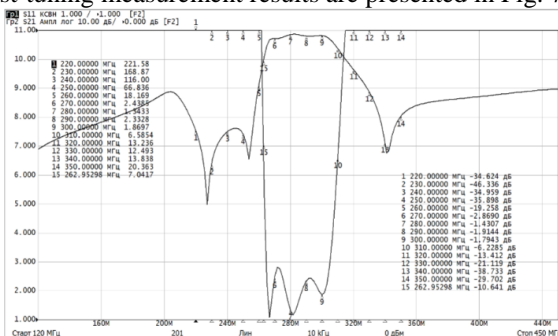


Fig. 8 — Output data after adjusting capacitors and inductors

Following final precision adjustments, the filter achieved compliance with all specified requirements. Fig. 8 displays the frequency response characteristics showing:

- Transmission coefficient within the -3dB passband limits
- VSWR reaching 1.5 at minimum point
- Satisfactory out-of-band suppression meeting all specifications

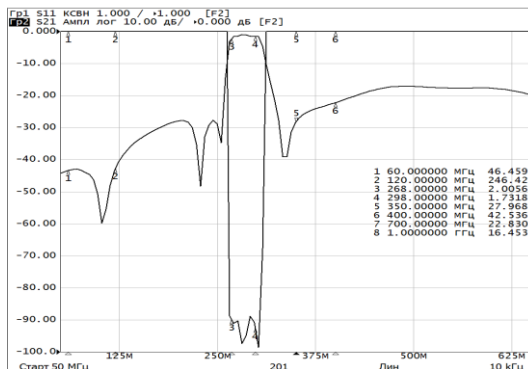


Fig. 9 — Final output data

Conclusion

The development successfully produced:

- complete schematic and PCB layout for a 7th-order band-pass filter
- functional prototype operating in 268-298 MHz range.

Through proper component selection, precise assembly, meticulous tuning, and design optimizations, the final implementation demonstrated full compliance with the technical requirements. The achieved performance parameters validate the design methodology and implementation approach.

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UDC 621.391

DESIGN AND IMPLEMENTATION OF MATCHING CIRCUITS FOR AN EMERGENCY RADIO BEACON ANTENNA

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Аннотация. В докладе рассматриваются разработка и реализация согласующих цепей для антенны аварийного радиобуя. Проанализированы методы разработки согласующих схем в УКВ- и СВЧ-диапазонах. На рисунках показано, что КСВН в большинстве случаев соответствует поставленным требованиям, а также, что антенна чрезвычайно чувствительна в сверхвысокочастотном диапазоне. Поэтому дальнейшему рассмотрению подлежат методы изоляции антенны, например специальная самоклеящаяся металлизированная лента в специальном пластиковом корпусе

Ключевые слова: системы автоматизированного проектирования (САПР), антенна радиобуя, коэффициент стоячей волны, цепь согласования, метод согласования двухконтурной цепью.

Annotation. In this report the design and implementation of matching circuits for an emergency radio beacon antenna is considered. The methods of development of the matching circuits in VHF and UHF ranges have been analyzed. It is shown in the figures that the VSWR in most cases meets the requirements, and so is shown that the antenna is extremely sensitive in the UHF range, so the antenna isolation methods are on further consideration, such as special self-sticking metallic cover in the special plastic casing.

Keywords: computer-aided design (CAD), radio beacon antenna, VSWR, matching circuit, dual-circuit matching method.

The antenna (Figure 1) is part of an emergency radio beacon and operates at three frequencies: 121.5 MHz (*AIS*), 162 MHz (*IDF*), and 406 MHz (*COSPAS-SARSAT*). The antenna can be connected to the transmitter in two

ways: either through a switch to one of three transmitters, each tuned to its own frequency, or through a switch to one of two transmitters, one of which is frequency-tunable in the range of 121.5–162 MHz (*AIS*). Accordingly, either three different matching circuits are required, each being an *LC* circuit, or two matching circuits, one of which is a dual-band filter. The essence of the dual-frequency matching method lies in replacing the elements of the L-section with resonant circuits. The circuit elements are selected so that at the resonance frequency, the parallel circuit has infinite impedance, and the series circuit corresponds to a single L-section, i.e., has zero impedance. The input impedance of the antenna system at the point of connection to the matching device was measured using a *KEYSIGHT E5063A* spectrum analyzer. The results were saved in *TOUCHSTONE* format for further synthesis and simulation.



Figure 1 — Researched antenna

Using the obtained data, *LC* matching circuits for the specified frequencies were synthesized in the *AWR DE CAD* system for the first implementation option. Each circuit is shown in Figure 2: a) L-section (121.5 MHz), b) mid-shunt section (162 MHz), and c) mid-shunt section (406 MHz).

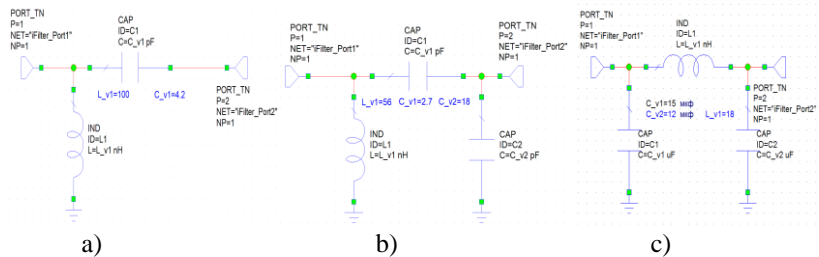


Figure 2 — Synthesis results

Next, each matching device was assembled on the radio beacon circuit board [1]. The voltage standing wave ratio (VSWR) was measured at the input

of each matching device using the *OBZOR-304/1* spectrum analyzer (Figures 3–5) (Table 1).

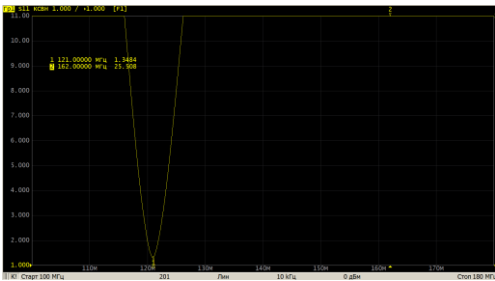


Figure 3 — VSWR of the signal at 121,5 MHz



Figure 4 — VSWR of the signal at 162 MHz

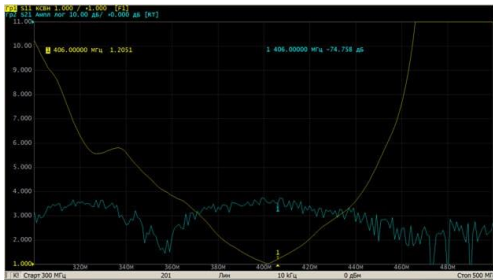


Figure 5 — VSWR of the signal at 406 MHz

Table 1. Antenna VSWR measurement results

Frequency, MHz	121,5	162	406
VSWR	1,35	2,36	1,21

The calculated VSWR values fully meet the technical requirements

Similarly, matching circuits were synthesized for the second implementation option of the transmitter connection, but this time one of the matching chains was designed as a dual-circuit filter (Figure 6). The basic method for constructing dual-frequency matching circuits is the L-section matching method. Using such a section, consisting of two lumped reactive elements, it is possible to transform any active load resistance to any active transmission line resistance. The matching chain for the 406 MHz frequency range remained unchanged compared to the first implementation option.

Using the *AWR Design Environment* CAD system, the VSWR at the input of the dual-frequency matching circuit was measured (Figure 7).

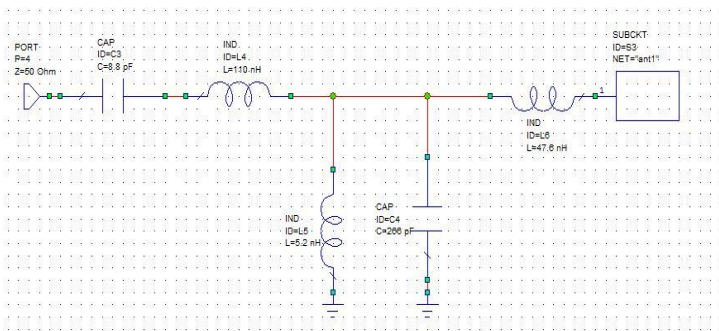


Figure 6 — Synthesis results

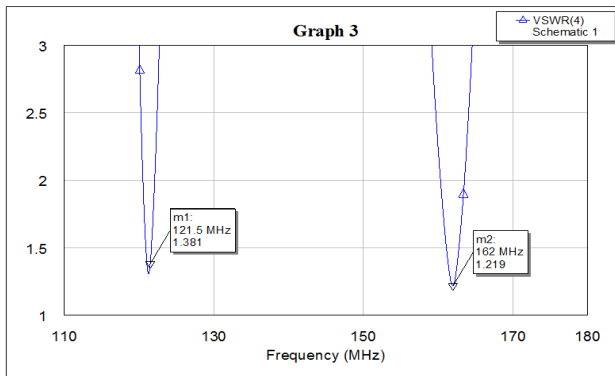


Figure 7 — VSWR of the dual-frequency matching circuit

Conclusion

Thus, two different implementations of antenna and transmitter matching circuits for an emergency radio beacon antenna have been developed. Due to accurate calculations and the correct choice of matching circuits, the output parameters fully meet the technical requirements.

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SIGNAL-CODE CONSTRUCTIONS IN THE 6TH GENERATION MOBILE COMMUNICATION SYSTEM

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Аннотация. В данной статье рассматриваются перспективные методы модуляции и кодирования информации, применяемые в системах мобильной связи шестого поколения (6G). Проведен детальный анализ технологий квадратурной амплитудной модуляции (QAM) и амплитудно-фазовой манипуляции (APSK) для различных сценариев использования: расширенной мобильной широкополосной связи (eMBB), сверхнадежной связи с низкой задержкой (URLLC) и массового интернета вещей (mIoT). Исследованы современные методы помехоустойчивого кодирования, включая полярные коды, LDPC, турбокоды и перспективные AI-коды, с оценкой их эффективности в зависимости от условий передачи. Особое внимание уделено техническим требованиям к радиотракту, проблемам обработки сигналов, а также закономерностям пик-фактора мощности (PAPR) в различных сигнальных созвездиях. Рассмотрены актуальные направления исследований в рамках консорциумов 3GPP, ITU и IEEE, включая интеграцию искусственного интеллекта (ИИ).

Ключевые слова: 6G, QAM, APSK, полярные коды, LDPC, турбокоды, AI-коды, eMBB, URLLC, mMTC, PAPR

Annotation. This paper discusses promising modulation and information coding techniques used in sixth generation (6G) mobile communication systems. Quadrature Amplitude Modulation (QAM) and Amplitude Phase Shift Keying (APSK) technologies are analysed in detail for different usage scenarios: enhanced mobile broadband (eMBB), ultra-reliable low latency communication (URLLC) and mass Internet of Things (mIoT). State-of-the-art interference-resistant coding techniques, including polar codes, LDPC, turbo codes, and promising AI codes, are investigated, with an evaluation of their performance as a function of transmission conditions. Special attention is paid to technical requirements for the radio path, signal processing problems, and peak power factor ratio (PAPR) patterns in different signal constellations. Current research directions within the 3GPP, ITU and IEEE consortia, including the integration of artificial intelligence (AI), are reviewed.

Keywords: 6G, QAM, APSK, polar codes, LDPC, turbo codes, AI codes, eMBB, URLLC, mMTC, PAPR

Introduction. The development of sixth-generation (6G) mobile networks aims to achieve extreme data transmission parameters: speeds of over 1 Tbps, latency of less than 0.1 ms and support for up to 10 million devices per square kilometre. These requirements form three key usage scenarios.

The eMBB (Enhanced Mobile Broadband) scenario — high-speed data transmission for multimedia applications. URLLC (Ultra-Reliable Low-Latency Communications) scenario — ultra-reliable communication with minimal latency (industrial IoT, autonomous systems). The mMTC (massive IoT) scenario — energy-efficient solutions for the massive Internet of Things. These scenarios require innovative modulation and coding methods that provide high spectral efficiency, immunity to interference and energy efficiency. The works of Pokamestov D.A. [1] emphasises the importance of adaptive algorithms capable of dynamically adjusting to channel conditions. The purpose of this paper is to conduct a comprehensive analysis of 6G signal-code designs, to evaluate their applicability in different scenarios and to outline promising directions of development.

Main part. In most cases, a new generation of mobile communication systems appears approximately every ten years. The first commercial network of the previous, fourth generation, 4G LTE (Long Term Evolution) was launched in 2009. And the fifth generation commercial networks, 5G NR (New Radio), started to be deployed in 2019 and are still developing [1].

Research on 5G NR by the International Telecommunication Union (ITU) under the IMT-2020 (International Mobile Telecommunications) project

started back in 2013, and its technical requirements were adopted in 2017. At the same time, the global consortium 3GPP (Generation Partnership Project) joined in the formation of the technical appearance of future networks. In 2016, the development of the fifth version, 5G NR, began, and already in 2017 the first specifications appeared. To date, work continues on the 18th and 19th versions of the specifications.

In most cases, 5G NR networks meet the current needs of users. However, technology continues to evolve, new services and services are emerging, and the amount of transmitted traffic increases exponentially every year. Large companies and startups are working on virtual and augmented reality applications that require low-latency and high-bandwidth connectivity.

In addition, the concept of IoT (Internet of Things) is transforming into IoE (Internet of Everything), according to which many devices will have access to the network [1].

Analysing modulation techniques for 6G. Quadrature Amplitude Modulation (QAM). QAM remains one of the most common modulation techniques due to its high spectral efficiency.

In 6G, schemes up to 4096-QAM are considered, but their application is limited by signal-to-noise ratio (SNR) requirements. For eMBB, high modulation orders (256-QAM, 1024-QAM) are used to achieve transmission rates up to 100 Gbps.

However, this increases the sensitivity to noise and nonlinear distortion in the radio path. For URLLC, lower orders (16-QAM, 64-QAM) are used to ensure transmission reliability. For mMTC, QPSK and 16-QAM with adaptive power control to minimise power consumption are optimal.

The challenges of QAM are related to high PAPR (Peak-to-Average Power Ratio) reaching 10-12 dB for 256-QAM, which requires the use of linear power amplifiers with low efficiency. Also sensitivity to phase noise and inter-symbol interference.

The review presents the current trends, usage scenarios, applications, services and services that are predicted to emerge in the future. Projected technical requirements for new networks are given: latency, transmission speed, spectral efficiency, and others.

An overview of the key technologies that enable these high performance communications is presented.

Amplitude Phase Shift Keying (APSK), unlike QAM, uses a circular arrangement of points in a constellation, which reduces PAPR and improves robustness to nonlinear distortion.

Table 1 — Comparison of QAM and APSK in a 6th generation mobile communication system environment

Parameter	QAM	APSK
Frequency efficiency	High	Normal
PAPR	High (10-12 dB)	Low (6-8 dB)
Resistance to nonlinearities	Low	High
Application	eMBB	URLLC, mMTC

Its some of the advantages are — PAPR is 30% lower than QAM [2] which simplifies the design of power amplifiers, also better robustness in fading channels. URLLC scenario application — 16-APSK and 32-APSK provide reliable transmission with moderate spectral efficiency.

Application for mMTC scenario — is energy efficiency through optimised power distribution.

Interference tolerant coding methods also play an important role in the delivery of information messages without loss of the original state. Polar Codes (Polar Codes), proposed by Arikan [3], are close to the channel capacity and are especially effective for short packets. This allows messages to be encoded and decoded at a higher rate and lower latency. For URLLC scenario — provide Block Error Rate (BLER) $<10^{-5}$ at low latency. Disadvantages: High computational complexity of decoding (SCL algorithm). LDPC codes (Low-Density Parity-Check) are widely used in 5G and remain relevant for 6G. They are the main way to transmit ultra-massive data streams up to 20 Gbit/s and for 6G up to 1 Tbit/s. For the eMBB scenario — support high encoding rates. For mMTC scenario — adaptive LDPCs reduce power consumption by 20% [4].

Turbo codes used in 4G are inferior to LDPC and polar codes due to high iterative decoding delay. AI-codes, a promising direction is the use of neural network decoders adapting to channel changes in real time. Applications — eMBB, satellite communications. Advantages — automatic optimisation of coding parameters. One of the important for qualitative and fast efficient method of information transmission in wireless communication channel is technical requirements to the radio path of radio modules of base stations. These are analogue components - linear power amplifiers (PA) with efficiency $> 60\%$. It is digital processing — digital pre-distortion algorithms to compensate for nonlinearities. PAPR parameter - Partial Transmit Sequence (PTS) and Selected Mapping (SLM) methods, methods to reduce peak-to-average power ratio (PAPR) in Orthogonal Frequency Division Multiplexing (OFDM) systems.

Conclusion. 6G signal-code constructions require a complex approach. Based on the currently considered methods of information transmission mastered in mobile communication system, promising research in 6G is

proposed — hybrid modulation schemes (QAM/PSK with dynamic switching) similar to MCS in the 5th generation, also AI-optimised signal constellations, and reconfigurable intelligent surfaces (RIS) [1] for wireless channel management. Currently, there is an active R&D effort by consortia such as 3GPP, ITU, IEE and others to standardise 6G by 2030.

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UDC 621.391

FEATURES OF THE IMPLEMENTATION OF A LAB STAND FOR BGP STUDY

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Аннотация. В статье рассмотрены возможности и необходимость протокола BGP в условиях роста интернет-инфраструктуры. Изучены возможности программной реализации BGP версии 4, включая многопротокольные расширения, и предлагается разработка стенда для мониторинга сессий, что позволит повысить надежность маршрутизации,

сравнить протоколы маршрутизации и увеличить безопасность сетевых решений.

Ключевые слова: BGP, протокол, мониторинг.

Annotation. In the paper, the importance and capabilities of the BGP protocol in the context of the growing Internet infrastructure are considered. The possibilities of the software implementation of BGP version 4, including multiprotocol extensions, have been studied, and the development of a session monitoring stand is proposed, which will improve routing reliability, compare routing protocols, and increase the security of network solutions.

Keywords: BGP, protocol, monitoring.

INTRODUCTION

BGP (Border Gateway Protocol) is becoming increasingly relevant in the context of the rapid growth of Internet infrastructure and the increasing value of network threats. BGP plays a key role in providing the routing information between autonomous systems (AS), and its correct operation is critically important for the stability and security of the global network.

However, despite its importance, BGP is susceptible to various vulnerabilities such as routing attacks and accidental configuration errors.

One of the main issues in this area is the ability to track and monitor BGP sessions to identify anomalies and prevent potential attacks. Effective monitoring methods can significantly improve routing reliability and reduce the risks associated with errors or malicious. Thus, BGP research not only contributes to a deeper understanding of its work, but also helps to develop more secure and sustainable network solutions.

THE MAIN PART

1. BGP Protocol Analysis

The Border Gateway Protocol (BGP) is an inter-domain routing protocol designed to provide loop-free routing between separate routing domains that contain independent routing policies (autonomous systems). The Cisco BGP Version 4 software implementation includes multi-protocol extensions that allow BGP to transmit routing information for IP multicast routes and multiple Layer 3 protocol address families, including IP version 4 (IPv4), IP version 6 (IPv6), and virtual Private networks version 4 (VPNv4).

BGP is mainly used to connect a local network to an external network to gain Internet access or to connect to other organizations. When connecting to an external organization, external BGP (eBGP) peer-to-peer sessions are created. Although BGP is referred to as the External Gateway Protocol (EGP), many networks within an organization become so complex that BGP can be used to simplify the internal network used within an organization. BGP peers

within the same organization exchange routing information through internal BGP Peering Sessions (iBGP).

2. Development of a laboratory stand

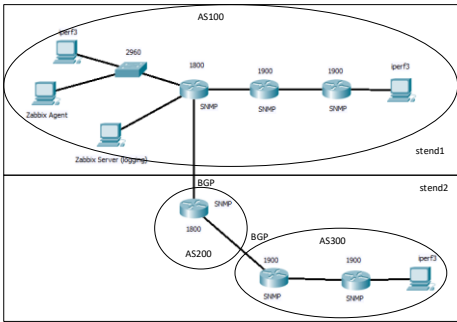
The base telecommunication rack is available to design the laboratory stand for BGP study, which is shown in Figure 1 and 2.



Figure 1 — *The base with* available equipment and interfaces of the routers 1900, 1800 for laboratory stand

However, the available equipment needs to be analyzed in order to solve the problem of implementing a BGP stand based on existing equipment, so the analysis of the capabilities of laboratory routers was carried out. There are six 1900 Series routers and two 1800 series routers available for traffic analysis and protocol capabilities. The traffic can be collected and display on a PC using Zabbix's universal monitoring tool to identify anomalies, compare protocols, and monitor BGP operations

The stand to study of BGP has been designed, the block diagram and the initial configuration for ASs are shown in Figure 2.



```

R3#
int loopback 0
ip address 192.168.200.1 255.255.255.0
router bgp 200
neighbor 192.168.300.1 remote-as 300
neighbor 192.168.300.1 ebgp-multihop
neighbor 192.168.300.1 update-source loopback 0
network 192.168.200.0
ip route 192.168.300.0 255.255.0.0 51.250.0.1

R2#
router rip
network 192.168.1.0
network 51.150.0.0
network 192.168.100.0
passive-interface gig
redistribute bgp 100 route-map METRICSETLAB
router bgp 100
neighbor 51.150.0.2 remote-as 200
network 192.168.100.0
route-map METRICSETLAB permit 10
match ip-address 1
set metric 2
route-map METRICSETLAB permit 20
set metric 5
access-list 1 permit 192.168.200.0 0.0.255.255

```

Figure 2 — Block diagram and the initial configuration of the routers
So, the stand capabilities are:

- to analyze the BGP protocol traffic in the network using logging on routers (SNMP) and displaying parameters in web interface of the Zabbix Server
- to create the traffic between the elements in different autonomous systems;
- to create the various of realization of the BGP;
- to analyze the traffic and information transfer between routes from the BGP routing domain to the internal OSPF routing domain;
- to imitate the connection the enterprise network to the several providers.

3. Monitoring and Maintenance

To monitor and analyze the traffic from the different routers, the Zabbix Server should be installed on the Archlinux platform, as well as Server to collect the SNMP logging from the routers

Figure 3 shows a part of the zabbix monitoring program, specifically the programs tab where you can configure the host.

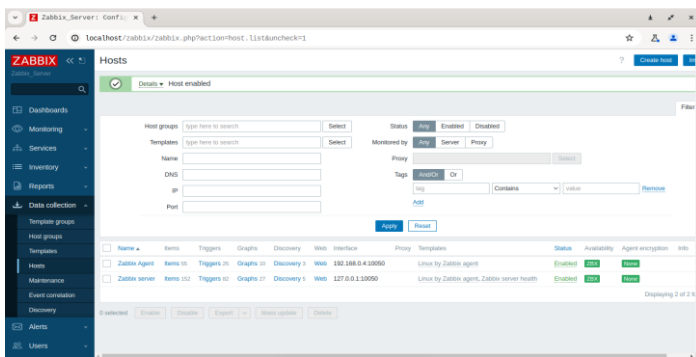


Figure 3 — Zabbix monitoring program interface (host configuration)

CONCLUSION

Thus, the lab stand has been designed for tracking and monitoring BGP sessions.

The possibility of tracking the protocol, its parameters, and delays has been identified. The possibility of comparing and improving the monitoring method to eliminate vulnerabilities is considered.

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UDC 004.738.5

A SYSTEM FOR AUTOMATING REQUESTS FOR STUDENTS' SCHEDULES USING A TELEGRAM-BOT

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Аннотация. Темой настоящей статьи является использование Telegram-бота для реализации системы автоматизации получения расписания занятий в удобном формате. Использование системы обеспечивает извлечение актуального расписания по запросу студента из общего файла с минимальными временными затратами. Рассмотрены ключевые инструменты работоспособности системы автоматизации получения расписания, такие как программное обеспечение чат-бота и программное обеспечение взаимодействия с excel-файлом.

Ключевые слова: Telegram, автоматизация расписания, бот, информационная система., программное обеспечение.

Annotation. The topic of this article is the use of a Telegram bot to implement an automation system for obtaining class schedules in a convenient format. Using the system ensures that the current schedule is extracted from a shared file at the student's request with minimal time. The key performance tools of the schedule automation system, such as chatbot software and software for interacting with an excel file, are considered.

Keywords: Telegram, schedule automation, bot, information system, software.

INTRODUCTION

Recently, modern information technologies have begun to play a special role in the curriculum management system, as they make it possible to optimize the organization of educational processes. The widespread use of messengers, such as Telegram, makes it possible to create systems for transmitting information with high efficiency. In the current reality, there is a need for instant access to up-to-date information about the schedule of classes for students of Sevastopol State University. This study presents an automated solution for providing students with a class schedule using a Telegram bot.

To begin with, a multifactorial analysis of the university's schedule management tools was conducted, taking into account their shortcomings and limitations. The results of the analysis allowed us to develop a solution involving the use of the Telegram service and a specialized module for processing Excel files. The system structure was developed taking into account the possibility of further scaling of the project while maintaining the overall flexibility of the system and an easy-to-use interface.

Our proposed solution has a whole list of important advantages:

1. Access from any device is provided by Telegram's cross-platform compatibility.
2. Users will always have up-to-date schedule information, as a real-time update feature is provided.
3. New users will not need to learn how to use the system for a long time, due to the intuitive clarity of the interface.
4. Complex planning scenarios are implemented thanks to reliable data processing and analysis capabilities.

It can be assumed that in the future the system has a huge potential for scaling by introducing it into other university services, as well as adding a personalized notification function. Successful integration of this solution will show how modern communication technologies can meet the practical challenges and needs of academic administration.

The fact that using our system significantly increases the convenience of using the timetable for students and teachers tells us that the project really corresponds to modern trends in digital education. So, the integration of the

Telegram bot with the university's schedule distribution system provides an effective and reliable alternative to existing traditional methods, as it provides access to real-time information and reduces the administrative burden in general.

THE MAIN PART

The system architecture consists of two key components. The Telegram bot is a system that connects the user's request with the server. The data processing module is responsible for working with current Excel schedule files. The server part of the system ensures data storage and timely updating. Implementation via the Telegram API allows for reliable message delivery to users.

The system's operating principle is based on a step-by-step request processing algorithm. The user interacts with the bot via a specially developed interactive menu for selecting options. The system sequentially requests and processes the necessary parameters, such as institute, course, student group. A special module extracts and processes information from the Excel schedule files. After processing, the data is formatted and transmitted to the user via the Telegram API.

The technical implementation of the system has a number of important features. The Python programming language was used to develop the bot in combination with the aiogram library, which ensures reliable interaction with the Telegram API. Excel files are processed using the Pandas library, which allows you to effectively work with tabular data.

The system is implemented with potential scaling and deployment on the basis of other universities. The procedure for updating schedules is maximally simplified for system administrators.

The user interface is based on the linear selection of all parameters, based on which the schedule is then displayed. An intuitive menu is implemented using built-in buttons, which speeds up the interaction process.

The interface is adapted for correct display on various devices, including smartphones, tablets and computers.

The visual representation of the system includes a diagram of the interaction of components (Figure 1) and an example of a Telegram bot interface with a schedule request (Figures 2 and 3).

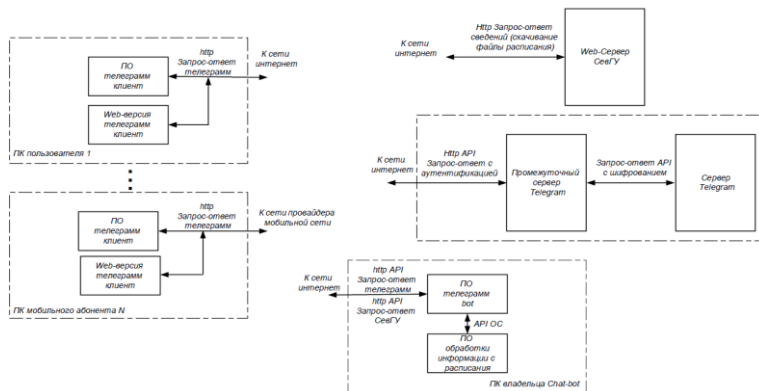


Fig. 1. Visual representation of the system

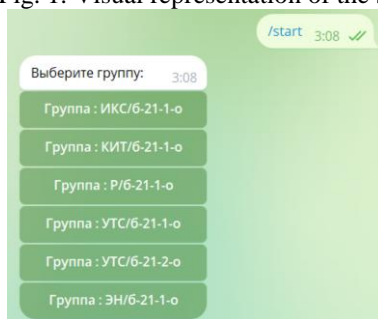


Fig. 2. Example of the Telegram bot interface

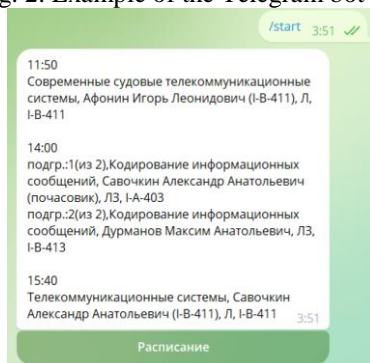


Fig. 3. The result of the Telegram bot's work

These materials clearly demonstrate the logic of operation and the convenience of interacting with the system.

The developed solution is a balanced combination of technological reliability and ease of use. The flexible architecture of the system makes it easy to adapt it to changing requirements. The cost-effectiveness of the solution makes it attractive to educational institutions. The implementation of this system makes it possible to significantly optimize the process of access to up-to-date schedule information for all participants in the educational process at the university.

CONCLUSION

The developed Telegram-based schedule management system for university successfully demonstrates how chatbot technology can optimize academic administration, providing students and staff with instant access to schedules while reducing administrative workload. Its efficient architecture, built on Python with aiogram and Pandas libraries, ensures reliable performance under significant daily loads while maintaining user-friendly multilingual interfaces.

Future enhancements, including deeper university system integration and advanced notifications, will further strengthen its role as a cost-effective digital solution for educational institutions.

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MODES OF MOTION OF THE BALL FEED IN PLANETARY AND BALL MILLS

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Аннотация. Данная статья представляет собой обзор и анализ направленный на сравнение режимов движения шаровой загрузки в планетарной и шаровой мельнице в контексте механической активации материалов. В работе рассмотрены основные понятия и принципы механической активации, представлены различные режимы движения шаров с подробными пояснениями и иллюстрациями. Данная работа позволяет лучше понять процессы, происходящие в мельницах, и оптимизировать условия для достижения получения композитного порошка для изготовления изделий методом селективного лазерного плавления.

Ключевые слова: Механическая активация, режимы движения, планетарная мельница, шаровая мельница

Annotation. This article is a review and analysis of the modes of ball loading motion in planetary and ball mills in the context of mechanical activation of materials. The paper reviews the basic concepts and principles of mechanical activation, presents different modes of ball motion with detailed explanations and illustrations. This work allows to better understand the processes occurring in mills and optimize the conditions to achieve the production of composite powder for the manufacture of products by selective laser melting.

Keywords: Mechanical activation, modes of motion, planetary mill, ball mill

Mechanical activation technology is used to change the structure of powder materials. It not only crushes and deforms substances, but also promotes mixing at the molecular level. This process stimulates chemical reactions and the movement of solid components. As a result of the interaction of powder particles during collisions, new bonds are formed, which is called

mechanical alloying. The modified powders after processing are used to fabricate fully dense samples by selective laser melting [1, p.28].

In recent years, mechanical methods of stimulating chemical processes by processing solid materials using grinding equipment have been widely used in industry. These methods can significantly enhance the processes occurring at interfaces, especially heterogeneous processes. Mechanical activation is able to solve many problems, such as increasing the reactivity of solids, changing the structure of materials, accelerating solid-phase reactions and others [1, p. 30].

Avvakumov E. Г. [2, p.56] explains that under prolonged exposure of an elastic body to periodic repetitions of forces not exceeding the elasticity limit, energy accumulation in the residual stress areas occurs, which leads to the automatic destruction of the elastic body due to the achievement of a certain energy level. The accumulated energy potential is released in the form of radiation of heat, light and electricity. In addition, part of the accumulated energy remaining in the surface layers is further dissipated and the rest is converted into energy of the newly formed surface. The energy accumulated in the process of grinding powder particles, not manifested in the temperature rise, leads to an increase in its chemical activity, thermal dissociation, decrease in melting point, sintering and other physicochemical phenomena. The substance after pulverization becomes activated, and the process of its activation is considered as pulverization of the substance.

For mixing and pulverization of solids, a variety of apparatuses with different ways of impact on the material, such as: splitting, impact, abrasion and others are used. In the work of Blinichev V. N., Bobkov S. P. and Gujumjan P. N. [3, p.73-78], three main types of mills are indicated depending on the impact speed: mills with low speed, for example: centrifugal, ball, ball-ring, rod mills, etc.; mills with medium speed, for example: centrifugal-planetary, vibrating, magnetic-vortex, etc.; and mills with high speed, where the grinding of material occurs due to free impact, for example: impact, hammer, jet, rotary, etc.; and mills with high speed, where the grinding of material occurs due to free impact, for example: impact, hammer, jet, rotary, etc.

Effective mechanical activation of plastic powder material requires a minimum energy density in the working space per unit volume of the mill. These conditions can be achieved by using apparatuses with low and medium loading speed. The most promising devices for this purpose are planetary and ball mills [7, 5, p.16].

A planetary mill is a system of several identical drum containers that rotate about their axis and about a common axis of rotation. A ball feed is placed in each of the containers and then as the container rotates, the balls

impact the material and grind it. Planetary mills have high capacity, efficiency and precision in grinding materials. In order to ensure the long-term operation of the planetary mill, it is necessary to carry out regular maintenance, check the condition of parts and assemblies, lubrication and replacement of consumables. It is also important to follow the rules of operation and safety when working with the device.

Most often three modes of operation of a planetary mill for grinding materials are distinguished (Fig. 1) [2, 5, p. 56]: Sliding, impact, vortex.

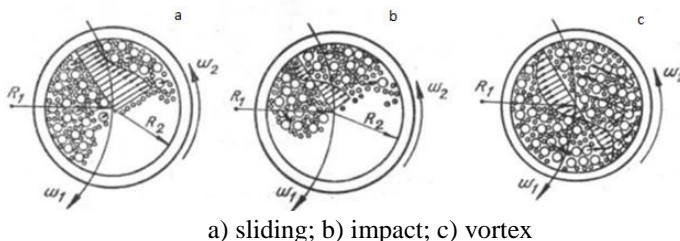


Figure 1. Modes of motion of ball loading in a planetary mill

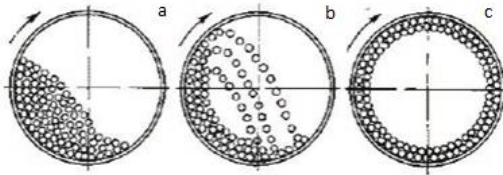
The movement of material in the opposite direction to the drum wall, known as “sliding” or “abrasion” (Fig. 1, a), is a process in which material particles are subjected to more intense wear. This phenomenon is particularly noticeable in the presence of a velocity gradient of the moving load. In addition, the abrasion of the inner surface of the drum caused by contact with the wall load is due to the opposite directions of motion of the wall and the load.

Impact mode (rolling over) (Fig. 1, b) is a process of material destruction under the influence of impact or friction. The peculiarity of this process is the shape of the load displaced in the direction of drum rotation, which leads to the deviation of the particle from the circular trajectory and movement along a parabola.

In the vortex mode of loading motion (Fig. 1, c), the balls follow as if along curved curves approaching an elliptical trajectory. Material destruction is mainly by impact, since the free path of the balls is substantially large and the ball travels at the highest velocity until it collides with another particle or wall.

A ball mill, in turn, is a cylindrical vessel within which a ball load is placed. As the cylinder rotates, the balls inside it begin to move in a spiral, grinding materials in their path. In a ball mill, the balls move only spirally without changing the direction of their rotation. This type of mill has a high capacity and can process large volumes of materials in a short time. The ball mill is easy to maintain and does not require special skills for its operation.

In the operation of a ball mill, the energy carried by the ball is determined by the angular velocity and rotational speed of the drum. There are three different modes of mill operation (Fig. 2), which can be distinguished: cascade, waterfall, self-fudging [4, p.28-34].



a) cascade; b) waterfall; c) self-feathering

Fig. 2. Modes of movement of the ball feed in the ball mill.

Cascade mode system in action: at low angular velocities of rotation, there is a movement of mill balls and material in one direction along the drum wall. However, if the angle of inclination of the loading surface exceeds the natural angle of slope of the balls, then the balls begin to roll over each other at a modest speed, which leads to a decrease in their energy (Fig. 2, a). The process of grinding the material is accomplished by smooth impact and abrasion, and although the movement of the mill bodies does not cause abrupt grinding, it does contribute to the process.

In the “waterfall” mode, there is an increase in the angular velocity of the mill drum rotation, which increases centrifugal forces and inertia. This causes the grinding balls to break away from the feed and significantly increase their energy. The balls move along a parabolic trajectory (Fig. 2, b). As a result of this process there is more intensive grinding of material due to impacts of falling balls.

Self-grinding mode (Fig. 2, c) - in this mode critical angular velocities are reached, the balls are pressed against the wall of the drum and move together with it without grinding the material.

Thus, having studied the modes of motion of ball loading in planetary and ball mills, we can conclude that each of them has its own features and application in various processes of grinding and mixing of materials. Planetary mills provide more intensive mixing and grinding due to the complex rotation of the ball load. On the other hand, ball mills are characterized by a simpler design and can be more economical to use. The choice between these two types of mills will depend on the specific production goals and the required composite powder characteristics. Further research in this area may lead to optimized grinding, mixing and improved efficiency in the production of composite powder for the manufacture of parts by selective laser melting.

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RAINY IMAGES STATIONARY BACKGROUND EXCLUSION ALGORITHM

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Аннотация. Приведены результаты разработки алгоритма удаления неподвижного фона на телевизионных изображениях, полученных в условиях дождя, с целью дальнейшей оценки интенсивности осадков. Приведен пример обработки реального изображения.

Ключевые слова: осадки, телевидение, обработка изображений.

Annotation. A development results of rainy images stationary background exclusion algorithm in purpose of precipitation intensity estimation by television images processing are presented. An example of real-world image processing is given.

Keywords: precipitation, television, image processing.

A development of rainy images stationary background exclusion algorithm in purpose of precipitation intensity estimation by television images processing [1] has been carried out.

Rain intensity can be estimated by estimating the number of drops in a video image. To perform such an assessment, it is necessary to separate raindrops from the background. In the case of using stationary video cameras, the background is motionless, so the part of the brightness corresponding to the background can be calculated as the average value of the pixel brightness over a certain long time interval. At the same time, in order to exclude the influence of moving objects in the scene on the assessment result, the motionless background can be estimated using only those parts of the image that contain only areas of uniform and low brightness and the probability of movement is low.

The exclusion of stationary background is performed by applying following expression

$$I_{rain}(x, y) = \begin{cases} [I(x, y) - I_{bg}(x, y)], & \text{if } [I(x, y) - I_{bg}(x, y)] \in [\Delta_{min}, \Delta_{max}]; \\ 0, & \text{otherwise;} \end{cases}$$

where $I_{rain}(x, y)$ — image after stationary background exclusion;

$I(x, y)$ — original image;

$I_{bg}(x, y)$ — image corresponding to stationary background;

x, y — horizontal and vertical pixel coordinates.

The threshold value Δ_{min} is selected in such a way as to exclude the influence of noise and compression artifacts on the calculation of the still background.

The threshold value Δ_{max} is selected based on the need to exclude large values of the difference image caused by objects moving in the frame.

When processing video sequences in real time, the image $I_{bg}(x, y)$ of the stationary background can be calculated by calculating a moving average of the frame sequence over a time interval of at least one minute. When processing video recordings, the image of the stationary background can be estimated by averaging the luminances over the entire duration of the video recording. Processing video recordings of several minutes in duration is an acceptable approach, since the change in rain intensity during such time intervals is usually small. An example of removing a stationary background is shown in Fig. 1.

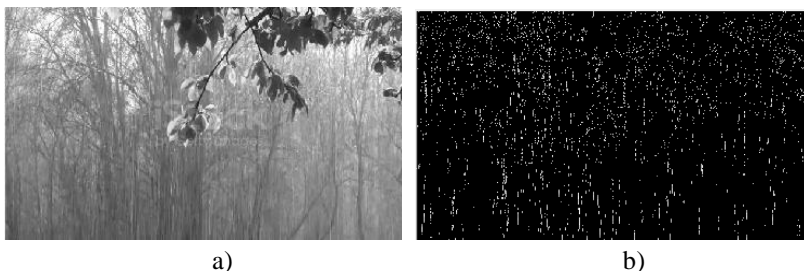


Fig. 2. Image processing at different stages of the algorithm: a) original image; b) image after still background exclusion;
c) the derivative of the image after still background exclusion

Thus, rainy images stationary background exclusion algorithm was developed and verified using real-world images.

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RESEARCH STUDY OF DISCONE ANTENNA DEPENDING ON GEOMETRIC CONFIGURATIONS

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Annotation. The paper analyzes the dependence of the characteristics of a discone antenna on the geometry of its radiating elements. Various cases of changes in the antenna's geometry are presented: adding cuts of uniform and widening width to the cone part, adding cuts to the disk part, and combining cuts in both parts. The results include graphs of the frequency dependence of the standing wave ratio at the antenna input, reflecting the relationship between the characteristics of the discone antenna and the amount of material used.

Keywords: discone radiator, wideband antenna, dependence of an antenna parameters on geometry.

Аннотация. В работе анализируется зависимость характеристик дискоконусной антенны от геометрии её излучающих элементов. Приводятся различные случаи изменения в геометрии антенны: добавления вырезов в конусной части равномерной и расширяющейся к основанию ширины, добавления вырезов в дисковой части. Также в работе приводятся результаты при наличии вырезов как в дисковой, так и в конусной частях одновременно. В качестве сравнительных результатов приводятся графики частотной зависимости коэффициента стоящих волн на входе антенны, отражающие зависимости характеристик дискоконусной антенны от количества используемого материала.

Ключевые слова: дискоконусный излучатель, широкополосная антенна, влияние геометрии на параметры антенны.

Introduction

Discone antennas are used for transmitting and receiving radio waves in various scientific fields, such as radio communication, radar, radio navigation, and satellite communication [1, p. 215]. These antennas have a wide bandwidth and good radiation directivity. The goal of the research was to

determine the minimum possible amount of material used while maintaining the functionality and acceptable characteristics of the antenna.

Main part

The study analyzed a discone antenna operating in the frequency range from 2.4 GHz to 7 GHz.

The geometric dimensions of the antenna are as follows: disk diameter — 25.5 mm, distance between the disk and cone parts — 0.53 mm, cone height — 30.67 mm, cone tip diameter — 1.8 mm, cone base diameter — 37.2 mm, and angle between the base and the side of the cone — 60° .

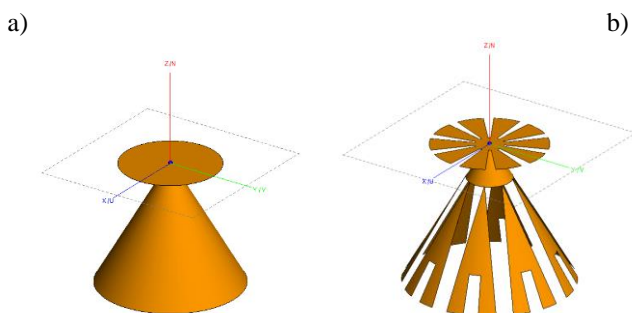


Figure 1 — External view and characteristics of the radiator without cuts (a) and with the maximum number of cuts (b)

To determine the minimum amount of material required to preserve the functionality and acceptable characteristics of the researched antenna, changes in the antenna's characteristics were analyzed when cuts were added to both parts of the antenna and separately to each part [2, p. 152]. The SWR limit was set to 2. The SWR graph of the antenna shown in Figure 1(a) was taken as the reference for further comparison of SWR of the other antennas. At the first stage, the number of trapezoidal cuts (10° each) in the cone part was varied until the limit of 18 cuts was reached. In this case, the SWR of the antenna changed insignificantly, and a shift of the entire operating frequency band toward higher frequencies was noted. However, this case was less interesting than the next one, so its graphs were not included in the article. Next, the number of rectangular cuts in the cone part was varied from 4 to 8. The SWR graph for this antenna variant is shown in Figure 2. In this case, the operating frequency range expanded [3, p. 60].

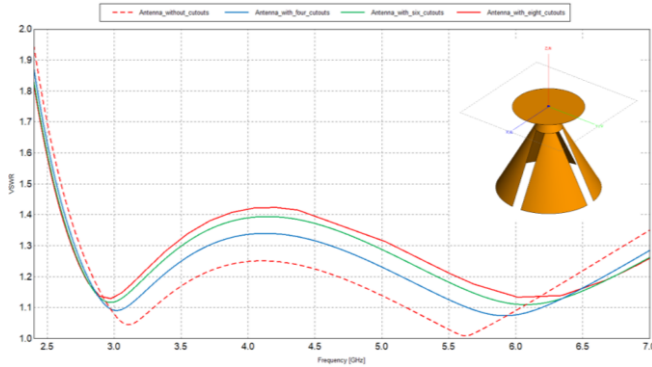


Figure 2 — SWR of the antenna with rectangular cuts in the cone part

At the second stage, the number of cuts in the disk part of the antenna was increased, considering triangular cuts (4 and 8), trapezoidal cuts (10°), and trapezoidal cuts with a larger disk radius in the center. After analyzing all the SWR graphs, the following conclusions were drawn: for triangular cuts, the operating frequency range shifts toward higher frequencies, and in the case of 8 cuts, the minimum possible SWR is observed at the extremum points on the graph, for trapezoidal cuts (10°), the SWR graph for a larger number of cuts shifts slightly toward higher frequencies, with values close to the minimum possible at the extremum points, for trapezoidal cuts with a larger disk radius in the center, even with the maximum amount of material used, the SWR exceeds the initially set value in the low-frequency range.

More variants of cuts in the cone part were tested because it was found that cuts in the cone part have a stronger influence on the characteristics than cuts in the disk part.

Thus, for further research, the second case was selected. The SWR graph for antennas of this configuration is shown in Figure 3.

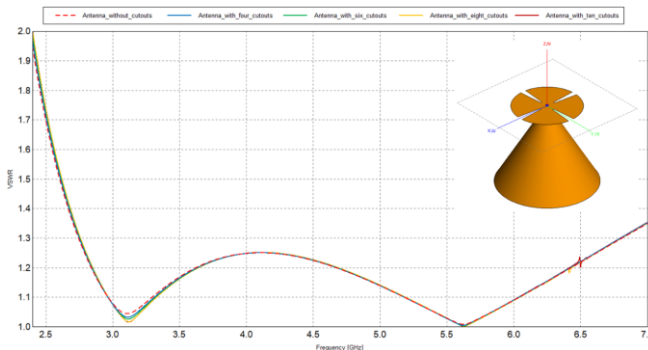


Figure 3 — SWR of the antenna with trapezoidal cuts (10°) in the disk part

At the third stage, trapezoidal cuts (10°) were added to the cone part and similar cuts to the disk part. The SWR graph for the resulting antenna is shown in Figure 4.

At the fourth stage, small cuts were added to the remaining "petals" of metal in the lower part. At the fifth stage, it was decided to combine the cases with cuts in the disk and cone parts to improve the characteristics (Figure 1b). The SWR for this configuration is shown in Figure 5.

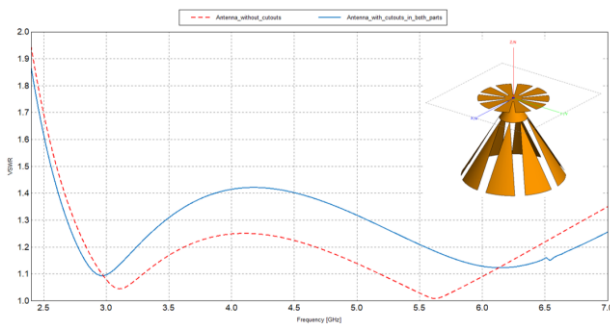


Figure 4 — SWR of the antenna with trapezoidal cuts in the disk part and rectangular cuts in the cone part

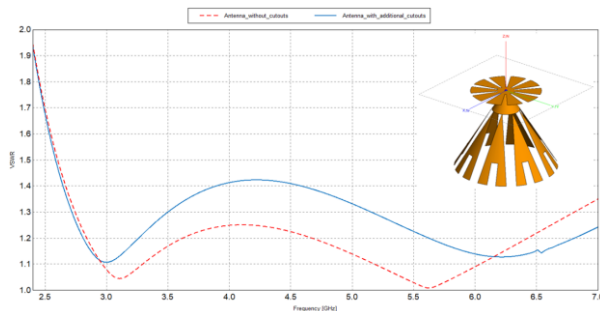


Figure 5 — SWR of the antenna with additional cuts in the cone part

Conclusion

Thus, the dependence of the antenna's characteristics on the amount of material used and the structure of the radiator was examined. The necessary ratio of material quantity and output characteristics of the antenna was determined.

It was found that the best SWR of the antenna is sufficiently low values and a wide operating frequency range is achieved in the case of cuts in both parts of the antenna, with additional cuts in each "petal" at the base of the cone part.

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**ANTENNA ARRAY OF DISCONE RADIATORS FOR
DIGITAL DIRECTION FINDER**

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Аннотация. В работе приводятся результаты расчёта характеристик антенной решётки дискоконусных излучателей, используемой в работе цифрового сканирующего пеленгатора. Диапазон рабочих частот пеленгатора 0,5—3 ГГц для удобства построение антенной системы разбивается на два поддиапазона: 0,5—1,3 ГГц и 1,3—3 ГГц. Для каждого поддиапазона разработаны кольцевые антенные решётки с 11 и 12 излучателями соответственно. Диаметр антенной решётки для

первого поддиапазона составил 0,8 м, для второго — 0,4 м. В результате проведённых расчётов показано, что каждая из разработанных антенных решёток позволяет определять приход электромагнитного излучения с любого направления в азимутальной плоскости.

Ключевые слова: дисконусный излучатель, цифровой сканирующий пеленгатор, антенная решётка, направления прихода электромагнитного излучения, кольцевая антенная решётка.

Annotation. The study presents the results of calculating the characteristics of the antenna array of discone radiators used in the operation of a digital scanning direction finder. The operating frequency range of the direction finder 0.5 — 3 GHz is divided into two sub-ranges for the simplification of building an antenna system: 0.5 — 1.3 GHz and 1.3 — 3 GHz. Annular antenna arrays with 11 and 12 radiators and 0.8 m and 0.4 m ring diameters respectfully have been developed for each sub-range. As a result of the calculations, each of the developed antenna arrays makes it possible to determine the arrival of electromagnetic radiation from any direction in azimuthal plane.

Keywords: disc-cone radiator, digital scanning direction finder, antenna array, directions of arrival of electromagnetic radiation, ring antenna array.

Introduction

To this day there is numerous technical and scientific tasks dedicated to improving direction finding systems. The main issues include the necessity in increased accuracy when determining the direction of signal source and improved and adapted to modern communication standards antenna systems. This study aims to develop an antenna system for a digital direction finder that meets required high standards in both communication and navigation.

Main part

The direction finding method based on correlation interferometer is implemented in this study in order to determine the direction of arrival using phase shifts between signals received by antenna array elements [2, p. 256].

In order to build the direction finder antenna system an annular antenna array with discone radiators was used (figure 1) [1, p. 38]. To ensure that we meet the required frequency range the antenna system was divided into two antenna arrays operating in the ranges of 0.5 — 1.3 GHz (AR1) and 1.3 — 3 GHz (AR2) respectfully.

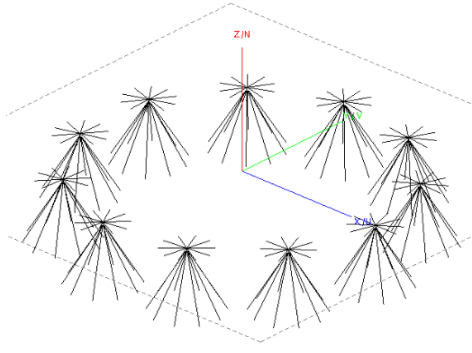


Figure 1 — Annual antenna array model

Figures 2 and 3 shows the frequency response of the VSWR for each of the previously developed radiators. In each of the sub-ranges the VSWR does not exceed the 1.9 mark.

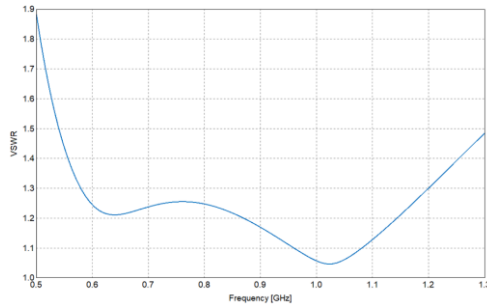


Figure 2 — Frequency response of the VSWR for the AR1 (0.5 — 1.3 GHz)

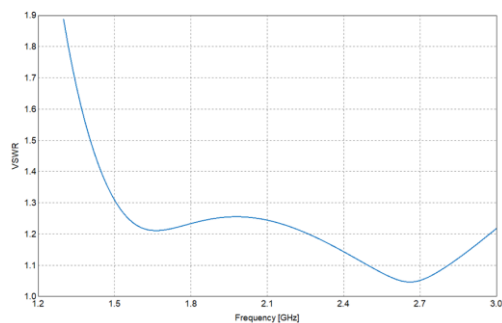


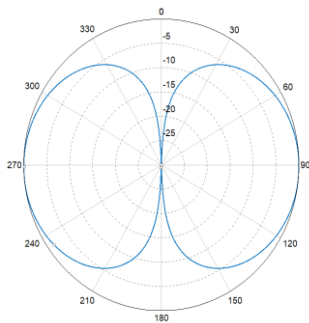
Figure 3 — Frequency response of the VSWR for the AR2 (1.3 — 3 GHz)

Figure 4 shows the radiation patterns of the developed radiators at the border frequencies of each of the sub-ranges.

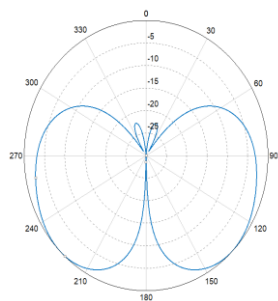
The problem of determining the direction of arrival of an electromagnetic wave in the calculation was solved in two stages.

The first stage — to determine the output phase shift of each of the radiators. Meanwhile the antenna array operates in reception mode and is irradiated by a dipole antenna located at 1000m away.

a)



b)



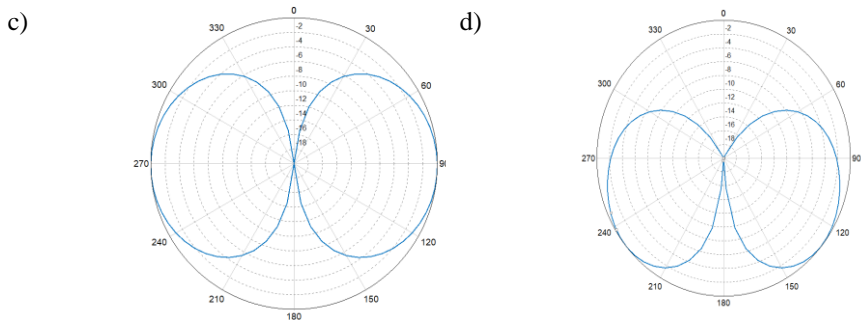


Figure 4 — Radiation pattern at border frequencies 0,5 GHz (a), 1,3 GHz (b) — for the AR1;
1,3 GHz (c), 3 GHz (d) — for the AR2

The second stage — to determine the direction of arrival of the electromagnetic radiation. Due this, the antenna array is calculated as transmitting, while 1V value voltages and previously determined phase shifts are applied to the input of each radiator. In this case peak of radiation pattern shows the direction of arrival of electromagnetic radiation. Figure 5 (a) shows the radiation pattern of AR1 at frequency 1,3 GHz, and figure 5 (b) — AR2 at frequency 3 GHz. In both cases the radiation source is shifted relative to the X axes by 26° .

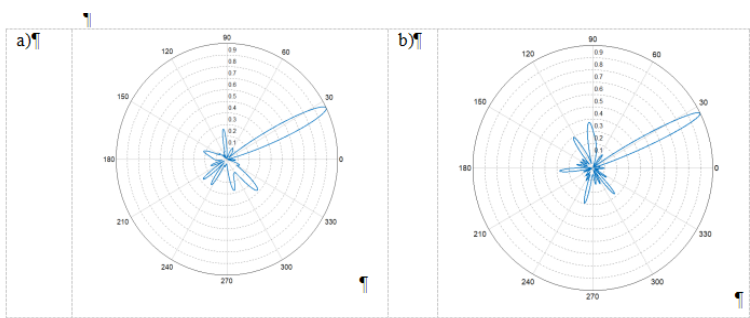


Figure 5 — Radiation pattern oAR1 at frequency 1,3 GHz (a), AR2 at frequency 3 GHz (b)

Conclusion

Thus, the article considered the basic principles of the direction finders and features of their antenna systems.

Also two antenna systems for a digital scanning direction finder and annular phased antenna array with 11 radiators with a diameter of 0.8m were developed. The second array is identical except for the number of radiators and the diameter of the ring — radiators in amount of 12 and the ring diameter being 0.4m.

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MULTIFREQUENCY ANTENNA SYSTEM WITH YAGI-UDA RADIATORS

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Аннотация. В работе приводятся результаты разработки многочастотной антенной системы, необходимой для работы устройства подавления БПЛА. Проанализированы методы построения антенн типа Yagi-Uda в печатном исполнении. Приведены графики, подтверждающие согласование разработанных антенн с питающей линией КСВ не хуже 1,5. Проведено моделирование работы каждой

антенны в условии размещения каждого излучателя в непосредственной близости друг к другу под одним радиопрозрачным корпусом. Показано, что влияния близкорасположенных излучателей, работающих на других частотах, несколько ухудшают характеристики каждого излучателя в отдельности. Однако их величина не превышает допустимых пределов. КСВ не поднимается выше значения 1,5, отклонение главного лепестка диаграммы направленности от оси антенны не превышает нескольких градусов.

Ключевые слова: печатный излучатель, антенна Yagi-Uda, подавление канала управления, взаимное влияние, многочастотная антенная система.

Annotation. The paper presents the results of the development of a multifrequency antenna system necessary for the operation of a UAV suppressing device. The methods of constructing printed Yagi-Uda antennas were analyzed. Graphs confirming the matching of the developed antennas with the feed line (SWR no worse than 1.5) are provided. The operation of each antenna was simulated under the condition of placing each radiator in close proximity to the others under a single radome. It was shown that the influence of closely located radiators operating at other frequencies slightly degrades the characteristics of each radiator individually. However, the magnitude of this degradation does not exceed permissible limits. The SWR does not exceed 1.5, and the deviation of the main lobe of the radiation pattern from the antenna axis does not exceed a few degrees.

Keywords: printed radiator, Yagi-Uda antenna, control channel suppressing, mutual influence, multiband antenna system.

Introduction

In modern day a large number of unmanned aerial vehicles (UAVs) are used for both civilian and military purposes. These UAVs operate on multiple frequency bands for control, data transmission, and navigation. A key feature of suppressing devices is that a separate generator with a power amplifier was used for each required operating frequency. Using a power combiner in this case is not practical, as it inevitably introduces losses into the microwave section. The goal of this research is to develop an antenna system necessary for the operation of a UAV suppressing device, containing three independent antennas.

Main part

The research study contained analysis of characteristics of each of the three director antennas, operating in bands with central frequencies of 1.6 GHz, 2.45 GHz and 5.8 GHz. In anti-drone guns, the antennas are placed in a single

space covered by a radome. The design of the antenna system considered in the work is shown in Figure 1.

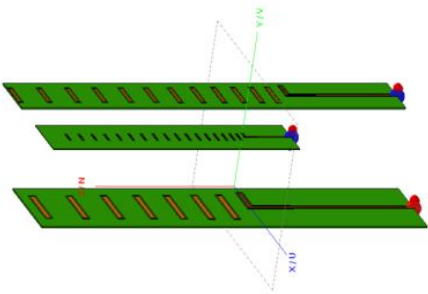
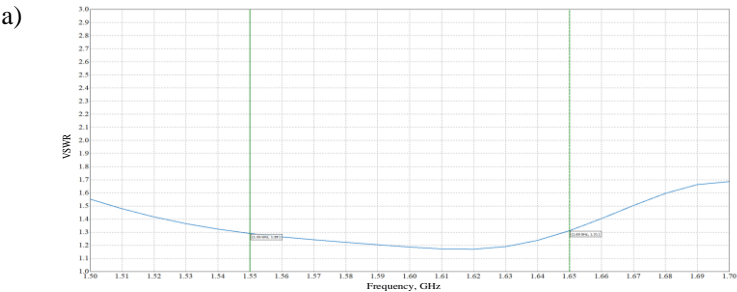


Figure 1 — Relative arrangement of three radiators

The input and radiation characteristics were calculated. The gain of the antenna with a central frequency of 1.6 GHz does not fall below 11.5 dBi, for 2.45 GHz it does not fall below 14 dBi, and for 5.8 GHz it does not fall below 15 dBi [1-3].

The standing wave ratio (SWR) in the range of 1.55–1.65 GHz does not exceed 1.31, in the range of 2.40–2.50 GHz it does not exceed 1.51, and in the range of 5.75–5.85 GHz it does not exceed 1.35. The SWR of the radiators is shown in Figure 2.

The three-dimensional radiation patterns, when the antennas are placed side by side, are shown in Figure 3. The figure shows that the maximum of the radiation patterns shifts by 5–7°, which has a negligible impact on the technical characteristics of the suppressing device.



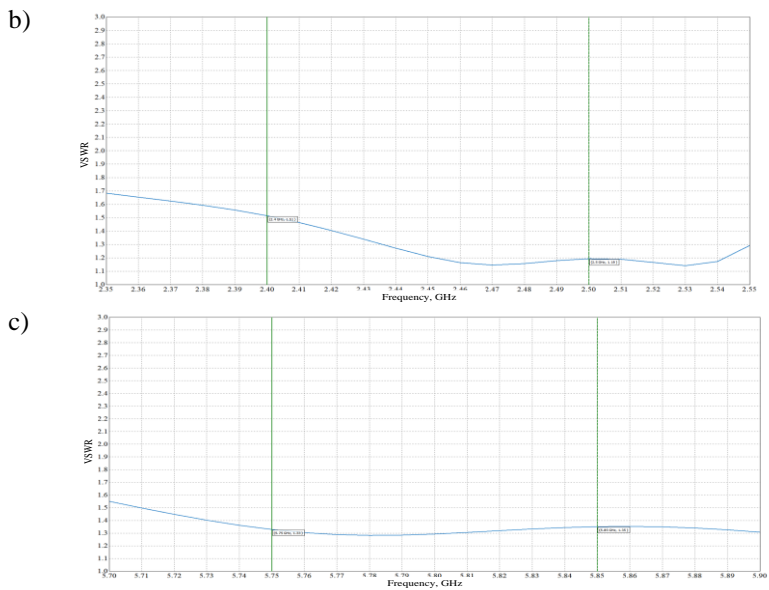


Figure 2 — Standing wave ratio of radiators with central frequencies of 1.6 GHz (a), 2.45 GHz (b), and 5.8 GHz (c)

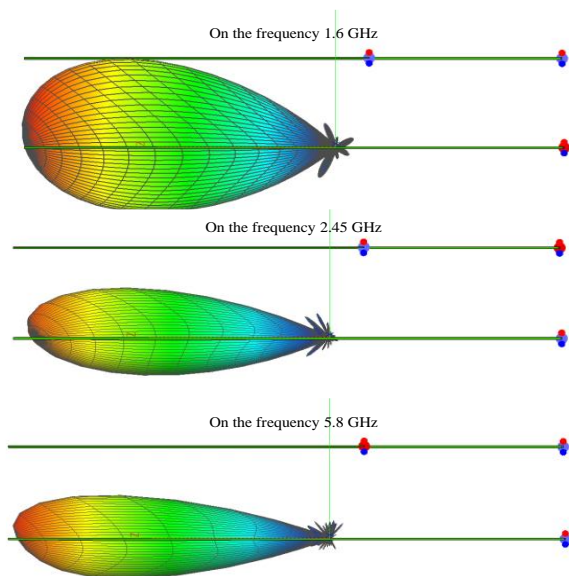


Figure 3 — Radiation pattern of each radiator when placed together

Conclusion

Thus, the methods of constructing printed Yagi-Uda antennas were analyzed. It was shown that such antennas are more compact compared to wire antennas, allow the formation of a radiation pattern of the required width, and are relatively easy to manufacture.

An antenna system necessary for the operation of a UAV suppressing device was developed, containing three director antennas implemented in printed form. The antennas operate in bands with central frequencies of 1.6 GHz, 2.45 GHz, and 5.8 GHz. The calculations show that placing the three antennas side by side does not degrade their characteristics.

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**DEVELOPMENT OF THE ANTENNA SYSTEM IN
FREQUENCY RANGE OF 800 — 900 MHZ**

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Аннотация. В статье представлены результаты моделирования двух антенн, работающих в составе устройства постановки помех каналу управления БПЛА. Обе антенны работают в диапазоне 800–900 МГц. Первая представляет собой печатный спиральный излучатель. Эта антенна имеет круговую поляризацию поля излучения и имеет входное сопротивление ~ 130 Ом, что требует согласующей цепи. Вторая представляет собой симметричный диполь сложной формы с линейной поляризацией. Эта антенна совместима с линией питания сопротивлением 50 Ом без дополнительных согласующих устройств.

Ключевые слова: печатная антенна, спиральный излучатель, линейная поляризация, круговая поляризация, согласующее устройство.

Annotation. The paper presents simulation results for two antennas operating within a UAV control channel jamming device. Both antennas function in the 800–900 MHz range.. The first is a printed spiral radiator. This antenna has a circular polarization of the radiation field and has an input impedance of ~ 130 Ω , requiring a matching network. The second is a complex-shaped symmetric dipole with linear polarization. This antenna is compatible with a 50 ohm supply line without additional matching devices.

Keywords: printed antenna, spiral radiator, linear polarization, circular polarization, matching device.

Introduction

In modern day, drone jammers are used to protect against unauthorized use of unmanned aerial vehicles (UAVs), which can pose a threat to security or privacy. The main reasons for their necessity are as follows: preventing potential collisions between drones and passenger aircraft or helicopters, especially near airports, safeguarding personal privacy from drone surveillance, which may capture video or photos without consent, ensuring the security of critical state or private facilities, such as military bases, government buildings, or infrastructure, countering the use of drones for terrorist purposes, such as delivering explosives. Drone jammers operate by disrupting the radio frequencies used for UAV control or interfering with GPS signals essential for navigation. This can force the drone to land or return to the operator. Drone jammers are sources of electromagnetic oscillations directed at UAVs. Therefore, one of the key components of a jammer is its antenna system. The goal of this study is to investigate and develop an antenna system for a UAV suppression device operating in the 800–900 MHz frequency range.

Main part

The designed radiators are intended to operate in the 800–900 MHz frequency range. Each antenna must have a gain of 7–9 dBi, with a standing wave ratio (SWR) at the input of each element not exceeding 1.5. All calculations were performed using the Gamma CAD software.

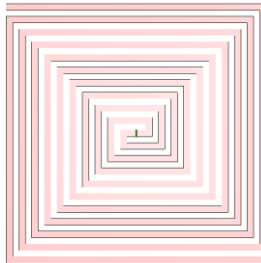


Figure 1 — Topology of a planar two-turn spiral radiator

The first radiator studied was a two-turn printed spiral antenna. Figure 1 shows the topology of this radiator, and Figure 2 presents its model in Gamma CAD. To achieve unidirectional radiation, this radiator must be supplemented with a shielding surface. Since the device is housed in a metal casing measuring 25×25×12 cm, it was decided to use the casing as the shield. The radiator dimensions were set to 25×25 cm, making the dielectric-based

radiator the lid of the casing. FR4 with a thickness of 2 mm was chosen as the dielectric material.

For the antenna in Figure 1, the input impedance was calculated (Figure 3). The results show that the active component varies between $75\ \Omega$ and $160\ \Omega$, while the reactive component ranges from $-30\ \Omega$ to $40\ \Omega$.

Figure 4 shows the SWR dependence of the antenna on a $130\ \Omega$ transmission line.

Figures 5(a, b) display the orthogonal radiation patterns at 850 MHz. Patterns at other frequencies in the range were omitted due to their minimal differences from those shown in Figure 5(a, b).

From Figures 5(a, b), it is evident that the beamwidth in the XOZ plane is 82° , and in the YOZ plane, it is 78° .

The antenna gain is approximately 8 dBi. The polarization is elliptical, with an ellipticity coefficient of 0.8.

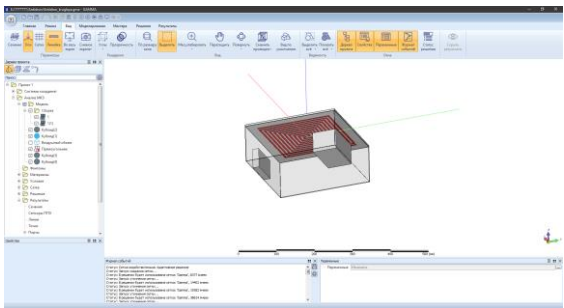


Figure 2 — Planar two-turn spiral radiator model in CAD Gamma

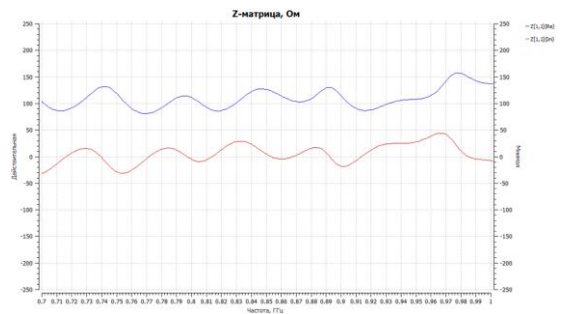


Figure 3 — Frequency response of the active and reactive parts of the impedance

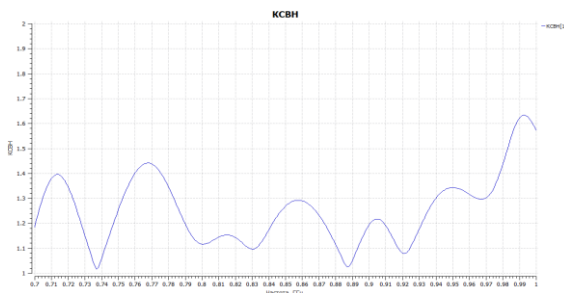
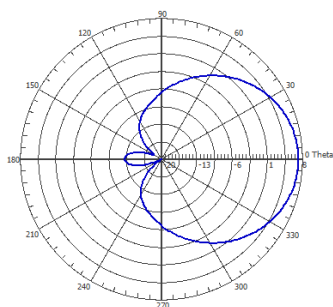


Figure 4 — Frequency response of the SWR for the wave resistance of the 130 ohm supply line

a)
Коэффициент усиления (Общая) (log)



b)
Коэффициент усиления (Общая) (log)

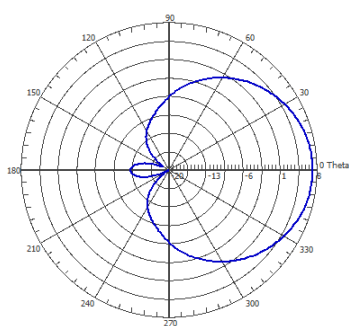


Figure 5 — Antenna radiation pattern in the XOZ plane at 850 MHz(a), antenna radiation pattern in the YOZ plane at 850 MHz(b)

The final antenna variant studied was a printed broadband antenna with linear polarization. Its topology is shown in Figure 6, and the model is presented in Figure 7. The input impedance for this antenna was calculated (Figure 8), revealing an active component between 42Ω and 60Ω and a reactive component between -12Ω and 8Ω . Figure 9 illustrates the SWR dependence for a 50Ω transmission line.

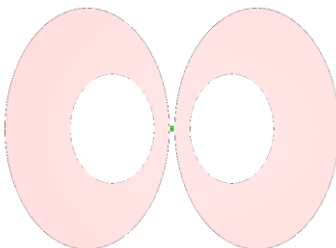


Figure 6 — Planar broadband vibrator radiator topology

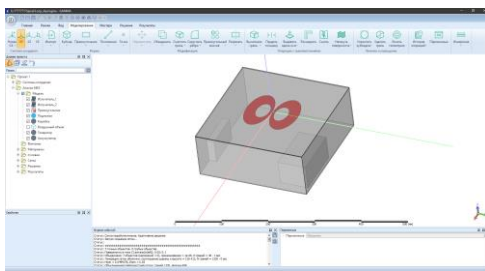


Figure 7 — Planar broadband vibrator radiator model in Gamma CAD

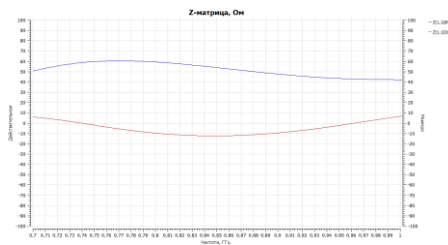


Figure 8 — Frequency response of the active and reactive parts of the impedance

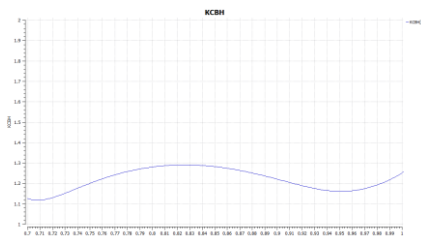


Figure 9 — Frequency response of the SWR for a wave resistance of 50 ohms

Figures 10(a, b) depict the orthogonal sections in antenna radiation patterns at 850 MHz. No diagrams were provided for other frequencies in the range, as they differ little from those shown in Figure 10 (a, b). As shown in the figures 10(a,b), the beamwidth is 84° in the XOZ plane and 81° in the YOZ plane, with a gain close to 8 dBi.

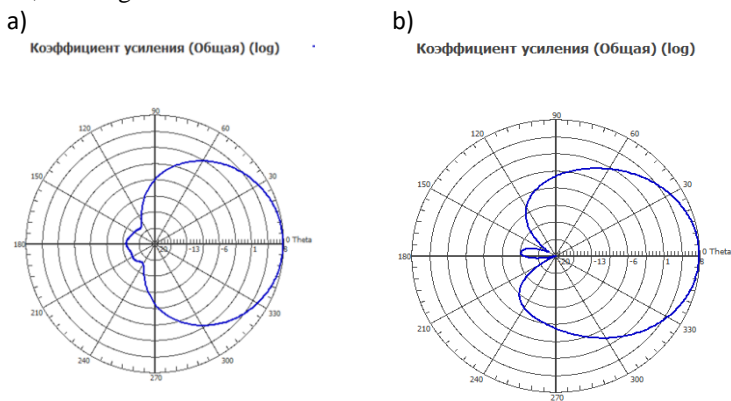


Figure 10— Antenna radiation pattern in the XOZ plane at 850 MHz(a), antenna radiation pattern in the YOZ plane at 850 MHz(b)

Conclusion

The study calculated the characteristics of three broadband spiral radiators operating in the 800–900 MHz range. The spiral antenna features circular polarization, while the planar symmetric dipole exhibits linear polarization. The antenna designs account for the structural constraints of the suppression device, including an aluminum casing (25×25×12 cm) with internal metal inserts for the RF generator and battery.

The spiral antenna demonstrates more uniform input impedance (active: 75–160 Ω , reactive: –30–40 Ω) and comparable beamwidth to the dipole. However, both antennas require additional impedance matching. For further development, the spiral structure was selected. The broadband linearly polarized antenna achieves an SWR below 1.3 without additional matching networks. The radiation patterns of all designed antennas provide dome-shaped coverage for UAV suppression.

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DEVELOPMENT OF A MATCHING DEVICE DESIGN WITH PRINTED SPIRAL ANTENNA

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Аннотация. В работе представлены результаты расчета и конструкторской разработки согласующего устройства, предназначенного для согласования входного сопротивления печатного спирального излучателя с линией питания с волновым сопротивлением 50 Ом. Согласующее устройство работает в диапазоне частот 800-900 МГц. Конструктивно согласующее устройство выполнено в виде печатной платы сложной формы, которая помещается в корпус устройства подавления канала подавления беспилотным летательным аппаратом. Экран микрополосковой линии выполнен таким образом, что не оказывает влияния на работу антенны.

Ключевые слова: печатная антенна, спиральный излучатель, четвертьволновый трансформатор, согласующее устройство, микрополосковая линия.

Аннотация. The study presents the results of the calculation and design development of a matching device designed to match the input resistance of a printed spiral radiator with a supply line with a wave resistance of 50 ohms. The matching device operates in the frequency range of 800-900 MHz. Structurally, the matching device is made in the form of a complex-shaped

printed circuit board, which fits into the body of the suppression device for the suppression channel by an unmanned aerial vehicle. The microstrip line screen is designed in such a way that it does not affect the operation of the antenna.

Ключевые слова: printed antenna, spiral radiator, quarter-wave transformer, matching device, microstrip line.

Introduction

Most printed spiral antennas exhibit input impedances higher than 50 Ω, necessitating matching networks. For a UAV control channel jamming device, a printed spiral antenna with an input impedance of ~130 Ω was developed. The integration of this antenna into the jammer imposes size constraints on matching components, demanding innovative design solutions.

Main part

A multi-step impedance transformer was employed as the matching network [1, p. 213]. Figure 1 shows a three-step transformer designed for the spiral antenna’s average input impedance of 130 Ω. Calculations were performed for such length in Gamma CAD using FR4 (2 mm thick) as the dielectric. The transformer’s total length (excluding feedlines) is 109 mm.

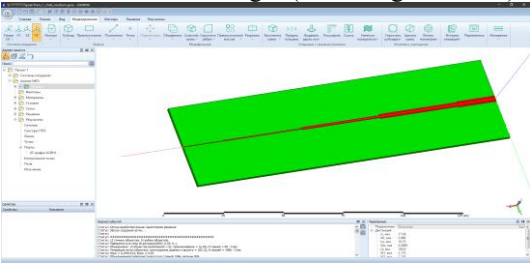


Figure 1 — Matching device model

Figure 2 illustrates the SWR frequency response when the transformer is loaded with 130 Ω.

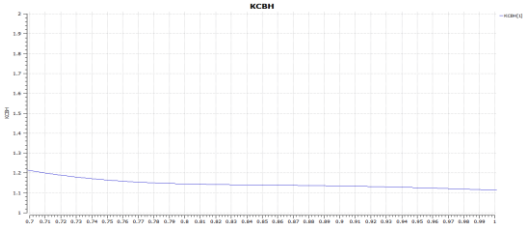


Figure 2 —Frequency dependence of the SWR at the input of the matching device, loaded with a resistance of 130 Ohm

Next, it is necessary to check how the matching device works with the calculated antenna. The scheme shown in Figure 3 was assembled in CAD Gamma for this purpose.



Figure 3 — Matching device test scheme

The circuit consists of an input port (block "Port1"), a calculated matching device, represented as S-parameters (block "S-parameter1") and a previously calculated antenna, also represented as S-parameters (block "Ant").

Figure 4 shows the frequency response of the SWR at the input of the matching device loaded onto the calculated antenna.

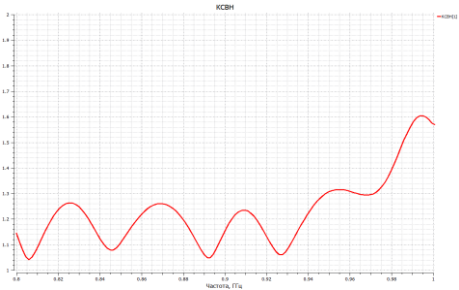


Figure 4 — Frequency response of the SWR at the input of the matching device loaded on the calculated antenna

The figure confirms that the SWR at the transformer's input remains below 1.3 across 800–900 MHz when loaded with the antenna. Further, to use this matching device inside the suppression device housing, it is necessary to change the geometry of the strip line so that the printed circuit board can be connected to the generator output without using additional cables or connectors.

Figure 5 shows a model of a matching device with a reduced longitudinal dimension.

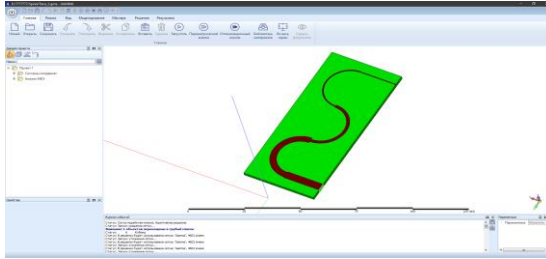


Figure 5 — Matching device model with a reduced longitudinal dimension.

Subsequently, following the same procedure as before, we calculated the input characteristics of the impedance matching device loaded with the designed antenna. Figure 6 presents the frequency dependence of the VSWR (Voltage Standing Wave Ratio) at the input of the compact matching device with reduced longitudinal dimensions when connected to the antenna. As evident from Figure 6, the input VSWR of the matching device does not exceed 1.3 across the entire operational frequency range from 800 MHz to 900 MHz.

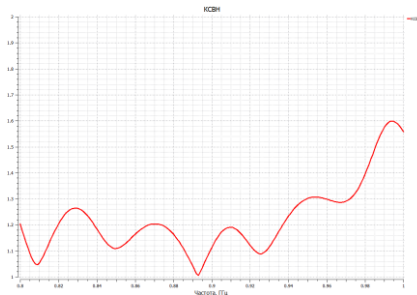


Figure 6 — Frequency dependence of the SWR at the input of the matching device loaded on the calculated antenna

The final design phase involved adapting the transformer for implementation on a specially shaped printed circuit board. Figure 7 shows the transformer side of the PCB, while Figure 8 displays the ground plane side. Notably, the ground plane was strategically reduced to simplify connector integration without compromising performance.

Figure 9 confirms that the implemented solution on the custom PCB maintains $VSWR \leq 1.4$ throughout the operational frequency range when connected to the antenna.

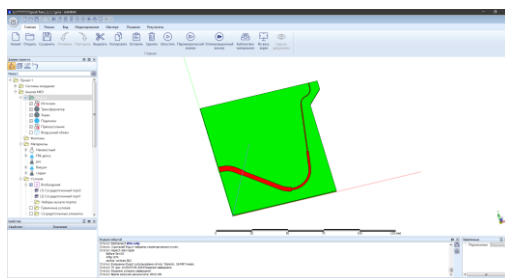


Figure 7 — Matching device model on a special-shaped printed circuit board, viewed from the transformer side

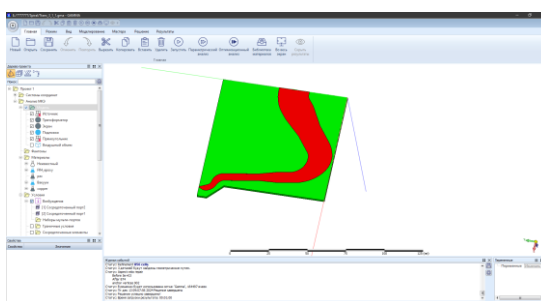


Figure 8 — Matching device model on a special-shaped printed circuit board, viewed from the ground side

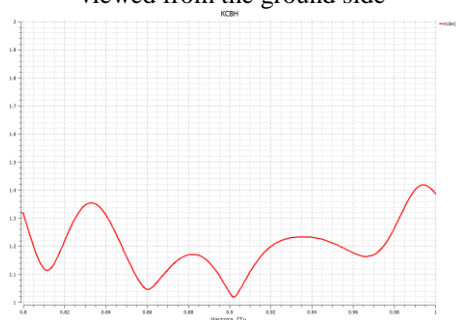


Figure 9 — Frequency response of the SWR at the input of the matching device loaded on the calculated antenna

Conclusion

A matching device in the form of a three-stage transformer with a total length of 12 cm has been developed for the spiral radiator. The transformer is

designed to match the input antenna resistance of 130 ohms with the supply line resistance of 50 ohms. For the convenience of placing the transformer inside the suppression device, a special-shaped printed circuit board was developed, onto which the transformer topology was transferred. The SWR at the input of the transformer loaded with the developed antenna does not exceed the value of 1.35.

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STUDY AND DESIGN OF A SYSTEM OF AUTOMATED SPECIAL ACCESS BASED ON BIOMETRICS

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Аннотация. Анализ современных биометрических систем и технологии Liveness Detection для организации автоматизированного контроля в помещении

Ключевые слова: ASC, машинное обучение, мониторинг.

Annotation. An analysis of modern biometric systems and Liveness Detection technology has been conducted for organizing automated access control to premises.

Keywords: ASC, machine learning, monitoring.

INTRODUCTION

Despite the rapid advancement of technology, access control and management systems remain highly relevant. Access control systems (ACS) help save resources, space, and employee time by resolving access-related issues [1]. Biometrics is a promising direction in ACS development, as it eliminates the risk of counterfeit access keys and avoids the need to recover them in case of loss [2]. Therefore, research into biometric technologies is highly relevant. This work focuses on analyzing the feasibility of using Liveness Detection technology in ACS systems [3, 4].

THE MAIN PART

A two-dimensional picture or a mask is not capable of recreating such detail, and it helps the system detect fakes better.

As for active methods, one can mention facial expression verification—while scanning the face, the system can ask the user to blink, look different directions, or show an emotion. Fakes such as pictures or videos cannot replicate these consistently.

When exploring this topic, one needs to have in mind the underlying technologies. One of them is high-resolution cameras that can image in multiple spectra and also perform spectral analysis of the reflected light and depth as well as surface contours of an object.

These cameras are essential to record fine facial details like skin texture or micro-movements. They can function in dim light and detect heat emitted by a living subject. Depth sensing enables proper identification of the three-dimensional features of the face, distinguishing it from two-dimensional images. Furthermore, by measuring reflective properties of light from an object, the system will distinguish between real and counterfeit material, since the light reflected off human skin is different from that reflected from man-made materials.

A Liveness Detection database can be formed using artificial intelligence and neural networks.

There is also a Python programming library that offers the feature to incorporate this technology in an access control system based on a Raspberry Pi microcomputer.

Figure 1 presents a scheme of ASC based on the Liveness Detection technology.

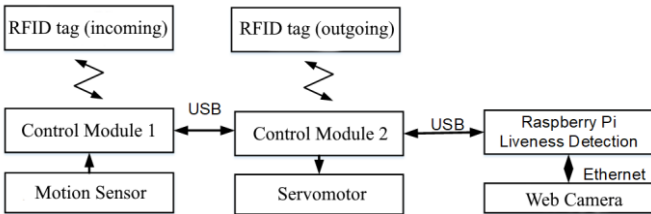


Figure 1 — ASC based on Liveness Detection technology

In contemporary practice, Liveness Detection is applied almost entirely using deep learning methods. The systems exist as a pipeline with a well-defined chain of operations, which begins from data collection and preprocessing. In this step, a good-quality dataset of both authentic and spoofed biometric samples is collected. The images or video frames are normalized, resized, and enhanced to obtain useful features, which are supplied as inputs to the training.

The next step is model training, during which Convolutional Neural Networks (CNNs) are employed extensively since they are good at learning

hierarchical features from image data. The networks are optimized using annotated data and trained by applying measure metrics such as accuracy (proportion of correct predictions) and loss (training error). This allows the system to differentiate safely between legitimate and spoofed inputs.

Once trained, the model is deployed in an actual operational environment. In this context, the system receives biometric data, immediately evaluates it, and determines a classification: live or spoofed. Field conditions performance of the model is typically evaluated with two primary measures—True Positive Rate (TPR), representing the ability of the system to correctly classify live individuals, and False Positive Rate (FPR), which is used to gauge how often spoofed inputs are wrongly accepted as authentic.

Liveness Detection has been useful across many industries. In consumer electronics, it secures smartphones and other personal devices with biometric unlocking. In financial institutions and banks, it verifies users when remotely accessing accounts and making transactions. Its application in access control systems is useful in preventing unwanted entry, while in healthcare, the technology ensures confidential patient information stays confidential.

Though Liveness Detection greatly improves biometric security, it is not challenge-free. Developers must be working constantly to minimize false acceptances and false rejections, especially in environments with diversity as found in real-world settings. Keeping performance also fast and robust on low-processing-power devices continues to be a technical priority, especially for deployment in mass market and embedded, as well as mobile systems.

Figures 2 shows a demonstration of an example of how the Liveness Detection technology works.

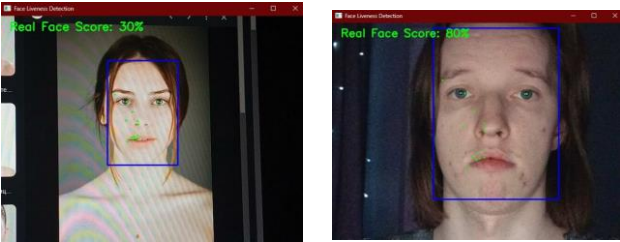


Figure 2 — The face in the image and the real face analyzing

CONCLUSION

Liveness Detection is an important tool in protecting biometric systems from spoofing attacks. The technology, using various methods such as micro-movement analysis, infrared scanning, and 3D modeling, always distinguishes

between real users and imitations. It significantly enhances security and renders biometric systems more responsive to modern threats.

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MODELING OF UNIDIRECTIONAL TURNSTILE ANTENNA

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Аннотация: Представлены методика и результаты моделирования однонаправленной широкополосной турникетной антенны. С помощью численного моделирования в среде САПР Gamma доказано, что компактная, простая по конструкции, печатная широкополосная антенна с однонаправленной диаграммой направленности, возбуждаемая с помощью точечного порта может быть выполнена на основе плоской четырёхплечей структуры (турникетной структуры), и может быть использована для управления беспилотными летательными аппаратами с земли. Проведен анализ электрических характеристик антенны смоделированной антенны.

Ключевые слова: моделирование, однонаправленная антенна, турникет, беспилотный летательный аппарат.

Annotation. The methodology and results of modeling of a unidirectional broadband turnstile antenna are presented. By means of numerical modeling in the Gamma CAD environment it is proved that a compact, simple in design, printed broadband antenna with unidirectional radiation pattern, excited by a point port can be made on the basis of a flat four-shoulder structure (turnstile structure), and can be used for controlling unmanned aerial vehicles from the ground. The antenna electrical characteristics of the modeled antenna have been analyzed.

Keywords: modeling, unidirectional antenna, turnstile, unmanned aerial vehicle.

Materials and methods. Nowadays, unmanned aerial vehicles (UAVs) of various types are more and more widely used, which require special antennas. It is obvious that these antennas should be small-sized, inexpensive, but with high electrical characteristics. This paper is devoted to investigate the feasibility of a unidirectional antenna based on the turnstile principle.

Based on the obvious conditions of operation of UAV radio control systems from the ground, we can formulate the basic requirements for the corresponding on-board antenna. It should provide:

- unidirectional radiation into the lower half-space;
- omnidirectional in the horizontal (azimuthal) plane;
- significant width of the radiation pattern (RP) in the vertical (angular) plane;
- acceptable polarization characteristics of radiation;
- wide bandwidth of operating frequencies.

An antenna with such electrical characteristics can be obtained based on the tourniquet principle [1]. “Classical” turnstile antenna (TA) consists of two mutually perpendicular vibrators, which are excited with equal amplitudes but with a phase shift of 90° . When the vibrators are placed in a horizontal plane, the RP in this plane will be nearly uniform and the polarization of the radiation will be linear. The radiation maxima, in the directions “zenith” and “nadir” will have a slightly higher level, and the radiation polarization will be circular or elliptical.

Such properties of TA are generally favorable for the task under consideration, since with circular or elliptical polarization, reliable communication will be ensured with linear polarization of radiation from the ground station side.

However, quasi-isotropic RP corresponds to a low value of the directivity coefficient (DC) - about one or, in decibels, about zero, and

polarization inconsistency additionally reduces the energy potential of the radio line. In addition, such an antenna practically does not suppress radio interference coming from arbitrary directions.

In the considered case of UAV control from the ground, the situation can be corrected by making the antenna directed only to the lower half-space. Technically, it is easiest to accomplish this by introducing a metal shield into the design, with the simplest design being a solid shield: the question of the effectiveness of other types of shields, such as vibrator shields, requires separate consideration.

The turnstile radiator can also be made flat, in the form of four foil strips on a dielectric base. If the base has a circular shape and the arms of the transmitter are excited near the center of the structure, it becomes possible to select the shape of the arms to obtain the largest possible band of operating frequencies. Such a task was set in the first stage of modeling, and in the second stage a model with a flat screen was investigated.

Modeling was performed in the specialized CAD Gamma when the four arms were excited by two point sources (ports). For certainty, the frequency band of the UHF range from 1500 to 3500 MHz was chosen with the average frequency f_0 equal to 2500 MHz (wavelength λ equal to 120 mm). The material chosen was a 1 mm thick foil-coated high-frequency dielectric FLAN with a foil thickness of 0.035 mm and a relative dielectric constant of 2.8.

The model radiating structure had an initial radius equal to a quarter of the wavelength, contained 4 wedge-shaped arms with a variable angle of expansion α that varied from a maximum possible angle of 90° downward. Ports with a wave impedance of 50 ohms were located on opposite sides of the base and connected to the arms through 1 mm diameter through-metal pins (Fig. 1 a). As a result of a series of calculations, it was found that the value of the angle α had practically no effect on the angular dependence of the absolute DC of the D_{Abs} model, which was fully in line with the expected one (see Fig. 1 b).

With the radius of the structure reduced by about 30% relative to the initial value of 0.25λ and the full angle of the wedges equal to 20° , the model input matching in terms of standing wave coefficient (SWC) 2.0 was provided in the relative bandwidth of about 15%, and in terms of SWC 3.0 - in the bandwidth of about 26%. The radiation ellipticity coefficient in the main direction was equal to 1.0, and within the conical cross-section of the RP along the angle of 60° was not less than 0.55.

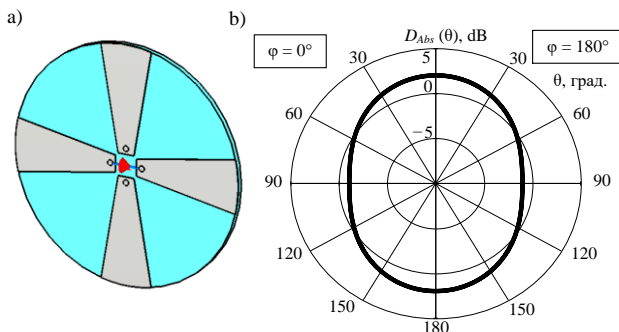


Fig. 1. View of the model of the study structure (a) and dependence of the D_{Abs} s model DC on the location angle θ (b)

At the next stage of research, a flat foil screen was added to the model, and the initial radius of the screen and its initial distance to the radiating structure were equal to a quarter of the wavelength. During the analysis, these parameters were varied in order to obtain a N_{FB} back radiation suppression level of at least 10 dB at the maximum possible operating frequency bandwidth.

As a result, it was found that with a screen distance of about 0.25λ at its radius of 0.375λ , the maximum DC value was 7.6 dB, and the back radiation suppression was at least 11 dB (Fig. 2).

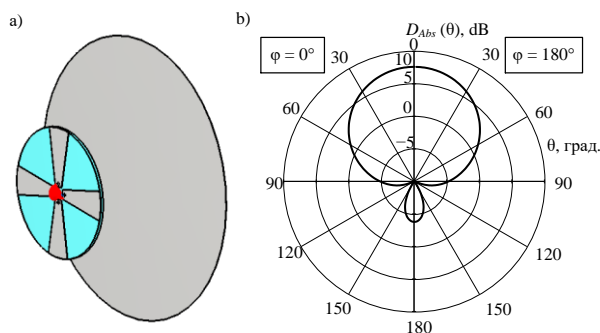


Fig. 1. View of the unidirectional antenna model (a) and the dependence of the D_{Abs} model RP on the site angle θ (b)

The irregularity of the RP in the conical section by the angle θ equal to 60° was insignificant, not more than ± 0.5 dB, the level of the D_{Abs} DC was not less than 1.2 dB, and the directivity in the left circular polarization was

not less than 0.8 dB, which corresponds to the ellipticity coefficient of about 0.8.

Unexpectedly, the relative matching bandwidth of the model input at VSWR level 2.0 did not decrease and amounted to about 15%, and at VSWR level 3.0 - about 26%.

Results. According to the results of modeling in the CAD Gamma, it can be stated that a compact, high-tech antenna based on a tourniquet with flat wedge-shaped arms and a flat shield can provide acceptable electrical characteristics for a UAV antenna. To proceed further to the development of a practical design, it is necessary to realize the excitation device of the radiating structure.

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UDC 621.396.67

TWO-SECTION MICROSTRIP ANTENNA WITH STRIP LINE FEEDING

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Аннотация: Предложен вариант реализации двухсекционной микрополосковой круглой формы с дополнительными короткозамыкающими штырями и с возбуждением микрополосковой линией и исследованы его электрические характеристики. Антенна является двухслойной и может быть изготовлена по печатной технологии, обладает минимальными габаритами по высоте и удовлетворяющими нас коэффициентом стоячей волны и

коэффициентом направленного действия. Работоспособность антенны в относительной полосе рабочих частот около 2 % при коэффициенте направленного действия около 9 дБ доказана результатами численного моделирования в САПР Gamma.

Ключевые слова: моделирование, двухсекционная микрополосковая антенна, микрополосковая линия.

Annotation. A version of realization of a two-section microstrip round shape with additional shorting pins and with excitation by a microstrip line is proposed and its electrical characteristics are investigated. The antenna is double-layer and can be fabricated by printed circuit technology, has minimum height dimensions and satisfying standing wave coefficient and directivity coefficient. The performance of the antenna in the relative operating frequency bandwidth of about 2% with a directional coefficient of about 9 dB is proved by the results of numerical modeling in Gamma CAD.

Keywords: modeling, two-sectioned microstrip antenna, microstrip line.

Materials and methods. Classical microstrip antennas of MSA [1] contain one radiating element in the form of a foil patch on a flat dielectric base, the second side of which is covered with foil and used as a screen. When feeding the MSA with a coaxial cable from the screen side, placing such an antenna on a metal antenna, in which it is impossible to drill a hole, cable feeding is a certain difficulty.

Sectionalized microstrip antennas (SMSAs) [2] are known, which are excited planarly by a coaxial cable, thus eliminating this difficulty. However, in this case the cable protrudes above the patch, which is undesirable for a number of applications. Another disadvantage of the known SMSA is the inability to select the dimensions of the antenna, guided by the requirements to the pattern and to the coordination with the feed cable separately.

This paper is devoted to finding variants of a two-section antenna that overcomes these drawbacks.

Consider a circular SMSA of radius a consisting of two identical sections 1 and 2 with a narrow gap between them. A section of coaxial cable 3 is laid along section 1, the outer conductor of which is connected to section 1 along its entire length. At the edge of the section, this conductor is also connected to the shield. In the center of the structure, the central conductor of the cable is connected to section 2 through a reactive matching element (RME) 4. For symmetry, a section of the same cable 5 is laid along section 2, but its central conductor is not used, and the outer conductor is connected both to the section and to the shield (Fig. 1).

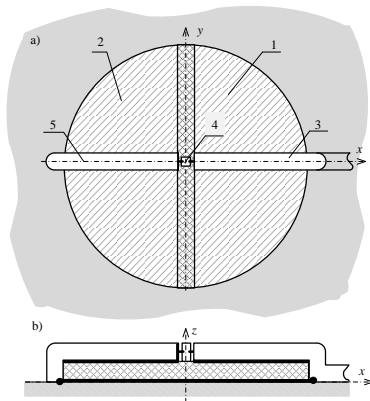


Fig. 1. Schematic of two-section SMSA with coaxial cable excitation: top view (a) and side view (b)

Each section forms a significant capacitance with the screen, and the cable section 3 at a certain length can have an inductive resistance connected to the capacitance in parallel. As a result, it becomes possible to match the SMSA with the cable near the parallel resonance frequency f_0 of the input resistance of each section Z_{InS} (Fig. 2).

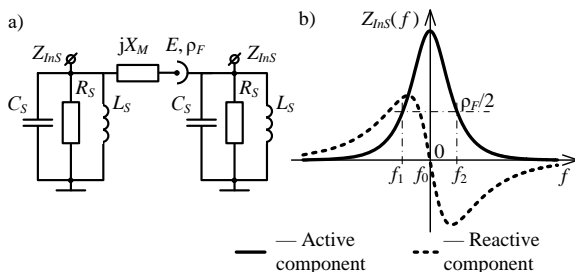


Fig. 2. Equivalent circuit of SMSA near the resonant frequency (a) and frequency characteristics of the input impedance of sections (b)

Since the SMSA, like all MSAs, is known to be narrowband [1, 2], the goodness of the equivalent $R_S C_S L_S$ circuits should be significant, hence the active resonance impedance of R_S should be much larger than half of the feeder wave impedance ρ_F . therefore, at two frequencies, f_1 and f_2 , (see Fig. 2 b) it is possible to compensate the reactance of each section by the series reactance of the RME jX_M .

The gap between the sections is a radiating slit, and the radiation of all outer edges of the structure compensates each other. The shape of the RP is determined by the length of this slit, which is equal to two radii of the structure a , and the resonance frequency is determined by the full length of the curvilinear path from the excitation points to the points where the sections short-circuit the screen. The parallel resonance corresponds to the excitation mode close to the idler, hence, this length should be an odd number of quarters of the wavelength λ taking into account the effective dielectric constant ε_{Ef} [1]. For a more flexible choice of antenna dimensions, additional shorting pins were introduced into the structure, which are symmetrically separated from the main shorting points by a varying angle α . Then the radius of the structure should obey the following relation

$$a = \frac{(2i+1)\lambda}{4\sqrt{\varepsilon_{Ef}} [1 + (90^\circ - \alpha)\pi / 180^\circ]}, \quad i = 0, 1, \dots \quad (1)$$

Numerical modeling of SMPA in the CAD Gamma environment in the UHF band (average frequency 2000 MHz) was performed

The radius varied from 0.3λ to 0.7λ . For each radius the radius of the structure, the position of the pins (angle α) and the value of the matching impedance jX_M were selected. It was found that formula (1) gave structure sizes within $\pm 10\%$ of the final ones, at which the relative bandwidth of the operating frequencies by matching reached 1.5%. At a structure radius up to 0.3λ , the RP had no side lobes and the maximum directional coefficient (DC) D was close to 9 dB. At a radius of 0.5λ , the DC was about 10 dB with a side lobe level (SLL) of about -10 dB. Further increase of the radius resulted in a decrease of the DC and an increase of the SLL (Fig. 3).

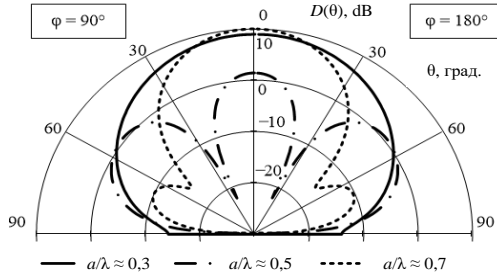


Fig. 3. Directional diagrams of SMSA at different radii of the structure

In the second model, excitation from the edge of the structure to its center was supplied by a symmetrical strip line with a wave impedance of 50 Ohm, the screens of which were formed by section 1 and a common screen. The strip at the edge of the structure was excited by a concentrated port, and a metal pin ending in the plane of sections was connected to the other end of

the strip for convenient connection of a matching element between the strip and section 2 (Fig. 4).

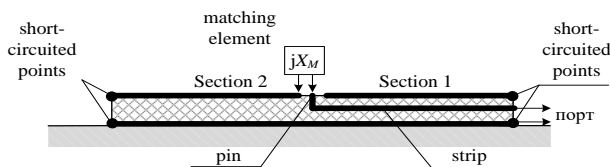


Fig. 4. Cross-sectional diagram of SMPA model with strip line excitation

It was found that the electrical characteristics of this variant of the SMSA model were practically unchanged compared to the first variant, only the impedance of the matching element had to be adjusted.

Results. By means of numerical simulation in a specialized CAD system the possibility of practical realization of a two-section SMSA is proved, which differs from the known one by the fact that the excitation to the sections in it is supplied by a strip line, as well as by the presence of short-circuiting pins, the position of which can be changed. As a result, it is possible to make SMSA flat, without a protruding cable, and to select the dimensions of the antenna more freely, focusing on the characteristics of the directivity diagram.

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THREE-SECTION MICROSTRIP ANTENNA WITH ROTATING POLARIZATION OF RADIATION

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Аннотация: Предложен вариант реализации трёхсекционной микрополосковой антенны круглой формы с устройством возбуждения на основе полосковой линии и исследованы его электрические характеристики. Антенна является двухслойной и может быть изготовлена по печатной технологии, обладает минимальными габаритами по высоте и удовлетворяющими нас коэффициентом стоячей волны и коэффициентом направленного действия. Работоспособность антенны с эллиптической поляризацией излучения в относительной полосе рабочих частот около 2 % при коэффициенте направленного действия около 10 дБ доказана результатами численного моделирования в САПР Gamma.

Ключевые слова: трёхсекционная микрополосковая антенна, вращающаяся поляризация излучения, печатная технология, моделирование.

Annotation. A version of realization of a three-section microstrip antenna of circular shape with excitation device based on a strip line is proposed and its electrical characteristics are investigated. The antenna is two-layer and can be fabricated by printed technology, has minimum height dimensions and satisfying standing wave coefficient and directivity coefficient. The operability of the antenna with elliptical polarization of radiation in the relative band of operating frequencies of about 2 % at a directional coefficient of about 10 dB is proved by the results of numerical simulation in CAD Gamma.

Keywords: three-section microstrip antenna, rotating radiation polarization, printing technology, modeling.

Materials and methods. Microstrip antennas (MSA) [1] have become widespread due to their simple design: their radiating elements are placed on a double-sided foil dielectric, which has a thickness much smaller than the radiation wavelength. The upper foil layer is shaped to act as a transmitter, while the lower layer, always larger, serves as a shield. Excitation of the IPA is usually accomplished using a coaxial cable mounted either in the plane of the radiator or at right angles to it. These antennas are classified as slot antennas because the radiated “magnetic” currents are generated by the voltage between the edges of the radiating structure.

Sectionalized microstrip antennas (SMSA) [2] are a form of MSA that feature a radiating structure divided into two or more segments by narrow gaps. For instance, in a two-segment design, the dimensions and configuration of the radiating slot (the gap between the segments) can be considered separately from the antenna parameters that set the operating frequency. In designs with three or four segments, the antennas are capable

of producing elliptical and circularly polarized radiation. The progression in SMSA technology has paved the way for models incorporating a stripline-based power supply system, along with additional pins that connect the segments to the ground plane [3]. However, the possible use of such elements for SMSAs with circular polarization has not been considered so far. The present study is devoted to the investigation of the possibilities of realization of a three-section SMSA with the mentioned structural elements.

Suppose a circular SMSA (Fig. 1) is equipped with a large-size screen or is located on a flat metal surface (indicated in gray in the figure). Its radiating structure consists of three identical sections: 1, 2 and 3, which are separated by small gaps. In the central part of the structure there is a circular cutout designed to accommodate concentrated elements. Along section 1 runs the outer conductor of coaxial cable 4, which is connected to the section and the shield at the edge of the structure. The center conductor of the cable is connected to the input of the matching device 5, and its outputs are connected to sections 2 and 3. To ensure symmetry, additional cable sections 6 and 7 run along sections 2 and 3, where the center conductors are not used and the outer conductors are connected to the sections and the shield at the edge of the structure.

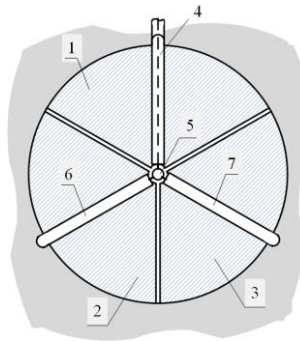


Fig. 1. Diagram of a circular three-section SMSA

One of the main disadvantages of this three-section SMSA configuration is the use of coaxial cables: one for the feed and two additional cables used solely for symmetry, but not as feeders. These cables, laid over the sections, break the plane of the antenna, which makes its use in a number of practical applications inconvenient. In addition, it increases the material consumption and complicates the antenna fabrication process.

To solve the above problems, it is proposed to replace the feeding coaxial cable with a section of symmetrical strip line (SL), as realized in a two-section SMSA [3]. The wide structure and electrical connection of the PL to the

antenna shield allow one of the sections to be used as the “top” shield of the line. Studies [3] confirm that the PL strips do not negatively affect the radiating function of the section, which ensures that the symmetry of the structure is preserved without the need to add additional elements.

Modeling was performed by means of CAD Gamma in the frequency band from 1000 to 3000 MHz at the calculated operating frequency of 2000 MHz.

Since our initial estimates of the essential dimensions were recognized as quite rough, the first iteration of the three-section SMSA was designed with excitation via a discrete port featuring a 50-ohm internal resistance and concentrated series RLC elements. Tests were conducted for a structure with a radius a_3 roughly equal to three-quarters of the wavelength ($i = 1$), which was deemed highly practical [3]. The outcomes validated this approach, as only a few iterative steps were necessary to reach acceptable performance.

In the subsequent modeling phase, several modifications were introduced by using SL-based excitation along with the gradual replacement of discrete RLC elements with SL segments that offered varying inductive impedances. This was accomplished by adjusting the segment widths and reshaping them—from straight elements to curved “meander” configurations with different numbers of bends. These SL segments were fabricated along the bottom side of the radiating structure, with their external ends linked to the sections via metallic pins.

The simulation yielded the following electrical characteristics: the relative operating frequency bandwidth, defined by a VSWR level of 2.0, was about 2%, with the best VSWR value at an average frequency of 2000 MHz being around 1.1. The directional and polarization properties were assessed using cross-sectional views of the unnormalized radiation pattern $F(\theta)$ for angles ϕ equal to zero and 180° (corresponding to the x-axis along which the strip is laid) and $90^\circ - 270^\circ$, as which the angular dependence of the absolute value of DC and the dependence of DC for the right and left circular polarizations were chosen (Fig. 3). The maximum DC value reached approximately 9.5 dB. As expected, the radiation patterns for the section that crossed the gap between the sections were less symmetrical—with a sharper drop-off toward the gap—compared to those for the section positioned perpendicularly.

For clarity, the described results were recalculated into angular dependences of the ellipticity coefficient (Fig. 4).

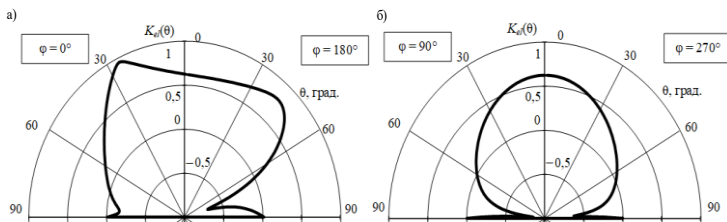


Fig. 4. Cross sections of the angular dependence of the ellipticity coefficient for the angle φ equals to zero (a) and equals to 90° (b)

At significant angular intervals the superiority of the right circular polarization is discernible. However, it transforms into linear and left-hand polarization (negative values of the ellipticity coefficient) in the worst-case scenario (see Fig. 7 b), which occurs outside the “funnel” at an angle θ of about 60° .

Results of the research. A comprehensive design methodology was developed using CAD Gamma to generate multiple models: an initial version with a discrete excitation port and concentrated reactive components, followed by intermediate and final iterations that progressively replaced the port and reactive elements.

An approach for a three-section SMSA implementation is introduced. It features an excitation system based on a stripline that includes a phasing unit with three strip segments. Each unit has distinct shapes and sizes.

Simulation results confirm that this SMSA configuration—entirely free of non-planar components—is highly practical for scenarios that require a narrowband antenna with elliptical polarization, a low-profile design, and the capability to be mounted on large metallic surfaces.

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A DEVICE FOR NOTIFYING THE STATUS OF A ROOM DOOR ON TELEGRAM

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Аннотация. В статье рассматривается разработка устройства, которое передает информацию о состоянии двери помещения (открыта или закрыта) в Telegram. Описаны принципы работы системы, включая датчики и программное обеспечение, обеспечивающие удобное и своевременное оповещение.

Ключевые слова: безопасность помещения, устройство оповещения, Telegram.

Annotation. The article discusses the development of a device that transmits information about the condition of a room door (open or closed) to Telegram. The principles of the system's operation are described, including sensors and software that provide convenient and timely notification.

Keywords: room security notification device, Telegram.

INTRODUCTION

Nowadays, technology has become firmly embedded in all areas of our lives, simplifying and automating many processes. One of these processes is monitoring the condition of doors and rooms. Thanks to the development of the Internet of Things (IoT) and messengers such as Telegram, it has become possible to create notification devices that allow you to receive information about the condition of doors and rooms.

The purpose of this work is to develop and implement a door and room alert system using the Telegram platform. This system allows users to receive notifications about any changes in the condition of doors and rooms. As part of the work, an analysis of existing solutions will be carried out, the possibilities of the Telegram API will be explored, and hardware for monitoring the condition of doors and rooms will be developed. Such a system will be useful in various cases, including home security, office building security, etc.

The results of this project will be useful for people who are interested in

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In the future, the dynamic notification system can be modified and applied in various ways, including household automation, indoor access control and security in office buildings and other public places.

THE MAIN PART

Thus, the work is devoted to the development of a door status notification device with reliable notifications in the Telegram messenger.

The principle of operation of the door and room notification device in Telegram is as follows.

The basis of the system is a magnetic reed switch, which serves as a reliable sensor for the door condition. Due to its simplicity and efficiency, the reed switch provides accurate and instant notification of every door opening or closing. The use of a magnetic reed switch made it possible not only to simplify the design of the device, but also to significantly reduce its cost, making the system accessible to a wide range of users.

The power supply unit provides electrical energy for all system components and protects the system from voltage surges and short circuits. When the door sensor detects a change in state (for example, the door has opened), it sends a signal to the control device, which analyzes the signal and, if necessary, activates the Wi-Fi module to send a notification via the Telegram API to Telegram-the user's channel or chat [2].

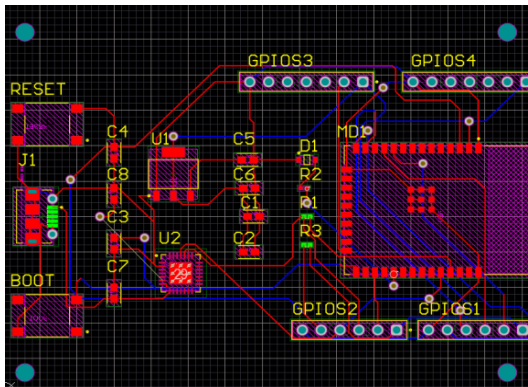


Fig. 1. - Tracing the door sensor board

The door sensor technology is based on a system that includes sensors for determining the position of the door and software for sending notifications to Telegram. The main requirements for the device during design:

- Providing reliable and secure notification of the door status via Telegram, the security of the transmitted data [4].

- Real-time notification implementation, minimizing delays between door status change and message receipt.
- The ability to scale the system, add new devices without significant changes in architecture.
- Energy efficiency, optimizing energy consumption for battery life, especially when using batteries.
- Easy setup and operation, including remote control of the device and monitoring of its status [3].

The management interface for the monitoring device is developed using the Telegram Bot API service. This service is a system that allows the user to receive notifications in the Telegram messenger about events related to the opening or closing of the door, notifications are sent to any device that has access to the Internet and with the Telegram application installed [1].

The management interface should be intuitive and user-friendly. It may include displaying the current status of the door (open/closed), a history of door status changes with timestamps, and configuring notification settings (frequency, sending conditions). The interface must be adapted to various devices, including mobile phones and tablets, so that the user can control the notification system from any device. The interface design shown in Figure 2 should be modern and minimalistic so as not to distract the user from the main functionality.

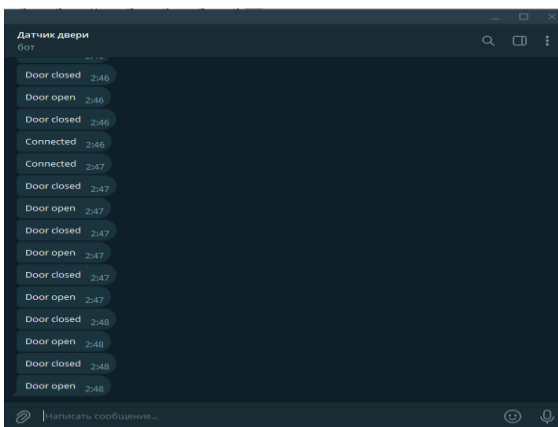


Fig. 2. - Smartphone control interface

Since the developed device uses a microcontroller, it is required to develop software, the program algorithm includes the following main blocks:

- initialization;
- connect to Wi-Fi;

- authorization and connection to the Telegram bot;
- continuous polling of the door sensor;
- when a change in the door status is detected, sending a corresponding notification;
- information output to the monitoring device.

At the beginning of the program, I/O ports are configured, necessary libraries are connected, a telegram bot is connected, etc.

The software continuously reads data from the magnetic reed switch mounted on the door. When the door closes or opens, the reed switch status changes, which is a signal to the system. After receiving a signal from the reed switch, the system processes it using the debossing algorithm to avoid false alarms due to possible contact rattling. The software uses the Telegram API to communicate with the messenger's servers. After processing the signal and confirming the door status change, the system sends a notification to the Telegram bot, which then forwards it to the user.

CONCLUSION

Thus, a door status notification system was developed and implemented using the Telegram platform. This device is an inexpensive and reliable solution for access control and indoor security.

The results of the study can be used to further improve the notification system, including integration with other smart devices in the home and the development of a mobile application for more convenient system management.

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CHARACTERISTICS OF ACOUSTIC WAVE PROPAGATION IN UNDERWATER CHANNEL

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Аннотация. В статье представлены результаты обзора особенностей распространения волн в гидроакустическом канале связи. Рассмотрены факторы, которые оказывают влияние на распространение в подводной среде звуковой волны. К ним относятся многолучевое распространение, затухание звуковой волны, шумы в подводной среде и эффект Доплера. Как правило затухание звуковой волны и многолучевое распространение в первую очередь связаны с неоднородностью среды распространения. Высокий уровень шумов в гидроакустическом канале связи связан с наличием большого числа различных источников шума, к которым можно отнести шумы судоходства, шумы, связанные с тепловым движением молекул воды и др. Эффект Доплера выражен в постоянном движении приемного и передающего устройств и ввиду этого при проектировании гидроакустических систем связи его требуется учитывать.

Ключевые слова: гидроакустический канал связи, затухания в морской среде, многолучевое распространение, шумы моря, эффект Доплера

Annotation. In this article results of overview of the characteristics of wave propagation in underwater acoustic communication channels are presented. This study investigates the parameters impacting underwater sound wave transmission. Key factors involve signal attenuation, multipath effects, underwater noise interference, and Doppler compensation requirements. Typically, sound wave attenuation and multipath propagation are primarily caused by inhomogeneities in the propagation medium. The high noise level in hydroacoustic communication channels results from numerous noise sources, including shipping noise, thermal noise from water molecular motion, among others. The Doppler effect manifests due to constant relative motion

between transmitting and receiving devices, necessitating its consideration in hydroacoustic communication system design.

Keywords: underwater acoustic communication channel, oceanic absorption, multipath propagation, underwater noise, Doppler effect.

Introduction

Currently, the task of ensuring high-quality communication in underwater channels faces numerous challenges, as the sea environment is a complex area where the radiated wave characteristics are significantly affected by the frequency range used. When constructing a communication channel in an underwater environment, three main frequency ranges are considered: acoustic (from 10 Hz to 1 MHz), radio frequency (from 3 Hz to 300 GHz), and optical (from 500 to 600 THz). As a rule, the radio frequency range is not applicable in the underwater environment because radio waves in the channel are subject to strong suppression. Therefore, optical and acoustic waves are used when building a communication channel in the underwater environment. The latter is used to organize long-range communication.

Main part of the study

Hydroacoustic systems are used for underwater communication and navigation. They face a number of challenges related to the attenuation of acoustic waves in the underwater environment and the selection of the optimal frequency range for signal transmission. These two aspects are closely linked and determine the efficiency of data transmission, communication range, and signal quality. Acoustic wave attenuation and frequency selection are key factors that must be considered when designing hydroacoustic systems.

The attenuation of acoustic waves in water is the loss of energy of a sound wave as it propagates through the aquatic environment [1]. This phenomenon occurs due to several factors that limit the range and effectiveness of underwater communication.

One of the factors is absorption. Absorption is the process by which acoustic energy is converted into heat and depends on the frequency of the wave. High frequencies have greater absorption, as their energy is more quickly converted to heat, leading to greater attenuation. This limits the propagation range of high-frequency waves. Conversely, low-frequency waves can travel greater distances with less energy loss. Figure 1 shows the dependence of the attenuation coefficient on frequency for various underwater regions of acoustic wave propagation.

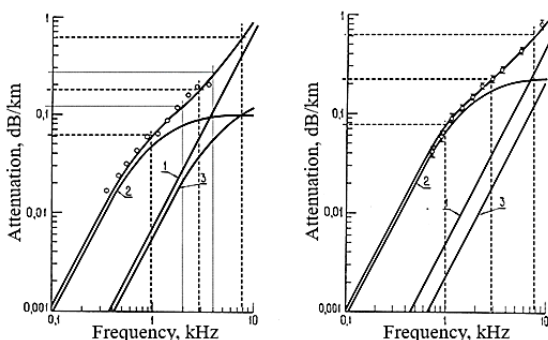


Fig. 1. - Dependence of the attenuation coefficient on frequency

Scattering can also occur in the underwater environment. Scattering happens when an acoustic wave interacts with inhomogeneities in the water, such as gas bubbles, plankton, or suspended particles. These elements alter the wave's trajectory, redistributing its energy, which causes a loss of power and degradation of the signal quality. This is particularly relevant at greater depths, where the concentration of particles in the water can be high.

Multipath propagation in the underwater environment means that acoustic waves can be repeatedly reflected from the surface and the seabed, leading to additional energy losses with each reflection. In this case, signals that propagate along different paths may experience interference, which leads to signal distortion.

The speed of sound is the most sensitive to changes in temperature and increases with increasing temperature in the sea. “The sea surface temperature varies from about 30°C in tropical latitudes to near-zero temperatures in the high latitudes of the Arctic and Antarctic. As depth increases, the water temperature drops to near-zero values and then does not change further” [1, p. 103].

“In tropical latitudes, this occurs at depths of around 1000 m, and at higher latitudes, at shallower depths. In tropical latitudes, at depths of 300 to 1000 m, the water temperature always decreases regardless of the time of year or weather conditions. This is the so-called main or primary thermocline. In higher latitudes, at a depth of about 300 m, the water temperature is already close to zero, so the main thermocline is absent, but at depths of 100 to 300 m in summer, when the sun provides more heat, a seasonal thermocline is observed” [1, p. 104].

The thermocline is always present in tropical latitudes, as summer and winter temperatures differ. At shallow depths of up to 100 m. water temperature is influenced by seasonal and daily temperature changes. “In

calm weather, the temperature of the upper layer, up to 10 meters thick, changes throughout the day. In stormy weather, the water in the upper layer mixes, the temperature equalizes, forming an isothermal layer, which can persist for a long time due to the high heat capacity of water” [1, p. 104].

Regular inhomogeneities in temperature and pressure in seawater. It changes the speed of sound with depth. Typical profiles of the distribution of sound speed with depth are shown in Figure 2.

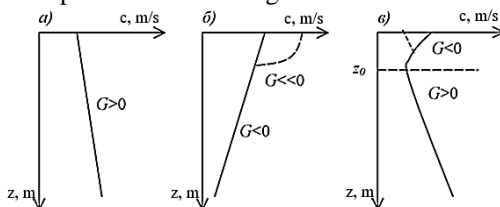


Fig. 2. - Typical profiles of the distribution of sound speed with depth

“In properly designed equipment, its own electrical noise can be neglected [2]. Seismic disturbances of the seabed, wind disturbances of the sea surface, and thermal motion of water molecules are the main sources of natural noise in the sea. In coastal waters and harbors, biological sources, such as snapping shrimp, dolphins, and other species of marine mammals and fish, contribute significantly to the overall noise level” [1, p. 104].

“The vertical axis of this figure plots the intensity of acoustic noise in decibels relative to the sound intensity of one micro pascal per hertz of bandwidth. For ease of analysis, the entire frequency spectrum can be divided into three ranges. In the first, low-frequency range, extending up to several hundred hertz, the spectral noise density is highest and is mainly determined by so-called distant shipping” [2, p.101].

The level of this maximum depends on the geographic location, commercial activity in the region and time of year. Distant shipping noise has a broad spectral maximum in the 30 Hz region and rapidly decreases after 100 Hz. This component has been constantly growing. “Ships create noise over a wide range of frequencies. Due to the fact that low-frequency oscillations in this range have low losses both during propagation and reflection from the boundaries of the aquatic environment, they propagate underwater over long distances, hundreds of miles. For the same reason, the intensity of low-frequency noise in the horizontal direction is much higher (by 12 or more decibels) than in the vertical direction” [2, p. 101].

“In the second, mid-frequency range, extending from several hundred hertz to tens of kilohertz, the spectral noise density is mainly determined by wind force. The sea surface, under the influence of wind, becomes agitated

and creates noise that propagates into the water column. As a result, the noise intensity in the vertical direction is slightly higher than in the horizontal direction. This noise has a broad spectral maximum in the 500 Hz region and decreases at higher frequencies by approximately 5 dB per octave" [2, p. 101].

Extending above 50 kHz, noise caused by the thermal motion of water molecules predominates in the high-frequency range. The spectral density of this noise increases by approximately 6 dB per octave and is isotropic in space.

A typical noise spectrum in a hydroacoustic communication channel is shown in Figure 3.

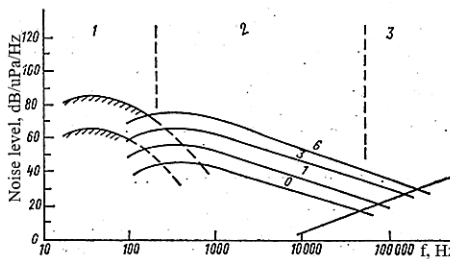


Fig. 3. - Typical spectrum of natural deep-sea noise depending on its condition in Beaufort scale.

It is necessary to increase the average frequency of the signals as analysis of the natural noise spectrum in the sea shows. The noise level in the 3 kHz range is approximately 15 dB higher than one in the 25 kHz range, which is used for voice communication.

Multiplicative interference of both artificial and natural origin is observed in condition of receiving acoustic signals. Phenomena of multipath propagation and random changes in the initial phase, intensity and frequency of acoustic oscillation can be considered as multiplicative interference of a natural character. The same phenomena are artificial and man-made. It is caused by the movement or simply the unstable position of the receiving and transmitting antenna in space.

The wavelength of signals used in hydroacoustic communication equipment is small. Hydroacoustic antennas have a non-spherical radiation pattern. Even slight changes in the position of the receiving and transmitting antennas relative to each other lead to significant changes in the initial phase of the oscillations. The spectrum of tonal interference in the hydroacoustic communication channel is shown in Figure 4.

The Doppler effect it occurs when the source or receiver moves relative to the water, which changes the frequency of the signal and causes additional

energy losses. For a stationary receiver and a moving source, the frequency increases, which can lead to frequency variations.

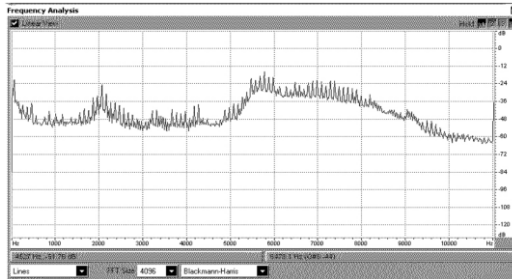


Fig. 4. - Spectrum of tonal interference generated by ship machinery.

For a moving receiver and a stationary source, the frequency also changes, which can cause errors in data transmission and huge energy losses. Typical motion vectors of the receiving and transmitting devices are shown in Figure 5.

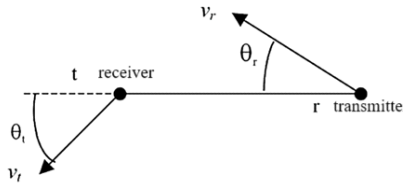


Fig. 5. - Motion vectors of the receiver and transmitter for determining Doppler frequency shift

Consequently, it is subject to the Doppler effect, and its carrier frequency changes according to the following expression, when an acoustic wave propagates in an underwater environment with moving receiving and transmitting devices:

- frequency of the sound wave emitted by the transmitter;
- speed of the acoustic wave propagation in the underwater environment;
- speed of the receiver and transmitter, movement;
- angle of the receiver and transmitter movement.

The influence of the Doppler frequency shift is quite significant due to the low speed of propagation of sound waves in the hydroacoustic communication channel, as well as the constant movement of the receiving and transmitting modules. The frequency of the carrier oscillation is generally comparable to the clock frequency when constructing hydroacoustic systems.

The Doppler frequency shift also affects the clock frequency, which leads both to a shift in the carrier oscillation and the duration of the signal pulses. Therefore, the Doppler frequency shift should be taken into account when building hydroacoustic systems. It is to be compensated for to improve the communication channel reliability.

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BEACH MEASURING BUOY

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Аннотация. В статье представлена концепция разработки морского метеорологического буя для решения проблемы недостатка информации о состоянии морской воды в прибрежной зоне. Это имеет значительное значение для безопасности отдыхающих и защиты экосистемы. Рассмотрена структурная схема буя, включающая в себя набор датчиков, измеряющих метеорологические и гидрологические параметры, устройство передачи информации — модуля GSM800С и управляющее устройство — микроконтроллер семейства STM32 и источник питания — литий-ионный аккумулятор. Обеспечение жителей актуальными данными о качестве воды, высоте волн, скорости ветра и других метеорологических и гидрологических параметрах позволит улучшить

информированность населения и повысить уровень безопасности при проведении водных мероприятий.

Ключевые слова: Буй, микроконтроллер, передатчик, датчики.

Annotation. This article presents the concept of developing a marine meteorological buoy capable of addressing the issue of insufficient information about the state of seawater in the coastal zone, which is of significant importance for the safety of vacationers and the protection of ecosystems. The structural diagram of the buoy is considered, which includes a set of sensors measuring meteorological and hydrological parameters, a data transmission device—the GSM800C module, a control device—a microcontroller from the STM32 family, and a power source—a lithium-ion battery. Providing residents with up-to-date information about water quality, wave height, wind speed, and other meteorological and hydrological parameters will improve public awareness and enhance safety during water-related activities

Keywords: Buoy, microcontroller, transmitter, sensors.

Introduction.

Today, there is a pressing issue regarding the prediction of the state of sea water in coastal areas, as well as a lack of information for the public about its current state. This article addresses the creation of a measuring buoy equipped with modern sensors that provide real-time information about water conditions, which is subsequently transmitted to a server. This ensures convenient access for users to up-to-date data through internet platforms and mobile applications. The main advantages of the proposed buoy include an enhanced set of measurable parameters, its resistance to vandalism due to a robust casing, the possibility of autonomous operation without solar panels, and the accessibility of components in the domestic market. Thus, our development will become an important tool for enhancing the safety and comfort of residents and visitors to coastal areas, as well as for protecting the marine environment.

The main part.

Beach meteorological buoys are specialized devices designed to collect and transmit data on marine conditions in coastal areas. The structural diagram of the beach buoy is shown in Fig. 1.

The buoy's structural diagram includes the following elements: specialized sensors for measuring temperature, atmospheric pressure, wave height, turbidity, as well as wind speed and direction.

For measuring atmospheric pressure, the "ADP-100" sensor from the company "Pelenr" was selected. It has a measurement range from 0 to 2000

hPa, with an accuracy of ± 0.7 hPa. Its design offers increased protection for marine conditions and the casing is made from corrosion-resistant materials.

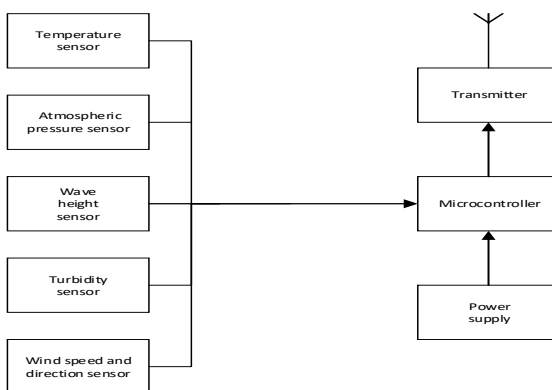


Fig. 1. - Structural diagram of interaction of application modules

For measuring wind speed, the WH-SP-WS01 sensor was chosen. This budget-friendly sensor is suitable for use in weather stations. It has a lightweight design, is easy to install, and features the following specifications: wind speed from 0 to 30 m/s, direction accuracy of $\pm 3^\circ$. It is made from a plastic casing and is resistant to environmental effects. It is compatible with most weather stations and monitoring systems and can operate within a power range of 5 to 12 V from an external power source.

For measuring water temperature, the digital temperature converter DS28B20 was selected. It has a temperature measurement range from -55 to $+125^\circ\text{C}$, an ADC resolution of 9 to 12 bits, and a measurement error of up to $\pm 0.5^\circ\text{C}$ (for the range from -10°C to $+85^\circ\text{C}$) with a data polling time of < 750 ms.

The turbidity sensor TSW-30 is capable of determining water quality by measuring its turbidity level. Turbidity is defined by the ratio of suspended particles in a liquid. To detect these particles, the sensor uses a light-sensitive component that measures the transmission and scattering of light, which directly depends on the number of particles in the water, affecting its turbidity level. The turbidity sensor has the following technical specifications: power supply voltage — 5 V; current consumption — 40 mA; response time — 500 ms; dimensions — 30 x 20 x 12 mm, and weight not exceeding 55 g.

For measuring wave height, the Wave sensor 2.0 was selected. The wave sensor is installed in the stable center of the buoy. It is equipped with a nine-axis accelerometer that collects data on the rise, fall, and oscillatory movement of the buoy's body. Based on the obtained data, it calculates information

related to wave activity. From the buoy's tilt direction in the neutral position, the primary wave direction and 16-directional wave distribution are calculated. The measurement interval is a minimum of 30 minutes (10 minutes for data collection and 2–5 minutes for data processing). It is energy-efficient; the power consumption in standby mode is 0.08 W, significantly increasing the system's working life and extending observation cycles. Enhanced durability through the use of modern materials makes the casing resistant to harsh marine conditions over prolonged periods. The sensor withstands temperatures up to 85°C. Wave height is measured in the range from 0 m to 30 m with a measurement accuracy of $\pm 0.1+5\%$, while the resolution is 0.01 m. Additionally, the sensor measures wave direction from 0° to 360° with an accuracy of $\pm 10^\circ$ and a resolution of 1°, while the wave period ranges from 0 s to 25 s, with a measurement accuracy of ± 0.5 s and a resolution of 0.01 s.

The choice of the STM32 microcontroller for creating the meteorological beach buoy is based on several factors ensuring high performance and reliability of the device. It is presented by microcontrollers based on the ARM Cortex-M architecture and offer a wide range of modifications for flexible adaptation of the system to performance requirements (table 1).

Table 1. STM32's advantages

Advantages	Features
Energy efficiency	The device operates for extended periods on batteries. It is crucial for autonomous marine platforms. Its high clock frequency and powerful computational capabilities enable the implementation of complex data processing algorithms, such as the analysis of meteorological parameters.
Low cost and high-quality connectivity	They are easy to integrate with various microcontrollers and control systems, facilitating rapid and straightforward development and setup of data transmission systems.
A variety of communication interfaces, including I2C, SPI, UART	STM32 simplifies the integration of various sensors and modules for collecting weather condition data: atmospheric pressure, temperature, wave height, wind direction.
Widespread availability and reliable coverage of	This allows for effective data transmission over significant distances, which is particularly important for buoys closed to shorelines

GSM networks across large areas	
Reliability, durability, and resistance to aggressive marine environments.	The structure of the beach meteorological buoy includes a frame on which all other elements are mounted. It must be strong and stable to withstand strong waves and winds. A lithium-ion battery with a capacity of 8000 mAh was chosen as the power source due to its long lifespan, high safety, and resistance to high temperatures.
Stable connectivity	It is essential for transmitting weather data. It's also important to consider energy efficiency; many GSM modules, including GSM800C , are designed with energy-saving modes in mind, which is particularly crucial for autonomous devices like meteorological buoys, which operate on batteries.
The casing also includes a shell—a protective outer layer designed to safeguard the internal components from moisture, salt, and ultraviolet radiation.	To prevent corrosion and wear is a main purpose of the shell
Polypropylene is a popular choice for the outer casing of marine meteorological buoy	Resistance to saltwater, non-corrosive and non-destructive capabilities in marine environments, chemical inertness (not reacting with most chemical substances in the water), lightweight nature (having a low density of 0.90–0.92 g/cm ³ , allowing it to float well), UV resistance (with stabilizers added, it does not degrade in sunlight), flexibility and impact resistance (withstanding wave impacts and collisions with vessels), and durability, ensuring years of service without frequent replacements.

A well-designed buoyancy system and anchor rope reduce the risk of device failure and minimize potential environmental damage, which is especially important when the buoy is used to collect meteorological data.

The buoy's stability on the water is crucial, as it allows the device to maintain a vertical position and avoid capsizing. This characteristic is provided by the buoyancy element housed in the base, secured by an anchor rope. The anchor rope keeps the buoy in the designated position, preventing its movement due to waves, currents, or winds, thus allowing accurate recording of meteorological measurements and avoiding distortions related to the device's movement. It also helps withstand various loads on the water's surface, ensuring durability and protection.

Conclusion.

Wave height, wind speed, and other meteorological and hydrological parameters will improve public awareness and enhance safety during water activities, providing residents with current data on water quality.

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LABORATORY STAND FOR STUDYING ANTENNAS FOR CONTROL AND NAVIGATION SYSTEMS FOR UNMANNED AERIAL AND SURFACE VEHICLES

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Аннотация. В статье рассматривается подбор оборудования для создания лабораторного стенда, предназначенного для изучения принципов работы и частотно-зависимых параметров тестовых антенн круговой поляризации. Ключевыми параметрами исследуемых антенн являются коэффициент эллиптичности, диаграмма направленности и входное сопротивление. Для обеспечения качественного выполнения лабораторных работ разработаны методические указания, включающие теоретические основы, пошаговые инструкции по проведению измерений и рекомендации по обработке результатов.

Ключевые слова: антенна круговой поляризации, система управления и навигации БПА, лабораторный стенд, измерение параметров антенны.

Annotation. The article considers the selection of equipment for the creation of a laboratory stand, intended to study the principles of operation and frequency-dependent parameters of test antennas of circular polarization. The key parameters of the antennas studied are the axial ratio, the pattern of directivity and the input impedance. In order to ensure the quality of laboratory work, methodological instructions have been developed, including theoretical basis, step-by-step measurement instructions and recommendations for processing results.

Keywords: circular polarization antenna, UMN control and navigation system, laboratory stand, antenna parameter measurement.

Introduction

The rapid development of Internet of Things (IoT) technologies, including concepts such as smart transport, delivery robots, unmanned aerial

mail, and other innovations, has created a growing demand for the development of control systems for groups of maritime, terrestrial, and aerial unmanned mobile vehicles (UMVs). One promising approach to addressing this challenge is the enhancement of energy characteristics in peripheral antenna equipment, which is utilized both within control subsystems and onboard UMVs themselves. The one of the direction for solution of this task is the improvement of the energy characteristics of antennas. So, the main purpose of system equipment modernization and enhancement is to provide the optimal technical and economic characteristics, and various works are dedicated to this task. For example, reference [1] presents the results of an analysis of direct radio frequency coverage on a shore-to-ship communication line, along with modeling Wi-Fi network coverage in Sevastopol Bay, which features a rugged coastline. Basing on the tasks for which unmanned mobile systems are used, different types of antennas are required.

Structure of the Laboratory Setup

The primary step in studying the characteristics of an antenna is constructing its radiation pattern (RP), which is a function $F(\varphi, \theta)$ of the angular variables φ and θ in a spherical coordinate system. For a transmitting antenna, the normalized RP characterizes the variation in radiated power levels in different directions relative to the phase center of the antenna. For a receiving antenna, the normalized RP characterizes the variation in received signal power levels depending on the direction of signal reception.

The second characteristic to be measured is the input impedance of the antenna, defined as the ratio of the complex amplitudes of harmonic voltages and currents at the antenna input. By "antenna input," we mean the cross-section or point where the transmission line is connected. The value of the input impedance must be known to match the antenna with the feeder. In a matched mode, the antenna radiates (or receives) the maximum power. If the receiving antenna is not matched with the load, a reflected wave appears from the load, characterized by the reflection coefficient. A mixed mode is established in the line, where the current and voltage along the line periodically take maximum and minimum values. In this case, alongside the reflection coefficient, the voltage standing wave ratio (VSWR) is introduced, which indicates the degree of antenna matching.

When studying antenna matching, it should be considered as a four-pole network, whose parameters are described by the scattering matrix. Matching in the transmission path is determined by the value of the S_{11} element of the scattering matrix, which is the complex reflection coefficient at the input. The S_{11} parameter also accounts for internal reflections from the antenna's structural elements. For example, in a horn antenna, mismatching will be

determined by the coaxial-to-waveguide transition, its connection to the horn, and reflections from the aperture of the horn.

In this work, the amplitude radiation pattern is measured over a wide frequency range in the E- and H-planes as a function of the angular (azimuthal) coordinate. The methodology is based on measuring the frequency dependence of the magnitude of the antenna's transmission coefficient S_{11} , which determines the amplitude RP. The antenna is considered as a four-pole network in this context.

The block diagram of the setup for measuring antenna characteristics is shown in Figure 1.

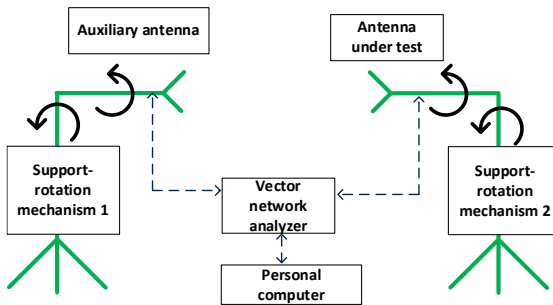


Fig. 1 — Structural diagram of the antenna system

To implement experimental measurements of the parameters of the antenna under test (AUT), a set of three auxiliary antennas (AA) is required:

- an antenna with linear polarization of radiation (ALP);
- an antenna with right-hand circular polarization of radiation (ARCP);
- an antenna with left-hand circular polarization of radiation (ALCP).

As ALP is used monopolar antenna (fig 2, a). Subsequently, it will be used as the basis for measuring the gain of the antennas under test. Two cylindrical helix antennas with different winding directions are used as ARCP and ALCP (fig 2, b). Measurements are performed in the frequency domain using a portable vector network analyzer "LiteVNA64" (VNA) with a frequency range of 50 kHz to 9 GHz.

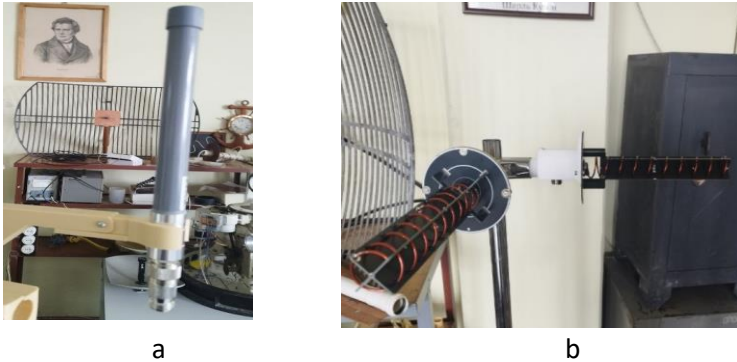


Fig. 2 — Set of AA

The test signal from Port 1 of the VNA (Fig. 3) is applied to the AA, which is mounted on a support-rotation mechanism 1. The signal from the AA is transmitted to the AUT, thereby creating a telecommunication channel. The AUT, mounted on a support-rotation mechanism 2, sends the received signal to Port 2 of the VNA.



Fig. 3 — Physical appearance of the VNA

The measurement of the antenna pattern is performed by estimating the transmission ratio S_{21} and VSWR. The measurement of the antenna's input impedance is performed by evaluating the complex reflection coefficient S_{11} . During the experiment, S_{21} and VSWR are measured using Ports 1, 2 of the VNA, S_{11} is measured using Port 1 of the VNA.

The frequency dependence can be observed both directly on the screen of the VNA and on the screen of a personal computer connected to the VNA for data processing and visualization (Fig. 4).

The results of measurements of frequency-dependent signal parameters are processed in the program and compared with theoretical calculations.

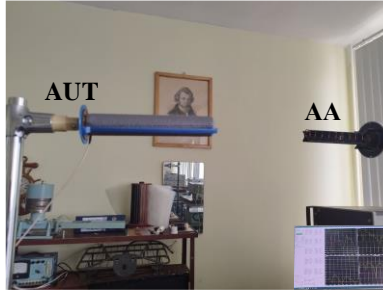


Fig. 4 — Configuration of the laboratory setup

To determine the axial ratio of the antenna under test, the transmitting antenna must be rotated around the Z-axis (Fig. 4). During this rotation, the S_{21} parameter readings vary between the minimum ($S_{21,min}$) and maximum ($S_{21,max}$) values. The axial ratio (K_{ar}) is calculated as the square root of the ratio of the minimum S_{21} value to the maximum S_{21} value:

$$K_{ar} = \sqrt{\frac{S_{21,min}}{S_{21,max}}}$$

For circular polarization, $K_{ar} > 0.8$; for linear polarization, $K_{ar} < 0.1$; and for elliptical polarization, $0.1 < K_{ar} < 0.8$.



Fig. 4 — Photograph of the experimental setup for determining the antenna's axial ratio

The dominant polarization angle (γ) is determined using the graduated scale of the transmitting antenna. First, the reference angle α_1 is identified, which corresponds to the position of the transmitting antenna when receiving a vertically polarized wave. Subsequently, the transmitting antenna is rotated

around the horizontal axis until the peak received signal is obtained, and the angle α_2 is recorded. The dominant polarization angle γ is then calculated as:

$$\gamma = \alpha_2 - \alpha_1$$

Conclusion

The laboratory setup for antenna parameter measurement was thoroughly described, and a systematic methodology was established. A four-turn non-regular cylindrical spiral antenna was experimentally investigated using this setup. The results confirmed both the reliability of the experimental configuration and the validity of the measured data, ensuring the setup's applicability for precise antenna characterization. This work contributes to the validation of experimental techniques for evaluating novel antenna geometries, particularly those with irregular structures

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WINDSHIELD HEAD-UP DISPLAY SYSTEM

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Аннотация. В статье представлен обзор устройств для проецирования данных на лобовое стекло автомобиля. Разработана структурная схема. Показана электрическая принципиальная схема системы проецирования данных.

Ключевые слова: Siemens, Car HUD system, проекция данных, проекционный дисплей.

Annotation. The article presents a review of devices for data projection on the car windshield. The structural scheme is developed. The electrical circuit diagram of the data projection system is demonstrated.

Keywords: Siemens, Car HUD system, data projection, head-up display.

1. Introduction

Car HUD systems only became popular in 2003. BMW company in co-operation with Siemens presented an improved Head-up Display. The device was optionally installed on 7 series cars in E 65 and E 66 models. This system was more informative and was equipped with colour displays with automatic brightness change. This provided greater safety and comfort for the driver while driving.

2. Highlights

The purpose of designing a data projection device is to collect information from a multitude of sensors and units with subsequent processing and output of information in the form of a projection on the windscreen in real time. The device will report abnormal situations in the operation of the car components. For example: increased coolant temperature, low oil pressure, low fuel level in the tank, etc. This device will indicate the occurrence of errors by means of a message on the visual display and audible signalling.

One should present the structural diagram of the device in Fig.1.

The “MCU” supports the necessary protocols to ensure the implementation of all required functions: reception and processing of the signal from the “Bt” unit and the “Wi-Fi” unit.

The ‘Keypad’ unit is a membrane keypad consisting of three buttons for setting the main options of the device.

The ‘Temperature sensor’ unit is designed to measure the temperature inside the car.

The ‘Light Sensor’ unit is designed to control the brightness of the display.

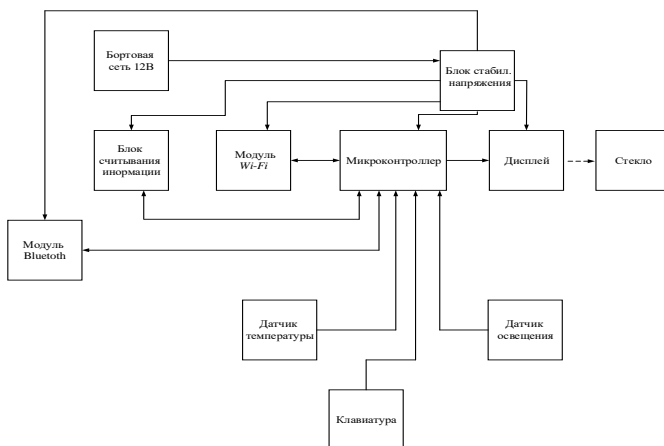


Fig. 1. - Structural diagram of the device

The 'Bluetooth Unit' is used to connect a smartphone. This is used to customise the interface, to output navigation prompts to the display. SPP protocol will be used to exchange data with mobile devices.

The 'Wi-Fi module' unit is designed to connect a device that will read information from the vehicle's electronic control units.

The 'Information reading unit' is connected to the vehicle's diagnostic socket. It will read out all the necessary information from the car's electronic units and transmit it to the Wi-Fi unit.

The 'Voltage stabilisation' unit is designed to convert the voltage of the car on-board network into the voltage required to power the device units.

The 'Display' unit forms an image with the necessary data and projects it onto the 'Glass' unit.

The 'Glass' unit is a small transparent reflector screen that is applied to the Windshield in front of the driver.

It is necessary to choose a microcontroller, which will provide the realisation of all functionality of the designed device: reception and processing of data received from the Bluetooth module and Wi-Fi module, information processing, formation and output of the image for projection. Also, the microcontroller should be equipped with the necessary number of ports to ensure work with all the necessary functional units. These requirements comply with the line of microcontrollers of the domestic company Milandr. For further development we will choose the microcontroller K1986BE92QI in a plastic case LQFP64.

These microcontrollers can be programmed directly in the system via SPI and JTAG serial interfaces.

The appearance of the K1986BE92QI microcontroller is shown in Figure 3.1.

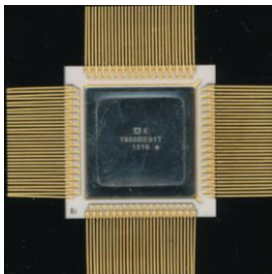


Fig. 2 - external view of microcontroller K1986BE92QI

In order to organise data transmission from electronic control units of the car to our device, it is necessary to organise data transmission from OBD-scanner ELM327 mini to our device via Wi-Fi module, it is necessary to reduce data delay. This solution will be implemented by using a specialised module. The modules based on Ai-Thinker SoC chip, namely Wi-Fi module ESP 01, are suitable for this solution.

ESP 01 is a Wi-Fi module board based on the ESP8266EX chipset. The module is equipped with 2MB Flash-memory chip, quartz resonator, indicator LEDs informing about the module operation mode. Clock frequency: 80/160MHz. Also, on the board there is an antenna in the form of a piece of track on the top layer of the PCB. The module can be configured using AT commands.

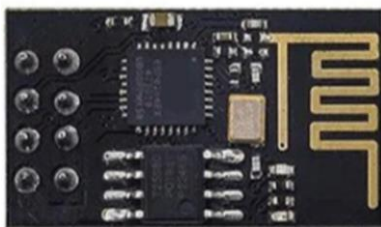


Fig. 3 - External view of the ESP 01 module

To organise the output of navigation prompts to our device and interface settings and selection, Bluetooth communication will be organised. This solution will be realised with the help of an embedded Bluetooth module, and the KT-6368A module has been chosen as the module. The KT-6368A is a dual mode data chip that supports Bluetooth 5.1, as well as the ability to enable

the BLE function. The BLE function will be used to display navigation guidance on the projection of the device.



Fig.4 - External view of the KT-6368A module

To form a clear and high-quality projection it was decided to use the HDMA544-A1-001 display. This display is manufactured using AMOLED technology, with a diagonal of 5.44 inches and a resolution of 1080×1920 pixels.

The developed device is intended for use when the engine is started. It is considered that in a car with the engine started, the voltage of the on-board network increases and is 13.4 volts. This is due to the operation of the generator. To provide power to the device from the on-board network of the car with a voltage of 13.4 volts when the engine is started, it is necessary to use a voltage converter of 3.3 volts.

To realise this task we have chosen the A307sgt-ADJ microcircuit. This chip is a step-down switching regulator capable of driving a 2 amp load. The chip has a fixed output voltage of 3.3 volts. This chip has a wide range of supply voltages from 7 to 40 volts.



Fig.5 - External view of microcircuit A307sgt-ADJ

To ensure correct operation of the chip, the necessary piping must be connected. Input capacitors to ensure stable operation and smoothing of voltage spikes. Output capacitors are also necessary to filter the output voltage and ensure stable operation. Short traces should be used to connect the input

and output capacitors. It is recommended to use capacitors with low equivalent series resistance to ensure low output voltage ripple and stable operation.

3. Conclusion

Considering the review and the shortcomings of the products on free sale, it was considered necessary to develop a system of data projection output on the car windscreen (HUD-system) taking into account all the advantages and disadvantages of existing devices.

The following were chosen as the main elements: microcontroller of domestic company Milandr K1986BE92QI, Wi-Fi module esp 01, Bluetooth module KT-6368A, display HDMA544-A1-001, voltage converter chip A307sgt-ADJ.

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CALCULATION OF RADIATION CHARACTERISTICS AND INPUT CHARACTERISTICS OF AN ANTENNA ARRAY FOR MOBILE COMMUNICATION SYSTEMS

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Аннотация. В статье представлен расчет характеристик антенны. Приведены результаты оптимизации размера передатчика и построения кластера антенной решетки на его основе. Рассмотрен анализ характеристик четырехэлементной антенной решетки.

Ключевые слова: 5G, частотная зависимость, кластер антенной решетки, четырехэлементная антенная решетка.

Annotation. Calculation of antenna characteristics is presented in the article. The results of optimization of the size of the transmitter and

construction of the antenna array cluster on its basis are demonstrated. Analysis of the characteristics of a four-element antenna array is considered.

Keywords: 5G, frequency dependence, antenna array cluster, four-element antenna array.

1. Introduction

Given that 5G is characterized by high frequency and fast fading, it is difficult to cover indoor signals by relying only on outdoor base stations. Hence, there is a need to develop an antenna for an indoor base station operating at these frequencies to ensure power compensation.

2. Highlights

The transmitter was designed to operate in the 5G NR n78 (3.3 - 3.8 GHz) and n79 (4.4 - 5 GHz) bands.

Figure 1 shows the antenna model in the Gamma software.

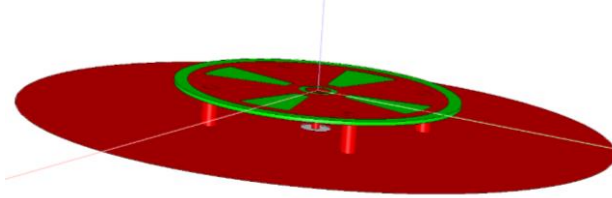


Fig. 1 - Model of the antenna array radiator in Gamma software

The developed transmitter forms a low-directional radiation pattern, practically not varying in the range of n78. The parameters of the radiation pattern are close to those of a symmetrical vibrator. However, the developed transmitter is significantly more broadband.

The antenna gain varies from 3.3 dB at 3.3 GHz, to 5.5 dB at 5 GHz. It can be seen that in the n79 band the gain almost does not change.

The developed antenna should be aligned with the feeding line with a wave impedance of 50 Ohm. The criteria for acceptable alignment was to obtain the value of standing wave coefficient at the input of the antenna less than 2.

Fig. 2 shows the calculated dependence of the standing wave coefficient on the frequency at the antenna input and the radiation pattern of the transmitter at $\alpha=0$ at 5 GHz. It presents that the developed radiator is matched with the feeding line over the entire operating frequency range from 3.3 GHz to 5 GHz with a standing wave coefficient value not higher than 1.9.

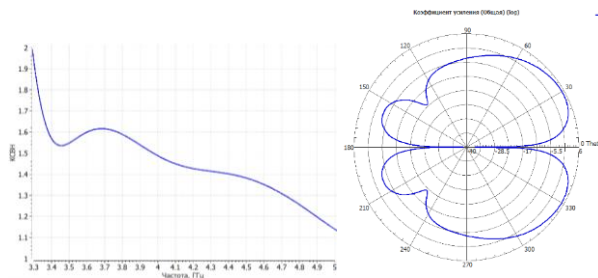


Fig. 2. - Frequency dependence of the standing wave coefficient at the transmitter input and the radiation pattern of the transmitter at $\varphi=0$ at the frequency of 5 GHz

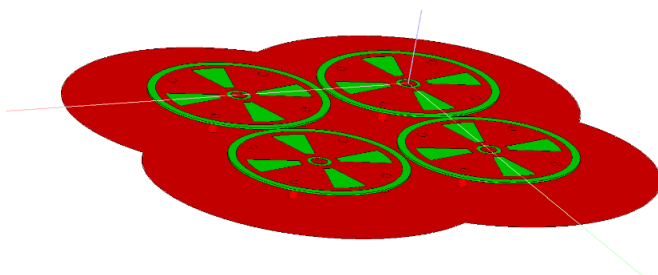


Fig. 3 - Antenna array model in Gamma software

The calculations were made at the two centre frequencies of the n78 and n79 operating frequency ranges.

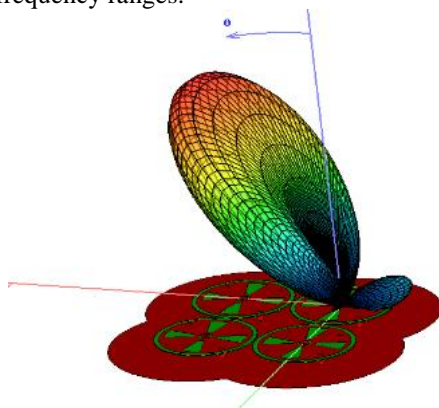


Fig.4- Three-dimensional radiation pattern of antenna array at 4.7 GHz with phase shift 0°, 00°, 150°, 150°

3. Conclusion

An antenna array transmitter operating in the fifth-generation mobile communication bands n78 and n79 is designed. It is shown that the transmitter is aligned with the feed line in the whole range of operating frequencies with VSWR not worse than 1.9.

The transmitter forms a weakly directional pattern (non-directional in the azimuth plane) with a gain varying from 3.3 dB to 5.5 dB.

The four-element antenna array based on the developed transmitter allows to control the directional diagram, forming radiations in a given direction.

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UDC 534.6

THE DESIGN FEATURES REVIEW OF LASER VIBROMETERS

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Аннотация. В статье рассматривается устройство виброметров на основе интерферометра Майкельсона, а также различные методы спектрального анализа. Лазерные виброметры обеспечивают бесконтактное измерение вибраций с высокой точностью, находя применение в различных сферах. Показано, что для обеспечения измерений стационарных объектов достаточно применения спектрального анализа Фурье, в то время как для корректного измерения нестационарных вибраций необходимо использование Вейвлет-аппарата.

Ключевые слова: лазерный виброметр, интерферометр, спектральный анализ, быстрое преобразование Фурье, вейвлет-преобразование, доплеровский сдвиг.

Annotation. The article examines the device of vibrometers based on the Michelson interferometer, as well as various methods of spectral analysis. Laser vibrometers provide non-contact vibration measurement with high accuracy, finding applications in various fields. It is shown that for measurements of stationary objects the application of spectral analysis of Fourier is sufficient, while for correct measurement of non-stationary vibrations the use of a Wavelet apparatus is necessary.

Keywords: laser vibrometer, interferometer, spectral analysis, fast Fourier transform, wavelet transform, Doppler shift.

Introduction

Laser vibrometers are highly precise non-contact instruments for measuring object vibrations, widely used in mechanical engineering, aviation, medicine, and scientific research. Their ability to detect displacements at the nanometer level without affecting the object is based on optical methods, such as interferometry, and subsequent signal processing using spectral analysis.

This article examines the design of laser vibrometers, the specifics of their operation, and data analysis methods, including interferometry, fast Fourier transform, and wavelet transform.

Main part

A laser vibrometer is an optoelectronic system that utilizes laser radiation to detect surface vibrations of an object. Let us consider the key aspects of its design and operation [2], as shown in Fig. 1.

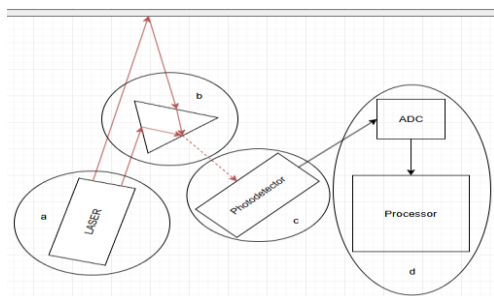


Fig. 1 — Block diagram of a laser vibrometer:

a) a source of coherent radiation; b) an optical system with an interferometer; c) a photodetector for recording the interference signal; d) a data processing unit for analyzing vibration characteristics.

The basic principle involves splitting the laser beam in the interferometer into a reference beam and a measurement beam. The reference beam is directed to a stationary mirror, while the measurement beam is aimed at the vibrating surface. After reflection, the beams recombine, forming an

interference pattern that is captured by the photodetector. Vibrations of the object alter the path length of the measurement beam, causing a phase shift in the signal. This shift, known as the Doppler shift, is proportional to the vibration velocity and is expressed by the formula:

$$f_D = \frac{2V}{\lambda}$$

where f_D is the Doppler frequency,
 V is the vibration velocity,
 λ is the laser wavelength.

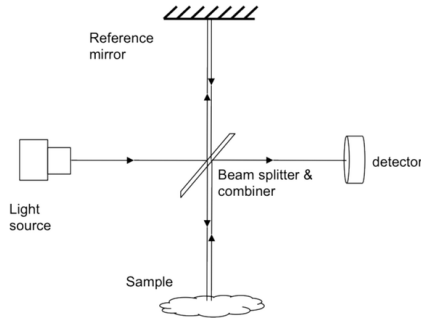


Fig. 2 — Michelson interferometer

For spectral analysis of the obtained data, the Fast Fourier Transform (FFT) method can be employed. This method converts the time-domain signal $x(t)$ into the frequency domain $X(f)$, enabling the identification of the frequency components of vibrations, their amplitudes, and phases.

$$X(k) = \sum x(n) \cdot e^{-\frac{i\pi kn}{N}}$$

where $x(n)$ represents the signal samples,
 N is the number of samples,
 k is the frequency index.

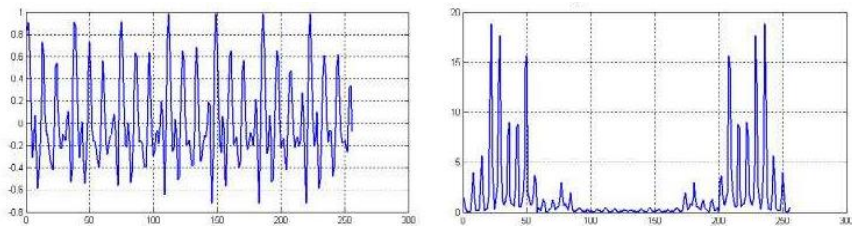


Fig. 3 — The sound signal is from the left in the time domain from the right in the frequency domain

The FFT is effective for stationary signals and identifies resonant frequencies, but it is less accurate for non-stationary processes. For such cases, wavelet transform analysis is applied. Unlike the FFT, the wavelet transform analyzes the signal simultaneously in both the time and frequency domains [3]

$$W(s, \tau) = \int (x(t) \cdot \psi\left(\frac{t - \tau}{s}\right) dt)^*$$

where $\psi(t)$ is the wavelet function,

s is the scale,

τ is the time shift,

* denotes complex conjugation.

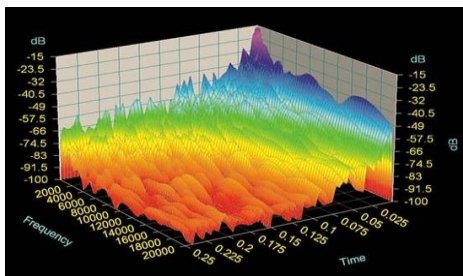


Fig. 4 — Wavelet transform of an unsteady signal

This makes it ideal for non-stationary vibrations, enabling the detection of temporal changes in the frequency composition that are not accessible when using the FFT.

The features of using laser vibrometers lie in their non-contact nature, high sensitivity, and ability to work with hard-to-reach surfaces. However, their effectiveness is limited by the requirement of a direct line of sight and

sensitivity to external factors, such as dust or ambient vibrations. These vibrometers can effectively measure vibrations with amplitudes as low as 5 nm at frequencies up to 10 kHz. The use of wavelet transform complements the FFT, enabling the analysis of non-stationary processes, such as transient operating modes of mechanisms, which underscores their value for diagnosing complex systems [1].

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DESIGN AND RESEARCH OF PRECODING MATRIX FOR MIMO 4x4 ANTENNA ARRAY WITH MODIFIED RADIATION PATTERN AND POLARIZATION PERFORMANCE

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Аннотация. В контексте массового внедрения и применения телекоммуникационных систем новейшего поколения 5G остро стоит проблема возникновения замираний в канале связи, которые приводят к существенному ухудшению качества связи. В связи с этим, более перспективными являются подходы к построению антенных систем базовых станций, позволяющие осуществлять динамическое адаптивное диаграммообразование на основании критерия минимума отношения сигнал/шум-интерференция SINR. В статье представлены результаты разработки антенной решётки 4x4, реализующей адаптивное формирование диаграммы направленности (ДН) в соответствии с

заданными матрицами весовых коэффициентов предварительного кодирования ММО. Представлены результаты разработки и исследования страниц матриц предкодирования, и показана возможность их применения для преодоления замираний в канале связи посредством подбора оптимальной ДН из предварительно заданного набора вариаций, включающих в себя различные вариации с несколькими пространственными лучами и разными видов поляризации излучения.

Ключевые слова: антенная решётка, ММО, печатная антенна, предварительное кодирование, диаграмма направленности, замирания.

Annotation. Considering the mass introduction and application of newest generation 5G telecommunications, there is an acute problem of fading leads to severe degradation of communication performance. Hence that, approaches allowing to implement a dynamic adaptive beamforming according to a criteria of minimal signal-to-noise and interference ratio SINR for the base station antennas are promising. The article presents the results of design of the 4x4 antenna array with adaptive beamforming based on predefined weight coefficients of MIMO precoding matrix. The results of design and research of precoding matrix pages are considered, and its possibility of applying for channel fading overcome by choosing the optimal radiation pattern from a predefined set includes various options with a few space fields and different polarizations are shown.

Keywords: antenna array, MIMO, patch-antenna, precoding, radiation pattern, fading.

Basics of MIMO Technology

Over the last decade, the number of wireless devices has increased dramatically, so that to organize access to the Internet requires a more efficient use of available resources. One of the key technologies of the latest generation mobile networks, such as 4G LTE and 5G NR, is the multiple input and output technology of MIMO. MIMO technology with the use of multiple antennas allows to significantly increasing the bandwidth of the communication channel due to the following methods [3]:

- a) Spatial multiplexing of multiple parallel data streams;
- b) Improvement of signal/noise ratio;
- c) Control of the antenna beam system (beamforming), which allows forming a multitude of beams, each of which «follows» the subscriber.

There are three main modes of MIMO in 5G NR networks:

- a) SU-MIMO: Single-user MIMO routes all the flows to one device at a time, switching to other users in turn with a time delay. Not all network resources are used, the capacity of the communication channel is limited.

b) MU-MIMO: Multi-user MIMO distributes the flows simultaneously between multiple devices, which increases the bandwidth of the communication channel and allows communicating with multiple devices immediately.

c) Massive-MIMO: «Massive» MIMO is a continuation of MU-MIMO, in case the number of antennas on the transmitting side is significantly greater than on the receiving. This significantly increases the capacity of the communication channel and bandwidth.

An important feature that provides functional MIMO antenna systems is the use of precoding. Precoding is a technology for forming PH multiple rays of AR.

The precoding matrix is a set of coefficients W $[M \times N]$ multiplied by the input streams of N antenna ports. As a result, for each of the M spatial flows (rays) forms its amplitude-phase distribution, and therefore its own DN. In this way, a set of variants of precoding matrices are laid down beforehand in the base stations, which form different combinations of DAY and polarization for each of the spatial flows. Depending on the conditions and distribution routes, different precoding options can be applied, which in the conditions of this route allow to obtain the highest bandwidth at the receiving point. The status information of the communication channel (CSI) is periodically updated using «pilot» signals, and depending on it, the selection of the optimal precoding matrix is carried out.

Design of a Single Antenna

Patch antennas (PA), formed by an emitting plate on one side of the dielectric substrate and a grounding plate on the other side, have been widely used as single emitters for building AP. Such emitters are characterized by a simple design, parameters, good operational and low mass-dimensional parameters, and allow the formation of all existing types of polarization with relative ease of coordination.

For the construction of MIMO AR, a patch antenna (PA) based on previous designed structure [1] has been developed and modified, whose construction truncated corners and an opening around the PA power point complement (Fig. 1). Working PA frequency range by criterion $S_{11} \leq -10$ dB is 4,7—5,3 GHz, what the range is n79 FR1. The axial ratio of the developed PA is up to 0,95, a beamwidth is about 60°. The antenna gain is (6,7—6,9) dBi.

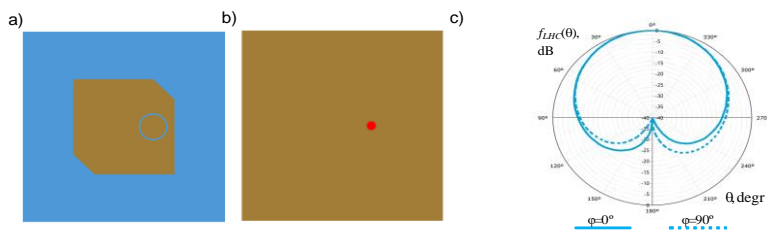


Fig. 1 — Designed PA: top view (a), bottom view (b), radiation pattern (c)

Design of Antenna Array

The MIMO 4x4 antenna array was developed on the basis of PA (Fig. 2), moreover:

- a) Antennas A1 and A4 form a left-hand circular polarization (LHC);
- b) Antennas A2 and A3 emitters form a right-hand circular polarization (RHC);
- c) All antennas are positioned symmetrically at a distance of $d1 = 32$ mm from each other.

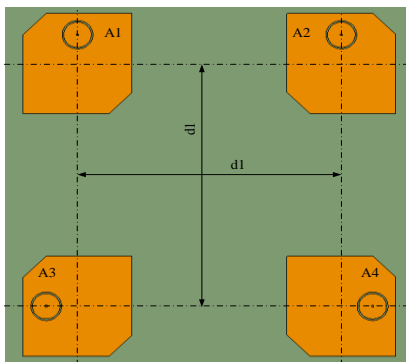


Fig. 2 — The structure of designed PA array

Design and Research of Precoding Matrix

Table 1 presents the proposed variants of the precoding matrix for MIMO array 4x4 with 4 spatial streams, which are of greatest interest. Thus, within one array can be formed four streams with different maximums of direction and polarization. This allows both to distribute information between streams so that the highest data transfer rate is provided at the receiving point, and to

provide independent transmission to four receivers using multi-beam radiation pattern, which can be used telecommunications, as were shown in [2].

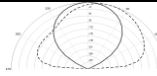
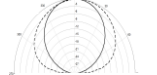
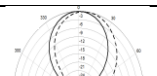

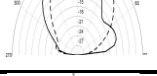
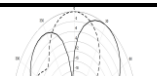
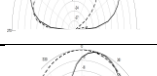
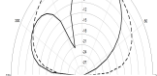
Table 1 — The proposed MIMO precoding matrix for designed PA array (the following abbreviations are used: PMI – Precoding Matrix Index; A – Single Antenna; M – Multiplier; SF – Space Field)

PMI Index	A	Matrix of weight coefficients W															
		M	SF1	SF2	SF3	SF4	M	SF 1	SF2	SF3	SF4	M	SF1	SF2	SF 3	SF4	
0 – 2	A 1	$\frac{1}{2}$	1	0	0	0	$\frac{1}{2\sqrt{2}}$	1	1	1	1	$\frac{1}{2\sqrt{2}}$	0	0	0	0	
	A 2		0	1	0	0		0	0	1	1		1	1			
	A 3		0	0	1	0		0	0	0	j		-j	1	-1		
	A 4		0	0	0	1		-j	j	1	-1		0	0	0	0	
3 – 5	A 1	$\frac{1}{2\sqrt{2}}$	1	1	0	0	$\frac{1}{2\sqrt{2}}$	1	j	0	0	$\frac{1}{2\sqrt{2}}$	1	0	1	0	
	A 2		1	-1	0	0		0	0	1	j		0	1	1	0	
	A 3		0	0	1	-1		0	0	j	1		0	j	0	-1	
	A 4		0	0	1	1		j	1	0	0		-j	0	0	1	
6 – 8	A 1	$\frac{1}{2\sqrt{2}}$	1	1	0	0	$\frac{1}{4}$	1	1	1	1	$\frac{1}{4}$	-1	j	j	j	
	A 2		0	0	-j	j		1	-1	1	-1		1	-j	-j	1	
	A 3		-j	j	0	0		j	j	-j	-j		j	-1	1	1	
	A 4		0	0	1	1		j	-j	-j	j		-j	1	1	-j	

Table 2 presents a few specific precoding matrix rows, which illustrates the concept of MIMO, and also might have prospective applications. The radiation performance in terms of beam direction θ_{\max} , beamwidth $2\theta_{0.5}$, antenna gain, and polarization performance is considered and simplified radiation pattern diagram is shown.

According to MIMO features, the designed PA array allows to use both single-beam and dual-beam patterns for different space fields, moreover, the different types of polarization from dual beams within a single antenna port are might obtained.

Table 2 — Proposed MIMO precoding matrix rows are of a greatest interest

No.	PMI/ SF index	θ_{\max}	$2\theta_{0.5}$	Gain	Polarizat ion Type	Axial Ratio	Radiation Pattern
Single-Beam Radiation Pattern							
1	3/1	0°	50°	6.6 dBi	Linear	0.006	
2	3/2	0°	54°	5.9 dBi	Linear	0.005	
3	8/2	0°	46°	9.2 dBi	Linear	0.003	
4	8/3	20°	50°	8.0 dBi	Linear	0.020	
5	1/1	0°	100°	6.5 dBi	LHC	0.910	
Dual-Beam Radiation Pattern							
6	2/1	32°/– 40°	40°/40°	7.2 dBi	RHC/RHC	0.800	
7	2/3	15°/– 60°	35°/35°	8.2 dBi	RHC/RHC	0.860	
8	7/1	32°/– 32°	40°/40°	1.6 dBi	RHC/LHC	0.870	

Thus, the MIMO 4x4 array for n79 range is designed and precoding options are proposed, allowing to carry out adaptive modification of the developed AP according to the conditions of the radio wave propagation path.

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UDC 621.314

HIGH-VOLTAGE POWER SUPPLY FOR POWERING PHOTOELECTRONIC MULTIPLIERS

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Аннотация. В статье рассматривается вариант реализации высоковольтного блока питания для лампы ФЭУ. Акцентируется внимание на характеристики данного источника, приводится принципиальная схема устройства, а также осциллограмма работы обратной связи одного из диапазонов напряжений, поступающих на микросхемы TL494, на которой построено данное устройство и вид данного прибора, смоделированного в программе комплексной системы автоматизированного проектирования Altium Designer.

В заключении статьи подводятся итоги и выдвигается возможность минимизации размеров конструкции путём использования современной элементной базы, а также улучшения КПД и ТТХ устройства, путём проведения дальнейшего ряда испытаний.

Данная статья будет полезна специалистам, работающим в сфере применения ФЭУ.

Ключевые слова: ФЭУ, высоковольтный источник питания, высоконадёжные источники питания, двухтактная схема преобразования, регулировка напряжений.

Annotation. The article considers the implementation of a high-voltage power supply unit for an electric power supply lamp. Attention is focused on the characteristics of this source, the ranges of output supply voltages, a schematic diagram of the device is given, as well as an oscillogram of the feedback operation of one of the voltage ranges supplied to the TL494 microcircuits on which this device is built and the type of this device modeled in the program of the integrated computer-aided design system Altium Designer.

In conclusion, the article summarizes the results and suggests the possibility of minimizing the size of the structure by using a modern element base, as well as improving the efficiency and performance of the device by conducting a further series of tests.

This article will be useful for specialists working in the field of Photo Electronic Multipliers

Keywords: power supply, high-voltage power supply, highly reliable power supplies, push-pull conversion circuit, voltage regulation.

Introduction

In the course of working with PV, it became necessary to use a high-voltage and compact power source with close to precision stabilization accuracy and the ability to adjust the voltage range.

Due to the lack of ready-made power supplies with the required parameters on the market, it was decided to develop this device for use in laboratory and field conditions.

The modern component base makes it possible to create highly reliable power supplies with low weight and dimensions.

Main part

Based on the technical documentation of the FEU-84 lamp, the optimal supply voltage range and rated current were selected. Based on these data, it was decided to develop a power supply using a push-pull conversion scheme, due to the lack of magnetization of the transformer core, which significantly reduces its size. The widely used, affordable and well-proven TL494 chip was chosen as the push-pull converter controller [1]. An external feedback circuit is built on the error amplifiers built into the microcircuit, which adjusts the output voltage by means of PWM modulation. Based on this microcircuit, a step-up DC-DC converter is made from 12 V to a rated output voltage of 1200 V with an output current of 5 mA. The output voltage can be adjusted within 25 percent of the nominal value in both directions by introducing a tuning resistor into the feedback circuit

The signal generated by the TL494 chip is sent to drivers made on low-power NPN transistors. The amplified signal is sent to the output switches,

which use powerful N-channel MOSFET transistors connected to the primary windings of the step-up transformer. Figure 1 shows an oscilloscope of the incoming signal to the MOSFET transistor switches from the drivers. A power supply unit with a stabilized voltage of 12 V and current was used as the primary source during laboratory tests. 500mA. For field applications, it is advisable to use lithium polymer batteries.:

- Due to their safety in case of overheating, which reduces the risk of fire and explosion.
- Long service life.
- Low self-discharge rate.
- High energy density.

The schematic diagram of the PS is shown in Fig. 2, the appearance of the printed circuit board modeled in the Altium Designer program is shown in Fig. 3.

Conclusion

Thus, a high-voltage, stabilized, compact PSU has been developed to power the power supply. Initial laboratory tests have been carried out, during which further upgrades of the circuit are possible to increase its efficiency, to highlight the best performance characteristics of the device. The possibility of minimizing the size of the structure by using a modern component base is revealed.

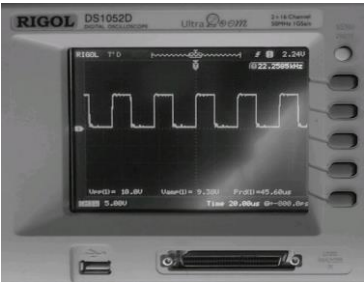


Fig.1.- an oscilloscope of the incoming signal to the MOSFET transistor

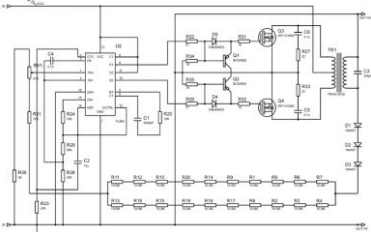


Fig.2.- The schematic diagram of the PS

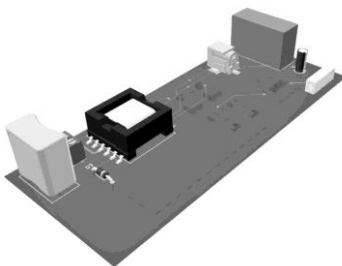


Fig.3. - The printed circuit board modeled in the Altium Designer program

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THE INFLUENCE OF THE PHONOGRAM CREST FACTOR ON THE ENERGY CHARACTERISTICS OF A LOW FREQUENCY AMPLIFIER

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Аннотация. Проведён анализ энергетической эффективности усилителя мощности низкой частоты и найдено выражение для расчёта КПД с учётом пик-фактора усиливаемой фонограммы. Показано, что при усилении реальных фонограмм с учетом отсутствия искажений при пиковых уровнях сигнала, КПД усилителя оказывается значительно ниже предельно достижимого для режима *B*. Приведены рассчитанные зависимости КПД от уровня сигнала для речевых фонограмм (пик-фактор 12 дБ) и музыкальных фонограмм (пик-фактор 25 дБ).

Ключевые слова: усилитель низкой частоты, режим *B*, КПД усилителя, звуковая фонограмма, пик-фактор, коэффициент полезного действия.

Annotation. The energy efficiency of a low-frequency power amplifier is analyzed and an expression is found for calculating the efficiency taking into account the crest factor of the amplified phonogram. It is shown that when amplifying real phonograms, taking into account the absence of distortion at peak signal levels, the amplifier's efficiency is significantly lower than the maximum achievable for mode *B*. The calculated dependences of efficiency on the signal level for speech phonograms (crest factor 12 dB) and musical phonograms (crest factor 25 dB) are given.

Keywords: low frequency amplifier, mode *B*, amplifier efficiency, sound phonogram, crest factor, efficiency factor.

The output stages of low-frequency power amplifiers usually use *B*, *H* or *G* modes to ensure energy efficiency [1, 2, 3]. At the same time, it is known that the efficiency of an amplifier depends both on the voltage of the output signal and on the supply voltage of the output stage. With a sinusoidal signal with an amplitude close to the supply voltage of the output stage, the maximum achievable amplifier efficiency is 78.5% [1, 2].

However, when amplifying a real phonogram, the supply voltage is selected based on the condition that there is no signal distortion at peak output voltage levels (see Fig. 1). As a result, the average level of the amplified signal, determined by the crest factor, is lower than the maximum apparent output voltage, which leads to a decrease in the power supply utilization factor and a decrease in efficiency.

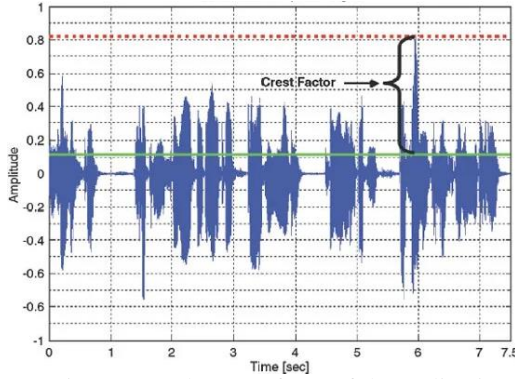


Figure 1. - The waveform of the audio signal

There is no analysis and calculations of the amplifier's energy efficiency in amplifying real phonograms in the literature, which is important for portable devices, so the topic of this work is relevant.

We will analyze the energy characteristics of a low-frequency amplifier operating in mode B and calculate its efficiency factor, taking into account the peak factor of the amplified phonogram.

The efficiency of the amplifier is determined [1]:

$$\eta = \frac{P_L}{P_0},$$

where η — amplifier efficiency;

P_L — power output to the load;

P_0 — power taken from the power supply.

The power P_L given to the load is calculated from the amplitude values of the current I_m and voltage U_m released on the load

$$P_L = \frac{1}{2} U_m I_m.$$

The power P_0 taken from the power supply by the amplifier operating in mode B is determined [1]:

$$P_0 = \frac{2}{\pi} I_m E,$$

where U_m — amplitude of the voltage at the output of the amplifier;

I_m — amplitude of the current in the load;

E — supply voltage.

Substituting the values P_L and P_0 for an amplifier operating in mode B into the formula for efficiency, taking into account the crest factor of the amplified signal, we obtain

$$\eta = \frac{\pi}{2\sqrt{2}} \frac{1}{CF} \left(\frac{U_{peak}}{E} \right),$$

where CF — (*Crest Factor*) crest factor of the amplified low-frequency signal;

U_{peak} — peak voltage of the output signal.

Crest factor — ration of peak and RMS value of voltage or current. In Figure 2 shows the envelope of an audio phonogram, and also shows the instantaneous signal power levels used to calculate the peak factor.

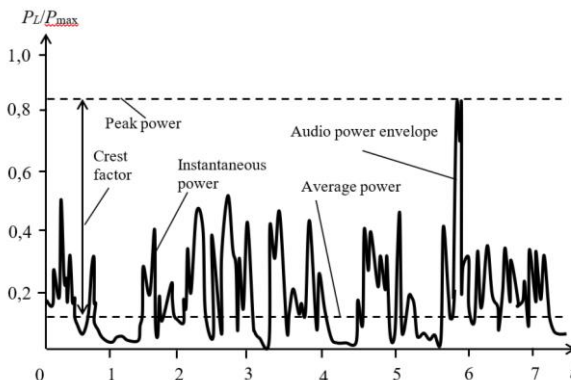


Figure 2. -The envelope of the instantaneous power of the audio signal

Figure 3 shows the changes in amplifier efficiency when amplifying real speech (peak factor 12 dB) and music (peak factor 25 dB) phonograms in the absence of distortion of peak signal levels depending on the relative output voltage. It can be seen that with the amplification of speech phonograms and the maximum signal, the efficiency of the amplifier is 28%, and for musical phonograms — 6.2%.

For comparison, Figure 3 shows a graph of changes in the efficiency of an amplifier operating in mode B with a sinusoidal input signal. The maximum achievable efficiency in this case is 78.5%. Consequently, the efficiency of the amplifier depends on the type of phonogram, and when a real musical phonogram with a peak factor of 25 dB is amplified, the efficiency of the amplifier decreases by more than 10 times.

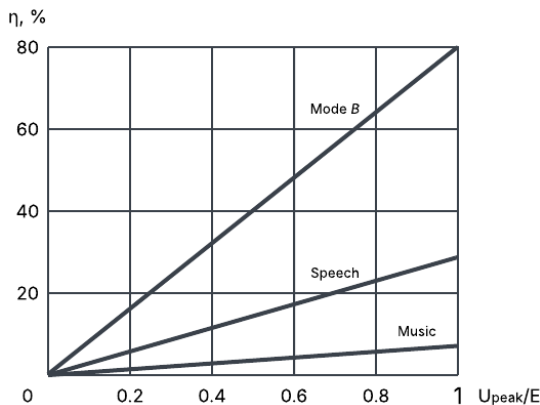


Figure 3. - Graph of efficiency of low frequency amplifier mode B and crest factors of phonograms speech and music

Thus, an expression is obtained for calculating the efficiency of an amplifier, taking into account the crest factor of the amplified phonogram. Graphs of efficiency changes during amplification of speech and musical phonograms depending on the signal level are presented. It is shown that when amplifying musical phonograms with a crest factor of 25 dB, the amplification efficiency decreases by more than 10 times compared to the ideal mode.

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DESIGN OF A WIDEBAND CML STATIC FREQUENCY DIVIDERS FOR RF CMOS 28 NM

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Аннотация. Разработан блок делителей частоты с использованием технологического процесса RFCMOS 28нм, который на вход принимает дифференциальные прямоугольные импульсы частотой 6—12 ГГц, а на выходе формирует дифференциальные I/Q прямоугольные импульсы типа меандр 6 МГц—6 ГГц. Делитель состоит из 10 делителей частоты на 2, мультиплексора 10 к 1 и выходного буфера. Представлены временные характеристики на выходах делителя 6 ГГц, 3 ГГц, 1,5 ГГц, 750 МГц и 375 МГц.

Ключевые слова: CML, мультиплексор, статический делитель частоты, 28нм.

Annotation. A block of frequency dividers based on a RFCMOS 28nm process has been developed, which receives differential rectangular pulses

with a frequency of 6—12 GHz at the input, and generates differential I/Q rectangular pulses of the 6 MHz—6 GHz meander type at the output. The divider consists of 10 frequency dividers by 2, a 10-to-1 multiplexer and an output buffer. The time characteristics at the outputs of the divider 6 GHz, 3 GHz, 1.5 GHz, 750 MHz and 375 MHz are presented.

Keywords: CML, multiplexer, static frequency divider, 28nm.

CML (Current Mode Logic) static frequency dividers are key components in high-speed RF devices. These dividers provide stable frequency division of the input signal without requiring synchronization, making them ideal for use in frequency synthesizers and transceiver chains.

Thanks to the 28 nm CMOS technology, CML dividers achieve high input frequency (up to tens of gigahertz), low power consumption, and a small footprint.

This work presents the design and optimization of a CML static frequency divider implemented in 28 nm CMOS technology, which generates differential quadrature (I/Q) signals at its outputs.

The developed divider operates with an input signal range from 6 to 12 GHz. For this input signal, the output generates an I/Q signal in the range of 6 MHz to 6 GHz. This result is achieved using a chain of 10 dividers, each providing division by 2.

The output of each divider is connected to a multiplexer, enabling the generation of a final output signal at the desired frequency. It should be noted that the multiplexer combines ten signals into one. The multiplexer is controlled using a 4-bit control signal.

Figure 1 shows the block diagram of the developed CML static frequency divider.

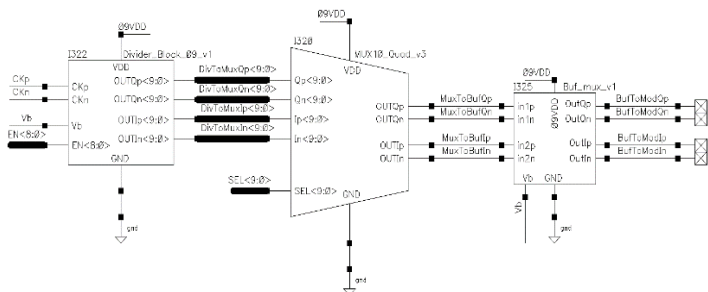


Figure 1. - Block diagram of the developed CML static frequency divider

The schematic implementation was created in Cadence Virtuoso following the block diagram architecture. Frequency division is performed within a chain of dividers which consists of 10 series-connected dividers by two. The chain of dividers block is presented in Figure 2.

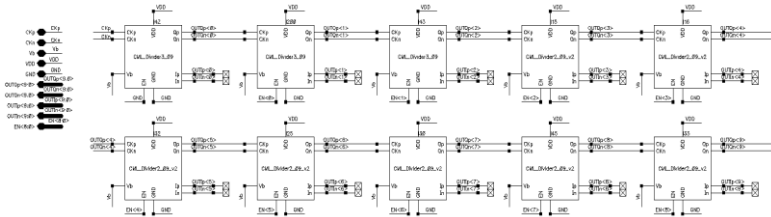


Figure 2. - Schematic of the dividers block

A frequency divider by two is implemented using two CML flip-flops [1, p.53], shown in Figure 3. When dividing by two, the first flip-flop receives an inverted signal from the output of the second flip-flop. The flip-flop operates on both the rising and falling edges, generating I/Q signals at the output. The Q output of the first divider feeds into the subsequent divider, while the I output goes directly to the multiplexer. This factor introduces phase skew in the I/Q signals. To address this issue, an 'enable' signal for the flip-flops was introduced.

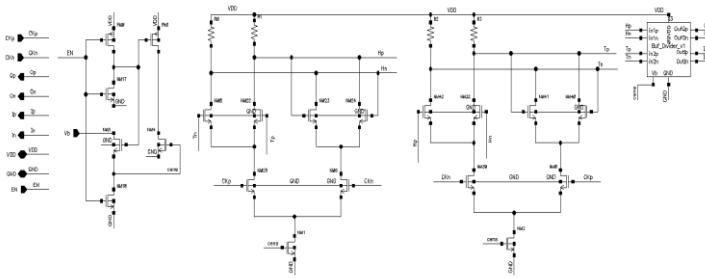


Figure 3. - Schematic circuit of the divider by two using two CML flip-flops with output buffer

The outputs of the first two dividers (6 GHz and 3 GHz) use an output buffer (Figure 3) to increase the load capacity. The subsequent outputs use a conventional CML Flip-Flop circuit without a buffer. This approach allows reducing the power consumption of the entire divider block circuit.

The output of each divider is routed to a 2-to-1 differential multiplexer. To minimize signal distortion at the multiplexer output, the highest frequency signals are assigned the shortest signal paths [2, p. 22]: the 6 GHz signal from the divider output passes through a single 2-to-1 multiplexer, the 3 GHz output takes 2, and so forth, up to a total of ten stages. This configuration forms the 10-to-1 multiplexer block shown in Figure 4.

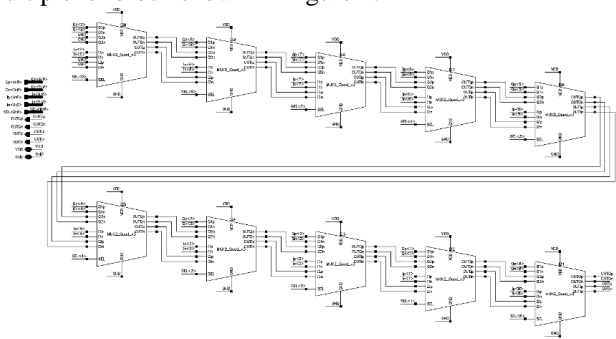


Figure 4. - The 10 to 1 multiplexer block built from 2 to 1 multiplexer

The 2 to 1 multiplexer circuit is illustrated in Figure 5 and is implemented using switching pairs for all I/Q inputs.

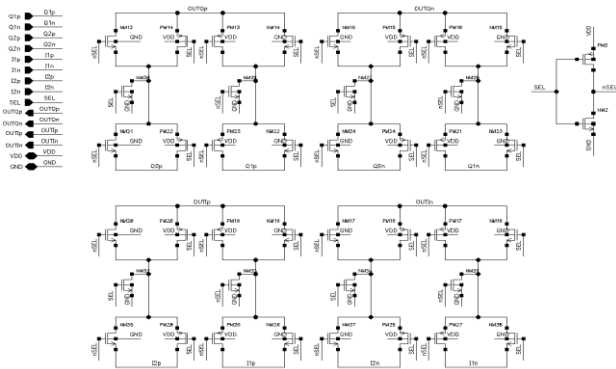


Figure 5 — The 2 to 1 multiplexer circuit implemented using switching pairs

Figure 6 displays the measured output timing waveforms at 6 GHz, 3 GHz, 1.5 GHz, 750 MHz, and 375 MHz frequencies generated by the divider block.

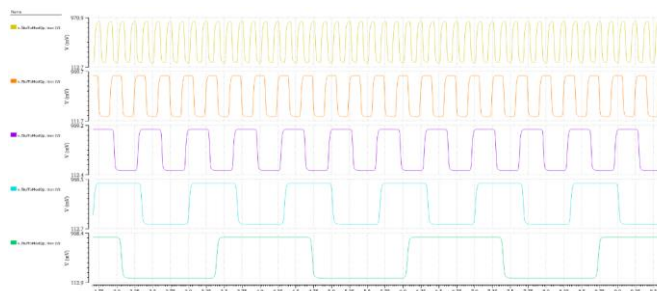


Figure 6 — The output timing waveforms at 6 GHz, 3 GHz, 1.5 GHz, 750 MHz, and 375 MHz frequencies

During the design of the frequency divider block, it was determined that the input frequency is not limited to 12 GHz and can extend up to 16 GHz, thereby expanding the operational frequency range. A digital control unit manages the divider block using SEL signal for output signal selection and EN signal which implements disabling unused dividers to minimize power consumption.

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EXTRACTING VITAL SIGN PARAMETERS OF MILLIMETER WAVE RADAR OUTPUT SIGNAL USING DR-MUSIC ALGORITHM

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Аннотация. В статье представлен улучшенный метод извлечения параметров жизненно важных показателей из сигналов радара миллиметрового диапазона. В документе описывается подход к обработке сигнала с использованием AWR6843 SoC от Texas Instruments для мониторинга частоты сердечных сокращений и частоты дыхания посредством бесконтактного зондирования на основе радара.

Для повышения точности оценки частоты сердечных сокращений в статье используется алгоритм дифференциальной рекурсивной классификации множественных сигналов (DR-MUSIC). Этот алгоритм эффективно подавляет дыхательные гармоники и усиливает сигнал сердцебиения с помощью комбинации адаптивной фильтрации методом рекурсивных наименьших квадратов (RLS), фазовой дифференциации и спектральной оценки MUSIC. Решая проблемы помех, DR-MUSIC повышает надежность измерений частоты сердечных сокращений в системах мониторинга на основе радаров.

Этот метод повышает точность бесконтактного определения жизненно важных показателей, что делает его ценным инструментом для медицинских и медицинских приложений мониторинга.

Ключевые слова: радар mmWave, алгоритм DR-MUSIC, оценка частоты сердечных сокращений, подавление дыхательных гармоник, обработка сигнала.

Annotation. This paper presents an improved method for extracting vital sign parameters from millimeter-wave radar signals. The document describes a signal processing approach using the AWR6843 SoC from Texas Instruments to monitor heart rate and respiratory rate through non-contact radar-based sensing.

To enhance heart rate estimation accuracy, the paper integrates the Differential Recursive Multiple Signal Classification (DR-MUSIC) algorithm. This algorithm effectively suppresses respiratory harmonics and amplifies the

heartbeat signal through a combination of Recursive Least Squares (RLS) adaptive filtering, phase differencing, and MUSIC spectral estimation. By addressing interference issues, DR-MUSIC enhances the reliability of heart rate measurements in radar-based monitoring systems.

This method improves the precision of non-contact vital signs detection, making it a valuable tool for medical and health monitoring applications.

Keywords: mmWave radar, DR-MUSIC algorithm, heart rate estimation, respiratory harmonics suppression, signal processing.

Introduction

Vital signs monitoring is an essential part of modern healthcare. In addition to traditional contact sensors, non-contact sensors are gaining popularity. The necessity of such monitoring arises from situations where physical contact with a patient is undesirable, such as in cases of severe burns. One effective method for non-contact monitoring is the use of millimeter-wave (mmWave) radar.

Measuring respiration rate and heart rate using mmWave radar involves transmitting a frequency-modulated continuous wave (FMCW) signal. The reflected signal, with a phase shift due to chest movements, allows for precise tracking of harmonic motion associated with vital signs.

Main part

For developing a vital signs monitoring system, we selected the Texas Instruments AWR6843 system-on-chip (SoC), which operates within the 60-64 GHz frequency range. The radar generates chirp signals with a duration of 40 μ s and a frequency modulation step of 13 MHz, allowing for 96 sequential transmissions per antenna in each scan cycle.

Traditional methods for heart rate estimation using mmWave radar often suffer from interference caused by respiratory harmonics. To address this challenge, we implemented the Differential Recursive Multiple Signal Classification (DR-MUSIC) algorithm, which improves signal clarity by effectively suppressing respiratory interference and enhancing heartbeat detection [1].

1. Preprocessing and Static Clutter Removal

Before analyzing the signal, static clutter is removed using phase mean elimination. This step enhances signal clarity by eliminating environmental noise that remains constant over time.

2. Phase Extraction and Baseline Drift Removal

The phase of the received signal is extracted using an inverse tangent function. Since body micromotions can cause baseline drift, median filtering is applied to remove low-frequency distortions, ensuring an accurate representation of the heartbeat signal [3, 4].

3. Respiratory Harmonics Suppression Using Adaptive Filtering

The core of the DR-MUSIC algorithm is an adaptive filter based on the Recursive Least Squares (RLS) method. To suppress respiratory harmonics, we use an adaptive filter based on Recursive Least Squares (RLS). The filter iteratively updates its weight vector $W(n)$ to minimize the error $e(n)$ between the desired signal $d(n)$ and the filter output $y(n)$:

$$e(n) = d(n) - U^T(n)W(n-1).$$

The weight update is given by:

$$W(n) = W(n-1) + G(n)e(n),$$

where $G(n)$ is the gain vector computed as:

$$G(n) = \frac{\lambda^{-1}P(n-1)U(n)}{1 + \lambda^{-1}U^T(n)P(n-1)U(n)},$$

and $P(n)$, the inverse autocorrelation matrix, is updated as:

$$P(n) = \lambda^{-1}P(n-1) - \lambda^{-1}G(n)U^T(n)P(n-1).$$

This filtering step effectively removes respiratory harmonics while preserving the heartbeat signal [5].

4. Signal Enhancement Using Phase Differencing

To further isolate the heartbeat signal, phase differencing is applied. The phase of the received signal $\varphi(t)$ is extracted using the inverse tangent function:

$$\varphi(t) = \text{atan}\left(\frac{B_Q(t)}{B_I(t)}\right) = \frac{4\pi x(t)}{\lambda_0} + \varphi_0,$$

where $B_I(t)$ and $B_Q(t)$ are the in-phase and quadrature components of the signal, respectively. By computing the difference between consecutive phase values, low-frequency components such as respiration are suppressed, leaving an enhanced heartbeat signal [2].

5. High-Resolution Frequency Estimation with MUSIC Algorithm

To accurately estimate the heart rate frequency, we use the Multiple Signal Classification (MUSIC) algorithm. The covariance matrix R_x of the signal is decomposed into signal and noise subspaces:

$$R_x = Q_s \Lambda_s Q_s^H + Q_w \Lambda_w Q_w^H.$$

The frequency spectrum is estimated using the MUSIC pseudospectrum function:

$$P(f) = \frac{1}{\sum_{m=P+1}^M \frac{1}{\Lambda_m} |v^H(f)q_m|^2},$$

where Λ_m are the eigenvalues of R_x , and q_m are the corresponding eigenvectors. The frequency corresponding to the highest peak in the spectrum is identified as the heart rate.

Conclusion

Enhanced method for heart rate estimation using mmWave radar, leveraging the DR-MUSIC algorithm to overcome challenges posed by respiratory harmonics was present. By integrating RLS-based filtering, phase differencing, and high-resolution spectral estimation, the proposed approach achieves high accuracy in vital sign monitoring. Future research directions include real-time implementation and adaptation to multiple vital signs monitoring applications.

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UDC: 621.396.677.83

PCB BROADBAND UHF LOOP DIPOLE

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Аннотация. В статье представлены результаты моделирования и конструкция широкополосного петлевого диполя диапазона частот UHF

в печатном исполнении. Представлены результаты измерений диаграмм направленности прототипа антенны. Описан анализ возможности применения в составе направленной директорной антенны. Представлены результаты моделирования разработанной антенны в составе директорной антенны.

Ключевые слова: Директорная антенна, петлевой диполь, UHF диапазон, широкополосный диполь, печатная антенна.

Annotation. The article presents the simulation results and the design of a PCB broadband loop dipole of the UHF frequency range. The results of measurements of the radiation patterns of the prototype antenna are presented. An analysis of the possibility of using as part of directional antenna is described. The simulation results of the developed antenna as part of the directional antenna are presented.

Keywords: Directional antenna, loop dipole, UHF band, broadband dipole, PCB antenna.

Introduction. Nowadays, due to the development of wireless data transmission systems, digital television and UAVs, antennas with an operating range of 300-900 MHz are becoming increasingly relevant. Modern PCB manufacturing technologies make it possible to make UHF band antennas more compact, including transferring matching devices to the antenna circuit board in the form of microstrip elements. Our task is to develop an analog of the classic loop dipole in PCB form, expanding the operating frequency band while maintaining antenna characteristics [1 – 3].

The antenna being developed.

The broadband antenna we have developed consists of two frame halves located on both sides of the printed circuit board. Due to the capacitive coupling between the upper sides of the frames, the antenna is AC-closed, which simplifies the design by the absence of adapter holes. The wide sides of the frames with slots provide the antenna with broadband. A microstrip line is located on the front side, which is a matching element. The appearance of the antenna in CAD is shown in Figure 1.

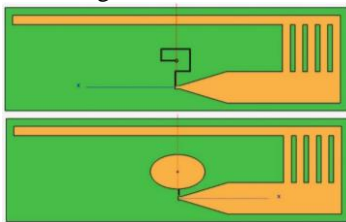


Fig. 1 — Broadband printed loop dipole.

Modeling of characteristics. Antenna characteristics were modeled in CAD. The figures show diagrams of the VSWR (Fig. 2) and the antenna input impedance (Fig. 3).

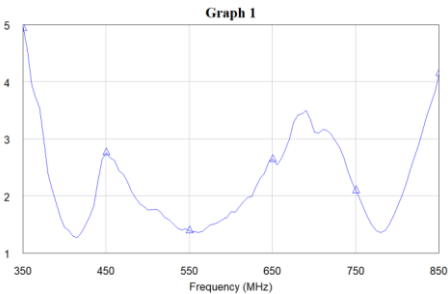


Fig. 2 — VSWR

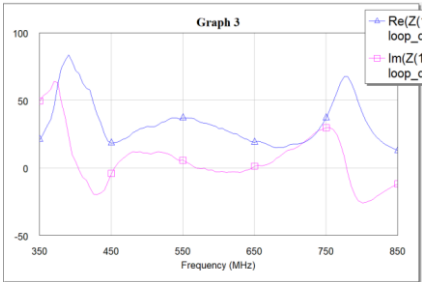


Fig. 3 — Input impedance.

It can be seen from the graphs that acceptable matching according to the $VSWR < 3$ criterion is observed in the frequency bands 370...670 and 720...830 MHz, while the active part of the input impedance lies in the range of 20... 70 ohms with a slight reactive component.

Measurement of radiation patterns. To measure the antenna radiation patterns, a prototype was made from FR-4 grade foiled fiberglass by chemical etching. An SMA connector was soldered to the back of the antenna. The prototype's appearance is shown in Figure 4.



Fig. 4 — Antenna prototype.

The measurement results were processed in the MathCAD program. Figure 5 shows antenna directional patterns in the vertical plane at frequencies of 600 and 800 MHz.

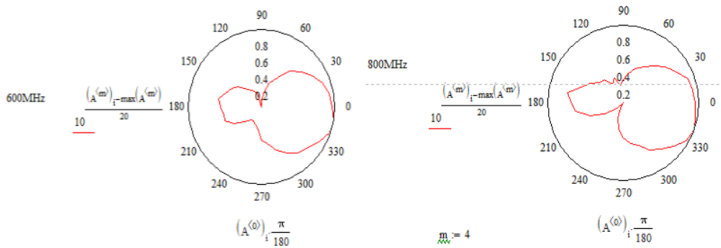


Fig. 5 — Directional patterns.

Using a dipole in a directional antenna. The developed broadband dipole can be used as an active element of the directional antenna to obtain a higher gain. Using Altair FEKO CAD modeled the use of the developed antenna together with a reflector, which is a printed broadband element in the form of a double ellipse, the model of a dipole with a reflector is shown in Figure 6.

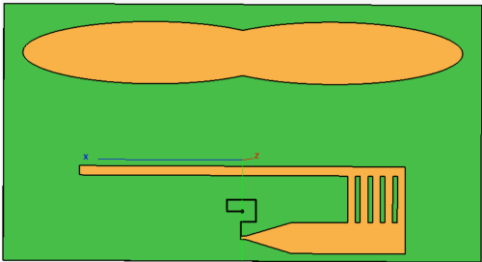


Fig. 6 — Model of a dipole with a reflector.

Figure 7 shows the radiation patterns of a dipole antenna with a reflector (on the left) and without (on the right). The gain of the antenna with a reflector was 5.19 dBi, while the antenna without a reflector has a gain of 2.5 dBi. The simulation was performed at a frequency of 600 MHz.

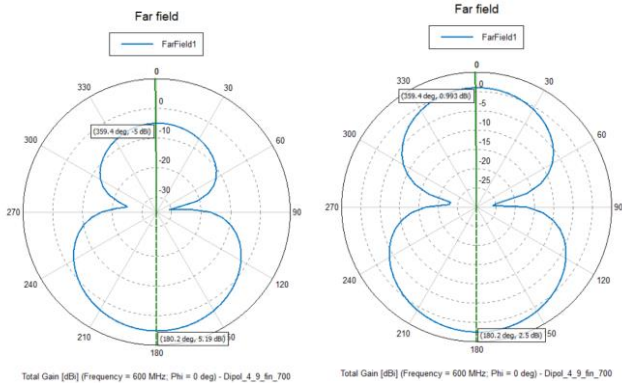


Fig. 7 — Directional patterns of a dipole with and without a reflector.

In addition, the reflector affects the matching of the antenna and the operating frequency band, which indicates the need to optimize the design and configuration of the matching microstrip line to ensure the best VSWR. Figures 8 and 9 show VSWR in the frequency range for a dipole antenna with a reflector (Fig. 8) and without (Fig. 9).

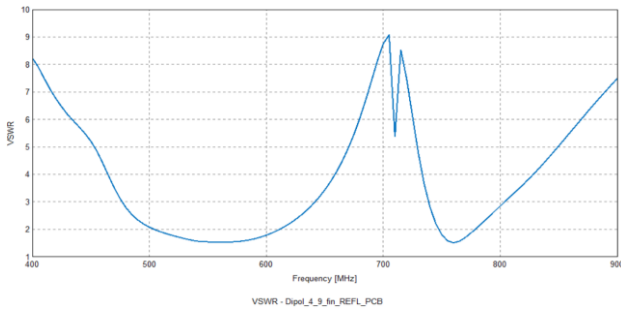


Fig. 8 — VSWR of a dipole with a reflector.

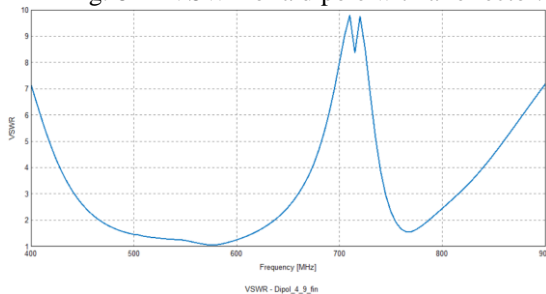


Fig. 9 — VSWR of a dipole without a reflector.

Conclusions. As a result of the research, a PCB broadband loop dipole UHF band was developed. Modeling of characteristics in CAD showed the operability of the idea, a prototype was made and radiation patterns were measured, and the possibility of using the developed loop dipole as part of a directional antenna was analyzed.

In the future, it is planned to optimize the design and input resistance of the antenna, to ensure better matching in a wider frequency range, it is planned to assemble a prototype of a directional antenna based on the loop dipole described in this article, and measure the characteristics.

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UDC 621.3

STUDY OF FBMC TRANSMITTING-RECEIVING PATH OPERATION IN A COMMUNICATION CHANNEL

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Аннотация. Представлены результаты исследования элементов прямо-передающего тракта по технологии банка фильтров поднесущих (FBMC) для применения в беспроводном подводном канале связи на

основе переменного магнитного поля. Разработаны программная реализация элементов модуля формирования сигнала по технологии FBMC и программная верификация. Проведены экспериментальные исследования параметров модуля формирования сигнала приемопередающего тракта с целью возможного дальнейшего применения в подводном канале связи.

Ключевые слова: FBMC, OQAM формирование сигналов, 5G.

Annotation. The results of the research of the elements of the transmitting-receiving path on the technology of the bank of subcarrier filters (FBMC) for application in the wireless underwater communication channel on the basis of the alternating magnetic field are presented. The software implementation of the elements of the signal formation module using FBMC technology and software verification have been developed. Experimental studies of the parameters of the signal conditioning module of the receiving and transmitting path for possible further application in the underwater communication channel have been carried out.

Keywords: underwater wireless communication, wireless magnetic-induction communication, FBMC, FPGA.

INTRODUCTION

The application of the marine Internet of Things is widespread [1]. Due to the impossibility of electromagnetic waves propagation underwater for long distances, research on the application of new technologies and methods of information transmission in the underwater environment is still relevant [2][3][4]. For example, acoustic data transmission method has long been known and actively used for communication between submarines, but it has serious limitations. The optical method can be referred to high-speed methods of information transmission, but it has a range limitation and requires direct visibility for its operation. The use of ultra-long waves to transmit short messages to submarines over long distances is widespread, but their information capacity of messages is extremely low. A promising method of transmission is the magnetic communication channel, which has a large capacity and is less demanding on propagation conditions.

Thus, the application of a wireless communication channel based on an alternating magnetic field is of interest, and one of the solutions for the formation of the transmitted signal may be the use of FBMC technology [5][6]. There are known attempts to apply this technology in underwater environment, but for acoustic communication channel [8].

The FBMC element of the FPGA is located between the processor, which sends data over the SPI interface, and the DAC, which generates analogue signals to the transmission path, as shown in fig 1.

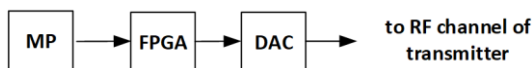


Fig. 1. Структурная схема расположения ПЛИС в тракте передачи

Previously, the following technical characteristics of the wireless communication channel using an alternating magnetic field were obtained [7]:

- data rate = 300 kbit/s;
- carrier frequency = 1 MHz;
- frequency bandwidth not more than 100 kHz;
- number of subcarriers -21 (20 data and one pilot subcarrier).

This article is devoted to the development of parts of the FBMC signal conditioning module for the receiving and transmitting path, as well as experimental studies of the parameters of the signal conditioning module to confirm the possibility of using FBMC technology in wireless underwater magnetic communication.

THE MAIN PART

Developed a software implementation of the module of signal formation of the transmitting part of the transceiver-transmitting path using FBMC technology, the logic diagram of which is shown in Fig. 2. The module consists of the following elements: the input element of the SPI interface, the formation of signals on the subcarriers, modules of the inverse Fourier transform, modulation and filtering modules on the subcarriers, output register. The subcarriers consist of the following elements: shift multiplication, delay, thinning and 16-QAM demapping.

One should consider the software implementation of the input register. The input register is a serial-to-parallel conversion that divides the arriving bit sequence into sets of 4 bits for 20 subcarriers. Once this conversion is complete, the module sends a ready signal to the subcarriers to begin data reception and processing.

The module 16-QAM modulation is quite simple to implement, as it is only necessary to find out at what input values should be obtained at what values of the real and imaginary components of the complex number and realise it using conditions. In this paper we have developed a software implementation of the filter. Filtering is performed on each subcarrier. The FIR filter is selected as the filter. Software verification of the receiving and transmitting path is developed. The result of verification was the confirmation of correct operation.

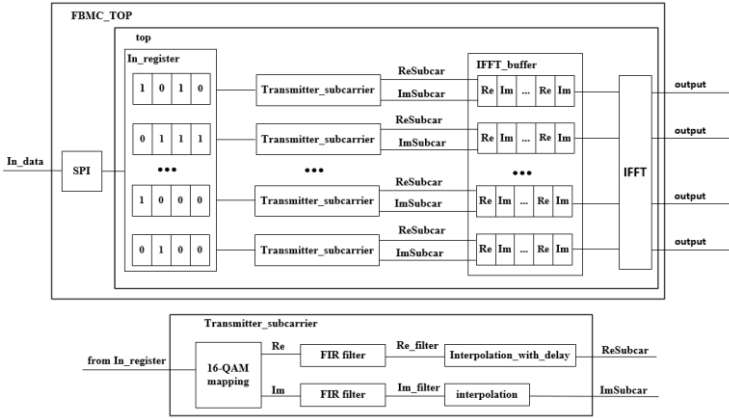


Fig. 2. Logic diagram of FBMC signal conditioning module elements

To perform interpolation, it is necessary to remember that this operation is the addition of zero samples. In the case of digital data, these are additional zero data sets. The difference between delayed interpolation and interpolation is the sequence of the data and the set of zeros. In the former case, the set of zeros is transmitted first followed by the data sequence, while in the latter case, the data sequence is transmitted first followed by the sequence of zeros.

When implementing a fast conversion module, the following points should be taken into account:

- the time of one clock cycle of the module is equal to the bandwidth of the signal;
- the number of incoming subcarriers must be equal to degree 2;
- the operation time of this module is much longer than the time of data supply to the module, therefore, it is necessary to use a buffer matrix, the number of columns of which will correspond to the ratio of the frequency of data reception from the previous module for the period of operation of the fast Fourier transform module;
- rotary coefficients should be multiplied by a number of powers of two in such a way that the resulting value minimizes the effect of rounding to an integer value, after which it is necessary to make a division by the same number;
- also do not forget that this module is the slowest module used in the signal conditioning module, as it processes data at a frequency equal to the bandwidth of the signal;
- it is necessary to provide a buffer, which will accumulate data from the subcarriers in order not to lose them, and shift register, which will shift further data in the case of processing the previous data module fast Fourier transform.

Within the framework of the work was developed and programmed the layout of the signal conditioning unit to study its characteristics. For this purpose, a bench was assembled to conduct a study of the parameters of the signal conditioning module for the receiving and transmitting path of the underwater communication channel, which consists of the following elements: two FPGAs, a dual-channel oscilloscope and a generator of bit test sequences. The schematic of the bench is presented in fig 3.

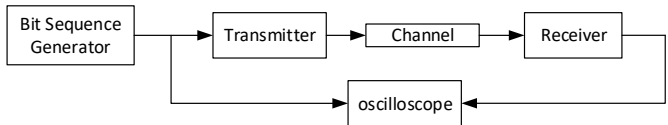


Fig. 3. Logic diagram of the stand

Figure 4 shows the results of experimental studies of some elements of the signal conditioning module. For example, the time of data processing on the subcarriers was 380 nanoseconds.

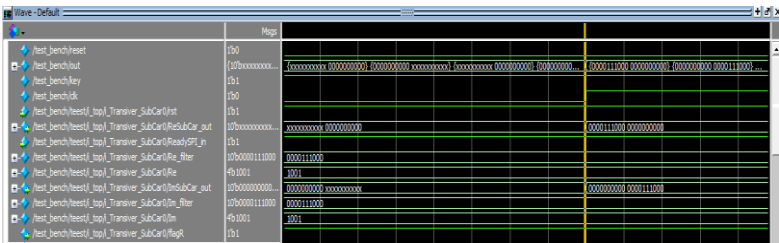


Fig. 4. Experimental results of the signal conditioning module

Figure 5 shows the results of the investigation of the software implementation of the generator by transmitting the verification sequence.

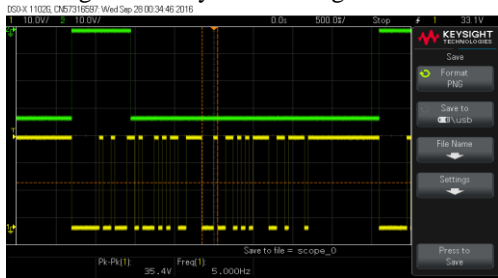


Fig. 5. Generator test sequence with start signal

Figure 6 shows the results of the study of the software implementation of the oscillator with the clk signal by passing a check sequence to it.

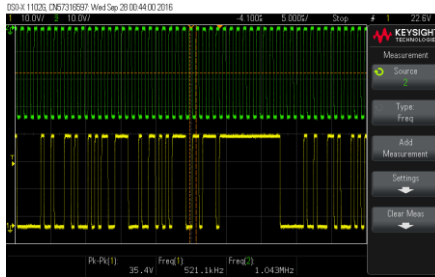


Fig. 6. Test sequence from an oscillator with clk signal

A study of the shaping module was carried out to see if it could be realised at a rate of $32 \times 100\text{kHz}$, i.e. the frequency bandwidth multiplied by the number of subcarriers received from the Fast Fourier Transform module. According to the results of the study, the time was $3.35 \mu\text{s}$, which is much less than the speed, and therefore such a realisation is possible.

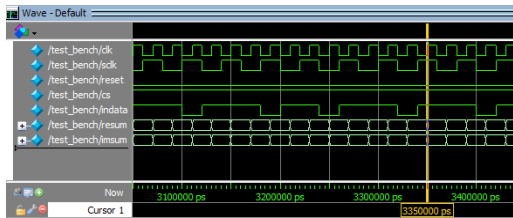


Fig. 7. Time diagrams of the FBMC signal conversion unit in the transmission path

During practical implementation of the module some problems were found. For example, when implementing modules of inverse fast Fourier transform there was a problem with the use of rotary coefficients. These coefficients in mathematical formulas are used in floating point form, while the FPGA can work with integer values. This problem can be solved by multiplying the pivot coefficient by such a number that the error is minimised. However, it is worth remembering that if you increase the size of the rotary coefficient after multiplication, you must divide by the same number. Since Systemverilog does not support floating point values, it is advisable to use a number of powers of two as a number, so that you do not have to divide directly, but simply shift by the required number of bits. The same applies to coefficients when implementing FIR filters. Also it is necessary to remember that when increasing any value, it is necessary to remember that the dimensionality of DAC will

depend on it. When implementing the software it is necessary to remember about synchronous operation of modules as because of this there can be a loss of data.

The obtained results of experimental studies of the parameters of the signal conditioning block for the receiving and transmitting path will be further used in the realisation of the receiving part of the signal conditioning module.

Conclusion. Thus, the results of the software implementation of the signal conditioning module using the FBMC technology in the hardware description language SystemVerilog are presented. The work of the main elements of the module is described, experimental studies of the time characteristics of signal generation for the receiving and transmitting path of the underwater communication channel based on an alternating magnetic field are carried out.

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UDC 621.3

**RESULTS OF IMPLEMENTATION OF CONTACTLESS
SENSOR FOR BREATH RATE AND HEART RATE
MEASUREMENT**

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Аннотация. В статье представлены результаты разработки системы бесконтактного измерения частоты дыхания и частоты сердцебиения человека на основе однокристалльного ЛЧМ-радары AWR6843. Сделан вывод о соответствии разработанной системы требованиям технического задания.

Ключевые слова: частота дыхания, частота сердцебиения, система мониторинга параметров здоровья, бесконтактное измерение.

Annotation. In the paper, the results of implementation of contactless sensor for breath rate and heart rate measurement on basis of single chip FMCW radar ARW6843 are presented. It is concluded, that the developed system's properties correspond to project charter.

Keywords: breath rate, heart rate, system of health parameters monitoring, contactless measurement.

INTRODUCTION

The preservation of human life and health has never been more critical, driving advancements in remote methods for measuring vital signs such as respiratory and heart rates. Recent research [1–5] explores various contactless and contact-based techniques for monitoring these physiological parameters.

The patent [1] describes motionless detection via microwave sensing device. An improved detection device eliminates signal loss in alternating ranges, enhancing accuracy in measuring heartbeat and respiration. The system comprises: a transmitting antenna and balanced microwave mixer, a power divider, low-frequency amplifier, and comparator, a reference oscillator and intermediate frequency amplifier. Signals are processed through multipliers and a microwave combiner, ensuring stable detection of vital signs in stationary subjects.

The patent [2] includes a method for coherent signal analysis for remote monitoring. This method involves emitting an electromagnetic signal, analyzing its reflection, and isolating the fundamental harmonic to determine body movement frequency and amplitude. By assessing these values, the system evaluates whether physiological parameters (e.g., heartbeat, respiration) fall within normal ranges, offering high measurement precision.

The utility model [3] represents a cross-shaped frame device, which integrates a bioradar, display, and microcomputer to analyze subjects' reactions to audiovisual stimuli. Key features include: real-time monitoring of heart rate, breathing rate, and posture changes, algorithmic comparison of responses to presented stimuli, automated assessment of psychophysiological reliability.

The device [4] for dual-channel non-contact monitoring is also known. This system employs a pulsed microwave generator and two spatially separated receiving antennas to track vital signs remotely. Each channel connects to phase detectors, with data transmitted wirelessly to a parent unit for processing.

In article [5], the current results of development and software implementation for hardware of the contactless breath rate and heart rate sensor are presented. It is concluded, that it is necessary to develop and optimize the sensor's algorithm and hardware.

In article [6], the principles of frequency-modulated continuous wave radar sensing are considered. The method is formed the basis of the sensor developed in this article.

Despite these innovations, many existing methods face implementation hurdles. This article presents the results of development of contactless sensor for breath rate and heart rate measurement.

THE MAIN PART

1. PCB design

As a result of development of the system, the sensor's printed circuit board (PCB) was developed.

In order to accomplish this task, it was decided to split the sensor into two modules: the microwave module and the interface module. The schematic diagram and antenna pattern of the sensor was developed.

Based on results of previous tasks, the PCB design was developed (see Fig. 1).

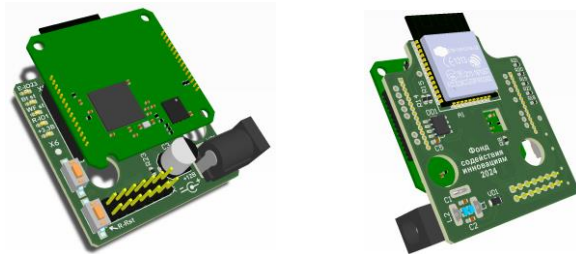


Fig. 1. The PCB of developed sensor

The sensor is intended to be installed 0,5—2,5 m away from human's chest.

Because the Multiple Input Multiple Output (MIMO) antenna structure is used, the monitoring of heart rate and breath rate for multiple targets is possible. Minimal angular separation inside the measurement area between measured targets should be not less than 30 degrees.

2. Embedded software design

The developed embedded software of microwave module consists of software for both digital signal processor (DSP) and general purpose processor, which are the parts of AWR6843 SoC radar.

The measurement area is divided into multiple configurable zones, in which the

The software of general purpose processor is responsible for communication with interface module of the sensor, for controlling the sensor's state and detecting, whether the measurement zone is occupied by a human.

The software of digital signal processor performs complex mathematical operations, including phase extraction, fast Fourier transformation (FFT),

phase unwrapping, values meaning, windowing, confidence metric calculation, which allows the measurement of vital signs, such as breath rate and heartrate [7].

The embedded software of interface module implements UART, Bluetooth and Wi-Fi interfaces for ESP32. It processes data received from microwave module: parses it, packing into a JSON and sending over Wi-Fi network to the graphical user interface application.

As a result, a program’s module which implements the measurement of vital signs was officially registered [8].

3. GUI software design

The graphical user interface was developed. It is implemented as an ASP.NET application, which uses the Blazor framework to implement component-based graphical interface.

Since the interface module of the sensor uses the MQTT protocol, the RabbitMQ broker was chosen as a media between GUI and sensor. This broker can be easily connected to a .NET application and also is cross-platform.

It was decided to use SQL database LocalDB as a mean of storing application’s data. The design of database includes two tables: one for sensor’s configuration and the another one for storing the measurements. The configuration table contains the coordinates of measurement zones and their activity states. The measurements result table contains timestamps, sensors’ IDs, measured heart rates and breath rates and measurement zones occupancy states. The stored measurements inside a specific time window can be loaded from the database and displayed on the heart rate and breath rate charts.

GUI software allows to upload sensor’s configuration from a file on a user’s device. The measurement results are plotted on two separate charts.

There is a visual measurement zone positioning tool that allows to view measurement zones inside of measurement area in different projections.

The appearance of the developed GUI is presented on Fig. 2.

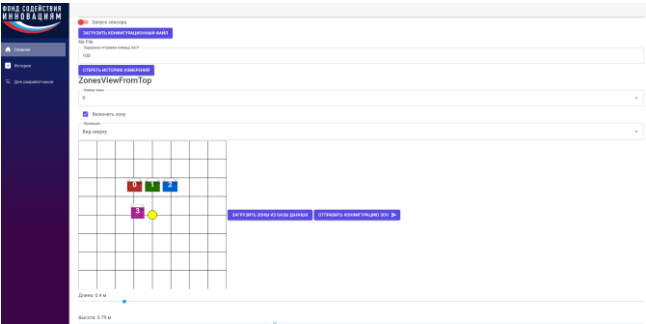


Fig. 2. The system's GUI

4. Testing the system

The developed system was tested in laboratory conditions (see Fig. 3).

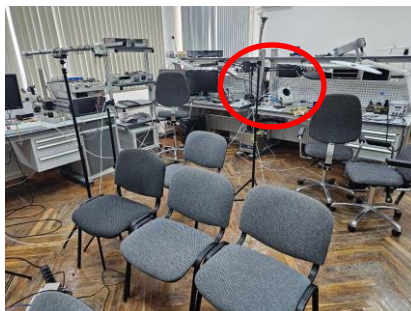


Fig. 3. The testing installation

In order to perform tests, the testing protocol was developed. According to this protocol, tests should have been conducted on both real adult people and artificial babies' models.

The results of measurements of contact sensor are presented in Table 1, the results of the developed system's testing are presented in Table 2.

Taking into consideration the results of measurements above, it was concluded that the main goal of the project was achieved. The developed system is able to measure the breath rate in a time interval less than 45 seconds and the heartrate in a time interval less than 70 seconds.

Table 1. The results of measurements of contact sensor

Test subject	Breaths per minute	Heartbeats per minute
1	9	82
2	16	58
3	9	68
4	7	56

Table 2. The results of the developed system's testing

Test subject	Breaths per minute	Heartbeats per minute
1	8	82
2	16	60
3	9	71
4	8	70

CONCLUSION

As a result of the project, the PCB of contactless sensor, the embedded software, including the software of digital signal processor and software of general purpose processor, and the graphical user interface software were developed.

As the result of testing, it was noted, that the developed system corresponds to project charter.

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UDC 52-65

THE COSMIC RADIATION TYPES, ORIGIN AND METHODS OF STUDY OVERVIEW

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Аннотация. Ввиду активного развития космических технологий и технологий связи значительным вредоносным, с одной стороны, и несущим важную информацию с другой – стало космическое излучение различных происхождений. В данной работе были рассмотрены различные типы космического излучения – земное, солнечное, галактическое, внегалактическое; методы и аппараты для их анализа и изучения. Отдельно проанализировано реликтовое излучение, ввиду наибольшей информационной ценности для астрофизики и радиофизики. Также описаны методы изучения реликтового излучения, и их оптимальное применение.

Ключевые слова: космическое излучение, телескоп, реликтовое излучение, радиоинтерферометрия, метод акустических пиков, фотометрический подход, спектрометрический подход

Annotation. Due to the active development of space technologies and communication technologies, cosmic radiation of various origins has become significantly harmful, on the one hand, and carrying important information, on the other. In this paper, various types of cosmic radiation were considered – terrestrial, solar, galactic, extragalactic; methods and devices for their analysis and study. The cosmic microwave background radiation is analyzed separately, due to its greatest informational value for astrophysics and radiophysics. Methods for studying cosmic microwave background radiation and their optimal application are also described.

Keywords: cosmic radiation, telescope, cosmic microwave background radiation, radio interferometry, acoustic peak method, photometric approach, spectrometric approach.

Introduction

Currently, there is an active development of many space and aerospace technologies that indirectly or directly affect the most important aspects of space exploration and their future conquest. However, all these technologies are affected by one extremely important factor – cosmic radiation. It can interfere with navigation in the air, study distant galaxies through telescopes of various types, and harm the health of astronauts, but also, by studying it, you can learn about the development of the universe, the composition of stars, and the nature of space formations.

This article will analyze the types of such radiation, devices and methods for studying it.

Main part

Terrestrial radiation is radiation with a wavelength of 3–80 microns, produced mainly by two groups of natural radionuclides (uranium-radium and thorium families). The greatest contribution is made by the decay of radon, which is about 2 mSv/year, or about half of the total radiation exposure. In addition to natural radiation sources, technology also makes a big contribution.

Solar radiation is electromagnetic radiation of various ranges (from 10^{-4} nm to 1 km), formed due to thermonuclear fusion of helium from hydrogen. The radiation is largely influenced by the photosphere, in which the spectrum of solar radiation is formed. It consists of highly rarefied gas 10^{-9} g/cm³ – mainly hydrogen (~74%) and helium (~25%), as well as a small amount of various metals that are ionized due to the temperature of the photosphere. However, it is worth noting that there are also absorption spectra in it, which arise as a result of the absorption of photons by photosphere atoms. Due to the fact that the Sun is a fairly powerful and very close source of radiation, its study is possible in many ways and in various fields. For example, the use of photovoltaic or thermoelectric receivers, spectrometers. With the help of these

devices, it is possible to study not only the properties of solar radiation, but also to carry out spectral analysis of other stars – to find out their mass, composition, density, and some other characteristics.

Galactic radiation – its source is objects outside the solar system, such as stars, quasars, and other formations with strong radiation. It usually has a wavelength from 1 mm to several kilometers, depending on the source. The components of other galactic rays are protons and alpha particles. It is worth noting that antiparticles such as antiprotons and positrons emitted by black holes are also found in its composition. The energies of the particles vary greatly depending on the source, from 10^6 eV to 10^{21} eV. As mentioned earlier, due to the influence of the atmosphere and technosphere, the study of certain types of radiation is difficult. Therefore, it is possible to study some particularly weak or distant sources using telescopes located in Earth orbit. Many of them are quite famous – Hubble, Webb, Chandra, Fermi. All of them study various radiation spectra, including optical, which makes it possible to study the redshift of many differently distant objects, which will help in studying the history of the universe, its expansion, and the movement of cosmic formations.

Extragalactic radiation is radiation of various ranges, from the microwave to the gamma range. It differs from others in extremely low intensity, as a result of which its study is difficult. The main sources are quasars, galaxy clusters, and active galactic nuclei. Unlike other types of radiation, it is diffuse, as it comes from a large number of different sources at a great distance from us. To study such radiation, there is even a separate type of astronomy – extragalactic. The study takes place mainly with the help of ultra-sensitive space telescopes - thus clusters of dark matter, blazars, radio galaxies, filaments were discovered [1].

Relic radiation is weak electromagnetic radiation that appeared after the Big Bang. It is also one of the varieties of extragalactic, the source of which is the primary recombination of hydrogen – that is, it was formed about 380 thousand years after the big bang. During its formation, it had a temperature of about 3000 degrees Kelvin, but now, due to the expansion of the universe, its temperature has dropped to ~2.75 K on average. By the way, white noise in the TV can occur precisely because of the background radiation [2].

The main reason for the research is that cosmic microwave background radiation provides information about the early stages of the universe's development, the formation and origin of galaxies, dark energy, and various structures. Using the temperature distribution, one can learn about the direction of the expansion of the Universe – that is, about the direction of the Big Bang (Fig. 1). As is now known, the temperature in the direction of the constellation Leo is slightly higher than the average, and in the opposite

direction – slightly lower, which allowed us to draw the above conclusions. In addition, it helps in the confirmation and formation of various theories. The study of anisotropy also allows us to draw conclusions about the structure of the cosmos as a whole. Temperature fluctuations allow us to judge some of the prerequisites for the formation of structures and the shape of the universe.

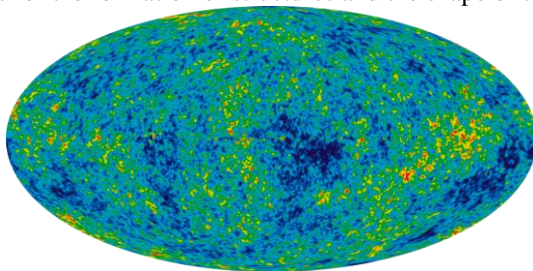


Fig. 1 – A map of the temperature distribution of the cosmic microwave background

Various devices and methods for studying and analyzing cosmic microwave radiation. Radio telescopes and spectrophotometers located in space and on Earth are used to study the cosmic microwave background radiation. The former directly detect this radiation and convert it into an audio signal for analysis, after which it is possible to calculate the radiation power spectrum (adjusted for significant noise). The latter are used to measure the spectrum – they allocate only a certain wavelength for study, which gives them significant noise immunity. The main approaches in radiation research:

The photometric approach consists in observing certain wavelengths. This allows you to observe only microwave radiation, but it gives poor visibility in the spectrum. There is some error due to the redshift.

The spectrometric approach is to study the spectrum for each small area, i.e. this approach will eventually take a considerable amount of time. There is an error due to the limited sample size.

Ultra-long-range radio interferometry consists of placing telescopes at a certain distance from each other and connected by a cable wire. The principle of operation of the radio interferometer is based on the fact that the front of the EM wave coming from the source can be considered flat. The use of radio interferometers to achieve high angular resolution, determine the radiation density in various directions. This method is more effective than others in studying at great distances with high accuracy.

The acoustic peak method consists of converting the received signal into an acoustic one and comparing the intensity at different time intervals. The acoustic peaks themselves are signs of a collision of radiation with matter –

matter tries to collapse, but bounces off, forming these peaks. This method allows you to more accurately determine the map of the universe.

Statistical methods – temperature fluctuations over different angular distances are considered, and the angular power spectrum is constructed. Allows you to determine the dependence of power on the harmonic number, determine the correlation of temperature and polarization [2].

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UDC 621.3

ISSUES OF IMPLEMENTATION OF SECONDARY BOOTLOADER FIRMWARE FOR AWR6843 CONTROLLER WITH COMMUNICATION AND FLASHING FIRMWARE VIA CAN INTERFACE

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Аннотация. В статье рассмотрен вторичный загрузчик для контроллера AWR6843. Представлены текущие результаты разработки алгоритма и программной реализации вторичного загрузчика через CAN интерфейс для контроллера AWR6843. Сделан вывод о результате проделанной работы и дальнейших улучшениях.

Ключевые слова: Вторичный загрузчик, CAN, SBL.

Annotation. The article deals with the secondary bootloader for AWR6843 controller. Current results of algorithm development and software implementation of the secondary loader via CAN interface for AWR6843 controller are presented. It is concluded about the result of the work done and further improvements.

Keywords: Secondary Bootloader, CAN, SBL.

INTRODUCTION

The AWR6843 is a millimeter-wave radar sensor from Texas Instruments [3], widely used in automotive and industrial applications. One of the key challenges in its deployment is the implementation of a secondary bootloader (SBL) that enables firmware updates and communication via the CAN (Controller Area Network) interface. This article discusses the key issues encountered during the implementation of such a bootloader and proposes potential solutions.

THE MAIN PART

1. Purpose

SBL [2] is designed to:

- 1) Updating the application meta-image in flash memory (SFLASH) via the CAN interface;
- 2) Download and run the updated application meta-image;
- 3) Providing fault tolerance: if the master image is corrupted, the SBL automatically loads a backup from factory defaults;
- 4) Checksum checks for data integrity.

2. Design and architecture

The secondary bootloader must perform two main functions: updating and loading image.

Image Updater (Fig. 1) update a new or existing application Meta-Image in SFLASH.

Image Loader (Fig. 2) download the existing application Meta-Image from FLASH into the RAMs of all subsystems.

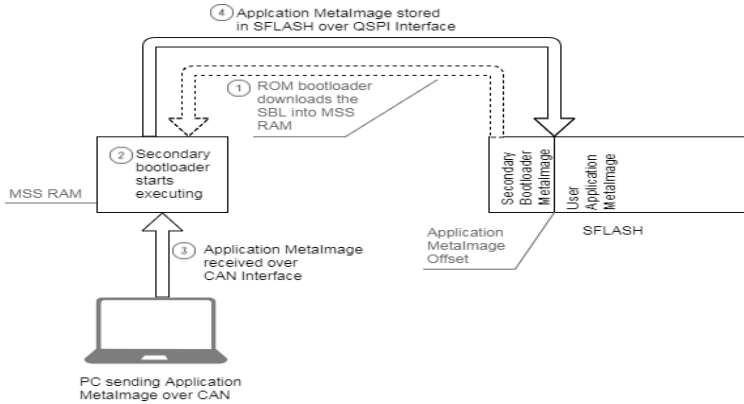


Figure 1. - Image Updater

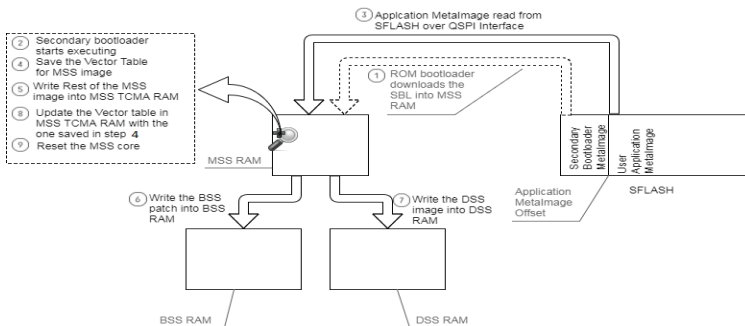


Figure 2. Image Loader

3. Memory management and execution location

One of the primary challenges in SBL implementation is deciding where to execute the bootloader code—Tightly Coupled Memory A (TCMA) or Tightly Coupled Memory B (TCMB).

TCMA: Simplifies the boot process since the primary bootloader already loads code here, reducing execution time. However, it limits the available memory for the user application.

TCMB: Frees up TCMA for the user application but requires additional code to copy the SBL from TCMA to TCMB during pre-initialization. This adds complexity and potential points of failure.

In the current implementation chose to execute the loader code from TCMB. In addition to the startup code responsible for copying the code into TCMB memory, the SBL code will be stored in TCMB memory.

4. Can communication and firmware flashing

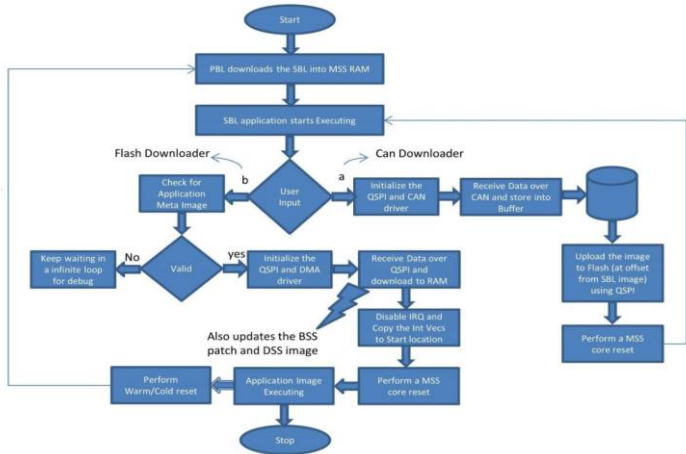


Figure 3. - SBL Design Flow

The algorithm of SBL operation (Fig. 3) and the algorithm of application operation (Fig. 4), which performs firmware image loading via CAN, were developed. The algorithm sends the image in separate packets, performs CRC comparison and check the application meta image validity.

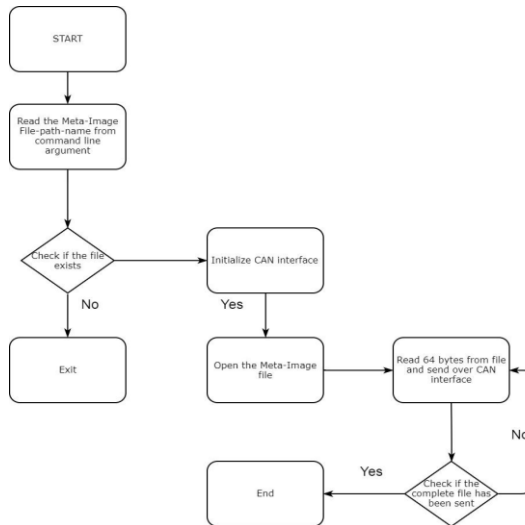


Figure 4. - Image Loader algorithm

CONCLUSION

Implementing an SBL for the AWR6843 with CAN-based firmware updates presents several challenges, including memory management, communication reliability, and fail-safe mechanisms. By following best practices—such as modular design, robust error handling, and thorough testing—developers can overcome these issues and create a reliable bootloader solution. CAN interface requires careful attention to initialization, message handling, and debugging, but the benefits of CAN (e.g., robustness in noisy environments) make it a worthwhile endeavor for automotive and industrial applications.

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UDC: 621.317

**DEVELOPMENT OF A HARDWARE-SOFTWARE COMPLEX
FOR MAGNETIC-DRIVEN COAGULATION CONTROL IN
MINIMALLY INVASIVE THERAPY**

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Annotation. В статье представлен программно-аппаратный комплекс для управления магнитным полем с целью коагуляции сосудов в области опухолей. Решается задача точного позиционирования магнитных наночастиц с помощью направленного магнитного поля. Прототип комплекса включает электромагниты с программным управлением и интерфейсом реального времени. Проведённые моделирования и лабораторные испытания подтвердили работоспособность системы и её перспективность для использования в клинической практике.

Ключевые слова: магнитное поле, наночастицы, коагуляция, аппаратно-программный комплекс, минимально инвазивная терапия

Annotation. This article presents a novel hardware-software system designed for magnetic-field-controlled vascular coagulation in the treatment of tumors. The proposed solution addresses the lack of clinical tools for precise magnetic field localization required for the aggregation of magnetic nanoparticles. The system includes programmable electromagnetic modules and a control algorithm to generate a directed field for targeting tumor-related vasculature. Simulation results and early prototype testing confirm the feasibility and effectiveness of the approach. The developed system is a step forward in the integration of minimally invasive therapies and magnetic targeting in oncology.

Keywords: magnetic field, hardware-software system, nanoparticles, coagulation, minimally invasive therapy

Introduction

Minimally invasive treatments have become increasingly relevant due to their lower trauma and higher effectiveness. One promising technique involves the use of magnetic nanoparticles for localized coagulation of blood vessels

supplying tumors. This process reduces the viability of neoplastic tissue and enhances the outcomes of chemotherapy and radiotherapy. However, current clinical practice lacks technical solutions for precise magnetic field control required for this approach. The aim of this work is to develop a hardware-software complex that enables accurate and safe magnetic field management for medical use.

Methods

The system is composed of two primary components: the hardware module and the control software. The hardware includes a configurable array of electromagnets positioned to surround the targeted body area. These electromagnets are powered by precision current sources controlled via a microcontroller system (STM32). The software allows for setting field strength, direction, activation timing, and modulation patterns.

Field distribution is modeled using finite element method (FEM) simulations to predict and optimize the nanoparticle path within vascular structures. Safety parameters include automatic shutoff thresholds, thermal monitoring, and fail-safe logic.

Results

The system prototype was developed on a modular testbed with interchangeable coil configurations. Simulation data showed that the field could be shaped to concentrate nanoparticles within a 5 mm radius in a predefined target zone. Control software was implemented in C++ with a graphical user interface for real-time field manipulation.

Preliminary laboratory tests confirmed that the system could create and maintain the necessary field gradients without overheating or hardware failure. The design meets the medical requirements for electromagnetic exposure and operational safety.

Discussion

Compared to existing magnetic guidance systems used in research settings, the proposed system provides more accurate control with real-time software feedback. This improves targeting efficiency and minimizes off-target effects. The modular design allows customization depending on anatomical region and therapy protocol.

Further integration with imaging systems (e.g., MRI, ultrasound) can enhance field navigation. The possibility to synchronize with chemotherapeutic agents opens new opportunities in hybrid therapies.

Conclusion

The developed hardware-software complex represents a promising approach to precise magnetic targeting in oncology. It fills a current gap in clinical tools for magnetic-field-guided therapies. Future work will focus on clinical trials, software enhancement, and development of adaptive control algorithms.

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UDC 51

PESSIMISTIC ESTIMATION FOR RECTANGULAR 3D DECOMPOSITION

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Аннотация. В статье рассмотрена проблема предсказания результата и длительности работы алгоритма декомпозиции трёхмерных бинарных тензоров на множество непересекающихся параллелепипедов, что в сумме покрывают все единичные ячейки. Введено понятие валентности для отдельной единичной ячейки и понятие средней валентности единичных ячеек. Построены графики зависимости отношения количества параллелепипедов к количеству единичных ячеек от средней валентности. Построены графики зависимости нормализованного времени выполнения алгоритма декомпозиции от средней валентности.

Ключевые слова: декомпозиция, бинарный тензор, предсказание, валентность, время выполнения.

Annotation. The article considers the problem of predicting the result and duration of the algorithm for decomposing three-dimensional binary tensors into a set of disjoint boxes, which in total cover all non-zero cells. The concept of valence for a single unit cell and the concept of the average valence of single cells are introduced. Graphs of the dependence of the ratio of the

number of parallelepipeds to the number of single cells on the average valence are constructed. Graphs of the dependence of the normalized execution time of the decomposition algorithm on the average valence are constructed.

Keywords: decomposition, binary tensor, estimation, valence, execution time.

INTRODUCTION

Binary images require dedicated algorithms for their processing and analysis. The major difference from traditional images is that binary tensor representation is highly redundant. “Specialized algorithms employ various lossless compressive representations that contribute not only to efficient memory usage but also contribute to fast processing” [1, p.755].

One of the most frequently used approaches is rectangular decomposition. This approach uses uniform rectangular areas (rectangles, parallelepipeds, etc.) of arbitrary size” [3, p. 4280].

A commonly accepted measure of the decomposition quality is the number of resulting blocks. This is justified by the fact that processing algorithms tend to use resulting blocks directly. Naturally sophisticated algorithms that end up with the least number of resulting blocks require more time than the simple non-optimal ones.

In this paper, prediction of time and resulting blocks is discussed.

THE MAIN PART

Rectangular decomposition means merging adjacent 1’s inside tensor. Naturally, relation between resulting blocks and mean neighbor count for each unit should be considered. We will call the neighbor number the valence, by analogy with graph theory. [2] Also we will call units in 3d tensor voxels, as they are used in voxel graphics.

We compared two 3d decomposition methods — delta-method which is known for fastest execution time [1, p. 757] and sub-optimal algorithm which is an extension of optimal 2d decomposition method [1, p. 767]. Both normalized execution time and box to voxel ratio are compared. Each graph is drawn using 200 points.

Given noisy nature of real data, decomposition is tested on noisy images. First scenario — each cell is equally likely to be filled with voxel, for each test probability is set to different number. Second scenario — voxel body where path between any two voxels exists, which also can be called connected. [2] Connected body is made by iteratively adding voxel to empty space near random voxel.

For each test, execution time, box to voxel ratio, and mean valence is calculated. We will call box to voxel ratio decomposition efficiency, as this ratio is used for measuring decomposition algorithm quality.

In Fig. 1 decomposition efficiency of delta-method is presented.

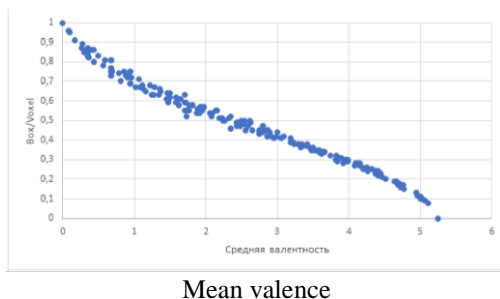


Fig. 1 — Decomposition efficiency of delta-method

Fig. 2 shows decomposition efficiency for sub-optimal method.

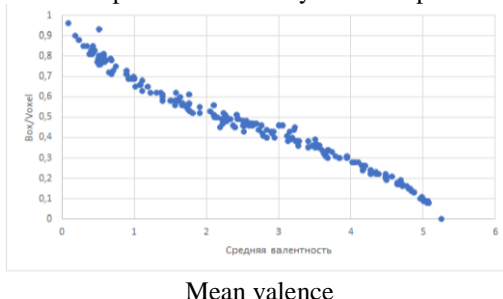


Fig. 2 — Decomposition efficiency of sub-optimal method

The graphs (Fig. 1, Fig. 2) show, that:

1) sub-optimal does not have particular advantage over delta-method on noisy data;

2) there is correlation between mean valence and decomposition efficiency so high that decomposition result for noisy image can be predicted.

We used custom implementation of sub-optimal algorithm [1, p. 767] that implements approximation for the maximum independent set on tripartite graph. Adjacent blocks that resulted from sub-optimal division were not merged.

As actual execution time is highly dependent on hardware and software implementation, execution time was divided by maximum value to get general shape.

Fig. 3 shows normalized execution time for delta method.

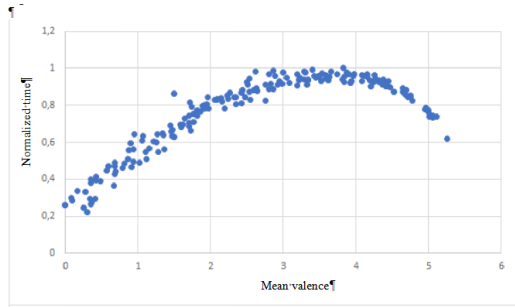


Fig. 3 — Normalized execution time of delta-method

Fig. 4 shows normalized execution time for delta method.

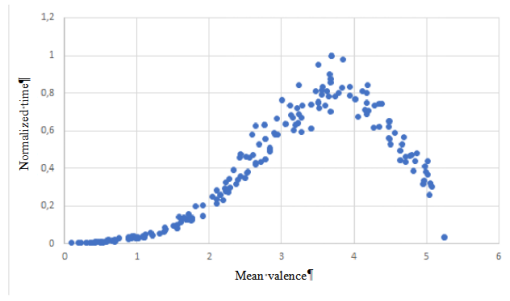


Fig 4 — Normalized execution time of sub-optimal method

Fig 4 — Normalized execution time of sub-optimal method

Graphs (Fig. 3, Fig. 4) show that:

- 1) mean valence approximately equal to 3,7 leads to maximum execution time;
- 2) execution time for sub-optimal algorithm is highly dependent on mean valence;
- 3) correlation between normalized time and mean valence allows to predict execution time.

Notice that these observations are true only for two given scenarios. Simplest counterexample is a cube made of 8 voxels, as mean valence is 3 and decomposition efficiency is $1/8 = 0,125$. However, these observations show worst-case scenario and give the upper boundary for normalized execution time and box to voxel ratio.

CONCLUSION

This article argues that the upper bound for the box to voxel ratio and normalized execution time obeys a certain law observed when decomposing noisy binary images. Numerical estimation may be excessively pessimistic, as this law is for worst-case scenario, but algorithms can be compared and guarantees can be made. Accurate assessment of execution time and decomposition efficiency requires further consideration.

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A THEORY OF NAVIGATION TECHNOLOGIES FOR AUTONOMOUS UNDERWATER VEHICLES

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Аннотация. Автономные подводные аппараты (AUV) стали центром последних разработок в области морских исследований. В исследовании рассматриваются вопросы развития емкости аккумуляторов и прорывы в области водородных топливных элементов. Очевидно, что эти усовершенствования касаются возможностей AUV выполнять более длительные задачи, которые ранее выполнялись пилотируемыми аппаратами и привязными дистанционно управляемыми аппаратами (ROV). В заключение отмечается, что в настоящее время АНПА играют все более важную роль в научной, коммерческой и военной сферах.

Ключевые слова: навигационные методы, автономный подводный аппарат, подводная локализация.

Annotation. Autonomous underwater vehicles (AUVs) have become the focus of recent developments in marine exploration. The study presents the issues of development in battery capacity and breakthroughs of hydrogen fuel cells. It is clear that these enhancements deal with AUVs' possibilities to execute longer tasks that were previously performed by manned vehicles and tethered, remotely operated vehicles (ROVs). In conclusion it is noted that nowadays, AUVs play an increasingly important role in the commercial, scientific and military fields.

Keywords: navigational methods, autonomous underwater vehicle, underwater localization.

AUVs are designed to perform a wide range of applications in different areas. "AUVs have become very popular to explore, collect data, and to create 3D reconstructions. At the oil and gas industry, AUVs inspect and repair submerged infrastructures and also have great potential in search, recognition, and localization tasks" [2, p. 2]. "Underwater navigation has always been a challenging research hotspot" [12, p. 5016].

In the civilian direction, AUVs are widely used in the field of studying and developing the riches of the world's oceans. The first civilian device was the AUV "Yantar", developed and delivered to the customer in 1991, designed to search for concretions at depths of up to 6,000 meters.

AUVs are underwater technical means with functional and design features. The creation and development of AUVs is a difficult task due to the strong requirements for this type of apparatus. Research in the field of creating promising AUVs continues.

The evolution of AUV technology is set to play a crucial role in exploring and understanding the depths of oceans and seas. "AUVs are also used for port and harbor security tasks such as environmental inspection, surveillance, detection and disposal of explosives and seabed exploration" [2, p. 2].

"Development of Autonomous Underwater Vehicles (AUVs) has permitted the automatization of many tasks originally achieved with manned vehicles in underwater environments" [4, p. 2]. "Design and implementation of new technologies and algorithms for navigation and localization of AUVs is a great research opportunity" [5, p.0535]. Construction and control of AUVs represent a challenging work for engineers which face constraints.

The research problem of navigation technologies for autonomous underwater vehicles is quite popular among scientists all over the world (table 1).

Table 1. A theory of Navigation Technologies for Autonomous Underwater Vehicles

Scientists	Main achievements
S.Yang, P.Li, Y.Liu, T.Yan, R. Li	an acoustic navigation that is an effective underwater navigation scheme [3]
I. Masmitja, J.G. Agudelo, G. Masmitja, S. Gomariz	“a development of a control system for an autonomous underwater vehicle dedicated to the observation of the oceans” [4, p. 2]
Zhao, J. Yuh	“the adaptive plus disturbance observer (ADOB) controller for underwater robots” [10, p.1769]
Y. Gao, L.Zhang, J. Zeng, I. Guan	“ autonomous underwater vehicle navigation enhancement by optimized Side-Scan Sonar Registration and improved post-processing Model based on factor Graph Optimization” [11, p. 695]
C.Wang, H. Yu	autonomous navigation as “critical for autonomous underwater vehicle [9]
S.Vadapall, S. Mahapatra	“the design of a robust state feedback optimal control strategy for an Autonomous Underwater Robotic Vehicle (AURV)” [8, p. 277]

Source: compiled by authors

Scientists P.Li, Y.Liu, T.Yan, S.Yang, R. Li studied the “ultrashort baseline system (USBL) that is an alternative navigation method” [3, p. 916].

S.Vadapall, S. Mahapatra developed the control strategy using a polytopic approach based on hydrodynamic parameter variation; “the dynamics of the AURV system are controlled by a robust optimal control technique” [8, p. 277].

I. Masmitja, G. Masmitja, J.G. Agudelo, S. Gomariz said that “the vehicle, a hybrid between Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vehicles (ASV), moves on the surface of the sea and makes vertical immersions to obtain profiles of a water column, according to a pre-established plan” [4, p. 47]. C.Wang, H. Yu considered autonomous navigation as “critical for autonomous underwater vehicle to complete underwater tasks, and attitude is an essential parameter of autonomous navigation” [9, p. 012001].

Zhao, J. Yuh stated that it was “desirable to have an underwater robot controller capable of self-adjusting control parameters when the overall performance degrades” [12, p. 695]. They presented the theory and practice of “the adaptive plus disturbance observer (ADOB) controller for underwater

robots, which is robust with respect to external disturbance and uncertainties in the system” [12, p. 695].

Y.Tang, L.Wang, S.Jin, J.Zhao, C.Huang, Y. Yu “propose an autonomous underwater vehicle-based side-scan sonar real-time detection method for underwater targets” [7, p. 690]. L.Zhang, I. Guan, J. Zeng, Y. Gao proved that “Autonomous Underwater Vehicles (AUVs) equipped with Side-Scan Sonar (SSS) play a critical role in seabed mapping, where precise navigation data are essential for mosaicking sonar images to delineate the seafloor’s topography and feature locations” [10, p. 1769].

Results and discussions.

AUVs provide conducting swath mapping (detailed 3D mapping of the seafloor using sonar) and large area surveys. They carry multiple payloads and provide synoptic coverage. AUV can image the seafloor and measure water quality simultaneously. The following main tasks solved by means of AUVs are:

1. Geological exploration: relief mapping, topographic and video shooting of the seabed, acoustic profiling.

2. Oceanographic research. “AUVs are untethered from a ship, allowing the robots to complete pre-planned missions without direct control from an operator” [1, p. 2]. An AUV collects high-resolution data after being deployed, “which are stored within the vehicle and collected by researchers once the AUV has surfaced” [2, p. 3].

3. Survey and search operations: inspection of underwater structures and communications, sunken objects. surveys of water areas and underwater hydraulic structures are carried out to ensure the safety and technical reliability of objects on the water, in order to promptly identify and eliminate possible defects or pollution.

4. Under-ice operations: maintenance of lighting systems, laying cables and pipelines. The method of underwater subglacial seismic exploration consists of the automatic placement of hydrophones in the water column at various depths from a vessel, for example a submarine, at a given distance between them both in the horizon and in rows one above the other.

5. Environmental monitoring. As marine ecosystems are affected by external inputs and pollutants, it may result to their biodiversity of their processes. It will have consequences on the global system. Underwater robots are used for environmental monitoring of water bodies in the following ways: measuring pollution (autonomous underwater vehicles collect water and sediment samples to analyze pollution levels); assessing water quality (robots monitor water parameters such as pH, oxygen content, and the presence of microplastics in real time).

6. Military work: patrolling, mine defense, reconnaissance (intelligence).

There are many proposed navigation technologies for autonomous underwater vehicles. “Recent studies have explored and compared two distinct frameworks: a centralized iterative UKF (Unscented Kalman Filter)-based approach, and a sensor fusion framework employing parallel local UKFs. These methods reflect ongoing efforts to refine AUV navigation through advanced filtering techniques. AUVs are typically outfitted with multiple sensors, such as inertial navigation systems (INS), ultra short baseline systems (USBL), and Doppler velocity logs (DVL), to facilitate autonomous navigation. A robust integrated navigation algorithm that combines INS, USBL, and DVL data” [2, p. 2].

The significance of autonomous navigation for AUVs is considered in studies. Some approaches indicate the growing influence of biomimicry in technological developments. The absence of additional underwater absolute positioning measurements introduces unknown errors in navigation system modeling in underwater missions.

Another method describes the system operation for effective real-time underwater target detection. It demonstrates a sonar technology integration in AUV systems. A novel statistical model for terrain-based navigation using side-scan sonar (SSS) data has been introduced by scientists [3-7].

The development of a semi-autonomous underwater vehicle also marked a notable advancement. These vehicles were equipped with multiple on-board CPUs, actuators, redundant sensors, an independent power source, and a robotic manipulator.

The field of underwater robotics include fault-tolerant control and coordinated control. These new features underscored the importance of reliability and coordination in underwater operations. It marks a significant progress in underwater robotics technology. A control system consists of the built-in PC104 computer. Figure 1 shows the control system block diagram.

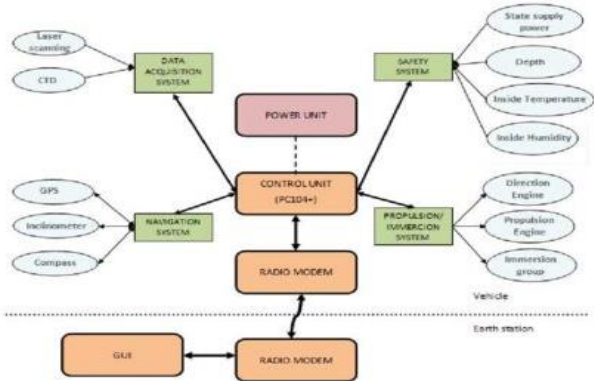


Figure 1. Diagram of control system structure

Conclusion. To accomplish a wide range of applications in various areas AUVs are designed. AUVs have become the focus of recent developments in marine exploration. The study presented the issues of development in battery capacity and breakthroughs of hydrogen fuel cells. It was clear that these enhancements deal with AUVs' possibilities to execute longer tasks that were previously performed by manned vehicles and tethered, remotely operated vehicles (ROVs). In conclusion it is noted that nowadays, AUVs play an increasingly important role in the commercial, scientific and military fields.

AUVs have great potential in recognition, and localization tasks. AUVs have a diving depth and can be designed for different operating conditions. The engines used push the water and allow the drone to move independently. They provide enhancement of environmental monitoring, oceanographic research, and various maritime operations.

The tasks of the AUVs will become more complex as more and more complex elements of artificial intelligence are introduced into the AUV software. There is still a lot of research to be done before supersonic underwater vehicles can be put into production. Scientists plan to do this by 2050. There is a lot of time to develop promising technologies.

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LOOP ANTENNA WITH ADDITIONAL BENDS PERPENDICULAR TO THE PLANE OF THE LOOP

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Аннотация. Работа посвящена разработке рамочной антенны с дополнительными изгибами, перпендикулярными плоскости рамки. Проведено исследование влияния геометрических параметров разработанной антенны на ее входные характеристики и характеристики излучения. Показано, что использование дополнительных изгибов позволяет уменьшить габариты антенны в плоскости рамки.

Ключевые слова: рамочная антенна, линейная поляризация, компактная антенна, моделирование антенн.

Annotation. The work is devoted to the development of a loop frame antenna with additional bends perpendicular to the plane of the frame. An investigation of the influence of the geometric parameters of the developed antenna on its input characteristics and radiation characteristics has been carried out. It is shown that the use of additional bends allows for reducing the antenna size in the plane of the frame.

Keywords: frame antenna, linear polarization, compact antenna, antenna modeling.

Introduction.

In a number of literary sources [1-4], significant attention is given to the practical application, structural implementation, symmetrization, and matching of such antennas. However, compact loop antennas have not been sufficiently studied. Various frame shapes may be used, and inductive excitation methods can also be employed.

Since the perimeter of the loop antenna must remain constant, introducing additional bends should lead to a reduction in the size of the antenna. Using bends that are perpendicular to the plane of the frame should result in a greater reduction in the physical size of the antenna compared to using bends within the plane of the frame.

The antenna is intended for use in Wi-Fi systems that enable wireless communication, connecting computers, smartphones, tablets, and other devices to the internet or each other. Wi-Fi uses radio waves instead of wires for data transmission and can be available in public places like cafes, airports, hotels, as well as in home networks where a router is connected to an Internet service provider. The antenna is designed to operate in the Wi-Fi frequency range of 2.4 GHz.

This paper presents the results of research on a loop antenna with additional bends perpendicular to the plane of the frame, featuring linear polarization of the emitted field. The choice of geometric structure for the radiator is determined by its directivity and the possibility of matching within the specified frequency band.

Main Part.

Essentially, the frame antenna is a further development of the loop dipole. A drawback of the frame antenna is its high input impedance; however, the operating frequency band is several times wider than that of a symmetrical vibrator. Frame antennas have a simple construction.

In the 2.4-2.5 GHz frequency range, the circular antenna has an active part of input impedance at 150 Ohm, which leads to a standing wave ratio (VSWR) greater than 3 at the edges of the band. The antenna radius in this case is 3 cm.

To reduce the radius of the loop antenna, it is proposed to use vertical bends.

A loop antenna with additional bends perpendicular to the plane of the loop is a specialized design that can be utilized to alter its radiation pattern and enhance emission characteristics. Such modifications may contribute to focusing the radiation in a specific direction or altering the signal polarization.

These structural features enable the use of such antennas in systems where high directivity and emission efficiency are required. The bends perpendicular to the loop's plane can also affect the bandwidth and radiation resistance, which is crucial for operation across different frequency ranges. However, the exact characteristics will depend on the geometry of the bends and the dimensions of the antenna itself.

A round frame antenna with additional bends is described in cylindrical coordinates by the equation $z = a \cdot \cos(b \cdot \varphi)$, where z is the applicate, a is a parameter characterizing the magnitude of the bends, b is a parameter characterizing the number of bends, and φ is the polar angle.

For an antenna with parameters: antenna diameter - 3 cm, $b = 16$, $a = 0.6$ cm, wire diameter - 0.2 mm, the dependence of the standing wave ratio on frequency and the dependence of the active and reactive parts of the input impedance are shown in Figures 1 and 2.

Within the operating frequency range, $VSWR < 2.1$, with a minimum VSWR value of 1.9. The active part of the input impedance is 80 Ohms, and the reactive part is 0 Ohm. Improvement in matching and reduction of the antenna radius can be achieved by increasing the magnitude of the bends.

The active and reactive parts of the input impedance of the antenna increase with frequency and almost linearly depend on the frequency. The active part of the input impedance of the antenna varies in the frequency range of 2.2 - 2.6 GHz from 60 Ohms to 120 Ohms, while the reactive part of the input impedance in this range changes from -170 to 110 Ohm.

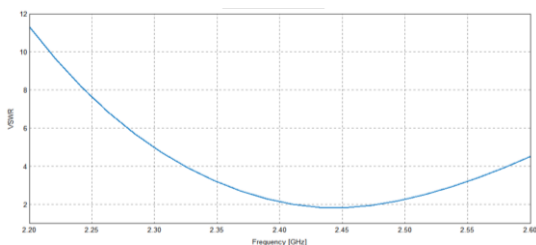


Fig. 1 — Voltage standing wave ratio of the antenna when $a = 0.4$ cm

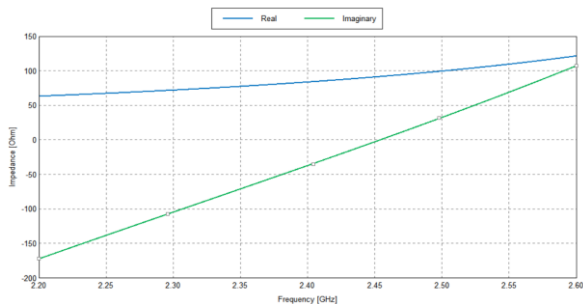


Fig. 2 — Input impedance of the antenna when $a = 0.4$ cm

For an antenna with the following parameters: antenna diameter = 2.1 cm, $b = 16$, $a = 0.6$ cm, wire diameter = 0.2 mm, the dependence of the standing wave ratio on frequency and the dependence of input impedance on frequency are shown in Fig. 3 and Fig. 4.

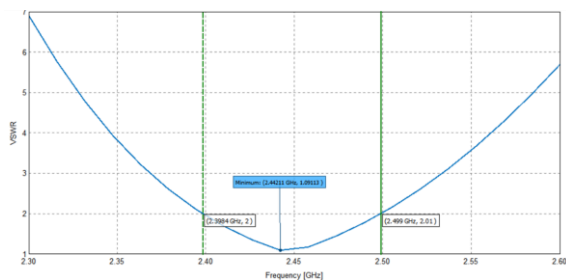


Fig. 3 — Voltage standing wave ratio of the antenna when $a = 0.6$ cm

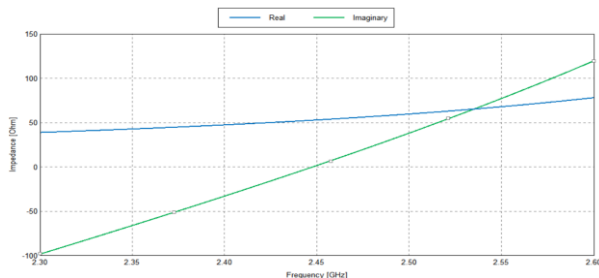


Fig. 4 — Input impedance of the antenna when $a = 0.6$ cm

From Fig. 3, it can be seen that in the operating frequency range, $VSWR < 2$, and the minimum value of the standing wave ratio is 1.09. The active part of the input impedance is close to 50 Ohms.

The cross-sections of the radiation pattern in the XOZ and YOZ planes for the parameter $a = 0.4$ cm are shown in Fig. 5. Fig. 6 shows the cross-sections of the radiation pattern for the parameter $a = 0.6$ cm.

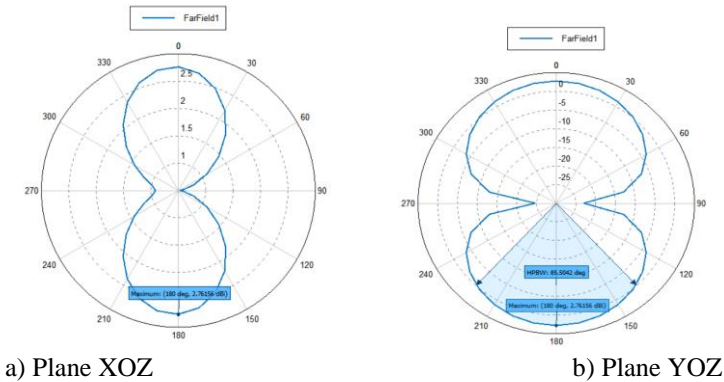


Fig. 5 — 2D radiation pattern cut for loop antenna with parameter $a=0.4$ cm

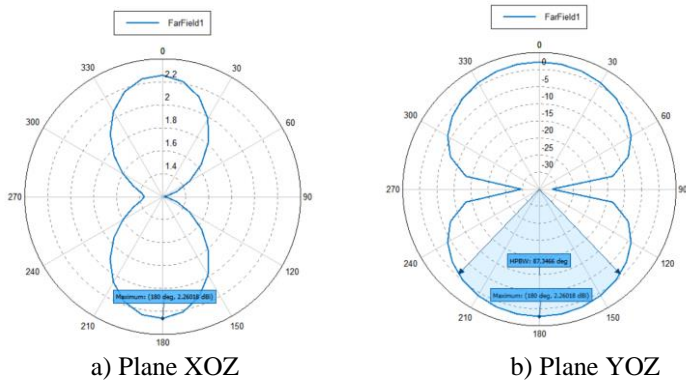


Fig. 6 — 2D radiation pattern cut for loop antenna with parameter $a=0.6$ cm

As shown in Figs. 5 and 6, at $a=0.4$ cm, the antenna achieves 2.8 dBi gain and 85.5° beamwidth, whereas increasing a to 0.6 cm reduces the gain to 2.3 dBi and slightly widens the beamwidth to 87.3° .

Conclusion

Ring antennas with additional vertical bends represent an interesting engineering solution. Such modifications to the design allow for a significant

reduction in the antenna's radius while maintaining its efficiency. This is especially useful for compact devices where space is limited. Additionally, matching the antenna to a 50 Ohm wave resistance without the use of additional matching devices simplifies the construction and reduces costs.

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UDC 004.45

LABORATORY STAND FOR STUDYING THE PRINCIPLES OF CONTROL AND MANAGEMENT IN TELECOMMUNICATION NETWORKS BASED ON ZABBIX SOFTWARE

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Аннотация. В статье рассматривается проектирование и реализация лабораторного стенда, предназначенного для изучения принципов контроля и управления в телекоммуникационных сетях с использованием системы мониторинга Zabbix. Описаны технологии и протоколы мониторинга, архитектура стенда, аппаратное и программное обеспечение. Представлены этапы установки и настройки компонентов системы. Работа направлена на развитие практических навыков в области мониторинга телекоммуникационной инфраструктуры и управления ею.

Ключевые слова: телекоммуникационные сети, мониторинг, лабораторный стенд, Zabbix, SNMP, сетевые протоколы, контроль и управление.

Annotation. The article discusses the design and implementation of a laboratory stand designed to study the principles of control and management in telecommunications networks using the Zabbix monitoring system. Monitoring technologies and protocols, stand architecture, hardware and software are described. The stages of installation and configuration of system components are presented. The work is aimed at developing practical skills in monitoring and managing telecommunications infrastructure.

Keywords: telecommunication networks, monitoring, laboratory stand, Zabbix, SNMP, network protocols, control and management.

INTRODUCTION

The development of telecommunication systems requires continuous improvement of methods for monitoring and managing network infrastructure. To ensure the reliability and security of networks, it is important to receive up-to-date information about the condition of equipment, analyze network traffic and respond promptly to failures. Zabbix software provides extensive capabilities for monitoring servers, network devices, and services. However, practical experience is required to use the system effectively.

To solve this problem, a laboratory bench was created that allows simulating a telecommunications network and studying Zabbix functionality in a controlled environment. The stand is designed for educational institutions and is suitable for training future specialists in the field of information technology and telecommunications.

THE MAIN PART

Network monitoring is based on various technologies and protocols that enable data collection, transmission, and analysis. One of the most important protocols is SNMP, which facilitates data exchange between the central management server and managed devices. Other technologies include Telnet and SSH for remote administration, NetFlow and sFlow for traffic analysis, and VLAN for logical segmentation. The Quality of Service Control (QoS) system is used to manage traffic priorities on the network.

In addition to protocols, various software solutions play an important role. Popular tools include both commercial and open source platforms such as IBM Tivoli Netcool, SolarWinds, Cisco Network Assurance Engine, Paessler PRTG, and Nagios. Zabbix was chosen as the base platform for this project due to its rich functionality, open source licensing, and strong community support.

The stand is installed in the laboratory hall B-412 of Sevastopol State University. Its hardware includes two Cisco managed switches of different levels, a Cisco router, and six personal computers. These devices are

connected to a local network divided into three virtual subnets (VLANs), with a central Zabbix server responsible for monitoring and data collection.

Based on the functional requirements, the structural, logical and general schemes of the stand were developed, which are shown in Figures 1, 2 and 3, respectively. They illustrate the interconnection of devices, VLAN configurations and routing, as well as the implementation of mirrored traffic flows for deep traffic analysis. All connections are made using category 5e twisted pair cables. This configuration allows you to realistically simulate a corporate network environment with multiple segments and managed nodes.

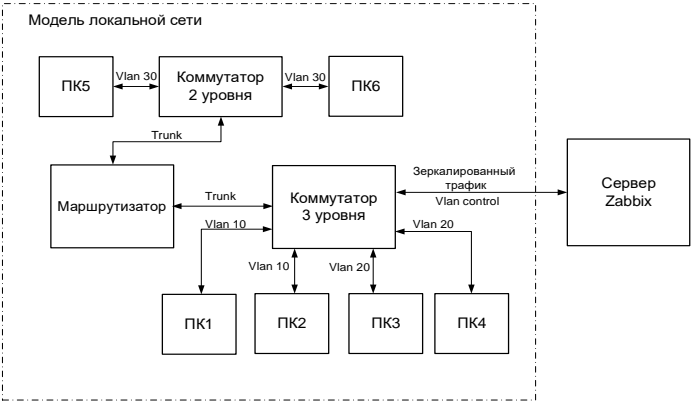


Fig. 1. Structural schemes of the laboratory stand

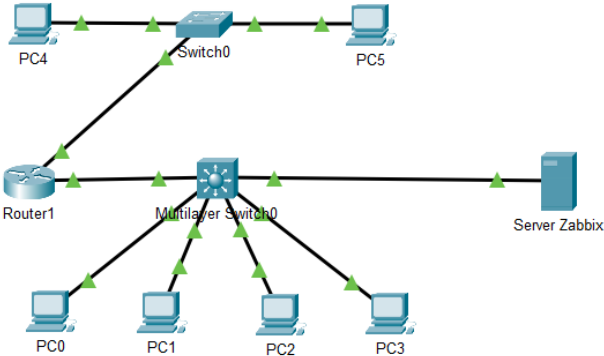


Fig. 2. Logical schemes of the laboratory stand

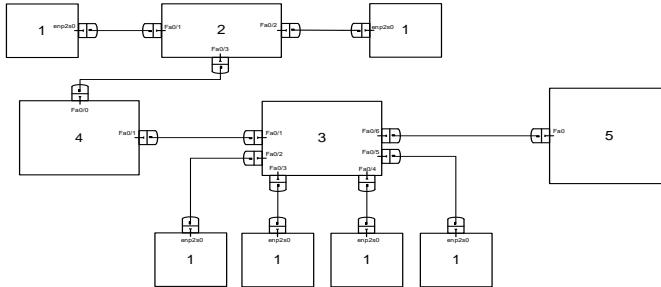


Fig. 3. General schemes of the laboratory stand

The software component of the stand is based on the Arch Linux operating system. A LAMP stack was deployed, including an Apache web server, a PHP interpreter, and MariaDB as a database management system. MariaDB was chosen as a modern, interoperable alternative to MySQL.

After preparing the software environment, key components of Zabbix were installed, including the server core, agent module and frontend. Zabbix agents have been configured on all client PCs and network devices to collect performance and availability data. These metrics are visualized in real-time via Zabbix frontend, allowing administrators to monitor system status, set alert triggers and receive notifications of anomalous conditions.

The installation process included fine-tuning configuration files, customizing templates to fit specific hardware, and testing the communication between the agent and the server. As a result, the monitoring system works flexibly and accurately, providing students with a comprehensive learning experience in deploying and managing such tools.

CONCLUSION

Zabbix-based lab bench development is proving to be an effective solution for mastering the principles of control and monitoring in telecommunications networks. It offers hands-on practice in designing distributed networks, configuring monitoring systems, configuring routing, and analyzing network traffic.

As a learning tool, the booth develops students' practical skills, deepens their understanding of network architecture, and prepares them for a real-world IT and telecommunications environment. Future enhancements may include the addition of new network nodes, implementation of distributed monitoring via Zabbix Proxy and integration with other network management platforms.

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DISTANCE MEASURING UNDER WATER WITH INCREASED ACCURACY

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Аннотация. Рассматривается технология измерения расстояния под водой с повышенной точностью. Технология предполагает одновременное излучение двух гидроакустических сигналов с различными частотами. Одновременно излучаются два электромагнитных сигнала с теми же различными частотами. Такой подход позволяет исключить влияние нестационарных процессов в акустическом канале в морской воде. Путем измерения разностей фаз принимаемых сигналов и применения известных формул можно определить расстояние под водой с высокой точностью.

Ключевые слова: акустическая волна, преобразователь, рамочная магнитная антенна, переменное магнитное поле, фазометр

Abstract. The technology for measuring the distance under water with increased accuracy is considered. Technology assumes simultaneous emission of two hydro acoustic signals with different frequency. At the same time two electromagnetic signal with the same different frequencies are emitted. Such an approach let us exclude the influence non-stationary processes in acoustic link in sea water. By measuring of phase differences of received signals and according to known formulas it is possible to determine the distance under water with high accuracy.

Keywords: acoustic wave, transducer, loop magnetic antenna, alternative magnetic field, phase meter

INTRODUCTION

Measuring distance under water is an important scientific and practical problem that schools around the world are engaged in. Determining distances to several reference points of autonomous unmanned underwater vehicle (AUV) is necessary procedure, without which it is impossible to make the AUV positioning in local coordinate system and it is impossible to moor it to bottom or mobile berthing device.

At present, only three types of wave processes are known, with the help of which it is possible to determine the distance under water: optical, hydro acoustic and alternating magnetic field. All three types have been studied quite well and capabilities of positioning systems built on their basis have been determined. However, all three approaches to the system design are not universal and, most importantly, have a large error in determining the main information parameter, the distance, which does not imply the use of these approaches in fully automatic AUV mooring systems to berthing device [5-10].

In the papers [1-3] fundamentally new approaches to determining the distance of the AUV relative to the mooring device are considered. For

distance determination according to the proposed approach two fundamentally different types of wave processes are used simultaneously: one is hydro acoustic, the other is electromagnetic [1, 2] or optical [3]. Both processes involve the design of phase radio engineering system for determining the main information parameter, the distance. The working formulas for both approaches are the same. The only difference is that in one approach, the reference signal of phase radio system for determining distances is transmitted using alternating magnetic field, in the other one it is used an optical communication channel. The main, information channel for determining distances is the hydro acoustic channel in both approaches.

However, the described approaches are workable when using somewhat idealized conditions for the propagation of all wave processes. In practice these conditions are fulfilled under a number of restrictions associated with the multi-path nature of the wave processes used and their non-stationarity. In the latter case, it has to be understood the parameters of propagation medium are constantly changing, even over short time intervals. In the point of reception of hydro acoustic signals the situation can be changed constantly. The study of both limitations and the design of methods for combating them is the subject of research by working group of authors. This article discusses an approach to minimizing the impact of the changes in parameters of hydro acoustic propagation environment.

NEW APPROACH TO SYSTEM DESIGN

It was decided to use not a sequential in time (related to frequency changing) radiation, reception, and measurements of phase difference with intermediate memorization of the result, but parallel radiation, reception and measurements of phase differences of signals with two different frequencies, and without any memorizing. Distance measurement according to the proposed approach involves the following equipment design and actions.

A. SYSTEM DESIGN

It is proposed a new approach to measuring the distance under water, which can be implemented using the device the schematic diagram of which is shown in Fig. 1. The system consists of two units: berthing device and AUV. On a board of berthing device there are placed two independent low-frequency oscillators (LFOi) of sound or ultrasonic bands of wavelengths, adder (ADD), transmitting acoustic transducer (TAT), transmitting loop magnetic antenna (TLMA). On a board of AUV there are placed receiving loop magnetic antenna (RLMA), receiving acoustic transducer (RAT), two pairs narrow-band filters (NBFij) for signal selecting, each from receiving loop magnetic antenna and receiving acoustic transducer, two phase detectors (PDi), and phase differentiator (DIF).

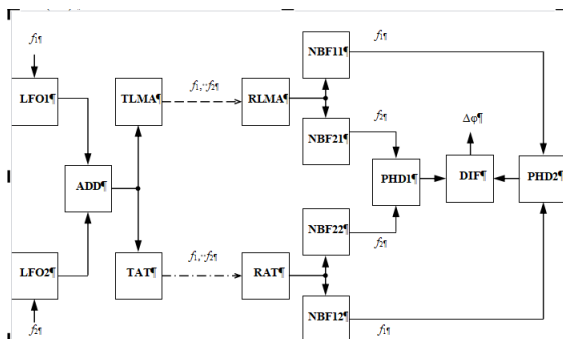


Fig. 1. The scheme of distance measurement

The device, which implements the proposed approach to measuring the distance under water, works as follows. With the help of the first oscillator continuous oscillations are generated with known frequency f_1 , initial phase φ_{01} and amplitude U_0

$$u_{01}(t) = U_0 \sin(2\pi f_1 t + \varphi_{01}). \quad (1)$$

At the same time, with the help of the second oscillator continuous oscillations are generated with known frequency f_2 , initial phase φ_{02} and amplitude U_0

$$u_{02}(t) = U_0 \sin(2\pi f_2 t + \varphi_{02}). \quad (2)$$

The frequencies of these oscillations are chosen to be low. The values of the frequencies of these oscillations lie in the sound or ultrasonic bands of wavelengths. These oscillations from the outputs of both oscillators are transmitted to the inputs of the oscillation combiner, and then the signal of sum of these oscillations is simultaneously supplied to the input of transmitting loop magnetic antenna and to the input of transmitting acoustic transducer.

Electromagnetic fields with frequencies f_1 and f_2 during its propagation over the distance D_m from transmitting loop magnetic antenna to receiving loop magnetic antenna obtains the phase shifts $\varphi_{11} = 2\pi f_1 D_m / c_l$ and $\varphi_{12} = 2\pi f_2 D_m / c_l$, and where c_l is the speed of light. At low frequencies f_1 and f_2 and at low distances D_m , up to hundred meters, the wavelengths of electromagnetic oscillations are much more than distance under the test D_m . In other words, the transmitting and receiving loop magnetic antennas operate

in the near field zone and their resulting radiated (received) electromagnetic field is predominantly an alternating magnetic field. So we can neglect the phase changes φ_{11} and φ_{12} .

So, we can assume the continuous oscillations, formed at output of receiving loop magnetic antenna, are in pairs common mode with respect to continuous oscillations entering the input of transmitting loop magnetic antenna and ones are described by the same expressions (1) and (2) (excluding the amplitude factor, that in phase radio engineering system is not matter).

These oscillations with frequencies f_1 and f_2 are isolated using the first pair of narrow-band filters (hereinafter referred to as filters) of reference channel separately.

On the other hand, with the help of transmitting acoustic transducer, acoustic waves with frequencies f_1 and f_2 are emitted in the direction of other end of measurement path, where ones are received by receiving acoustic transducer. An acoustic wave with frequency f_1 during propagation over distance D_a from transmitting acoustic transducer to receiving acoustic transducer also obtains phase shift $\varphi_{21} = 2\pi f_1 D_a / c_a$, where c_a is the speed of sound in water. An acoustic wave with frequency f_2 also obtains phase shift $\varphi_{22} = 2\pi f_2 D_a / c_a$. This pair of phase shifts cannot be neglected since their values can reach several thousands of phase cycles of 2π magnitude each.

The sum of electrical signals at output of receiving acoustic transducer is fed simultaneously to inputs of the second pair of filters of information channel. At output of first filter the oscillation with frequency f_1 are present; and at output of second filter the oscillations with frequency f_2 are present

$$u_{21}(t) = U_0 A_1 \sin \left(2\pi f_1 t + \varphi_{01} + \frac{2\pi f_1}{c_a} D_a \right) \quad (3)$$

and

$$u_{22}(t) = U_0 A_2 \sin \left(2\pi f_2 t + \varphi_{02} + \frac{2\pi f_2}{c_a} D_a \right), \quad (4)$$

and, as earlier, the amplitude factor has no matter.

Continuous oscillations from output of first filter of first pair of reference channel, described by expression (1) and from output of first filter of second pair of filters of information channel, described by expression (4), are fed to the inputs of first phase difference meter, at output of which signal

proportional to phase difference of signals (1) and (3) $\Delta\varphi_{m1} = 2\pi f_1 D_a / c_a$ is formed.

Continuous oscillations from the output of the second filter of the first pair of the reference channel, described by expression (2), and from the output of the second filter of the second pair of the information channel, described by expression (3), are fed to the inputs of the second phase difference meter, at the output of which a signal proportional to the phase difference of signals (2) and (4) $\Delta\varphi_{m2} = 2\pi f_2 D_a / c_a$ is formed.

After that signals from the outputs of first and second phase meters are entered the inputs of phase differentiator, at the output of which a signal proportional to $\Delta\varphi = \Delta\varphi_{m1} - \Delta\varphi_{m2}$ is obtained. So, distance between transmitting acoustic transducer and receiving acoustic transducer can be determined as

$$D_a = \frac{\Delta\varphi c_a}{2\pi(f_1 - f_2)}.$$

It has to be understood, the phase difference meter is able to adequately display the measured phase difference if the value of this phase difference lies within the range from 0 to 2π . In other words, the phase difference meter generates a signal proportional to a certain value, $\Delta\varphi_{mi}$ which is associated with the real phase shift φ_i ratio

$$\Delta\varphi_{mi} = \varphi_i - n \cdot 2\pi = \frac{2\pi f_i}{c_a} D_a - n \cdot 2\pi,$$

where n is a certain integer number, which can reach several thousand or more. So, it is important to remember that a frequency difference ($f_1 - f_2$) should not lead to a change in the phase difference of the signals by an amount greater than 2π . In other words,

$$f_1 - f_2 \leq \frac{c_a}{D_a}.$$

Thus, oscillations with two different frequencies f_1 and f_2 are emitted and received simultaneously. Accordingly, all changes in phase differences are carried out simultaneously. It is natural to assume the changes in environment at point of reception of hydro acoustic signals can be neglected and distance measurements can be carried out with high accuracy.

The effect of using the proposed approach is associated with the emergence of the ability to measure the distance under water with high accuracy.

B. Electromagnetic Waves Propagation in Water

Theory and practice have proven that electromagnetic waves are very quickly attenuated when they propagate in water, especially in seawater. This is an indisputable fact. It is due to the presence of water conductivity. As soon as the electric field intensity vector is formed in the water and the EMF is induced in this area, conduction currents immediately are appeared, which actually lead to the attenuation of the electric field. Further along the course, the magnetic field is not formed and the electromagnetic wave does not propagate.

However, the transmitting loop magnetic antenna primarily forms an alternating magnetic field, not an electric one. If we take into account that the communication range according to the proposed approach is small, up to a hundred meters, then it can be argued that the transmitting and receiving loop magnetic antennas operate in their near zone and their resulting radiated (received) field is mainly an alternating magnetic field.

It should remember a copper or aluminum sheet is not a shield for an alternating magnetic field; for an electric field, yes, and for a magnetic field, no. The fact of the presence of penetrating abilities of an alternating magnetic field even in an aqueous medium, even for relatively high frequencies, has been repeatedly proven and investigated by several schools.

Preliminary studies were also carried out by authors and are presented in [4]. According mentioned research the induced voltage in receiving magnetic loop antenna were calculated and measured. The dependence of received signal voltage in dB to 1 μ V from distance between antennas is shown in Fig. 2.

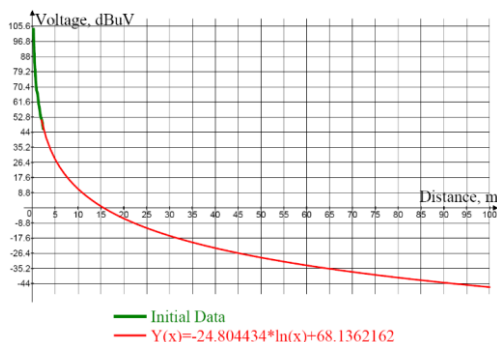


Fig. 2. Received signal voltage with respect to distance.

The curve in green depicts the real measurements in aquarium (maximal distance 2.5 m). The curve in red is the result of regression analysis, which was made by Advanced Grapher program. As it can be seen, the integral

attenuation of signal of the frequency in 1.3 MHz on a distance in 100 m reaches the value in -150 dB. Taking into account the real sensitivity of not a good receiver in 1 μV the needed input voltage has to be equal to 30 V only.

So, the operation distance can reach 100 m and more up to 300 m. This operation distance depends on the sensitivity of receiving part of telecommunication equipment and the out power of transmitting one. The improving the sensitivity up to 0.1 μV will result in increasing the operation distance up to 200 m (the results of regression analysis). Additional increasing in operation distance can be achieved by increasing of input power. The upper limit of operation distance is determined the conditions of existing of the boundary of near/far field zone rather than the energy of communication link. For the frequency about 1 MHz this limit will be 300 m.

It has to be understood in mentioned above work the operating frequency was about 1 MHz. This operating frequency is suitable for proposed in present paper approach using the modulation of the carrier in 1 MHz with information low-frequency signal of audio band, as it was proposed in [2]. The increasing of working frequency results in decreasing of size and weight of loop magnetic antennas. However, the operation distance is decreased as well, as the near field zone is decreased. The main idea of resent discussions consists it validation of the use of alternating magnetic field for ensuring the reference channel in phase radio engineering system of distance determination.

CONCLUSION

Comparison of the proposed approach with already known approaches shows that the proposed approach exhibits new technical properties, consisting in increasing accuracy of phase radio engineering system of distance determination. This accuracy increasing is achieved by simultaneous emission and reception of hydro acoustic and electromagnetic signals. So any changes in underwater propagation environments equal affect on both signals propagation.

Thus, oscillations with two different frequencies f_1 and f_2 are emitted and received in hydro acoustic channel simultaneously. Accordingly, all changes in phase differences are carried out simultaneously. It is natural to assume the changes in environment at point of reception of hydro acoustic signals can be neglected and distance measurements can be carried out with high accuracy. Furthermore, the duration of measuring procedure is reduced in times that will be especially useful at the implementing of mooring procedure.

Additionally, it was shown the use of relatively high frequencies in reference channel of phase radio engineering system of distance determination is possible. It assumes the modulation of high frequency carrier with information low-frequency signal of audio band. According to the proposed

approach, the amplification of modulated signals received by the receiving loop magnetic antenna can be carried out by several million times, as it happens, for example, in super heterodyne receivers. Such an amplification is possible due to the conversion of carrier frequencies in the receiver paths and the implementation of partial amplification of signals on different frequencies. High signal gain on the receiving side reduces the radiated power on the transmitting part of the link.

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DEVELOPMENT OF STRUCTURAL ELEMENTS OF MOISTURE METER OF PETROLEUM PRODUCTS

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Аннотация. В работе рассмотрены результаты исследований по обоснованию режимов эксплуатации, разработке и изготовлению опытного образца измерительной камеры прибора для изучения влагосодержания в нефти и нефтепродуктах микроволновым методом. Приведен аргументированный выбор материалов и расчет конструктивных элементов. Расчеты выполнены с использованием стандартных методик, применяемых в нефтяной отрасли. Оценка прочностных характеристик элементов разработанной конструкции проведена с помощью программного продукта SOLIDWORKS Simulation. Показано, что в критических условиях эксплуатации при давлении 6,3 МПа и температуре 100°C конструктивный элемент функционирует корректно. Подтверждена правильность разработки конструктивных элементов и выбора материалов для их изготовления. Показано, что нагрузки на различные части конструкции разработанного

прибора распределены неравномерно, разброс значений по изделию иногда превышает несколько порядков, при этом основная нагрузка сосредоточена в месте сварки трубы с противоположными сегментами технологического измерительного канала. Исследования на усталость показали, что для разрушения данного сегмента необходимо приложить не менее 34 500 циклов нагрузки при заданных расчетных параметрах.

Ключевые слова: нефть, нефтепродукты, вода, влагомер, моделирование, измерительная камера

Annotation. The paper examines the results of studies on the substantiation of operating conditions, development and fabrication of a prototype construction of a measuring chamber of a device for studying the water content in oil and oil products using a microwave method. A reasoned choice of materials and calculation of structural elements is given. Calculations were carried out using standard methods used by the oil industry. The strength characteristics of the elements of the developed design were evaluated by the software product SOLIDWORKS Simulation. It is shown that in the critical operating conditions at a pressure 6.3 MPa and a temperature 100°C, the structural element operates properly. The correctness of the development of structural elements and the choice of materials for their manufacture are confirmed. It is shown that the load elements on different parts of the design of the developed instrument are applied unevenly, the scatter on the product exceeds sometimes in numerical equivalent several orders of magnitude, while the main load is concentrated in the place of welding of the pipe with opposite segments of the technological measuring channel. Studies on fatigue showed that to destroy this segment, it is necessary to apply at least 34,500 load cycles for the specified calculation parameters.

Keywords: oil, oil products, water, moisture meter, modeling, measuring chamber

I. Introduction

The modern oil industry is the basis for the development of the entire world economy. In terms of oil volume and production, Russia occupies one of the leading places in the world, being an oil-producing, refining, consuming and exporting state of oil.

The produced “crude” oil is a multi component mixture consisting of oil, gas and water, and the level of water availability in old fields can reach up to 90%. The availability of reliable information on the content of oil and water in the extracted products makes it possible to judge the efficiency and profitability of the development and operation of fields. In addition, significant funds are spent on the extraction of water in the composition of oil, on its separation and disposal.

The main petroleum products obtained from the extracted oil are motor gasoline, diesel fuel and motor oils. In the process of transportation, reception, storage and delivery of which they are intensively watered and polluted, followed by deterioration in quality. Therefore, the problem associated with an adequate determination of the amount of water cut of oil and petroleum products in the process of production, transportation and processing in order to accurately determine the amount of “marketable” oil, as well as a clear definition of the water content in petroleum products in accordance with GOST R 8.615-2005 and GOST R 8.595-2004, is a very urgent task [6, 7]. At the same time, practice shows that in real production it is necessary not only to use high-precision measuring instruments in laboratory conditions, but also to constantly monitor changes in water content at all technological stages of production in the oil industry.

In works [2, 3] it is shown that there is a fairly significant variety of methods and a huge assortment of moisture meters based on them is produced. Each method has its advantages and disadvantages and, accordingly, occupies its niche in commercial accounting in systems for measuring the quantity and quality of oil and petroleum products in the production, transportation, processing, use and storage of petroleum products. At the same time, any of these methods has its own features of hardware design and, accordingly, software, they may differ in the conditions of the working environment and the specifics of technological processes, the range of measurement of moisture content and the main metrological characteristics.

II. Problem statement

As can be seen from the introduction, the development of a high-precision inexpensive device for measuring the water content in a wide range in oil and petroleum products at various stages of technological processes in the oil industry is a very urgent task. Currently, the authors are working on the development and instrumental implementation of a new microwave method for measuring the water content in oil and petroleum products [1]. At this stage of the creation of a moisture meter, in order to debug the developed method and its electronic design, as well as the development and development of measurement methods, it became necessary to create a prototype of the device. For these purposes, it is necessary to solve problems related to the need for reasoned calculation at development and manufacture of structural elements of the design chamber of an experimental device, with the choice of materials with the necessary properties, taking into account the peculiarities of its operation. It is also necessary to take into account the peculiarities of the regulatory documentation currently in force in the Russian Federation, in the field of production, processing and characterization of the properties of the extracted oil and petroleum products obtained on its basis.

The aim of the work was to conduct research on the justification of operating conditions and the development and design of a prototype and a measuring chamber of a device for studying the water content in oil and petroleum products. At the same time, a reasoned choice of materials and the calculation of structural elements of the device have to be carried out. To assess the strength of structural elements, the SOLIDWORKS Simulation software product was used.

III. Justification of operating conditions and material choosing

The device being developed and being created is planned for in-line measurement of the moisture content of oil and petroleum products in a wide range of water availability (from 0 to 30% by volume of water content). Device will be used in delivery of the test product by oil producing enterprises and transportation of petroleum products to consumers through oil pipeline transport using technological pipelines. It is known that technical pipelines operate in a variety of sometimes critical conditions, are exposed to high pressures and wide temperature ranges, and are exposed to corrosive effects. The above aspects require increased attention to the reliability of the systems in operation, which largely depend on the correct choice of materials for the structures of the products being developed and the high-quality manufacture of their elements.

The materials selected for the manufacture of the moisture meter must ensure its reliable operation during the design service life, taking into account the specified operating conditions (design pressure, minimum negative and maximum design temperatures), the composition and nature of the measured medium (corrosiveness, explosiveness, toxicity, etc.), the influence of ambient temperature and humidity. According to the current regulatory documents [5, 8, 17], when calculating the structural elements of the measuring chamber of the moisture meter, it was conditionally assumed that its testing, refinement and technical operation would take place on oil pipelines, fuel oil pipelines, oil pipelines, gasoline pipelines, as well as special-purpose pipelines (thick and liquid lubricant) operated at design pressure up to 6.3 MPa and temperatures not exceeding 200°C. Thus, the product will function in a system related to hot pipelines operating at high pressure and transportation of medium aggressive media, during operation, both in the in-shop version and in open areas. According to the classification presented in [9, 16], the value of the pipeline in which it is planned to use the developed product can be distinguished as “pipeline II group B (c)”. This means that the pipeline transports the medium of group B (c) (flammable liquids) with the parameters of category II (pressure within 2.5-6.3 MPa and temperature up to 350°C).

Based on the foregoing, according to GOST 32569-2013 [8], the material for the manufacture of the body of the measuring chamber of the developed

moisture meter is inox (stainless steel) grade 12X18N10T, produced in accordance with GOST 5632-2014 [10], as well as pipes based on it manufactured in accordance with GOST 9940-81 and GOST 9941-81 [11, 12]. Based on the description of this material (steel) in accordance with GOST 32569-2013 [8], products from it are suitable for transporting various media with maximum pressure up to 40 MPa in the temperature range from -253°C to 700°C.

In the initial calculation the nominal diameter of the pipe, on the basis of which the axis of the manufacture of the measuring chamber of the moisture meter was planned, was chosen equal to 100 mm. Then the size of the internal profile of the process measuring channel located in the central part of the 100 mm measure perpendicular to the flow of movement of the studied oil-water emulsion will be 80×80 mm [1]. In this case, the measuring chamber is filled with a petroleum product with a dielectric constant $\varepsilon = 3 \div 4$ without taking into account the presence of water. The addition of water to the petroleum product increases the value of the integral dielectric constant of the mixture. Let's take the worst case scenario by accepting $\varepsilon = 3$. According this assumption, the critical wavelength of testing microwave signal was calculated [1] and one was 1.09 GHz. The real operating frequency was chosen equal to $f = 1,3$ GHz. For this operating frequency the microstrip microwave antennas were built into the measuring chamber with best manner.

The thickness of the wall of the pipe of the selected diameter was determined by the formula presented in GOST 32388-2013 [9, 13]:

$$S_R = \frac{|P|D_a}{2\varphi_y [\sigma] + |P|},$$

where, P is the internal pressure (MPa), D_a is the inner diameter of the pipe (mm), σ is the permissible stress at the design temperature (MPa), φ_y is the strength coefficient of the longitudinal weld. In the calculation it was accepted: $D_a = 100$ mm, $P = 6.3$ MPa, $\sigma = 160$ MPa (for steel 12X18N10T at temperature $T = 200$ °C), $\varphi_y = 0.65$ (taking into account the welded measuring channel).

As a result of the calculation the wall thickness was equal to 3.1 mm. Usually the calculated wall thickness obtained by the presented formula is less than the minimum thickness of the pipes of this diameter produced by the manufacturer. Therefore, in real life, the strength of the pipeline is usually not calculated, the diameter of the pipeline is determined from the hydraulic calculation, and the wall thickness is taken to be the minimum for a given diameter.

However, it is necessary to take into account that at manufacture of the measuring chamber of developed moisture meter in considered pipe billet in order to create a technological measuring channel, two segments of $80 \times 80 \text{ mm}^2$ [1] in size were cut out. These segments were located opposite each other, while the structural elements of the channel were additionally welded. Such a technical solution leads to deterioration in the mechanical strength of the pipe billet. With this in mind, according to GOST 9940-81 the pipes were chosen from steel 12X18N10T with an outer diameter in 102 mm with a greater wall thickness, equal to 6 mm. Segments for the manufacture of a technological measuring channel were welded from a sheet of steel 12X18N10T with the thickness of 10 mm. Flat flange plug was calculated with the formula, according to GOST 32388-2013 [9, 14]:

$$S_{R3} = 0,5D_b \sqrt{\frac{P}{[\sigma]}},$$

where, P is the internal pressure (MPa), D_b is the diameter of placing of mounting bolts (mm), σ is the permissible stress at the design temperature (MPa). It was accepted: $P = 6.3 \text{ MPa}$, $\sigma = 160 \text{ MPa}$ (for steel 12X18N10T at $T = 200^\circ \text{C}$). Choosing $D_b = 120 \text{ mm}$ and according to the calculation, the thickness of the flat flange plug of the measuring channel will be equal to 11 mm.

However, according to Fig. 1 under the flange plug 11 mm (1), fastening it to the flange (2) welded to the walls of the internal channel (4) there is a plate made of fiberglass (2) with a thickness in 10 mm. Furthermore, a microstrip antenna is built-in plate and one were not taken into account at calculation.

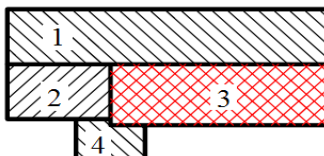


Fig. 1. Sketch-section of the connection of the flange plug with the flange and antenna in the technological measuring channel.

Therefore, in the manufacture of a real device, the flange plug (1) and the flange (2) were chosen with thickness in 9 mm. The estimation of such a design with the help of mathematical modeling was carried out and described below. It is also necessary to note the presence of a technological hole in the

center of the flange plug, which serves to install a connector for excitation of antenna.

According to [4, 18], the bolted connection of the flange plug with the flange was calculated, when calculating the following principles: pressure $P = 6.3$ MPa; linear size of the technological measuring channel $h = 80$ mm; the number of fastening bolts $z = 16$, the material of the bolts is steel 14X17N2, the permissible bolt stress $\sigma_t = 287$ MPa (at $T = 200^\circ\text{C}$), the safety factor $n = 1.5$. The calculation showed that the flange plug can be attached to the flange with 16 bolts M6 made of steel 14X17N2.

The connection of the measuring chamber of the moisture meter with the valve or process pipeline is planned due to detachable flange connections welded to the body and consisting of flanges, gaskets and connecting bolts with nuts. The tightness of the connection is achieved by gaskets made of elastic material installed between the end surfaces of the flanges. The flanges, the number and size of the connecting bolts to them were determined based on GOST 12821-80 [15], for the nominal passage diameter $D = 100$ mm and the nominal pressure $P = 6.3$ MPa and were purchased as a finished product. The flange material was steel 12X18N10T.

An experimental version of the microwave measuring chamber for the testing the oil and petroleum products is shown in Fig. 2. One was developed on the basis of the design and justifying mentioned above.

IV. Verification of Selected Parameters of Structural Elements

In order to test the developed structure for strength under given operating conditions its research was carried out using mathematical modeling using the SOLIDWORKS Simulation software product. When modeling, the conditions were assumed that all parts of the structure have welded joints, without elastic gaskets, which reduces the strength of the structure during its study.



Fig. 2. A prototype of the measuring chamber of the microwave moisture meter of petroleum products.

The calculations were carried out at temperatures of 20°C and 100°C , using a maximum pressure of 6.3 MPa for the load. While both static studies and fatigue studies at 1000 cycles, optimally characterizing the reliability of

the structural elements of the developed microwave moisture meter were carried out.

The selected program performs calculations based on the analysis of finite elements, which ensures the reliability of the numerical method for analyzing the developed structure. The calculation process begins with the development and drawing of a model drawing, which the program divides into small segments of simple shape (elements) connected at common points (nodes). Finite element analysis programs consider the model as a network of discrete interconnected elements. The finite element method predicts the behavior of the model by comparing the information obtained from all its constituent elements.

A. Selecting a Mesh for Moisture Meter Design Calculations in SOLIDWORKS Simulation

High-quality creation of a mesh for calculating product parameters in SOLIDWORKS Simulation is one of the main steps in analyzing the design of the developed device. The program creates a mesh automatically, based on the global element size, tolerance and characteristics of local mesh management.

The program determines the size of the element for the model, taking into account its volume, surface area and other geometric characteristics. The size of the mesh is created (the number of nodes and elements) depends on the geometry and dimensions of the model, the tolerance of the mesh, the mesh control settings, and the characteristics of the contact. In the early stages of structural analysis, where approximate results may be suitable, it can specify a larger element size for a faster solution. For a more precise solution, a smaller element size may be required.

In the calculations, the mesh type used is a grid on a solid, the partition used is a mesh based on curvature, while the mesh quality plot is high. An example of a mesh created by SOLIDWORKS Simulation for calculating product parameters based on the design of a microwave moisture meter for oil and petroleum products with plugged flanges is shown in Fig. 3. The resulting grid includes 141787 nodes in the presence of 95093 elements.

B. Performing Static Studies of the Moisture Meter Measuring Chamber Design in SOLIDWORKS Simulation

It is known that when loads are applied to a solid one is deformed and the action of the applied loads is transmitted through its entire volume. External loads include internal forces and reactions that compensate for their effects and return the body to a state of equilibrium. Therefore, first of all, static studies of the structure were carried out, which calculated displacements, reaction forces, loads, stresses and safety distribution.

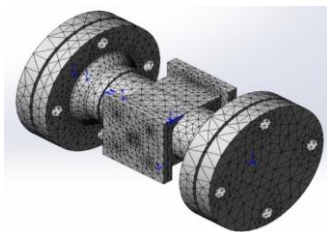


Fig. 3. Mesh for calculating the parameters of the product in the SOLIDWORKS Simulation.

It is known that the material is destroyed in a place where the loads exceed a certain level, so the calculation of the margin of safety is based on the criteria for destruction. An analysis of the calculation of such criteria is discussed below.

The calculation of the plots of one of the criteria for assessing the strength of the developed structure (static or resultant displacement (URES)), expressed in millimeters is shown in Fig. 4.

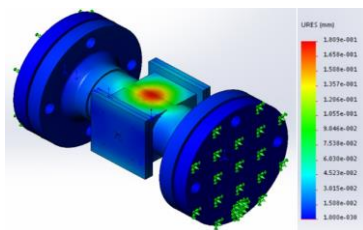


Fig. 4. Diagrams of the resulting displacement at the calculation parameters: $P = 6.3$ MPa, $T = 100^\circ\text{C}$.

This figure shows the location of the calculated plots at a temperature T in 100°C and a pressure P in 6.3 MPa. It can be seen from the figure that the minimum resulting displacement is 0.00 mm, and the maximum is 0.180 mm (at the welding point of the pipe with opposite segments of the process measuring channel). At the same pressure and room temperature, we have a maximum resulting displacement in the same design unit equal to 0.155 mm, which differs slightly from the temperature option.

The second determining criterion under consideration is equivalent deformation (ESTRN). Diagrams with this criterion are not presented due to their low information content caused by insignificant (non-critical for the design) values. At a temperature in 20°C , the minimum equivalent deformation in the product was 4.23×10^{-8} , and the maximum at the welding site of the pipe with opposite segments of the technological measuring channel

did not exceed 1.0×10^{-2} , at 100°C . These values were 1.88×10^{-7} and 1.28×10^{-2} respectively. At the same time, the view is that the values change slightly, which is due to the temperature plastic deformation.

The next objective criterion for assessing strength is the effect of various stresses on the structural elements of the product being developed. The components of these stresses largely depend on the directions in which they are applied and, based on this, are calculated. For some rotations of the coordinate axes, the shear stresses disappear. The remaining three components of normal stress are called principal stresses. The directions associated with the main stresses are called the main directions.

Von Mises stress given below in the calculations, in contrast to the stresses discussed above has no direction, and one is completely determined by the value expressed in units of stress. Von Mises stress is a criterion for evaluating the plasticity of materials. In the case of its numerical excess relative to the yield strength of the material under study, it becomes obvious that this material is destroyed and that it is not used under current operating conditions.

The diagram of the statistical analysis of stress according to von Mises with a strain scale increased by 227.7 times for clarity is shown in Fig. 5. For both 20°C and 100°C the maximum von Mises stress plots were located at the welding point of the pipe with opposite segments of the process measuring channel and ones were $5.28 \times 10^1 \text{ N/mm}^2$ and $1.19 \times 10^2 \text{ N/mm}^2$ respectively. The minimum von Mises stress plots on this moisture meter design were $7.0 \times 10^{-3} \text{ N/mm}^2$ and $2.11 \times 10^{-2} \text{ N/mm}^2$ respectively.

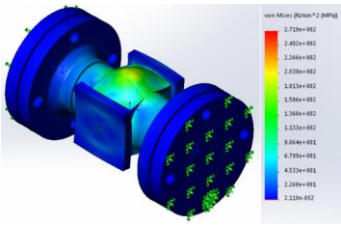


Fig. 5. Diagram of the statistical analysis of Von Mises stress at a strain scale of 227.7 and calculation parameters: $P = 6.3 \text{ MPa}$, $T = 100^\circ\text{C}$.

Based on the reference data, the yield strength used in the calculations of chromium stainless steel was $1.72339 \times 10^2 \text{ N/mm}^2$. Thus, the calculation of the stress according to von Mises shows the possibility of using this design for the stated purposes, though not with a very large margin of safety. Diagrams of deformation of the shape of the structure, demonstrating the qualitative

direction of the plots of deformation of the product at the applied pressure and temperature also are present in Fig. 5.

C. Conducting Fatigue Studies of a Moisture Meter Design in SOLIDWORKS Simulation

The next stage of the study using the SOLIDWORKS Simulation software product was the fatigue calculations of the materials of the structure of the device being developed. Fatigue of materials is one of the main reasons for the failure of the main number of products operated by man, made of different materials, including metals. During the operation of the product, the repetitive operations of the load applied to it and unloading over time lead to weakening of its structural elements, despite the fact that the applied stresses are sometimes much less than the permissible load limits. This phenomenon is called material fatigue. Each cycle of such a stress fluctuation slightly weakens the object, but after a certain number of such cycles, the strength is lost and the object is destroyed.

The above static studies of the design of the device under development do not predict and do not provide significant information about the destruction from fatigue, calculating only the reaction of the product exposed to operational loads. The fatigue test calculates the service life of the product based on the fatigue characteristics of the materials

The diagram of damage due to fatigue of materials after 1000 load cycles with the calculation parameters: $P = 6.3 \text{ MPa}$, $T = 100^\circ\text{C}$, is shown in Fig. 6. It can be seen from the diagram that with the given parameters on the outer shell, the area located at the welding site of the pipe with opposite segments of the technological measuring channel suffered the most.

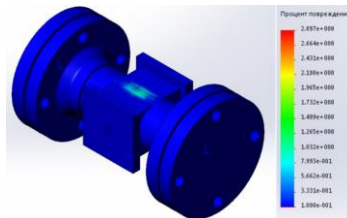


Fig. 6. Plot of damage due to fatigue of materials after 1000 load cycles with calculation parameters:

$$P = 6.3 \text{ MPa}, T = 100^\circ\text{C}.$$

Moreover, it should be noted that for the destruction of this segment, according to Fig. 7, it is necessary to apply at least 34500 cycles. The minimum damage in the main volume of the product was less than 0.1%, with a possible service life of more than a million cycles.

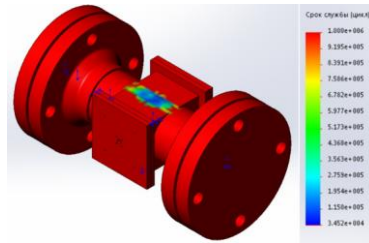


Fig. 7. Diagram of the service life in the calculation of fatigue of materials after 1000 load cycles at the parameters calculation: $P = 6.3$ MPa, $T = 100^{\circ}\text{C}$.

However, inside the steel case there is a node with a maximum damage of about 3%, located in place of a fiberglass plate with a thickness of a 10 mm with microstrip antenna placed inside it. However, in the calculation, a sheet compound is used, which has a lower tensile strength in comparison with fiberglass, due to the absence of the latter in the SOLIDWORKS Simulation program. Therefore, in real conditions, with the original material, this unit will last much longer.

Studies of material fatigue after 1000 load cycles at $P = 6.3$ MPa and $T = 20^{\circ}\text{C}$ showed that on the entire steel case, the minimum damage in the main volume of the product was less than 0.1%, with a possible service life of more than a million cycles. However, the damage on the compound plate described above was up to 20% with complete destruction at 5150 cycles. This is due to different values of the strength characteristics of this material at different temperatures

V. Conclusion

Thus, as a result of the research, the operating conditions were substantiated and the design of a prototype measuring chamber for studying the water content in oil and petroleum products with a reasoned choice of materials and calculation of structural elements was developed and manufactured.

When estimating the strength of the structural elements of the experimental measuring chamber of the device created using the SOLIDWORKS Simulation software product, it can say that in the most critical operating conditions used in the calculations at $P = 6.3$ MPa and $T = 100^{\circ}\text{C}$ this design can operate and the correctness of the choice of its elements and materials for them is confirmed. However, it is obvious that the load elements on different parts of the structure of the developed device are applied unevenly. The spread on the product sometimes exceeds several orders of magnitude in numerical equivalent. In this case, the main load is concentrated in the place of welding the pipe with opposite segments of the process

measuring channel. Fatigue studies have shown that in order to destroy this segment, it is necessary to apply at least 34500 load cycles with the calculation parameters: $P = 6.3 \text{ MPa}$, $T = 100^\circ\text{C}$.

The design is sufficient for the intended purposes, but after working out the method and methods of measurement on it, the design features of the measuring chamber of the device will be finalized in order to minimize and uniformly distribute the loads on the elements of the structure, which should significantly increase the life of its (device) trouble-free and safe long-term operation.

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DEVELOPMENT OF MICROWAVE MEASURER FOR WATER CONTENT IN OIL PRODUCT

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Аннотация. Обсуждается новый метод определения процентного содержания воды в водно-масляной смеси. Метод основан на использовании микроволнового канала связи для измерения фазового сдвига с одновременной оценкой степени поглощения микроволнового сигнала в исследуемой смеси. Измеренная степень поглощения сигнала приблизительно определяет процентное содержание воды в смеси, что позволяет выбрать соответствующую калибровочную кривую из памяти устройства. Измеренная разность фаз микроволнового сигнала дает точное значение содержания воды по выбранной кривой. На основе предложенного метода разработана схема устройства и рассмотрены теоретические аспекты его работы. Создан и испытан экспериментальный лабораторный стенд для измерения объемного процентного содержания воды в нефти и нефтепродуктах.

Ключевые слова: нефтепродукты, вода, метод измерения влаги, водно-масляная смесь, микроволновые колебания, фазовый сдвиг, поглощение микроволнового сигнала

Annotation. A new method for determining the percentage of water in a water-oil mixture is discussed. The method is based on the use of a microwave communication channel to perform the phase shift measurements with a simultaneous assessment of the degree of absorption of the microwave signal in the mixture under the test. The measured degree of absorption of microwave signal approximately determines the percentage of water in the mixture. One makes it possible to choose corresponding calibrated curve from the memory of device. The measured phase difference of microwave signal gives exact value of water content at a chosen curve. Based on the proposed method the schematic diagram of the device has been developed and the theoretical possibilities of its operation have been considered. An experimental laboratory setup for measuring the volume percentage of water in oil and petroleum products has been made and tested.

Keywords: oil products, water, moisture meter method, water-oil mixture, microwave oscillations, phase progression, microwave signal absorption

INTRODUCTION

Measuring the percentage of water content in petroleum products and environmental monitoring of petroleum products in water is a very important task [2, 3]. To solve this, moisture meters for oil and petroleum products are used. However, the moisture meters available on the market do not always

meet the needs because the data obtained from them can be distorted and inaccurate. In addition, these devices are quite complex to manufacture and operate, which leads to a high overall cost [1, 6, 7].

In this regard, a completely new device meeting all requirements has been developed. It differs from other methods in that it is simple to implement and has enhanced metrological characteristics. Its operation is based on the homodyne method of obtaining useful measuring information [4, 5]. During the work, the components and assemblies of a microwave measuring instrument for water content in petroleum products were developed and manufactured [4].

The goal of the first stage was to create a design for a modified device for experimental studies on the destabilizing factors influence on the measuring water content accuracy in petroleum products. The capability for simultaneous measurement of microwave phase progression and microwave absorption of the test signal was implemented as a result of changes and modifications.

Equipment design

A. Homodyne signal conversion

Homodyne signal conversion is the basis for the operation of the meter of water content in petroleum products, which is being developed in described design. According this approach, the initial microwave signal is the heterodyne signal for signal conversion in microwave mixer. For this approach achieving the input microwave signal is fed to the directional coupler, while its output signals are common-mode.

First signal is information signal; one passes the medium under the test. This microwave signal obtains the phase shift in dependence the dielectric constant of the oil-water mixture. Additionally, this signal obtains attenuation according the same reasons. The second microwave signal is the reference one. This signal enters the microwave mixer directly.

While maintaining the initial phase of the original microwave signal to eliminate potential DC measurement problems one of the microwave signals undergoes a frequency shift. When these microwave signals are multiplied in a microwave mixer, homodyne signal conversion occurs. The initial phases of the original microwave signal and the test signal mutually compensate each other.

we can unambiguously measure the phase shift of the microwave signal by means of this approach. The low-frequency signal of the combined low-frequency component of the aforementioned difference at the output of the microwave mixer contains the phase shift.

A controlled phase shifter is showed in the figure 1. It plays an important role in the system as it is used to shift the frequency of one of the signals.

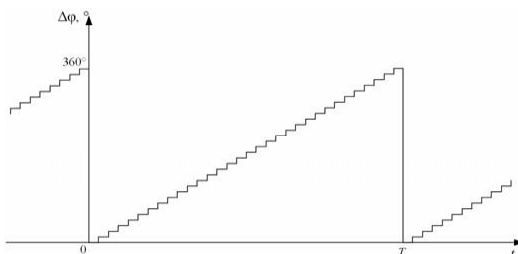


Fig. 1. - The law of phase change of the microwave signal.

A linear, monotonically increasing, phase shift is introduced into this signal $\Delta\varphi$, and the time it takes for the value $\Delta\varphi$ to change from 0° to 360° is denoted as T . Thus, the frequency of the input microwave signal changes according to an amount $F=1/T$. The value depends on the reference oscillator frequency. The signal of latter controls the phase shifter. The use of a temperature-controlled reference generator provides a stability of the frequency shift F . It is used to obtain signals of the required level, and the digital counter generates the parallel code necessary to control the phase shifter.

B. Equipment structural diagram

Fig. 2 shows a simplified block diagram of a moisture meter for petroleum products implemented using the described operating method.

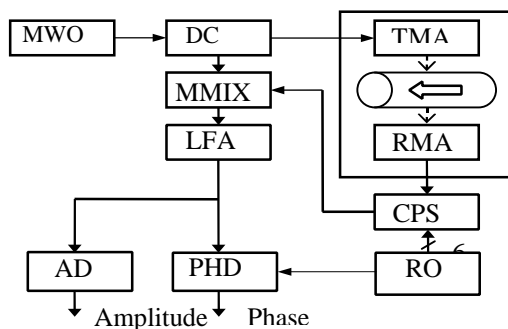


Fig. 2. - The structure diagram of modified measurer

The measurer for determining water percentage in the oil-water mixture using different types of the oil consists of the microwave directional coupler DC, the microwave oscillator MWO, the microwave mixer MMIX, linear

amplitude detector AD, the low-frequency amplifier LFA, phase detector PHD, the transmitting microwave antenna TMA, the receiving microwave antenna RMA, the controlled microwave phase shifter CPS, reference oscillator RO.

One should dwell on the operation of the measuring transducer. A high-frequency oscillator generates a sinusoidal signal

$$u_0(t) = U_0 \sin(\omega t + \varphi_0), \quad (1)$$

where ω is the frequency; φ_0 – initial phase; U_0 is the amplitude of the microwave signal.

While passing through the directional coupler, a signal is supplied to the input of the microwave antenna and radiated to the measuring chamber of the device under development, in which the controlled oil product is located. Exactly the similar microwave antenna further receives the signal. A signal receives a phase overflow φ_x that depends on the dielectric properties of the oil product itself and on the water content in the mixture, when passing through the layer of space containing the oil product.

A signal enters the phase shifter. A monotonically increasing phase shift of the original microwave oscillations is formed relative to the signal. The monotonic shift at a rate of 2π per T is equivalent to shifting the frequency of microwave oscillations by an amount of

$$\Omega = 2\pi / T \quad (2)$$

The microwave signal at the output of the controlled phase shifter changes in the following manner and takes the following form:

$$u_1(t) = k_1 U_0 \sin[(\omega + \Omega)t + \varphi_0 + \varphi_x + \varphi_{LF}], \quad (3)$$

where k_1 is a certain proportionality coefficient that takes into account the amplitude characteristics of all links; φ_{LF} is the initial phase of the low-frequency signal supplied to the phase shifter control input.

While part of the energy taken from the output of the directional coupler is simultaneously applied to its other input, this signal is fed to one input of the microwave mixer. The system multiplies the microwave signals

$$\begin{aligned} u_{cm}(t) &= k U_0 \sin[(\omega + \Omega)t + \varphi_0 + \varphi_x + \varphi_{hw}] U_0 \sin(\omega t + \varphi_0) = \\ &= k U \frac{k U_0^2}{2} \{ \cos[\Omega t + \varphi_x + \varphi_{LF}] - \cos[(2\omega + \Omega)t + 2\varphi_0 + \varphi_x + \varphi_{LF}] \} \end{aligned} \quad (4)$$

where k is the proportionality coefficient that accounts for the transmission coefficients of all stages and components of the measurement unit, as well as the attenuation in the petroleum product under investigation.

A low-frequency harmonic signal with frequency ω is extracted at the multiplier output, containing Ω information about the phase shift φ_x introduced by the petroleum product. The combination component with double the frequency of the original microwave oscillations is a byproduct of the conversion and is suppressed at the mixer output by a simple low-pass filter.

The low-frequency signal is fed to one input of the phase detector after being extracted and amplified, while the control signal from the phase shifter is applied to its other input. Consequently, the output of the phase detector yields a voltage proportional to the phase shift caused by the water content in the petroleum product.

During the development of the device, the question arose regarding the accuracy of its readings when the type of petroleum product changes, especially when its electrophysical properties are unknown. Obviously, in this case, the device will produce ambiguous results. Since the dielectric permittivity of the petroleum product under study can vary from 2 to 4, at low water percentages in the mixture, the device might interpret an increase in the petroleum product's dielectric permittivity as a rise in the integral dielectric permittivity—and consequently as an increase in water content—which would not correspond to reality.

C. Combined method of obtaining useful information

The problem of unambiguous determination of water content in petroleum products with unknown electrophysical properties can be solved in the following way. The microwave oscillations described by expression (1) are emitted by the transmitting microwave antenna through the layer of the test mixture towards the receiving microwave antenna. In this process, the microwave signal acquires a phase shift equal to

$$\Delta\varphi = 2\pi f_1 d \sqrt{\varepsilon_{\text{mix}}} / c .$$

The signal then undergoes sequential transformations, resulting in an output from the phase detector that is proportional to the phase shift of the microwave signal as it propagates through the layer of the tested mixture of petroleum product and water. Based on its calibration curve, obtained earlier during the calibration of the measuring device, the exact water content in the petroleum product is determined.

For different dielectrics with varying electrophysical properties, separate calibration curves are constructed, each stored in the device's memory. In this case, the calibration curve used in previous measurements is selected. If the measurements are being performed for the first time, the first curve stored in the computing device's memory is applied.

The low-frequency signal from the output of the selective amplifier is rectified by an amplitude detector, producing a signal proportional to the attenuation of the microwave oscillations in the medium under study. The amplitude measurement process itself does not serve for the precise determination of water content in the mixture but rather provides an approximate estimate of the water level. The more water present in the mixture, the greater the attenuation of the microwave signal passing through it. These measurement results are compared with the data obtained from the precise

phase-based determination of water content. If the results do not match, this indicates that a petroleum product with different electrophysical properties than those actually present in the mixture was selected. In this case, the deviation of the dielectric permittivity of the petroleum product, chosen based on the calibration curve, from its actual value in the mixture is interpreted by the measuring device as a change in water content. This initial interpretation does not align with the data obtained from the amplitude method.

Depending on the preliminary water content percentage obtained via the amplitude method, the computing device selects the calibration curve that provides the best match between the current phase-based water content measurements and the approximate level determined by the amplitude method.

It should be understood that discrepancies in the readings of the amplitude and phase methods for determining the water content in the mixture will be observed only for small levels of water content, when the contribution of water with a large value of dielectric constant ($\epsilon_{wat}=80$) to the integral dielectric constant of the mixture with a dielectric constant $\epsilon_{diel}=2-4$ are quite small. As the level of water content in the mixture increases, the difference in the electrophysical properties of the dielectrics will be leveled.

D. Development of a microwave module

On the basis of the structural diagram described above a basic electrical diagram of the microwave primary conversion unit, which is the main unit of the meter of water content in petroleum products, was developed. It is the primary converter that performs all the necessary conversions of microwave and low-frequency signals, provides the extraction of useful information about the water content in petroleum products, contained in the phase shift of the microwave signal. A schematic diagram of a microwave part of measuring unit made in the ORCAD package is shown in Fig. 3. The appearance of the assembled primary measuring unit is shown in Fig. 4.

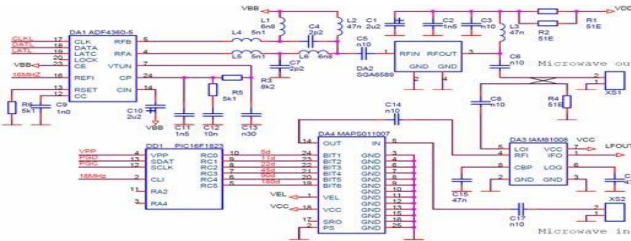


Fig. 3. - The electrical schematic diagram of microwave part of measuring unit.



Fig. 4. - Appearance of the microwave measuring unit.

The primary conversion unit was designed with redundancy, incorporating additional features for measuring transmitted microwave signal levels. While the core measurement principle relies on phase analysis, making amplitude measurements seem redundant at first glance, these provisions were intentionally included in the design.

As a result of iterative studies, it was found that the required maximum level of the output power of the meter should be 15-18 dBm with the possibility of reducing this value within -10 dB. In other words, it was decided to change the power level adaptively based on the results of measuring the degree of attenuation of the microwave signal in the meter path. This option was incorporated into the design of the primary converter.

The primary conversion unit contains the ADF4360-5 of frequency synthesizer, which forms the required microwave oscillations of the required frequency. The power level of the generated oscillations is low and a power amplifier SGA6589 is included in the circuit to ensure the required power level. On the other hand, a frequency synthesizer is capable of generating microwave signals with a variable output power level of 9 dB. The use of these integrated circuits makes it possible to generate a microwave signal with a required power level of about 15-18 dBm with the possibility of adjustment within -9 dB. Microwave mixer was realized on integral circuits IAM8008 of Analog Devices. The study of the operation of the microwave mixer in various modes made it possible to determine the required output power of the microwave signal at the output of the power amplifier of the microwave unit of the primary converter, as well as to determine the level of the reference signal for homodyne frequency conversion. When the level of water content in the mixture changed within a wide range, the range of change in the attenuation of the microwave signal in the measuring path reached a value of up to 50 dB and higher. At the same time, it was necessary to distinguish the useful signal at the expense of the simplest circuit design solutions that did not lead to an increase in the cost of the entire measuring device. At the same time, it was necessary to keep in mind the maximum power level at both input inputs of the mixer.

The controlled microwave phase shifter was realized on MAPS01007 of Macom. The operation frequency of phase shifter is from 1.2 till 1.4 GHz. This device has 6 digits of phase control and one realizes the low of phase change similar to one shown in Fig. 1. The difference consists in the number of phase steps; 6 digits realize 64 steps of phase changing, not 32 as shown in Fig. 1. As a result the shape of low-frequency signal at the output of microwave mixer after homodyne frequency conversion is shown in Fig. 5.

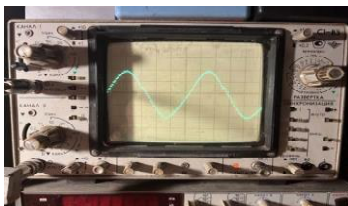


Fig. 5. - Signal waveform obtained at the output of the microwave mixer.

The electrical circuit of the primary measuring unit is complex, with its operation algorithm implemented using two embedded Microchip microcontrollers. The primary converter also includes a linear low-frequency path for amplifying and processing the signal from the microwave mixer after homodyne conversion. This path consists of standard high-pass/low-pass filters, scale amplifiers, a linear detector, and a level limiter. The unit incorporates conventional voltage stabilizers for power supply. The measuring chamber and primary converter's appearance are shown in Fig. 6.



Fig. 6.- Appearance of measuring chamber and primary converting unit.

E. Development of a device for displaying measurement results

Complete requirements for the indication device cannot yet be established; full-scale experimental studies on destabilizing factors' impact on accuracy are needed first. However, formalizing corrective data input methods and aligning them with the end user is critical. The display of measurement results is essential, including data storage in the device's memory, on its

indicator, and external recording/control systems. Currently, the focus is solely on displaying measurements from the microwave unit of primary transformation, which generates a digital signal corresponding to water content in oil products, transmitted via a CAN digital interface. The display device must receive this data and present it on a graphical display, with no additional functions required at this stage. Minimum design requirements include a microcontroller with CAN interface, CAN driver, LCD graphic display connector, and a power supply for both the indicator and primary microwave converter. The device's appearance is shown in Fig. 7.



Fig. 7. Appearance of solving unit.

Conclusion

A method for determining water content in oil products has been developed and validated. The main components of the water-content meter have been designed, manufactured, and tested.

As shown in Fig. 5, using a 6-bit transponder phase shifter (64 approximation steps), the microwave mixer output closely matches a pure sinusoid, improving signal quality and measurement accuracy.

The proposed flow-based method and instrument measure water content by analyzing microwave signals passing through the mixture. It combines phase-shift and absorption measurements, comparing them analytically to select a pre-stored calibration curve. This enhances accuracy, enabling reliable water percentage determination even with unknown oil types.

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UDC 66-97

RESEARCH AND DEVELOPMENT OF A REMOTE CONTROL SYSTEM FOR UAV

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Аннотация. В работе приводятся результаты анализа условий по обеспечению связи «борт -земля» и выявлены проблемы обеспечения связи между БПЛА и НПУ. Для максимального увеличения дальности управляемого полета разработана общая схема решения на основе модуля позиционирования антенной системы, далее - АС, что позволило использовать максимальный потенциал каналов передачи данных. Модуль позиционирования антенны использует информацию о точном положении БПЛА для ориентации АС с высоким коэффициентом усиления в направлении БПЛА. Рассмотрены вопросы конструктивно-технологической реализации.

Ключевые слова: система управления, остронаправленная антенна, мобильная связь.

Annotation. The paper presents the results of an analysis of the conditions for providing bort-Earth communications and identifies the

problems of ensuring communication between UAV and NPS. To maximize the range of controlled flight, a general solution scheme based on the antenna system positioning module hereinafter referred to as the speaker has been developed, which made it possible to use the maximum potential of data transmission channels. The antenna positioning module uses information about the exact position of the UAV to orient the high-gain speaker in the direction of the UAV. The issues of constructive and technological implementation are considered.

Keywords: control system, highly directional antenna, mobile communication.

Introduction

UAV are currently among the most promising types of equipment in the aviation environment. There have been trends in automating UAV flight modes, including automatic take-off and landing, increasing the UAV's payload, in particular, receiving high-quality video from the UAV while maintaining the UAV's high maneuverability. It is not possible to solve these problems without ensuring a stable connection between the control point and the UAV.

The purpose of the presented work is to create an antenna system that allows maximizing the range of controlled flight of UAVs. The basis of the antenna system is the positioning module. The antenna positioning module uses information about the exact position of the UAV, which allows you to constantly point the antenna with a high gain in the direction of the UAV and maximize the potential of data transmission channels.

Main part

The development of UAV control systems in our country and abroad, as well as the development of communication systems and radio electronics, make it necessary to constantly review the requirements for communication channels between the UAV and the ground control point. Today, it is possible to navigate using autopilot (AP), while there may be no connection between the UAV and the NPU. In this case, the flight mission is performed offline. But this fact does not give reason to say that the control link can be excluded from the UAV.

Most serial UAV control systems are developed without open access to software algorithms and design calculations. Nevertheless, the interest in UAVs forces us to create our own UAVs from scratch. The positioning of UAVs according to the built-in sensors was first used for the automatic orientation of cruise missiles [1, p. 28] in the 20th century. And the developers of such UAVs share information using the Internet on forums, websites and "blogs".

Evaluating the possible options for control signal transmission systems and payload information, the type of communication remains optimal and widely used, in which information is transmitted directly between the UAV and the NPU. In this case, it is possible to realize the possibility of transmitting information at a high speed that is inaccessible to satellite communication systems, and at the same time not depend on fixed communication systems cellular communication. Let's consider the structural diagram of the UAV remote control system with a 360° antenna positioning system Figure 1. The antenna system, due to the antenna positioning unit, constantly monitors the movement of the UAV and ensures signal transmission in the desired direction.

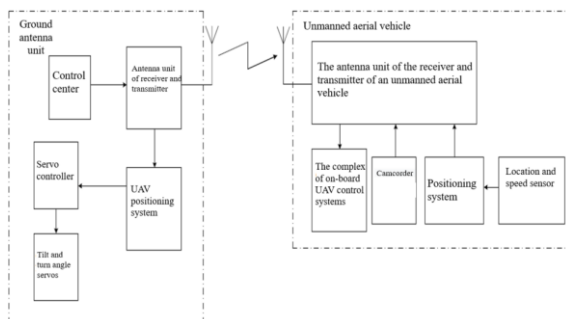


Figure 1 — Block diagram of the UAV remote control system

The position of the antenna system is determined using GPS/GLONASS telemetry coming from the UAV; when the UAV is at rest before takeoff to determine the initial coordinates, and when the UAV is in flight mode.

One of the possible ways to ensure stable communication is to create an antenna with electromechanical displacement of the antenna of the 360° continuous rotation tracking system for UAVs, which transmits the main signal power in a given direction. The advantages of such a management system include:

- Automatic switching between frequencies GPS, Wi-Fi, radio channels to minimize interference.

- Predicting the trajectory of the UAV and correcting the antenna direction.

- High reaction speed, no wear, suitable for high-speed UAV.

- Accounting for the angles of roll, pitch and yaw of the UAV to correct the direction of the signal.

- The use of MIMO (Multiple Input Multiple Output) technology increases the bandwidth and stability of communication.

The layout of the 360° positioning antenna is shown in Figure 2.

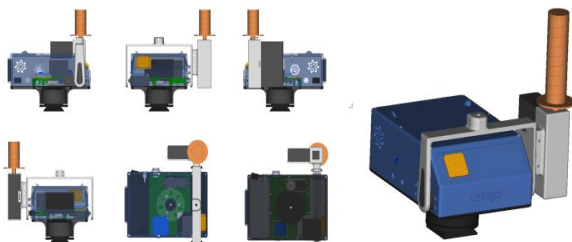


Figure 2 — 360° positioning antenna layout

Evaluating the possible options for control signal transmission systems and payload information, the type of communication remains optimal and widely used, in which information is transmitted directly between the UAV and the NPU. In this case, it is possible to realize the possibility of transmitting information at a high speed that is inaccessible to satellite communication systems, and at the same time not depend on fixed communication systems (cellular communication).

Based on the calculation results, typical requirements for the characteristics of the on-board receiving and transmitting equipment of an unmanned vehicle have been synthesized. It is shown that, if the specified requirements are met, it is possible to provide communication with an unmanned vehicle at ranges of 200-300 km in the frequency range of 400-600 MHz and a data transfer rate of at least 2 Mbit/s. GPS navigation signals can be jammed, intercepted, and substituted.

There is a system for intercepting UAV control by so-called "GPS spoofing", but only for those devices that use an unencrypted civilian GPS signal. Radar stations, optical and acoustic detection devices are used for detection [11, p. 30].

In addition to the properties of radio waves, it is necessary to carefully select antennas to achieve maximum performance when receiving/transmitting a signal. The graphical representation of the antenna gains, depending on the orientation of the antenna in space, is called a radiation pattern. Consider the radiation pattern of a patch antenna with a gain of 13 dBi Figure 3.

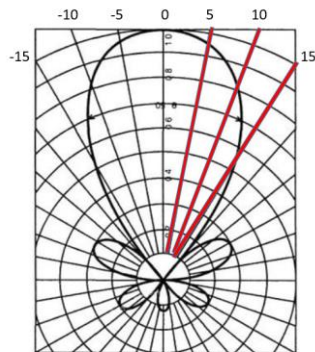


Figure 3 — Directional pattern patch antenna with a gain of 13 dBi

The radio wave propagation range of the antenna is 2.4 GHz with a gain of 13 dBi. Transmitter power: 1W, 800mW and 400mW Figure 4.

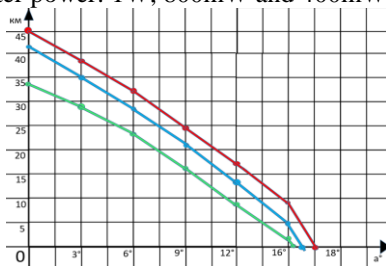


Figure 4 — Diagram of the directional antenna power variation depending on the deflection angle

Conclusion

Thus, a remote control system for an unmanned aerial vehicle was developed, taking into account modern requirements for the use of UAV and existing limitations on ensuring stable communication and flight safety requirements. It has been established which basic modern technologies are used in UAV remote control systems. An effective approach to the organization of stable communication has been identified and the advantages and disadvantages of remote control systems have been identified, which have become the basis for the development of the device. A schematic diagram of a remote control system has been developed.

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INNOVATIVE APPROACHES TO GAS HYDRATE PRODUCTION MODELING BASED ON NUMERICAL SIMULATION

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Аннотация. В статье рассматриваются инновационные инженерные подходы к моделированию процессов добычи газовых гидратов с использованием численного моделирования. Представлен анализ влияния ключевых параметров на эффективность извлечения газа: амплитуды снижения давления, начальной абсолютной проницаемости и водонасыщенности. На основе математической модели, учитывающей уравнения сохранения массы, энергии и импульса, проведено численное моделирование процесса депрессуризации газогидратного пласта. Результаты показывают, что оптимальная амплитуда снижения давления и низкая водонасыщенность способствуют повышению эффективности извлечения газа. Продемонстрированы возможности трехмерной визуализации для анализа пространственного распределения физических свойств коллектора, что обеспечивает важную информационную основу для оптимизации стратегии добычи. Рассмотрены экономические аспекты разработки газогидратных месторождений и перспективы применения искусственного интеллекта для повышения точности прогнозирования параметров коллектора. Предложенные инновационные подходы к моделированию вносят значительный вклад в развитие инженерных процессов освоения

газогидратных месторождений и приближают перспективу их коммерческого использования.

Ключевые слова: Газовые гидраты, инновационные инженерные процессы, численное моделирование, депрессуризация, проницаемость, водонасыщенность, оптимизация добычи, трехмерная визуализация, искусственный интеллект, газогидратные месторождения.

Annotation. This article examines innovative engineering approaches to modeling gas hydrate production processes using numerical simulation. The analysis of key parameters' influence on gas extraction efficiency is presented: pressure reduction amplitude, initial absolute permeability, and water saturation. Based on a mathematical model that accounts for mass, energy, and momentum conservation equations, numerical simulation of the gas hydrate reservoir depressurization process was conducted. Results show that optimal pressure reduction amplitude and low water saturation contribute to increased gas extraction efficiency. The capabilities of three-dimensional visualization for analyzing spatial distribution of reservoir physical properties are demonstrated, providing an important information basis for production strategy optimization. Economic aspects of gas hydrate field development and prospects for artificial intelligence application to improve reservoir parameter prediction accuracy are considered. The proposed innovative modeling approaches make a significant contribution to the development of engineering processes for gas hydrate field exploitation and bring the prospect of their commercial use closer.

Keywords: Gas hydrates, innovative engineering processes, numerical simulation, depressurization, permeability, water saturation, production optimization, three-dimensional visualization, artificial intelligence, gas hydrate fields.

Gas hydrates are solid crystalline compounds formed under specific thermobaric conditions from water and low-molecular gases, predominantly methane. They form when gas molecules are "trapped" inside a lattice of water molecules, creating a structure similar to ice but containing significant amounts of natural gas. In nature, gas hydrate deposits are widely distributed in deep-sea sediments and permafrost zones, where necessary conditions of high pressure and low temperature exist for their stable formation.

According to expert estimates, global gas hydrate resources may exceed conventional natural gas reserves by more than twice [1]. This enormous energy potential makes gas hydrates one of the most promising candidates for future energy development, especially in the context of growing global demand for environmentally cleaner energy sources. Despite significant resource potential, commercial production of gas hydrates still remains

unrealized due to technological, economic, and environmental challenges [5]. Traditional hydrocarbon production methods require significant adaptation to work with gas hydrates, considering their specific properties and occurrence patterns. Currently, five countries, including Japan, USA, Canada, South Korea, and China, have conducted pilot projects for gas hydrate production. Particularly significant was the second round of pilot production in China in February 2020, when 861,400 m³ of gas was produced in a month with an average daily flow rate of 28,700 m³, which was 2.8 times higher than the total gas production in the first round lasting 60 days. China became the first country in the world to use horizontal drilling technology for testing gas hydrate production in offshore areas [5].

A key problem is the development of effective engineering processes that will provide stable and economically viable gas production from hydrates. The purpose of this study is to analyze the effectiveness of various gas hydrate production parameters using innovative approaches to numerical modeling and artificial intelligence. This will determine optimal engineering solutions for gas hydrate field development.

The main methods of gas extraction from hydrates are: depressurization (reducing reservoir pressure below the equilibrium pressure of hydrate formation); thermal stimulation (increasing reservoir temperature); inhibitor injection (pumping chemicals that disrupt the hydrate structure); replacing methane in the hydrate structure with carbon dioxide; as well as various combined methods [2, 5].

International research experience and field tests have revealed that the depressurization method is the most promising in terms of energy efficiency and practical feasibility. However, despite progress, commercial exploitation of gas hydrate fields faces a number of engineering challenges, such as low permeability of hydrate-containing rocks, instability of hydrate dissociation process, technical complexity of ensuring optimal production conditions, risks of secondary hydrate formation, and environmental aspects of development [6].

To solve these engineering problems and optimize production processes, the development of comprehensive mathematical models is necessary. Such models allow analyzing complex physicochemical processes occurring in a gas hydrate reservoir during its development. The modeling considers the following key equations:

Mass Conservation Equation:

$$\partial\rho/\partial t + \nabla \cdot (\rho v) = S \quad (1)$$

where ρ is fluid density, v is velocity field, S is source-sink term representing possible mass inflow or loss.

Momentum Conservation Equation:

$$\rho \cdot \partial v / \partial t + \rho(v \cdot \nabla)v = -\nabla p + \mu \nabla^2 v + f \quad (2)$$

where p is pressure, μ is fluid viscosity, f is external force term. This equation models gas flow and its interaction with hydrate.

Energy Conservation Equation:

$$\partial(\rho e) / \partial t + \nabla \cdot (\rho e v) = -\nabla \cdot q + Q \quad (3)$$

where e is internal energy per unit mass, q is heat flux density, Q is heat source term.

Special attention is paid to modeling phase transitions, which are a key process in production. Kinetic equations for phase transition have the form:

$$d\theta / dt = k(\theta_s - \theta) \quad (4)$$

where θ is hydrate content, θ_s is equilibrium content, k is phase transition rate constant.

To solve this system of equations, finite element or finite difference methods are used, which allow processing complex boundary conditions and nonlinear problems characteristic of gas hydrate field development.

The effectiveness of gas hydrate extraction is influenced by several key parameters that require thorough analysis to optimize production strategies. In gas hydrate production, pressure reduction is a key factor contributing to hydrate decomposition and gas release. The depressurization process changes the phase state of hydrates from solid to gaseous or liquid. Numerical simulation results show that a 30% pressure reduction achieves the best indicators of gas production volume and rate [2].

The pressure reduction amplitude is calculated using the formula:

$$\Delta P = P_{initial} - P_{final} \quad (5)$$

where ΔP is pressure reduction amplitude, $P_{initial}$ is initial pressure before production, P_{final} is final pressure after production.

Interestingly, at higher depression values (50%), despite high initial gas production, a temperature drop is observed due to excessive pressure reduction, leading to secondary hydrate formation in some reservoir areas. This limits gas release at later development stages, indicating that excessive depressurization does not necessarily improve overall production efficiency.

The numerical simulation results from Zhao et al. (2012) demonstrate that while lower downhole pressure accelerates hydrate dissociation, an appropriate balance must be maintained between production speed and reservoir stability. Their findings indicate that the pressure drop in hydrate reservoirs is slower than in conventional gas reservoirs due to water output accompanying gas hydrate dissociation. This slower pressure decline is beneficial for reservoir stability but inevitably extends the production timeline. These insights align with our observations that moderate pressure reduction (approximately 30%) provides optimal gas production efficiency compared to more aggressive depressurization approaches [2, 4].

Permeability is a physical parameter describing the ability of fluids (liquids and gases) to flow through porous media. The higher the permeability, the easier it is for gas and water to move through the rock, and the faster gas is released from hydrates. According to Darcy's law, the relationship between fluid flow rate and permeability is expressed as:

$$z = -u \cdot \nabla P \quad (6)$$

where z is flow rate, u is permeability, and ∇P is pressure gradient.

Modeling results of various initial absolute permeability values show that gas production volume and rate significantly increase with permeability growth. The highest gas production was achieved at 1500 mD permeability, demonstrating a significant advantage of increased permeability for the production process.

Water saturation represents the ratio of water volume to pore volume in the rock. During gas hydrate production, changes in water saturation significantly affect gas migration and release. Under high water saturation conditions, hydrate decomposition is limited, as water presence can impede gas flow. The water saturation effect is described by the following relationship:

$$S_w + S_g + S_H = 1 \quad (7)$$

where S_w , S_g , and S_H are water, gas, and hydrate saturation, respectively.

Modeling various levels of initial water saturation (20%, 40%, 60%, 80%) showed that gas production volume and rate gradually decrease with increasing water saturation. Maximum gas production is achieved at 20% water saturation, whereas at 80% a significant production decrease is observed. This is explained by the fact that high water content impedes gas migration, increasing the complexity of its release and, consequently, reducing overall production efficiency [2].

Advanced analytical approaches provide new insights into the complex dynamics of gas hydrate production beyond individual parameter effects. According to numerical modeling results, gas production dynamics over time can be divided into three stages: initial rapid growth stage, stabilization stage, and decline stage.

At the initial stage, due to significant pressure reduction effect, rapid hydrate decomposition and increased gas release occur. This phase typically lasts from several hours to tens of hours, and gas production increases exponentially until reaching an initial peak.

As production continues, gas production gradually stabilizes. At this stage, gas release rate slows down, forming a relatively stable production platform. During this time, hydrate decomposition rate and gas flow rate reach a certain balance.

Eventually, as hydrate depletes, gas production begins to decline. This stage usually occurs in the late development phases, when the driving force for gas release weakens, and production efficiency significantly decreases.

Reservoir physical characteristics, including permeability, porosity, and water saturation, exhibit uneven spatial distribution due to geological factors. Numerical modeling allows observing areas of increased permeability, which are often associated with fracture development or specific pore structures in the rock. Three-dimensional visualization of spatial distribution of permeability and other reservoir parameters provides researchers with a visual data representation, helping to quickly identify key areas for optimal field development. This is particularly important when planning production well locations and optimizing their operation modes [2].

Recent research shows that using artificial intelligence (AI) can significantly improve prediction accuracy of gas hydrate field parameters. Traditional methods for estimating porosity and gas hydrate saturation often face difficulties related to the need for complex calibration of empirical equations, especially in clay reservoirs. Neural networks application allows predicting porosity and gas hydrate saturation based on well logging data without requiring rigid mathematical models. Research in the Krishna-Godavari basin showed that neural networks can predict porosity in the range from 33% to 76%, and gas hydrate saturation from 3.39% to 86.92% [3]. A key advantage of using AI is the ability to work with incomplete or noisy data, which is especially important when studying gas hydrate fields where direct measurements are often limited. After training on data from one well, a neural network can successfully predict parameters in neighboring wells, significantly reducing research costs. Combining traditional numerical modeling with AI methods opens new possibilities for more accurate planning of gas hydrate field development and optimization of production processes. For example, a group of scientists have estimated density using a written neural network. A comparison of the results calculated by the manual method and those estimated using ANN is presented in Figure 1 [3].

Economic studies indicate that gas hydrate field development can be commercially viable under certain market conditions and technological development. According to preliminary estimates, the minimum gas price at which production from gas hydrate fields becomes economically feasible is about 12 dollars per thousand cubic feet in the absence of free gas, while the presence of an underlying gas layer can reduce this threshold to 7.5 dollars per thousand cubic feet.

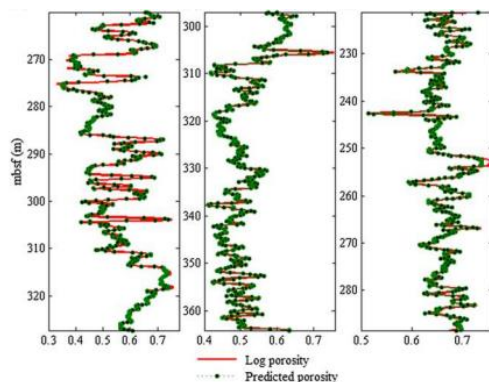


Figure 1. Traditionally estimated porosity and ANN predicted porosity

Analysis shows that gas production from offshore gas hydrate fields is approximately 3.5–4.0 dollars per thousand cubic feet more expensive than from traditional offshore gas fields, provided sufficiently large gas hydrate accumulations exist. It is important to note that the economic assessment of a specific project strongly depends on the productivity of the target zone, amount of gas in place, associated geological environment, existing pipeline infrastructure, as well as local tariffs and taxes. Considering that gas hydrate fields are often located in remote regions or deep-water areas of the seabed, infrastructure development costs can significantly affect the project's economics. Additionally, technological innovations in gas hydrate production, including artificial intelligence application for more accurate field parameter prediction, can substantially reduce future costs, making such projects more economically attractive [4].

The conducted analysis of gas hydrate production technology based on numerical modeling shows that factors such as pressure reduction amplitude, initial permeability, and water saturation in the production process have a significant impact on gas release efficiency. An optimal pressure reduction strategy not only promotes hydrate decomposition but also effectively increases gas production, thereby optimizing resource utilization. Reservoir heterogeneity significantly affects production efficiency, confirming the importance of detailed analysis of spatial distribution of reservoir physical properties. The application of three-dimensional visualization technology and artificial intelligence provides researchers with powerful tools for optimizing field development strategy.

Economic assessment of gas hydrate field development indicates the potential viability of such projects under certain market conditions, although costs remain higher than for traditional gas fields. As technologies develop,

artificial intelligence is implemented, and costs decrease, gas hydrate fields may become an important component of the global energy portfolio.

Future research should focus on developing methods for dynamic monitoring and mechanisms for adjusting production parameters in real-time using artificial intelligence. Through continuous model improvement and field testing, we can provide scientifically based guidance for efficient gas hydrate field development and facilitate their integration into a sustainable energy future.

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2.4 GHZ FOUR-ARM IRREGULAR HELICAL ANTENNA FOR UNMANNED VEHICLES

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Аннотация. В этой статье представлены результаты проектирования двух прототипов четырехсторонних нерегулярных спиральных антенн 2,4-2,5 ГГц (4АИА). Получен многовекторный азимутический рисунок излучения и направленный вертикальный рисунок излучения с основными пучками, возвышенными на 20° над горизонтом. Актиаль отношение излучения разработанных антенн больше 0,8 в верхнем полупространстве. Первая модель (4АИА-1) обеспечивает усиление в 5 дБи при габаритах $20 \times 5 \times 5$ см. а вторая модель (4АИА-2) обеспечивает усиление не менее 2 дБи при габаритах $7 \times 4 \times 4$ см.

Ключевые слова: антенна, круговая поляризация, система управления и навигации

Annotation. In the paper, the results of designing two prototypes of 2.4–2.5 GHz four-arm irregular helical antennas (4AIIA) are presented. An omnidirectional azimuth radiation pattern and a directional elevation radiation pattern with main beams raised by 20° above the skyline are obtained. The actual ratio of the developed antennas' radiation is greater than 0.8 in the upper half-space. The first model (4AIIA-1) provides a gain of 5 dBi with dimensions of $20 \times 5 \times 5$ cm, and the second model (4AIIA-2) provides a gain of no less than 2 dBi with dimensions of $7 \times 4 \times 4$ cm."

Keywords: Antenna, circular polarization, control and navigation system.

Introduction

The empowerment of prospects of unmanned aerial and surface vehicles applications in regard to civil technologies of IoT and E-navigation requires finding and implementing solutions, which provides improving the efficiency of control of unmanned mobile vehicle groups. For example, in [1] the results of analyzing of the zone of direct radio frequency coverage on the coast-ship radio link and modeling the coverage area of the Wi-Fi network in the sea bay, which has a rugged coastline, are described. Improving the characteristics of on-board and ground station antennas is one approach to solving this problem.

Development of a design model for a weakly directional circular polarization antenna

The antenna model is designed for the 2.3 — 2.6 GHz frequency band using in radio systems based on Wi-Fi standards. It is proposed to form a radiating antenna structure as a four-way irregularly helix system. Previously, a similar radiating antenna structure was described in [4]. The antenna design (fig. 1) includes the following structural elements:

- foil-coated composite epoxy material of the reflector with microstrip topology of the feeding circuit and the microwave connector;
- cylindrical polypropylene tube with applied bands of copper conductors;
- radome fairing.

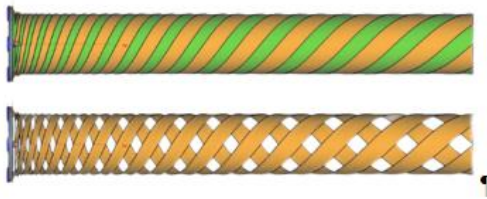


Fig. 1 — A simplified model of a four-way irregular cylindrical spiral antenna without taking into account the frame (a) taking into account the dielectric carrier cylindrical frame (b)

The polarization structure of the radiation field of the proposed antenna is determined by the consecutive phase shifts of the currents supplied to the feed points of the helix radiators. To feed the helix radiators, a 1×4 microstrip power divider with delay lines and matching stubs has been designed, ensuring that the phase shift between the feed points of adjacent helix radiators is approximately 90 degrees relative to each other. It is also necessary to provide a location for installing the SMA connector on the edge of the board (fig. 2).

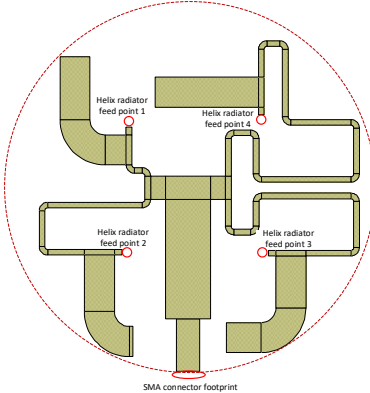


Fig. 2 — The microstrip splitter topology in CAD AWR DE

Based on the provided study, a prototype of the antenna design (4AIHA1.1) has been developed. Model characteristic 4AIHA1.1:

- Band of operating frequencies: 2.3 – 2.6 GHz;

- The omnidirectional azimuth radiation pattern and directional elevation radiation with main beams raised by 20° above skyline;
- The coefficient of ellipticity: > 0.8 in the upper half-space;
- Peak gain: 5 dBi;
- Antenna dimensions: $20 \times 5 \times 5$ cm;
- Input impedance: 50 Ohm. VSWR: < 1.5 .

The photo of 4AIHA1.1 is shown in Figure 3. Comparison of the theoretical and experimentally measured radiation patterns at the frequency of 2.4 GHz in the XZ planes is presented (Figure 4).



Fig. 3 — The photo of 4AIHA1.1

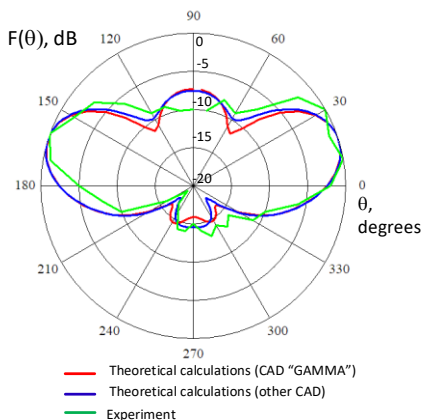


Fig. 4 — The 4AIHA1.1 radiation pattern at 2.4 GHz

To use the antenna on small-sized mobile objects, it is necessary to optimize its mass and dimensional characteristics. For this purpose, a dielectric with high permittivity, low density, and good workability should be used as the supporting cylindrical frame (Figure 5).



Fig. 5 — The photo of 4AIHA1.2

Model characteristic 4AIHA1.2:

- Band of operating frequencies: 2.3 – 2.6 GHz;
- The omnidirectional azimuth radiation pattern and directional elevation radiation with main beams raised by 30° above skyline;
- The coefficient of ellipticity: > 0.8 in the upper half-space;
- Peak gain: 2 dBi;
- Antenna dimensions: 7x4x4 cm;
- Input impedance: 50 Ohm. VSWR: < 1.5 .

Figure 6 shows the modeling radiation patterns of antenna in the XY plane.

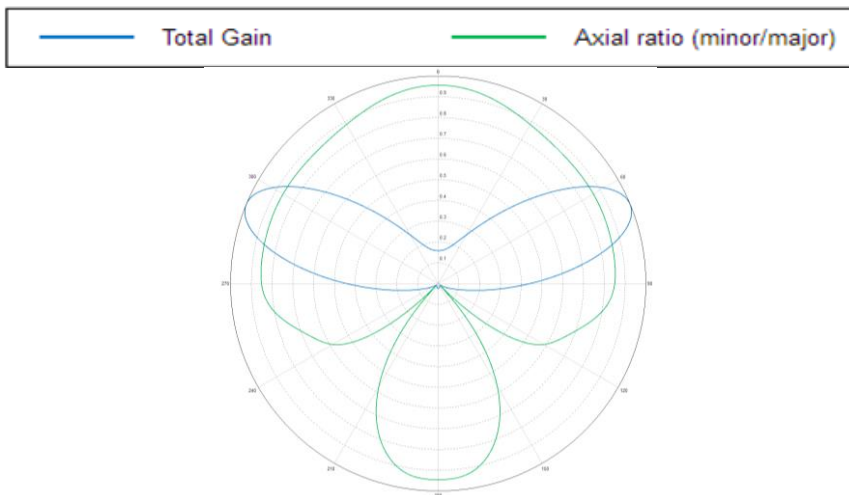


Fig. 5 — The theoretical gain and axial ratio of 4AIHA1.2 at 2.4 GHz

Conclusion

Four-turn irregular helix spiral antennas with an omnidirectional radiation pattern in the azimuth plane have been developed. Each of the antennas has a gain of at least 2 dBi. Moreover, each of the antennas considered can be effectively used for organizing a wireless communication channel and data transmission, as each antenna has its own elevation angle of the main lobe relative to the horizon.

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SIMULATION OF SOUND PROCESSING IN COCHLEAR IMPLANT

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Аннотация. В данной работе представлены результаты обработки звука для систем кохлеарной имплантации. Рассмотрены принципы построения структурной схемы кохлеарных имплантов. Разработана структурная схема речевого процессора для стратегии обработки звука с применением рекурсивной фильтрации и рассмотрены основные достоинства использования данного алгоритма обработки для системы кохлеарной имплантации с использованием 8 и 16 электродов.

Ключевые слова: рекурсивный фильтр, кохлеарный имплант, алгоритм обработки звука, цифровая обработка сигналов, слуховая система.

Annotation. This paper presents the results of sound processing for

cochlear implant systems. The principles of construction of the structural scheme of cochlear implants are considered. The structural scheme of sound processor for processing strategy with recursive filtering has been developed and the main advantages of using this treatment algorithm for cochlear implantation system with 8 and 16 electrodes have been considered.

Keywords: recursive filter, cochlear implant, sound processing algorithm, digital signal processing, listening system.

Introduction

According to estimates by the World Health Organization, up to 5% of people suffer from severe or severe neurosensory impairment and are forced to use systems that compensate for hearing loss. Cochlear implants (CI) are one of these devices that, by acting on electrical impulses on the auditory nerve, allow patients to perceive sounds and speech. Despite significant progress in cochlear implants, the development of improved sound coding algorithms remains a key and most pressing challenge. These algorithms should take into account the characteristics of the perception of acoustic signals by the human ear to ensure maximum natural perception of sounds, music and speech.

The report presents the main principles of work of CI, gives structural diagrams, considers the features of construction and proposes an algorithm for coding sound based on the use of a recursive filter.

Main part

Cochlear implant (CI) is the most advanced and technological hearing compensation device, which by acting on electrical impulses on the auditory nerve allows patients to perceive sounds and speech.

In general, the CI consists of two parts (Figure 1): internal, which is implanted to the patient near the temporal bone and external, which consists of a transmitter connected by magnetic link with the internal part, and external part (body) that is worn behind the ear and includes: microphone or microphone grate, speech processor and system power supply [3].

The principle of CI is based on the principle of encoding the frequency of sound in the ear snail. The hair cells in the snail are arranged so that in the initial part of the snail there are cells that encode high frequencies (from 5 to 20 kHz) as they move closer to the top of the snail hair cells are stimulated by lower frequencies. The top of the snail is sensitive to low frequencies (from 20 to 250 Hz). Between the base and the top is the middle part of the snail, which is stimulated by the frequency range (from 250 Hz to 5 kHz). Accordingly, the electrode grating in CI is placed into the ear snail and each of the electrodes located stimulates a certain frequency range.

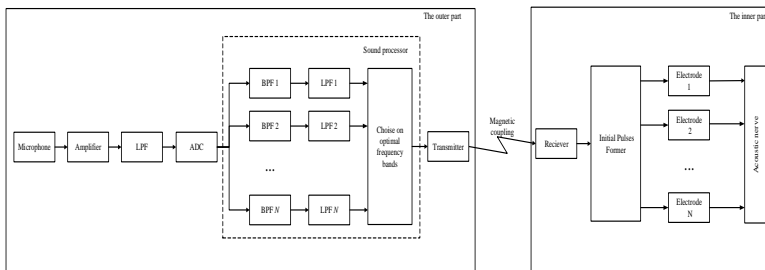


Figure 1 - CI Strut Diagram

The sound processor is one of the most important components of CI, because it is precisely in it that the processing of sound that subsequently enters the human auditory nerve takes place. The most important role in speech processor is played by the used sound processing algorithm, it is essential that the algorithm has a high accuracy and efficiency, which is why Goertzel algorithm has found its application in CI systems.

The Goertzel algorithm is a more efficient method that is used to compute individual members of the discrete Fourier transformation (DPC). When processing each band of frequencies, it is sufficient to calculate the spectral components only for those frequencies that fall within the specified band-pass filter (BPF) range. The basis of the Goertzel algorithm is the use of a recursive filter, that is a filter with an infinite pulse characteristic [2].

Figure 2 is a structural diagram of the speech processor, the basic processing of which sound occurs using a recursive filter (Goertzel algorithm).

The audible signal to the CI is passed through a set of band-pass filters (BPF), each of which gives off a certain frequency range, breaking the signal into several separate bands. The Goertzel algorithm is then applied to each frequency band to calculate the discrete Fourier conversion (DPC), which allows information about amplitude and signal phase at different frequencies. From the resulting DPC is extracted an envelope that shows the change of amplitude in time and reflects the dynamic changes of sound.

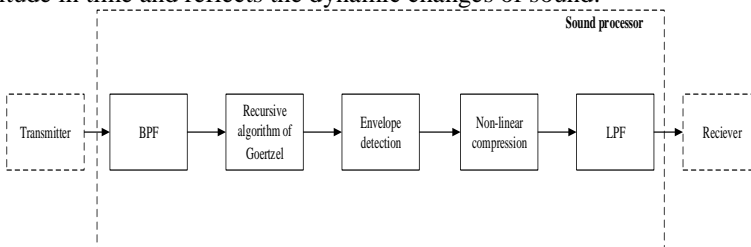


Figure 2 — Sound processor structure diagram

Because the human auditory nerve has a limited dynamic range of sound perception, the surrounding is subjected to non-linear compression to increase the dynamic range of the signal. To eliminate high-frequency components that are not perceived by the auditory nerve, the compressed surrounding passes through a low-frequency filter (LFF) and then passes to the CI electrodes.

Modern CI uses an electrode grid, which is usually made up of 8 to 22 electrodes [3]. Increasing the number of electrodes leads to a narrowing of the frequency band that each electrode encodes. Thus, the detail of the frequency components is increased with the detail of the sound, which has a positive effect on the quality of the perceived sound. So too few electrodes sound begin to stack on each other, which makes it very difficult to normal perception of sounds. However, increasing the number of electrodes leads to a disproportionate increase in the cost of CI. All these factors, combined with the increasing risks of surgical intervention, have led to the fact that CI's with more than 16 electrodes are rarely used in practice. The optimum number of electrodes in terms of sound quality and cost is from 8 to 16 [1].

On figure 3 presents the different stages of sound processing for a system with 16 electrodes, low-frequency and high-frequency initial signal (a), signal after treatment by the band-pass filter (b) and surround after the algorithm Gerzel (c). The third graph is of greatest interest because it is actually the sound that goes to the electrode and, as a consequence, into the human ear.

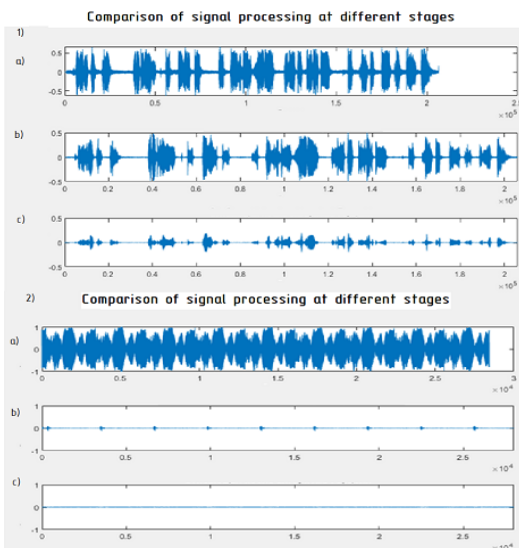


Figure 3 — The original LF (1) and HF (2) signal graphs when using 16 electrodes.

The graphics of sound processing at different stages for a system with 8 electrodes, signal after treatment by bandwidth-passing filter (b), and enveloping after algorithm Goertzel © 4 are presented on the figure 4.

Based on the graphs obtained, a study was carried out, from which it is possible to draw the following conclusions: CI systems with 16 electrodes for low-frequency signal allow the best possible detail of sound and a complete information about the different frequency components of sound.

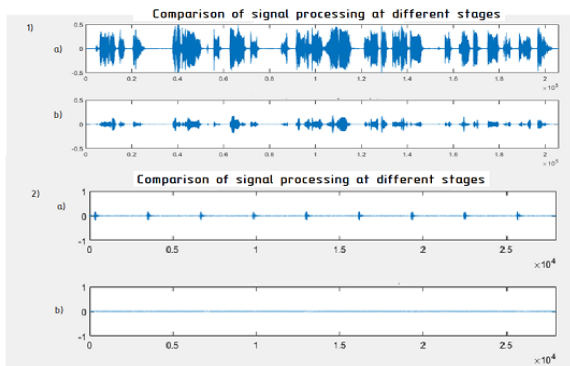


Figure 4 — The initial graphs of LF (1) and HF (2) signal when using 8 electrodes.

For 8 electrodes as a result of processing, some high-frequency components can be lost and the audio detail is lost, which is due to the larger processing band for each electrode, as a result of which there is a reduction in the detail of sound components, their «blurring» [4].

The simulation of a 16-electrode high frequency CI system has shown that the signal is well detailed. For the 8-electrode system, the result was that none of the electrodes received significant level information about data content in the signal spectrum, which may indicate that the narrow band signal is in a very wide frequency band. This suggests that the sound cannot be fully restored when using an 8-electrode CI. It is likely that a person will be able to hear it, but the signal will have a very low volume.

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CHOICE OF FREQUENCY RANGES FOR COCHLEAR IMPLANT SYSTEMS WITH DIFFERENT NUMBER OF ELECTRODES

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Аннотация. В кохлеарных имплантах выбор наиболее оптимального диапазона частот для заданного количества электродов является наиболее важной задачей, напрямую влияющей на качество звукового восприятия. Правильное распределение частот между электродами напрямую может влиять на качество и разборчивость речи, а также на эффективную и безопасную для человека стимуляцию слухового нерва. В данной статье представлены результаты расчётов диапазонов частот для количества электродов 8, 12 и 16 и проанализированы преимущества и недостатки каждого из вариантов.

Ключевые слова: кохлеарный имплант, выбор частотных диапазонов, обработка звука, диапазоны частот для речевого процессора, электродная решетка.

Annotation. In cochlear implants, choosing the most optimal frequency range for a given number of electrodes is the most important task that directly affects the quality of sound perception, the correct frequency distribution between electrodes can directly affect the quality and intelligibility of speech,

as well as effective and safe auditory nerve stimulation. This article presents the results of frequency range calculations for number of electrodes 8,12 and 16 and analyzes the advantages and disadvantages of each option.

Keywords: cochlear implant, frequency band selection, sound processing, frequency bands for speech processor, electrode grating.

Introduction

Cochlear implantation is an effective method for restoring hearing for people with deep and severe types of hearing loss. The most important thing to ensure the best adaptation to CI is the correct setting of the speech processor, especially the selection of optimal frequency ranges that will stimulate the auditory nerve. If you pick up the frequency ranges incorrectly, it will directly affect the quality of sound perception and speech intelligibility. This paper analyzes the frequency ranges for sounds that people need to hear in everyday life and uses them to calculate the frequency ranges for a CI device with 8, 12 and 16 electrodes.

Main part

In the general case CI consists of two parts. The internal part, by surgical intervention is placed to the patient in the area of the temporal bone. The outer part includes a transmitter, which is connected to the implantable part by means of magnetic communication. The outer part also includes a housing containing a microphone (or microphone ray) for sound capture, a speech processor for processing incoming sound signals and a power supply unit that provides energy to the entire system [2].

The principle of operation of CI is based on the encoding of sound frequencies in the ear snail, similar to the natural human hearing. In the ear snail, the basic principle of sound coding is the principle of the place where a certain frequency of sound corresponds to a certain location of the hair cell. The hair cells closer to the base of the snail respond to high frequencies located in the range from 5 to 20 kHz, and the cells closer to the top of the snail respond to low frequencies from 20 to 250 Hz. For frequencies in the middle range from 250 Hz to 5 kHz, the average part of the snail is responsible. Therefore, when the brain receives information about which hair cells vibrate it can recover information about the frequency of sound, for example, if the ear snail will receive a high-frequency sound, then it will cause the hair cells to vibrate at the base of the snail, If the frequency is low, it's at its peak [1].

Human hearing has a number of basic characteristics, such as the threshold of hearing, the frequency, dynamic and differential ranges of hearing. The most interesting part of this study is the frequency range of hearing - the frequency ranges of sounds that a person perceives. With normal hearing the range is from 20 Hz to 20 kHz, with impaired hearing due to illness or age

changes also the range changes and becomes smaller, for example, in a person aged 80 years the frequency range is from 20 Hz to 8 kHz. Sounds below 20 Hz are called infrasound, sounds above 20 kHz are called ultrasounds. It is important to note that the frequency of the tone of the male voice varies from 70 to 180 Hz, and in women from 180 to 330 Hz.

The range of levels of sound that a person perceives is called dynamic ranges of hearing. With normal hearing it is 130 dB, with hearing disturbances the frequency and dynamic range narrow, so that a person hears fewer frequencies.

Because with the age of a person, due to the noise effects of higher frequencies, his audible frequency ranges are narrowing, for example, according to some data that surgeries operate on, a person under 30 years old should hear up to 16 kHz, up to 50 years old to 12 kHz, and up to 8 kHz should hear absolutely everything. According to some studies, for a comfortable life a person needs to hear up to 5–8 kHz this will be enough for comfortable perception of speech and most kinds of music. Table 1.1 shows the main frequency ranges for different sound sources. It is important to note that in sound sources that are represented by different musical instruments, their frequency range is taken into account without taking into account the characteristics of the various sounds, for example, such as overtone.

In cochlear implants, the key factor is the choice of maximum frequency, as it directly depends on how far and at what frequencies from each other in the ear snail will be located electrodes in a person. For the human ear, on the basis of experimental data, a formula was obtained that is presented below, it allows to calculate the frequency distribution perceived by the ear for snail for human [1].

$$FG_H(x) = 0.1654 \text{ kHz} \left(\exp \frac{(0.13815(35\text{mm} - x))}{1\text{mm}} \right) - 1.$$

Table 1 — Sound sources and their ranges.

Sound sources	Frequency range
Mobile phone speaker	300–8000 Hz
Broadcasting	30-15 kHz
Human voice	100-4000 Hz
Flute	240-2300 Hz
Contrabas	40-300 Hz
Cello	65-880 Hz
Acoustic and electric guitar	80-1600 Hz
Piano Royal	27-4200 Hz

The result of its calculation is a frequency and place in the spiral of the snail on which you need to install an electrode to obtain a certain frequency. In the formula, 35mm is the total long ear snail, and x is a variable value that is selected according to the maximum frequency originally chosen.

Modern cochlear implants use an electrode grid, which usually consists of 8 to 22 electrodes. The most frequently used CI systems contain the number of electrodes 8,12 and 16. Because it is the best combination of price, sound quality and safety when performing medical intervention for its installation. Thus, in this study the frequency range calculation will be for the most popular number of electrodes 8,12 and 16 [3].

The maximum frequency will be chosen to be 10 kHz and 6 kHz, because the range up to these frequencies includes the full spectrum of human voice, most musical instruments and often used human sound sources.

For the selected maximum frequency of 6 kHz, the calculated value is x=9, with the actual maximum frequency value being 5,839 kHz. Therefore, part of the snail is used from 9 mm to 35 mm inclusive. In this case with 8 electrodes they will be installed every 3.25 mm, for the case with 12 electrodes every 2.2 mm at the value x = 8.6, a maximum frequency of 6.18 kHz and part of the snail used equal to 26.4 mm, and for 16 electrodes are set every 1.65 mm with the same value x as for 12 electrodes. The different selection of value x for different number of electrodes is mainly due to too precise and impracticable values of distance to install electrodes, which are not feasible in real conditions.

Since we get a central frequency as a result of the calculation, it is necessary to determine the ranges within which it will be located. Using the formula below, you need to calculate the geometric mean of two adjacent intervals f_1 and f_2 respectively. The result of the calculation is a range of intervals within which the frequency range will be given

$$f_0 = \sqrt{f_{min} \cdot f_{max}}$$

The minimum and maximum frequency for the entire range is calculated by expressing the required value from the formula to find the geometric mean.

Tables 2–4 show the frequency ranges obtained, the central frequency and the location in mm for the maximum frequency $f_{max} = 6$ kHz and 8 kHz and for the number of electrodes 8,12 and 16. With $f_1 \dots f_2$ – the resulting frequency range, and f_0 – the central frequency.

Table 2 — Frequency range values for 8 electrodes

Electrode number	$f_1 \dots f_2$ if $f_{max} = 6$ kHz	f_0	Place, mm	$f_1 \dots f_2$ if $f_{max} = 10$ kHz	f_0	Place, mm
1	0.059...0.151	0.094	31.75	0.068...0.184	0.112	31.25

2	0.151...0.337	0.241	28.5	0.184...0.431	0.301	27.5
3	0.337...0.626	0.471	25.25	0.431...0.842	0.617	23.75
4	0.626...1.077	0.831	22	0.842...1.53	1.148	20
5	1.077...1.784	1.396	18.75	1.53...2.686	2.04	16.25
6	1.784...2.892	2.281	15.5	2.686...4.626	3.537	12.5
7	2.892...4.667	3.667	12.25	4.626...7.882	6.05	8.75
8	4.667...7.305	5.839	9	7.882...13.379	10.269	5

Table 3 — Frequency range values for 12 electrodes

Electrode number	$f_1 \dots f_2$ if $f_{max} = 6$ kHz	f_0	Place, mm	$f_1 \dots f_2$ if $f_{max} = 10$ kHz	f_0	Place, mm
1	0.039...0.09	0.059	32.8	0.044...0.106	0.068	32.5
2	0.09...0.184	0.138	30.6	0.106...0.223	0.165	30
3	0.184...0.311	0.246	28.4	0.223...0.385	0.301	27.5
4	0.311...0.481	0.392	26.2	0.385...0.614	0.493	25
5	0.481...0.713	0.591	24	0.614...0.937	0.765	22.5
6	0.713...1.025	0.859	21.8	0.937...1.393	1.148	20
7	1.025...1.449	1.223	19.6	1.393...2.037	1.69	17.5
8	1.449...2.023	1.716	17.4	2.037...2.947	2.456	15
9	2.023...2.801	2.384	15.2	2.947...4.232	3.537	12.5
10	2.801...3.855	3.29	13	4.232...6.047	5.064	10
11	3.855...5.283	4.517	10.8	6.047...8.619	7.222	7.5
12	5.283...7.216	6.18	8.6	8.619...12.245	10.269	5

Table 4 — Frequency range values for 16 electrodes

Electrode number	$f_1 \dots f_2$ if $f_{max} = 6$ kHz	f_0	Place, mm	$f_1 \dots f_2$ if $f_{max} = 10$ kHz	f_0	Place, mm
1	0.028...0.063	0.042	33.35	0.032...0.073	0.048	33.15
2	0.063...0.125	0.096	31.7	0.073...0.145	0.11	31.3
3	0.125...0.2	0.162	30.05	0.145...0.237	0.191	29.45
4	0.2...0.294	0.246	28.4	0.237...0.355	0.294	27.6
5	0.294...0.413	0.352	26.75	0.355...0.507	0.428	25.75
6	0.413...0.561	0.484	25.1	0.507...0.704	0.601	23.9
7	0.561...0.747	0.65	23.45	0.704...0.958	0.824	22.05
8	0.747...0.981	0.859	21.8	0.958...1.286	1.113	20.2
9	0.981...1.275	1.121	20.15	1.286...1.708	1.485	18.35
10	1.275...1.645	1.451	18.5	1.708...2.254	1.965	16.5
11	1.645...2.109	1.865	16.85	2.254...2.96	2.586	14.65
12	2.109...2.691	2.384	15.2	2.96...3.87	3.387	12.8
13	2.691...3.423	3.037	13.55	3.87...5.045	4.421	10.95

14	3.423...4.342	3.857	11.9	5.045...6.563	5.757	9.1
15	4.342...5.496	4.887	10.25	6.563...8.522	7.481	7.25
16	5.496...6.949	6.18	8.6	8.522...11.059	9,708	5.4

One should analyze each of the results obtained briefly.

Half of the 8 electrodes are engaged in a range up to 1 kHz, with the other half providing the remaining range up to 7.3 or 13.3 kHz. This is mainly due to the need for a person in the greatest detail of sound in the range of lower frequencies. In the case of 12 and 16 electrodes, a similar situation can be observed.

Obviously, with the number of electrodes increases and detail of sound. Therefore, 8 electrodes are not the best option for use in CI. Therefore, the best options are to use 12 and 16 electrodes [4].

It can be seen that as a result of the calculation of frequency ranges the maximum frequency increased, for example, in the case of 12 electrodes the maximum central frequency is 6.18 kHz, but the last frequency range for 12 electrode includes the maximum boundary frequency 7.216 kHz. This is mainly due to the fact that when calculating the geometric mean, the maximum frequency becomes larger, which is an error. The maximum frequency for a cochlear implant is determined primarily by the maximum center frequency because it determines the location of the electrodes in the ear snail.

It is also important to note that, regardless of the chosen maximum central frequency for any number of electrodes, about half of their total number is allocated to a frequency range up to 1 kHz, which provides better perception and detail above all human speech.

Summing up the above, we can conclude as follows. In cochlear implants the best combination of sound quality and cost provides a device with 12 and 16 electrodes, while 8 electrodes are not the best option, because the detail of sound in the high frequency area will be provided very poorly.

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**ANALYSIS OF EXISTING SOUND PROCESSING
ALGORITHMS AND THEIR DEVELOPMENT DIRECTIONS IN
COCHLEAR IMPLANTS**

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Аннотация. В современном мире количество людей с полной глухотой или тяжелыми снижениями слуха растёт ежегодно. Это может быть связано с наследственностью, приобретёнными нарушениями, естественными изменениями человека или же разрушительным влиянием повышенной нагрузки на слух. Некоторые из людей, которые сталкиваются с нарушениями слуха устанавливают кохлеарные импланты, устройства, которые восстанавливают слух и для них очень важно слышать звуки окружающего мира наиболее детализировано и естественно. В кохлеарных имплантах самую важную роль играет выбранный алгоритм обработки звука, так как именно от него зависит то, что будет слышать пациент. В данной статье проанализированы преимущества и недостатки наиболее популярных алгоритмов звука.

Ключевые слова: кохлеарный имплант, стратегия обработки звука, CIS, ACE, SPEAK.

Annotation. In the modern world, the number of people with complete deafness or severe hearing loss is increasing every year. This may be due to heredity, acquired impairments, natural human changes or the destructive effect of increased hearing stress. Some of the people who face hearing impairments are installing cochlear implants, devices that restore hearing and for them it is very important to hear the sounds of the surrounding world in the most detailed and natural way. In cochlear implants, the most important role is played by the chosen sound processing algorithm, because it is what the patient will hear. This article analyzes the advantages and disadvantages of the most popular sound algorithms.

Keywords: cochlear implant, sound processing strategy, CIS, ACE, SPEAK.

Introduction

Every year the number of people with various hearing impairments increases rapidly. This is influenced by various factors, such as the destructive effect of noise or accidents. Therefore, the safe and high-quality restoration of hearing is becoming an important issue in today's world. In some cases, hearing impairment can help hearing aids, but for some patients who are diagnosed with sensory or deep ear loss the only solution is to install a cochlear implant. This device stimulates the auditory nerve directly, bypassing damaged snail cells. The KI device includes a speech processor, in which the sound is processed according to a certain algorithm (strategy). It is the chosen sound processing strategy will depend on the natural perception of sound and above all its quality. During the many years of development of CI systems by various leading companies in their development has been developed a lot of different algorithms in each of which have their own advantages and disadvantages.

This article discusses the main differences in the sound processing principles of the three most popular algorithms, which are the main ones for all others. An analysis of sound processing algorithms and the advantages of specific CI models was carried out using the most popular models from companies Cochlear Limited, Advanced Bionics and MED-EL.

Main part

Within this article, the most interesting is the external part of the CI that contains a speech processor. Because it is the speech processor that receives the signal that comes from the microphone and processes it with the aid of an algorithm of processing sound, to subsequently transmit information through a magnetic link to the internal part containing the receiver.

Over the years of development of CI systems, different manufacturers have offered different sound processing algorithms (strategies), which usually differ in the number of electrodes used. The most popular sound encoding strategies are CIS, SPEAK and ACE [2].

Strategy CIS (Continuous Interleaved Sampling) or continuous sample alternation is currently the most commonly used by various implant manufacturers. Initially, the sound previously transmitted to the microphone or the microphone grating is divided by band filters into frequency bands, the number of which is determined primarily by the number of electrodes used in the CI. The previously obtained frequency bands are then passed through the rectifier and filter of the lower frequencies, which makes it possible to highlight the surrounding band from each band. The chain of pulses previously modulated by the resulting shim is fed to electrodes in an unoverlapping sequence with constant speed. Due to the relatively high stimulation speed (between 1000 and 20000 pulses per second depending on the type of implant)

the channels are not overlapping. Therefore, all electrodes are stimulated not simultaneously, but during each cycle, with the amplitude of the pulse being proportional to the intensity of sound in each frequency channel, which allows to provide a high frequency of stimulation of the auditory nerve. Similar strategy is used in the following KI: Nucleus 5, Nucleus 6, Combi 40/40+, Rondo and many others. The main advantages of this strategy are low energy consumption and ease of implementation, and the disadvantages are low efficiency in noisy environments and «mechanical» sound [3].

SPEAK (Spectral peak) strategy or spectral peak allocation strategy is owned by Cochlear. It is based on the principle of the selection of the strongest sound frequencies and suppression of others; it is necessary to convey to the most important sounds necessary for understanding speech. Its advantages include the convenience for situations where there is a large number of background noise, and the disadvantages limited stimulation speed and distortion of the original sound signal by focusing on certain frequencies and losing other less intense but no less important.

The last of the most popular strategies ACE (Advanced Combination Encoders) combines in itself the best characteristics of the strategies CIS and SPEAK. This strategy combines high stimulation frequencies as in CIS and specific frequencies as in SPEAK. This strategy is able to stimulate with maximum frequency about 14400 Hz, which improves the perception of sound in noisy environments and silence. Thus, the signal is processed in the number of frequency bands corresponding to the number of electrodes and after the construction of the surrounding channels are selected only those channels where the amplitude is greatest.

Each of the CI producers may have their own incentive strategies, which tend to be similar to one of the 3 main incentives, as well as in modern CI implemented the selection of stimulation algorithm depending on the individual characteristics of each user. Consider some of the most popular CI manufacturers, their most purchased models and sound algorithms used in them. For any user, not only the quality of sound is very important, but also a number of other factors, for example price or functions that can provide more convenient use of the device. Therefore, additional functions offered by manufacturers will also be considered.

Cochlear Limited is one of the market leaders in cochlear implants, this company has gained its worldwide fame through the reliability and application of the latest technologies and developments in their devices. In 2022, the company developed a Nucleus 8 sound processor that uses the listening technology of SmartSound iQ2 with SCAN 2 and built-in Forward Focus. This processing strategy is automatically adjusted to the environment and thanks to The Forward Focus function can remove unwanted ambient noise during a

conversation or adapt to sounds in the surrounding space. The most important thing for the ordinary user, the processor does not require any human intervention, everything happens automatically, but if the user has discomfort he can adjust the processor as it will be convenient, which is certainly a huge advantage. The processor itself is waterproof and has the function of connecting to Bluetooth LE Audio, that allows you to transfer data about calls or any sound coming from the phone directly to the processor. The indicative cost for CI on such a speech processor varies from \$ 28,000 to \$ 38,000, not including the cost of operation [4].

Advanced Bionics also offers cutting-edge technology and focuses primarily on speech quality. The Naida CI Marvel model uses the HiRes Bionic Ear algorithm with Clear Voice III. This algorithm provides high-speed auditory nerve stimulation, what helps transmit more information about sound. At the same time, the speech processor uses up to 120 spectral bands for sound analysis, which provides a better and more detailed view of the environment. Also, like the Nucleus 8 sound processor, a continuous automatic adaptation of the sound to the human environment has been implemented. The Clear Voice III function provides noise suppression by analyzing the input signal, separating speech from background noise and amplifying the speech signal. The most interesting in this implant is the unique microphone T-Mic, instead of a microphone located on the voice processor behind the ear, it is installed in the ear shell. Advanced Bionics claims that it is this microphone that allows sound to be perceived as close to natural sounds by using the acoustics of an ear shell to collect sound, like people with normal hearing [5].

The last of the most popular firms is MED-EL their main goal is to provide maximum natural sound perception for a person with CI. The RONDO 3 audio processor model uses FineHearing, Adaptive Dynamic Range Optimization (ADRO) and Automatic Sound Management 3.0 algorithms. Thanks to the automatic sound control system and adaptive intelligence technology, this CI also implemented a system of noise suppression to adapt to the environment. The ADRO system allows you to adjust the dynamic range of sound depending on the level of the input signal, allowing you to listen for loud and quiet sounds. The advantages of this device include a cordless design, wireless charging, which eliminates the need to replace batteries and is easy to use [1].

Summing up, we can make the following conclusion. In each of the popular models CI implemented the technology of adaptation to ambient sounds and each of the companies strives to improve processing algorithms so that users have a feeling first of all sound as close as possible to natural.

For the CI user, not only the quality of the sound they will hear is important, but also the ease of use, the ability to change settings according to their individual characteristics and energy efficiency.

The development areas are primarily the improvement and maximum approximation of sound to the natural, reduction of CI size to improve user comfort and enhance the perception of music, especially classical. Because of the limited dynamic range in CI, classical music can have problems with listening.

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UDC 681.3

THE SURVEY OF MAXIMUM OPERATING RANGE OF Wi-Fi COMMUNICATIONS

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Аннотация. Современный прогресс в развитии телекоммуникационных систем обусловил широкое распространение технологий беспроводной связи, включая локальные беспроводные сети Wi-Fi, в различных сферах деятельности. В контексте внедрения беспроводных сетей актуальной становится задача оценки максимально возможной зоны покрытия сети одним маршрутизатором. В статье представлены результаты исследования максимального радиуса действия сети Wi-Fi стандарта IEEE 802.11n с использованием MATLAB/Simulink модели, учитывающей технологию адаптации кодирования и модуляции. Получены и исследованы зависимости коэффициента битовых ошибок и скорости передачи данных от расстояния; по результатам моделирования, ожидаемая максимальная дальность связи Wi-Fi составляет до 280 м.

Ключевые слова: Wi-Fi, 802.11n, максимальная дальность действия, адаптация кодирования и модуляции, Simulink.

Annotation. The modern advance in telecommunications have led to the widespread use of wireless technologies, such as local wireless Wi-Fi networks, in various fields. The article considers the wireless networks adoption, the task of maximum operating range estimation for Wi-Fi IEEE 802.11n standard's network using MATLAB/Simulink model, taking into account the adaptation of coding and modulation technology. The bit error rate and data rate curves versus range are obtained and studied; according to the modeling results, the expected maximum Wi-Fi communication range is up to 280 m.

Keywords: Wi-Fi, 802.11n, maximum communication range, adaptation of coding and modulation, Simulink.

Introduction

The IEEE 802.11 family of standards regulates the requirements for signals and equipment used in wireless Wi-Fi local area network technology. The OSI physical layer determines the frequency range, channel width, modulation types and code rate to be used, as well as establishes communication quality metrics in terms of minimum permissible non-linearity distortion values [2].

The report presents the results of a study of the 802.11n wireless communication channel model, which corresponds to the most common standard today Wi-Fi 4. Theoretically defined maximum range, as well as the dependence of change in data transmission rate from the distance, taking into account the use of Adaptive Coding and Modulation (ACM) technology.

Main part

Let us consider the key features of the physical layer of wireless networks standard 802.11n:

1) Use of two frequency ranges:

a) frequency range of ~ 2.4 GHz with channel width 20 MHz;

b) frequency range of ~ 5.0 GHz with channel width 40 MHz.

Note. Within the current study, limit ourselves to considering and estimating the maximum range of a lower frequency range (~ 2.4 GHz), since a higher frequency range suffers more attenuation, and as a consequence is characterized by a shorter communication distance.

2) The estimation of the distortion level in the communication channel and in the chains of the transmitting and receiving modules is carried out by measuring the level of the Error Vector Magnitude (EVM), which is defined as the average vector module of the difference between the reference and received signal values (Fig. 1).

3) Application of the technology of ACM, which depending on the level of distortions in the communication channel on the basis of the criterion of the permissible EVM determines the optimal modulation type and code rate (CR) for this environment at the moment.

4) Application of multiplexing with orthogonal frequency division (OFDM), which allows to reduce the effect of multibeam propagation on the quality of the received signal.

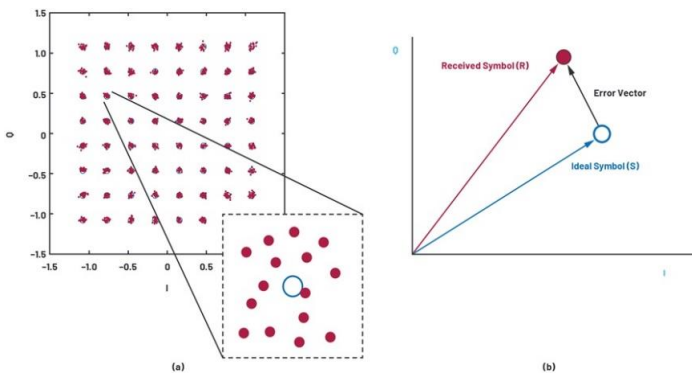


Fig. 1 — Definition of EVM

The study used a wireless communication channel model that takes into account the characteristics of the physical level 802.11n, implemented in the MATLAB/Simulink environment [1] (Fig. 2).

The designed model consists of functional Tx module, simulating a wireless router with 20 dBm radiation power and antenna gain factor 0 dB,

wireless communication channel with Additive White Gaussian Noise (AWGN) with a spectral density of -80 dB and an antenna with a gain of 0 dB. Under the conditions of this study, we assume that the Wi-Fi router is placed in the conditions of a simple distribution route, without multibeam propagation conditions and without the presence of signals from other Wi-Fi routers. Therefore, the noise power is limited only by the receiver's sensitivity, it was chosen equal to -100 dBm, which corresponds to the reception sensitivity of most chips used for receiving and processing of Wi-Fi and Bluetooth signals.

The model includes feedback for imitation of ACM technology, which, depending on the level of distortion estimated by EVM value, switches the type of modulation and code rate in the communication channel.

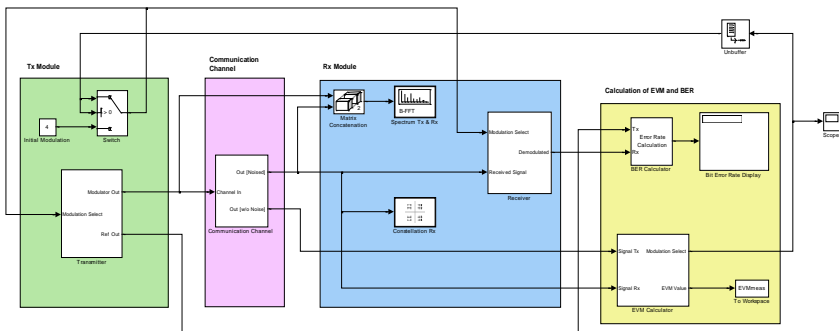


Fig. 2 — The model of wireless communication channel with Tx/Rx-blocks using Simulink

Since the distance increases the switching to a more noise-resistant type of modulation, this leads to a decrease in data transmission speed.

The determination of the change in data rate is calculated from the formula where single OFDM-symbol transmits a quantity of information $D_{\text{OFDM}} = 52$ bit; the duration of single OFDM-symbol is $T_{\text{sybm}} = 3,2 \mu\text{s}$; there is a guard interval after each symbol with a duration of a $T_{\text{gi}} = 0,8 \mu\text{s}$ used for suppression of intersymbol interference impact; the data rate might be obtained using coderate of a CR and a modulation position of a M so:

$$DR = \frac{D_{\text{OFDM}} \cdot \log_2(M) \cdot CR}{T_{\text{sybm}} \cdot T_{\text{gi}}}.$$

The study consists of conducting a series of consecutive experiments with a simulated communication channel model and measuring EVM at the

receiving point with an increase in Range by 1 meter. The DataRate value is obtained, and Bit Error Rate (BER) is calculated as follows [2]:

$$\text{BER} = \left(1 + \frac{\log_2 M}{2(\sqrt{M} - 1)}\right) \cdot \frac{\left(1 - \frac{1}{\sqrt{M}}\right)}{0,5 \log_2 M} \cdot \operatorname{erfc} \left[\sqrt{\frac{1,5}{(M - 1) \cdot \text{EVM}_{\text{rms}}^2}} \right].$$

Fig. 3 presents the resulting curves of DataRate (a) and BER (b) versus range from the Wi-Fi transmitter with a 20 MHz channel width.

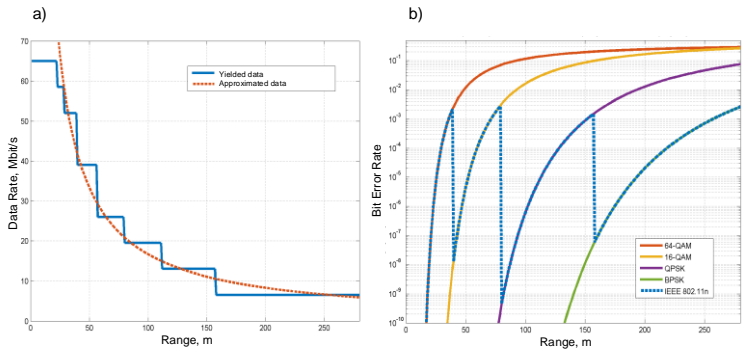


Fig. 3 — The Data Rate (a) and BER (b) curves against Range

Table 1 presents the results of the evaluation of coverage area for 802.11n.

Table 1 — The results obtained by modeling

Range, m	EVM _{max} , %	Modulation Type	CR	DR _{max} , Mbit/s
0—22	4,46	64-QAM	5/6	65,0
23—28	5,62		3/4	58,5
29—39	7,94		2/3	52,0
40—56	11,22	16-QAM	3/4	39,0
57—79	15,85		1/2	26,0
80—111	22,39	QPSK	3/4	19,5
112—157	31,62		1/2	13,0
158—280	56,23	BPSK	1/2	6,5

Based on the results of the model study, it was found that theoretically the maximum range of 4th generation Wi-Fi communication for the simplest distribution route when using

undirected antennas is approximately 280 meters. If you use a transmitting and receiving antenna with a given gain factor, the maximum range is increased by $\sqrt{(G_{TX} \cdot G_{RX})}$ times.

Based on the resulting dependencies, the change in data transmission speed as it is removed from the transmitter can be approximated by the hyperbolic law of $\sim 1/R$ with a maximum coverage area of the 4th generation Wi-Fi up to 280 meters.

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THE X-BAND MICROWAVE IMAGE REJECTION MIXER USED FOR RADAR APPLICATIONS

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Аннотация. Одной из главных проблем, ограничивающих применимость традиционных супергетеродинных приёмников, является наложение спектров радиосигнала и сигнала зеркального канала приёма. В статье представлены результаты разработки топологии микроволнового смесителя с фазовым подавлением зеркального канала в X-диапазона, предназначенного для применения в приложениях радиолокации и спутниковых систем связи. Разработанная топология при размерах платы 90×40 мм обеспечивает подавление зеркального канала на 21 дБ при уровне динамического диапазона до 9 дБм.

Ключевые слова: смеситель, X-диапазон, подавление зеркального канала, диодный смеситель.

Annotation. One of the main problems limiting the applicability of conventional superheterodyne receivers is the overlapping of radio-signal and image channel signal spectrums. The article presents the results of microwave image rejection mixer layout design intended for radar and satellite communications applications. The designed layout at a size of 90×40 mm provides image channel signal suppression by 21 dB at a dynamic range of up to 9 dBm.

Keywords: mixer, X-band, image rejection, diode mixer.

Introduction

A mixer is a device that carries out the transfer of the input spectrum from the radio frequency range f_{RF} (RF) to the lower intermediate frequency range f_{IF} (IF), as shown in the Fig. 1.

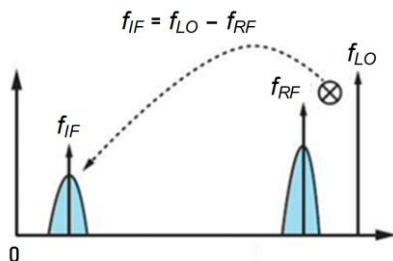


Fig. 1 — The operating principle of Mixer

The frequency conversion is performed by analogically multiplying the RF signal with the local oscillator (LO) signal on non-linear elements, which can be semiconductor diodes or transistors. As a result of multiplication in the output spectrum, the total ($f_{LO} + f_{RF}$) and difference ($f_{LO} - f_{RF}$) frequencies, the last of which is selected as IF.

It is known that mixers are used in all superheterodyne devices.

Suppose that two frequencies enter the mixer:

1) radio-signal frequency («operating channel»): $f_{RF} = f_{LO} - f_{IF}$;

2) the interference component, which is mirrored to the frequency of the LO, known as «image channel»:

$$f_{IC} = f_{LO} + f_{IF}.$$

By multiplying the frequencies, both the spectrum of the working channel and the spectrum of the image channel (IC) are converted, as shown in the Fig. 2.

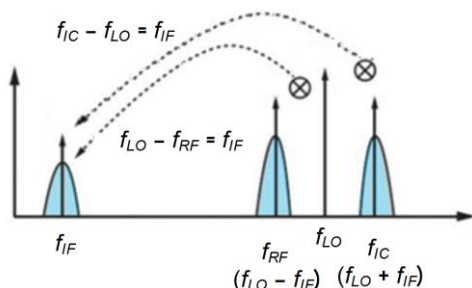


Fig. 2 — The principle of image channel forming

This leads to distortion of the IF spectrum, deterioration of the signal/noise ratio and reception of incorrect information. The emergence of IC is the main shortcoming of superheterodyne receiver architecture.

Typical image rejection mixer (IRM) block diagram shown in the Fig. 2, implements the principle of suppression of IMR by using two quadrature splitters and two mixers which carry out the subtraction of frequencies of IF signal [1]. Options are also available with square heterodox or phase-shift inputs $\pm 45^\circ$.

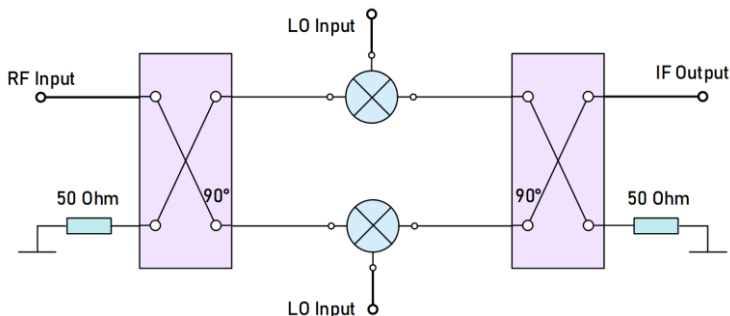


Fig. 3 — Typical IRM block diagram

Main part

The three-lane directional coupler (DC) layout is chosen, which has the following advantages taking into account the relatively low interjunction between the channels:

- 1) Relatively high bandwidth, which can provide full coverage of X-band (8-12 GHz);
- 2) High accuracy of quadrature phase shift between output signals;
- 3) Easy to design and implement.

The results of the modeling of designed DC are shown in Fig. 4.

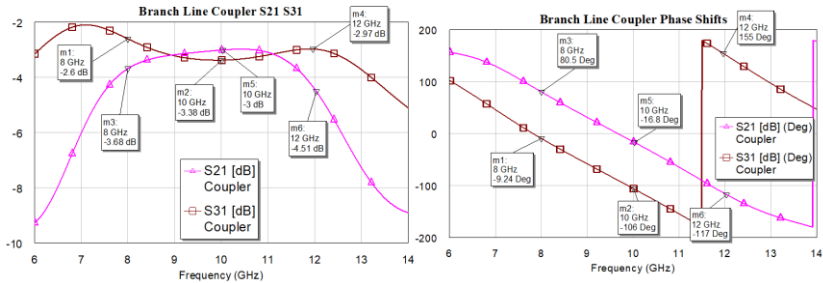


Fig. 4 — The designed DC modeling results

As the mixer, a passive balance dielectric mixer based on the tappet has been chosen, which has the following advantages:

- 1) High dynamic input range, which is essential for radar applications;
- 2) Sufficient separation between the RF, IF and LO channels;
- 3) Increased broadband.

However, the topology has the following disadvantages:

- 1) High heterodyne signal strength is required to provide an acceptable conversion factor;
- 2) The conversion factor is known to be less than one, which leads to signal weakening;
- 3) It is not supported with IF up to 1 GHz.

Schematic of the designed mixer is shown in Fig. 5.

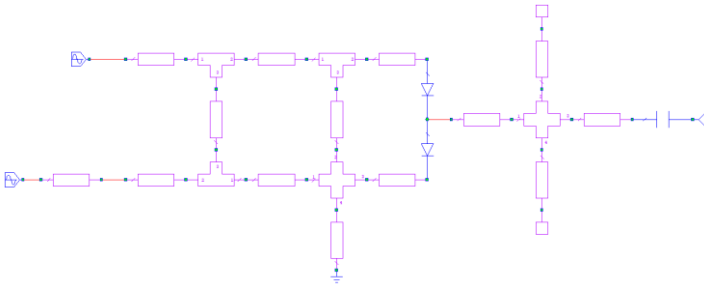


Fig. 5 — The schematic of designed mixer

Fig. 6 shows view of the total IRM PCB with sizes of 90×40 mm.

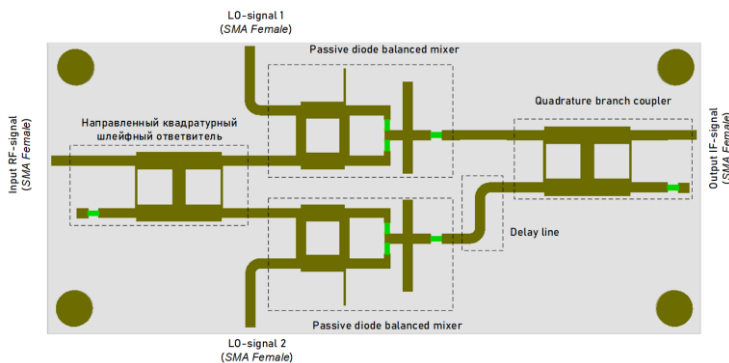


Fig. 6 — View of the total IRM PCB

Table 1 presents the results of the IRM modeling.

Table 1 — The results obtained by modeling

Parameter ($f_{RF} = 10.5 \text{ GHz}$; $f_{LO} = 11 \text{ GHz}$)	Value
Layout sizes	90×40 mm
Operating frequency range	8—12 GHz
Recommended LO power	13 dBm
Conversion factor	−10,4 dB
IC signal suppression factor	21 dB
Input 1dB Compression Point	8,8 dBm
LO-IF signal Suppression	42,6 dB
RF-IF signal Suppression	36,7 dB

Thus, developed a passive X-band mixer topology that provides suppression of IC up to 21 dB and intended for satellite communication and radar applications.

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UDC 616-07

THE REVIEW OF PHYSICAL PRINCIPLES OF MEDICAL MICROWAVE THERMOMETRY

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Аннотация. Микроволновая радиотермометрия представляет собой неинвазивный метод измерения внутренней температуры тела, который основывается на измерении теплового излучения в СВЧ-диапазоне и может быть использован для своевременного обнаружения тепловых аномалий. В статье описаны физические принципы, лежащие в основе медицинской микроволновой радиотермометрии, а также представлены основные методы измерения температуры внутренних тканей. Рассмотрены структурные особенности архитектуры приёмного тракта, а также конструктивные особенности построения антенн-аппликаторов.

Ключевые слова: микроволновая радиотермометрия, радиометр Дикке, антенна-аппликатор, тепловая аномалия.

Annotation. The microwave radiothermometry is a non-invasive method of inner body temperature measurement based on measure of a thermal radiation in a microwave range and can be applied for timely detection of thermal anomalies. In the article the physical principles underlying medical microwave radiothermometry are described, also the basic methods for internal tissues temperature measurement are presented. The structural features of receive chain architecture and construction features of antenna-applicators are considered.

Keywords: microwave radiothermometry, Dikke radiometer, antenna-applicator, thermal anomaly.

Main part

Medical Microwave Thermometry (MMWT) is a non-invasive method of measuring the body's internal temperature, based on measuring the intensity of the patient's own internal tissue electromagnetic radiation in the ultra-high frequency range (UHF). This method allows to measure and visualize on the screen the internal temperature of tissues at a depth of several centimeters.

Infrared thermography is also used in medicine, its main difference from MMWT is that it can measure and visualize skin temperature, but its depth of measurement is limited to the skin layer of a biological object 100 μm thick. Therefore, the method of measuring the microwave radiation of biological tissues is more correct because it allows detecting thermal anomalies at a depth of up to several centimeters. Medical devices with which such measurements can be made, are called microwave radiometers, and the sensor of a product that directly contacts with the human body - an antenna-replicator or medical antenna [3].

Let's briefly explain on which physical laws are based the operation of these devices.

First of all, since any physical body with a temperature above absolute zero (-273) is a source of electromagnetic radiation in the wide frequency range, the intensity of radiation can be determined by formula (1) Bar presented below:

$$B(f, T) = \frac{2 \cdot \pi \cdot h \cdot f^3}{c^2 \cdot (e^{\frac{hf}{kT}} - 1)},$$

where h – Planck constant $6.22 \cdot 10^{-34}$ J/s; f – frequency, Hz; c – light speed $3 \cdot 10^8$ m/s; k – Boltzmann constant $1.38 \cdot 10^{-23}$ J/K; T – absolute temperature, K.

Because for a biological body temperature of 37°C , the maximum radiation is in the infrared (IR) range for a wavelength of about $10\ \mu\text{m}$, with the microwave frequencies ($10^8 \dots 10^9$) the radiation intensity is 5-6 orders less than in the IR range. Therefore, in the frequency range of $10^8 \dots 10^{10}$ Hz and at biological body temperature quantum energy is much less than thermal noise energy ($hf \ll kT$), therefore, by placing the exponent in a Taylor row and limiting itself to the first two members, we get the following formula (2):

$$B(f, T) = 2 \cdot \pi \cdot kT \frac{f^2}{c^2}$$

From the formula above, it can be concluded that in radio frequency the intensity of radiation is directly proportional to the temperature of the biological object. It is on this principle that the method of microwave radiothermometry is based.

Medical radiometers are often designed using the formula (3) of Nyquist-Johnson:

$$U^2 = 4 \cdot R \cdot kT \cdot \Delta f,$$

where U^2 – the square of average noise stress at the ends of the conductor with a certain resistance (R) at temperature of T , Δf – frequency band.

From formula (4) above, it follows that the power of the noise signal at the output of the antenna will be equal to:

$$P = \frac{U^2}{4R} = kT\Delta f$$

It can be concluded that by measuring the output power of the antenna, it is possible to obtain non-invasive information about the temperature of a biological object. Microwave receivers, which measure the power of the noise signal coming from the output of the antenna, are called microwave radiometers.

Assuming a temperature of 310 K, a frequency band of 500 MHz, and the power of noise will be about of $2 \cdot 10^{-12}$ BT. It follows that the radio thermometer should measure very weak noise signals, therefore it must be a very high-sensitivity device. As a rule, in medicine the allowable power is 0.1 K. In addition, since the temperature of the biological object is 310 K, formula (4) results in the following: relative error of the power meter to ensure the cutting capacity 0.1 K, should be 0.03%.

Standard microwave power meters have an error of 5-10%, but for medical radionuclide meters, it is important not only to receive weak noise signals, but also to have a measurement error much smaller than the HF meters.

Figure 1 shows the structural diagram of a full-power radionuclide meter - the simplest measurement of the biological object's own radiation [2].

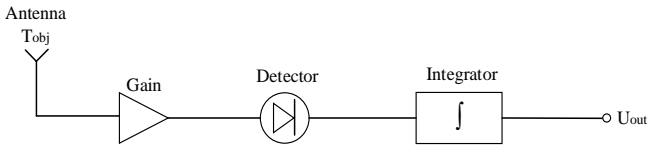


Figure 1 - Structural diagram of the full-power radiometer

This radiometer amplifies, detects and averages the noise signal coming from the antenna. On the output of radiometers in addition to noise coming from the biological object (T_{obj}), also present and noise of the entrance path and antenna (T_{amb}).

$$T_{out} = (T_{obj} + T_{amb}) \cdot k \cdot \Delta f \cdot K_g,$$

where K_g – amplifier gain (not including inner amplifier noise).

From the biological object comes a noise signal, then on the output of the radiometer will also be a noise signal, but due to the accumulation of its

dispersion much less than the dispersion of the input signal. The sensitivity of the radiometer is characterized by a fluctuation error of the noise signal at the radiometer output, which is determined by the following formula (5):

$$\delta T = \frac{T_{obj} + T_{amb}}{\sqrt{\Delta f \tau}},$$

where τ – time constant of integrator, s; δT – mean of the temperature fluctuation at the instrument outlet. For a noise signal with normal distribution, the difference between maximum and minimum temperature values is approximately $6\delta T$.

From formula (5), it follows that by increasing the accumulation time τ it is possible to reduce the fluctuation error of the radiometer. Therefore, the longer the accumulation process occurs, the less fluctuation error of the radiometer. If the input bandwidth of the UHF channel is 500 MHz to provide fluctuation error $\Delta T = 0.1$ K, then the constant time is $\tau = 4$ s.

It can be concluded that microwave radiometers are devices with relatively low speed.

At the same time, full-power radiometers are practically not used in practice, as they require stability of the upscaling factor of 0.03%, which modern amplifiers cannot provide.

Figure 2 shows the structural diagram of the R. Dicke.

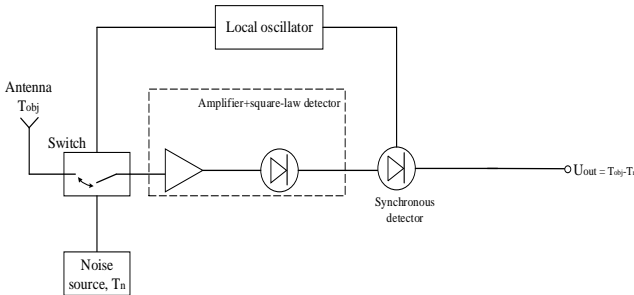


Figure 2 – Structural diagram of the radiometer R. Dicke

In contrast to the full-power radiometer, a switch is installed in the input part of the radiometer Dike, which alternately connects to the UHF receiver input of the antenna directed at the object and the reference noise source having a known temperature. In the Dicke radiometer, it is not the full power of the noise signal that is measured but the difference between the reference signal with a known noise temperature and the signal coming from the antenna. This reduces the requirement for the stability of the gain

factor, but has other features. For example, the input impedance of a biological object can be changed by tissue characteristics, since the dielectric permeability of fat tissue with low moisture content differs from that of tissue with high moisture content by 5-7 times. Therefore, if the antenna is tuned to fat tissue, it will have a higher reflection coefficient for fabric with high moisture content. It is obvious that the reflection of the signal on the antenna input will have a large imprecision in the measurements, so most professional radiometers use reflection compensation schemes. Most often used such radiometers directly in medicine.

Antennas-applicators are subject to certain requirements, as the design of such an antenna must take into account the peculiarity of the organ being studied, due to the fact that one antenna cannot cover all medical problems and characteristics of each patient. Therefore, medical antennas should have good coordination with biological object with high dielectric permeability (from 10 to 50); have good noise resistance in connection with working in the field of unwanted sources of electromagnetic interference, who make phones or computers. And the antenna should receive without reflection the incoming noise signal, but not receive radiation of external interference [1].

Summing up all the above, we can make the following conclusion. The parameters and accuracy of the measurement are very important in microwave radiometry, because it can depend on the timely detection of any disease in the human body. The correct design of a radiometer directly affects the safety and correctness of its use and from the parameters of antennas-adapters depends on the accuracy of measurement, which is most important in medicine.

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THE DESIGN FEATURES OF ANTENNA-APPLICATORS USED IN MEDICAL RADIOMETRY

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Аннотация. Для измерения температуры внутренних тканей в медицинской микроволновой радиотермометрии применяются специальные антенны-аппликаторы, которые учитывают биофизические свойства как исследуемых органов, так и кожного покрова. К конструкции антенн-аппликаторов предъявляется комплекс требований к габаритным размерам, помехозащищённости в условиях неблагоприятной электромагнитной обстановки и совместимости с биологическими объектами, благодаря чему широкое распространение получили печатные антенны. В статье рассмотрены основные виды печатных антенн-аппликаторов, применяемых в микроволновой радиотермометрии, рассмотрены их конструктивные особенности, показана необходимость применения диэлектрических надстроек для обеспечения согласования импедансов излучателя и исследуемого объекта, а также для увеличения глубины измерения поля.

Ключевые слова: медицинская микроволновая радиотермометрия, антенна-аппликатор, печатная антенна, волноводная антенна, болюс.

Annotation. In medical microwave radiometry the special antenna-applicators which take into account the biophysical peculiarities both of the organs and skin to be examined are used. Demands to overall dimensions, noise immunity under unfavorable electromagnetic conditions and compatibility with biological objects are placed on the structure of antenna-applicators, thus the patch antennas are become widely used. In the article the main types of patch antenna-applicators and its structural features are considered, a need for usage of dielectric extensions to provide both an impedance matching of a radiator and an object to be examined and increase the depth of measurement is shown.

Keywords: medical microwave radiometry, antenna-applicator, patch antenna, waveguide antenna.

Medical microwave thermometry (MMWT) is a painless way to measure the temperature of internal organs without penetrating the body. The method is based on the recording of natural electromagnetic radiation from body tissues in the UHF (ultra high frequency) range. The MMWT allows to determine and display on the screen internal tissue temperature at a depth of up to several centimeters. It is important to note that the temperature of a biological object in different parts of the body and at different depths varies. The temperature, proportional to the output power of the antenna measured by a microwave radiometer is called the radio brightness temperature. In the medical literature, tissue «internal temperature» is more common.

The structure of the antenna that will be used in MMWT must take into account the characteristics of the organ being studied. Since different organs and tissues differ in biophysical properties, and also different patients may have anatomical features, it is impossible to create a universal antenna that will cover all medical problems. Due to these factors, each organ needs its own antenna design.

Antennas used in radar and communication systems have good coordination with airspace, the antennas used in medicine must have a good coordination, first of all with the biological object whose dielectric permeability is high enough from 10 to 50. In addition, the antenna must be good noise protection, because during the measurement of the antenna is in the field source of electromagnetic interference that create phones and computers. Also the antenna should receive without reflection a noise signal from the biological object, but not receive radiation of external interference.

Summing up, the following technical requirements for antenna applicators can be formulated. High noise protection: the presence of a second screen, special radiation-absorbing coating and special design feature of the antenna, which lead to natural shielding of the working aperture of the antenna by the surface layers of the organism. Optimal alignment with biological object in wide bandwidth and low electrical losses. Also important is the immaturity of the antenna and good hygienic properties, due to the fact that the antenna contacts directly with the human body. Also important are the design requirements that are imposed on medical antennas, namely: airtightness of the structure from the effects of dust, water and electricity, protection of the structure of the antenna from static electricity, sanitary compliance, hygiene standards and meeting the requirements of ergonomics and medical aesthetics.

This article will cover the application antennas that receive microwave radiation. The MVHRT uses waveguide, vibratory, frame or in-cavity antennas, but since patch antennas have become more common in recent

years, the main focus will be on their varieties that are used in microwave radio thermometry.

Patch antennas have a radiator patch on a dielectric base, the thickness of which does not exceed 2 mm, also patch antennas have advantages in cost, mass and in the small effect on skin temperature. In many cases, patch antennas are used together with the bore. Bolus is a thin layer of dielectric that is placed between the antenna and the biological object, its size is slightly larger or approximately equal to the size of the aperture of the antenna, it allows to harmonize the antenna and increase the distance between the emitter and the biological object, in this way, the reactive fields that arise and the emitter does not enter the biological object. This allows you to increase the depth of measurement.

The patch elliptical antenna-applicator will be considered on example given in work [3], it works in the centimeter range of wavelength. In this paper it is used to measure the radiographic temperature on the chest surface, the labia, the abdominal wall and the outer side of the hip. This antenna consists of: microstrip line, RF connector, elliptical emitter, non-metallized elliptic section and dielectric base, metallized on one side. Consider its device in more detail. On one side of the dielectric base is patch an elliptical radiator connected to a microstrip line. The opposite side of the substrate is metallized, but there is no metallization directly under the elliptical emitter, this part and in contact with the biological object. In the elliptical antenna, the emitter is connected to the RF-connector by means of a microstrip line, this approach reduces the cost of the product and increases its process ability. In the antenna, the increase of noise resistance is realized by the presence of a copper screen with rectangular flanges. The main feature of this antenna is that it by pumping air in volume over the dielectric with a special pump, is attached to the biological object. Under the antenna screen negative pressure is created to create this effect, which ensures a good fit of the antenna to the patient's skin. The temperature of the antenna and skin is measured directly during the examination of the biological object with the help of fiber-optic sensors. At the same time, the elliptical antenna provides a good enough coordination in different parts of the human body.

The patch slotted antenna is used for diagnosis of breast diseases (MJ). On one side of the substrate is applied a topological slot emitter in the form of a «butterfly». The opposite side of the dielectric that is in direct contact with the biological object is not metallized. In the emitter slot, an elliptical field is formed, close to the field of flat wave. Due to the expansion of the slot, the slit lines of the electric field are bent and the magnetic field in the emitter increases. Therefore, this emitter is a combination of slotted and magnetic emitter, and this leads to the expansion of the bandwidth at the

antenna. Since the active component of the wave impedance depends on the opening angle of the «butterfly», then by selecting the opening angle, you can get the necessary impedances. The metal screen above the emitters has an influence on the alignment of the antenna and its effect increases when the height of the screen is reduced, therefore the height of the screen must be taken into account when designing the antenna. In the aperture near the excitation system, there are reactive fields that reduce the depth of measurement.

The article [1] presents a patch three-frequency antenna-applicator with a rectangular emitter, shown in the figure 1.

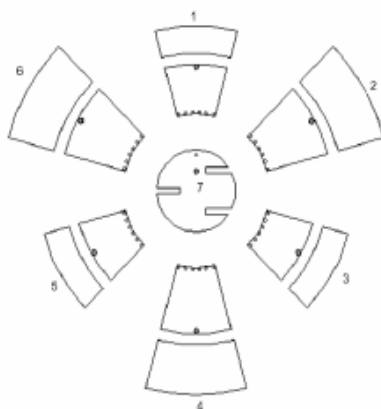


Figure 1 — A three-frequency antenna-applicator structure

The feature of this antenna is that it allows to simultaneously receive electromagnetic radiation from tissues in three frequency ranges: 1.4 GHz, 2.6 GHz, 3.5 GHz. It is obvious that each of these ranges has a different depth of measurement, which makes it possible to localize the thermal anomalies at depth. The picture shows that this antenna has seven emitters, which work in different frequency ranges. In the range of 3.5 GHz work emitters 1, 3 and 5, in the range of 2.6 GHz 2, 4 and 6, and in the range of 1.4 GHz emitters 0 and 7. On one side of dielectric base patch emitter, opposite side of substrate is metallized. The excitation of the antenna is carried out through the points marked in figure 1. The measurement of the radio-bright temperature in this antenna is carried out through a 3 mm thick bolus, with dielectric permeability equal to 10.

In addition to patch antennas, microwave thermometry also uses waveform antennas. Such antennas are a segment of the waveguide that is filled with dielectric and open on one side. The waveguide is connected to the input cascade of the radionuclide meter with a coaxial cable, so the

output of the antenna has a coaxial connector. The open end of the waveguide contacts the biological object; the opposite end is short-circuited. To ensure alignment, waveforms are filled with a dielectric with a dielectric permeability of the order of 10-25. The excitation of such an antenna is carried out by means of a pin, which is installed inside the waveguide along the power lines of the electric field. Waveguide antennas have disadvantages in terms of low noise resistance, significant weight and the ability to injure patients with sharp angles on the working surface. However, they also have their advantages in terms of simplicity of design, good wide band consistency and high depth of measurement. To reduce the size, usually increase the dielectric permeability, and to increase the noise protection antenna placed in an additional screen.

The article [2] presents a patch antenna with a spiral emitter (Figure 2).

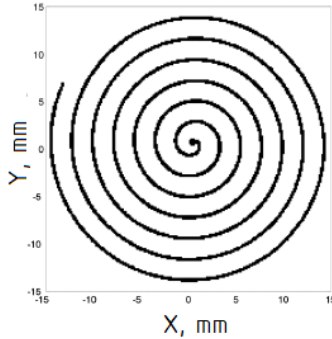


Figure 2 — Patch antenna with spiral emitter

The opposite side of the substrate is metallized. A thin layer of dielectric is applied to the spiral emitter to harmonize with the biological object. The excitation of the spiral emitter is carried out by means of a coaxial cable, the internal conductor of which is sealed through a hole in the center of the antenna at the beginning of the spiral line, and the screen on the metallized base. To prevent the reflection of electromagnetic waves, the final point of the spiral is closed to the active load. One of the main advantages of such antennas is simplicity in design, to the disadvantages are electrical losses and small measurement depth.

In some areas of medicine, miniature antennas are required for measurements, but this entails a reduction in the aperture of the antenna and as a consequence affects the reduction in measurement depth. This increases the resolution and reduces the mean temperature range. To reduce the size of the antenna, it usually increases the dielectric permeability of the dielectric in the waveguide. Such antennas have found their application in

dentistry, temperature measurement of children and many other.

Having summed up all the above, one can make a conclusion. In microwave radiation thermometry, the type of antenna applicator used plays a big role as it directly affects the ease of use and measurement accuracy. The antenna applicator determines how effectively tissue heat radiation will be measured and is the link between the device and the skin of the biological object.

Each of the antenna types examined has advantages and disadvantages, and different sensitivity to interference, measurement depth and design features. Incorrect antenna selection, for example, with insufficient depth of measurement, will not allow a reliable estimate of the human internal temperature and as a consequence it may be fatal to the patient.

The choice of an antenna-applicator in microwave radiothermometry should be justified by the specific objectives of the study and the individual characteristics of each patient.

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UDC 358.41

APPLICATION OF AUTONOMOUS AND REMOTELY OPERATED UNDERWATER ROBOTS IN THE OIL AND GAS INDUSTRY

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Аннотация. В данной статье рассматривается применение технологий подводной робототехники, а именно АНПА и ТНПА, в нефтегазовой отрасли. Нефтегазовая отрасль является одним из главных секторов для глобальной экономики и потребления ресурсов. Добыча данных природных ресурсов сопряжена с большим количеством рисков как для человека, так и для экологии. Эта статья объясняет принципы и особенности работы АНПА и ТНПА, основные преимущества и недостатки использования АНПА и ТНПА, а также целесообразность и эффективность их использования в нефтегазовом секторе.

Ключевые слова: АНПА, ТНПА, экология, газ, нефть, технология, робототехника.

Annotation. This paper examines the application of underwater robotics technologies, namely AUV and ROV, in the oil and gas production industry. Oil and gas production is one of the main sector for the global economy and resource consumption. The extraction of these natural resources is associated with lots of risks to both human operation and for environmental impact. The article explains the principles and work features of AUV and ROV, the main advantages and disadvantages of using AUV and ROV technologies and substantiates the feasibility and efficiency of their use in the oil and gas sector.

Keywords: AUV, ROW, ecology, gas, oil, technology, robotics.

Today, oil and gas production sector is one of the key sectors in both the energy and economic spheres. The global production of these minerals shows increasing every year. According to the US Department of Energy, «Global production of oil, gas condensate and light hydrocarbons rose by 600,000 barrels per day (bpd) in 2024, reaching 102.2 million bpd. The U.S. Energy Information Administration (EIA) predicts that production growth will total 1.9 million bpd in 2025» [3].

At the same time, the risks of negative environmental impact of the oil and gas production industry are growing every year. For example, among of some of the most significant types of negative influences on ecological situation caused by:

- Oil spills and gas leaks. The problem is caused by accidents on underwater pipelines, platforms and wells. Subsequently, the oil film coats water surface and killing marine life due to oxygen blocking;

- Pollution by oil platform wastes (by-products of oil and gas production). These platforms generate by-products such as drilling fluids, domestic and process wastewaters;

– Damage to the marine ecosystem from physical impacts, caused by drilling, platform installation and using of anchoring systems.

As it is clear, there are plenty of serious problems conducted by oil and gas production industry. These above problems contribute to strong environmental degradation, especially in case of serious accidents at oil and gas production facilities. Along with the task of efficient development of describing natural resources, there is also a task to prevent environmental damage. In order to reduce environmental damage, engineering provides modern methods to cope with the expected problems. Nowadays there is an effective and innovative method to solve the questions is the integration of underwater robotics into the oil and gas sector. Before considering the application of underwater robots in the gas and oil facilities, there is a need to briefly review with the basic types of underwater robots.

The first basic type of underwater robot is a remotely operated vehicle (ROV). An ROV is a remotely controlled submarine from above the surface of the water. An ROV is attached to controller by a tether. The tether makes possible to launch an ROV into the water from the ship. Also, the tether limits the distance from the ship an ROV is able to travel on its own. There are a plenty of variations of the tethers, which mostly depends on the depth an ROV is planned to be submerged. Some technical characteristics, including the maximum immersion depth and speed, determine the tether type.

The materials from which an ROV structure is made also has a crucial impact. A lightweight material must be used for the main frame, waterproof and strong enough to withstand a huge water pressure at depth. As the practical experience shows, most often different types of materials are used to manufacture an ROV body. For example, the ROV «Ariana – 1» made at Shiraz University is made of ABS plate, although «Because of high thermal conductivity of the body, the head cover of the box is made of bronze to send out the heat generated by the electronic board» [7].

An ROV is controlled by the operator through the series of optical cables. These cables transmit command and control signals from the operator to the ROV, which allows positioning and navigation. Electrical systems must be kept in sealed compartment, the systems its own must have insulating coatings to protect the systems against of external influences such as water contact, corrosion, condensation settling with subsequent reduction in insulation resistance, and motor vibrations. There are large number of devices used for tracking an ROV status. Typically, an ROV has a plenty of sensors to track the surroundings. These include temperature and pressure sensors, humidity sensors, accelerometers and gyroscopes (to track the movement and orientation). Most often an ROV has a camera to transmit a view of the depths. Also, some sensors are required to internal system status tracking. It includes

current and voltage sensors (monitoring energy wastes), load sensors (in case of mechanical impact on an ROV modules) and leak detectors (to ensure watertightness).

Task-specific customization of an ROV to perform a wide range of tasks. For instance, it is possible to mount LIDARs and RADARs for seabed mapping. Mounting of special attachments (manipulators, barometers, etc.) allows to perform the tasks for grabbing from the seabed or taking water samples. The second type of underwater robot is autonomous underwater vehicle (AUV). An AUV is a robot that explores and operates underwater using programmed instructions rather than receiving input from the operator. Furthermore, modern AUVs have artificial intelligence and machine learning algorithms. It makes possible to make independent decisions for correcting underwater robot's path or making conclusions about faults in underwater structures. Since an AUV is a pre-programmed unit, there is no need to use tethers or the series of optical cables. All necessary instructions, such as route and performance parameters (velocity, depth, mission time), are loaded to a robot software before the mission.

Underwater an AUV uses gyroscopes and accelerometers as an insertional navigation system (INS) to track the movement and orientation and a Doppler velocity log (DVL). A DVL is an acoustic sensor used for an AUV measurement of speed relative to the seabed. The sensor based on Doppler effect – the change in frequency of sound as it moves. It sends sound waves to the seabed and receives reflected waves with a changed frequency: the closer an AUV to the seafloor, the higher the reflected sound signal it receives. Both of the navigation principles are necessary for an AUV and perform in conjunction. Among other sensors used by an AUV are pressure sensor, temperature sensor, humidity sensors, SONARs and chemical analyzers. Another technological feature of an AUV is a ballasting system. Ballasting system allows a better control of the robot's buoyancy. By water pumping in or pumping out an AUV controls surfacing and submerging abilities. An AUV is made of fairly strong and lightweight materials like aluminum, titan and composite materials to withstand pressure at depth. Internal equipment includes hermetically sealed components to protect electronics. Communication between an AUV and the ship in depth also involves technicalities, as Wi-Fi signals and radio waves propagation deteriorates with increasing depth. Due to this reason, quality communication is possible with the use of acoustic signal transmission. Acoustic modems provide song signals through the water, which an AUV inputs using its own detector. The speed of information transmitting is low, most often it reaches about 1000 bps. Therefore, only simple command such as «start mission», «stop mission», «vehicle state» and others are sent by the operator [6].

Due to modern advantages in robotics, robots are able to perform tasks efficiently in demanding environments. There are many examples of successful use of ROV in the oil and gas sectors. In most cases, ROVs are used in purposes of maintaining and repairing the subsea communication. The ROVs have enhanced handling due to their direct communication with the operator and high-precision control system. It makes possible to efficiently perform tasks where high precision positioning is required. The tasks include repairing damaged infrastructure, mantling and dismantling objects.

For example, the ROVs are actively used for maintenance and repair of pipelines in Russia's Sakhalin-2 project. The application of ROVs is discussed because of difficult technical conditions and climatic factors, in view of which the work of divers is not possible. According to the IRM system company, which took a part in Sakhalin-2 pipeline repair system, «Temperatures as cold as -54°C have been recorded in the depths of a long winter season. The combination of shallow-water pipelines and buried pipelines are therefore greatly affected by ice issues, which also obstruct access. Divers may not work under ice, and so pipeline repair strategies had to include use of an ROV in shallow water» [1].

The use of ROVs also helps to decrease the environmental damage during underwater works. Modern underwater robotics paves the way for more ecologically friendly subsea operations. For instance, Oceaneering company, a global provider of engineering production, developed Liberty™ Resident System. The system is a new self-contained underwater docking station. According to their 2023 report, «Our self-contained, battery-powered Liberty™ Resident System does not require a dedicated vessel to be on standby during operations. By using this system, a typical Inspection, Maintenance, and Repair (IMR) campaign in the North Sea could see 33 MT per day of CO₂ saved as compared to using traditional ROV systems» [2].

Application of ROVs in the oil and gas production industry allows for an increasement of economic benefits. Several factors contribute to profit growth. First of all, lower personnel costs due to the reduced number of divers involved into operations. Consequently, lower medical and insurance costs. Secondly, lower vessel operating costs. As were mentioned before, due to usage of autonomous docked stations, such as Liberty™ Resident System, allows the ROV to be unassigned to a special vessel. Thirdly, underwater robots are able to expedite inspection of workspace and problems detection, using state-of-art sensors and HD cameras. It reduces time costs and promotes lower financial losses due to minimizing the risks of accident development. Westerton Access company, which specializes in the development and providing of inspection methods, reports the following figures as of Summer 2024: «In monetary terms, if the rig is making J200,000 per day and it needs to spend 10 days at

the shipyard for inspection, it will not be operational nor generate any income. As a result, J2 million in revenue will be lost» [8].

Despite of all the advantages, there are several disadvantages of ROVs application. Firstly, limited mobility due to use of the tethers. Secondly, highly qualified staff is demanded for exploitation and maintenance. Thirdly, a high cost of vessel charter with a ROV (the lower cost found is about 20000 US dollars). Fourth, most of the ROVs operates in limited depths (about 3000 meters). AUVs are also frequently used in the oil and gas sector. Due to a combination of factors such as autonomy, adaptivity and multifunctionality through using modern sensors, autonomous underwater robots bring a lot of benefits. The most common tasks AUVs deal with are monitoring of the underwater infrastructure and surveying vast areas for mapping purposes. Before the mission, the UAV mission is programmed. Customizing the mission preset includes setting the trajectory, control points and survey parameters. The navigation systems, including mentioned before INS and DVL, are calibrated highly accurate because of absence of tracking by GPS.

AUVs can carry a lot of the tools necessary to perform inspection and monitoring tasks. These includes water salinity sensors (can be used to estimate corrosion risks), multibeam echo sounder MBES (leaks detecting by evaluating the water column), RADARs, LIDARs, optical high-resolution cameras (also for mapping) and more. Newer methods for underwater robotics for quality assessment are also highlighted. For instance, a using of special robotic arm with devices to check the quality of pipe coating. In 2020 was started a new SPICE (Subsea Precise Inspection with Close Eyes) project by Japan's Kawasaki Heavy Industries. According to their report, «Kawasaki decided to launch a joint research project proposed by TotalEnergies to integrate TotalEnergies' electrical potential measurement technology, called Light Touch Cathodic Protection called «LTCP», with SPICE to make the AUV capable of measuring the electrical potential gradient of a pipeline, allowing the detection of potential coating defects» [5].

AUVs are also in demand in seafloor exploration and mapping. Among these tasks a special case should be highlighted. In a special case, the AUV conducts an initial exploration of a previously unexplored area. For example, scientists from Spanish university of Girona compiled an approach for inspecting underwater terrain. The mapping module inputs information from sensors (e.g. sonars or MBES) to build a 3D map of the area. The planning module calculates the safe path (derived from sensors data) from the start point to the finish point. The mission controller coordinates the work of the other modules [4].

The effectiveness of using AUVs in search activities is also unquestionable. For example, in 2022, Ocean Infinite company used their

AUVs during the search for the wreckage of crushed airplane MH370. It is noted that «During their search they noted that their fleet emitted 72% less CO₂ on average and covered 125,000 square kilometers of seabed in just 138 days – a far cry from the 837 days it would take typical survey vessels» [9].

Although, some shortcomings are noticeable in AUV using. First of all, difficult to operate and navigate. Secondly, limited load capacity, which makes AUVs ineffective in tasks that require objects manipulation. Thirdly, high cost of production and maintenance. Summing up, nowadays the use of underwater robotics in oil and gas production industry, such as ROVs and AUVs, is evolving and gaining popularity due to many factors. In general, the following reasons are outlined to conclude that AUVs and ROVs are highly effective:

- Increasing safety during underwater operations;
- High economic payback;
- Reduction of time costs;
- Flexibility to perform a wide range of tasks;
- Greater environmental tolerance compared to traditional methods.

There are several significant disadvantages of AUV and ROW technologies, the main ones are the high cost of manufacturing and the need for specially qualified personnel. With further development of technologies, it is possible to find more optimal solutions, which will reduce the cost of production, maintenance of the underwater robots and required skills of operators.

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COMPARATIVE ASSESSMENT OF POLARIZATION CHARACTERISTICS OF A SPIRAL ANTENNA IN VARIOUS CONFIGURATIONS

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Аннотация. Проведено исследование поляризационных характеристик спиральной антенны в различных конфигурациях. На основе сравнительного анализа полученных данных выбран оптимальный вариант спиральной антенны. Оценка проводилась с использованием программы электромагнитного моделирования, в расчетах использовался метод моментов.

Ключевые слова: спиральная антенна, поляризационные характеристики, сравнительный анализ, оптимальная конструкция,

электромагнитное моделирование, метод моментов, радиоэлектроника, телекоммуникации.

Annotation. A study of the polarization characteristics of a spiral antenna in various configurations has been conducted. Based on a comparative analysis of the obtained data, the optimal variant of the spiral antenna was selected. The assessment was carried out using an electromagnetic modeling program, with the method of moments employed in the calculations.

Keywords: spiral antenna, polarization characteristics, comparative analysis, optimal design, electromagnetic modeling, method of moments, radio electronics, telecommunications.

Introduction.

To achieve effective utilization of modern microwave antennas, their polarization becomes an important parameter. Antennas with circular polarization offer several advantages, including guaranteed reception of electromagnetic waves with different polarization vector orientations, reduced radio wave interference, and the ability to create two communication channels using a single antenna.

There is a need to optimally choose between two types of cubic spiral antennas—those with open and shorted sides—by evaluating their ability to generate elliptical (circular) polarization within a specified frequency range.

Main Part.

In [2], a scientific investigation into constructive solutions for increasing the gain coefficient of microwave and millimeter-wave spiral antennas was conducted. A broadband spiral antenna is presented, which includes a flat spiral printed circuit board, a matching symmetrical transformer, and a metallic cylindrical resonator filled with a dielectric material. The results of modeling and experimentation demonstrated an increase in the gain coefficient of the studied antenna by 2 dB within the operating frequency range.

In [3], electromagnetic modeling of cylindrical and conical single-turn spiral antennas above a reflector was performed. Based on a comparative analysis of the obtained data, the optimal variant of the spiral antenna in the form of an inverted cone above a reflector was selected. As a result of the study, it is proposed to use the radiators, manufactured according to the prototype, as components of onboard and ground-based antenna systems for communication complexes.

The calculations used in this work were performed using the FEKO CAD system [1]. The studied antenna represents a spiral cube, with its excitation point located on the top face. The length of the cube's side L is 170 mm, which

ensures tuning of the antenna to the minimum operating frequency of 480 MHz.

In the first variant of the study, the fractal structures of the cube faces are connected in the middle by bridges (shorted), while in the second variant, they are open. The structures of the antenna prototype are made of copper foil with a thickness of 0.3 mm. The internal part of the prototype is hollow, and the substrate of the faces is made of a dielectric material—polystyrene foam—with a relative permittivity close to one and low losses.

The investigation of the polarization characteristics of the antenna was carried out in the frequency range of 0.48 – 10.0 GHz with a step of 1.0 GHz. It was found that in the lower part of the range, from 0.48 to 1.0 GHz, the antennas emit a field with linear polarization. As the frequency increases, starting from 2.0 GHz, a field with elliptical polarization forms along the Z-axis. In the upper frequency region, the axial ratio approaches 1, which corresponds to circular polarization. The results of the electrodynamic modeling of the polarization characteristics of the spiral antenna in various configurations are shown in Fig. 1.

The results of the investigation of the overall gain coefficient of the spiral antenna with shorted sides are shown in Fig. 2.

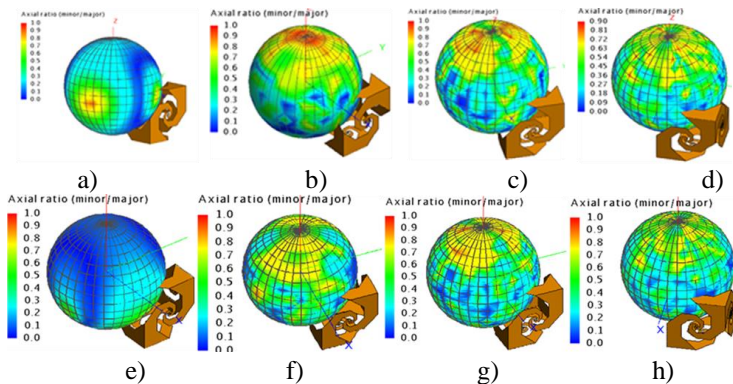


Fig. 1 – Axial ratio of the antenna:

- with shorted sides for frequencies: 0.48 GHz (a), 2.0 GHz (b), 6.0 GHz (c), 10.0 GHz (d); - with open sides for frequencies: 0.48 GHz (e), 2.0 GHz (f), 6.0 GHz (g), 10.0 GHz (h).

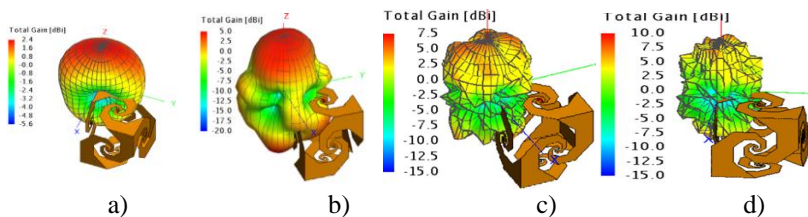


Fig. 2 – Antenna gain coefficient with shorted sides for frequencies: 0.48 GHz (a), 2.0 GHz (b), 6.0 GHz (c), 10.0 GHz (d).

The results of modeling the overall gain coefficient of the spiral antenna with open sides are shown in Fig. 3.

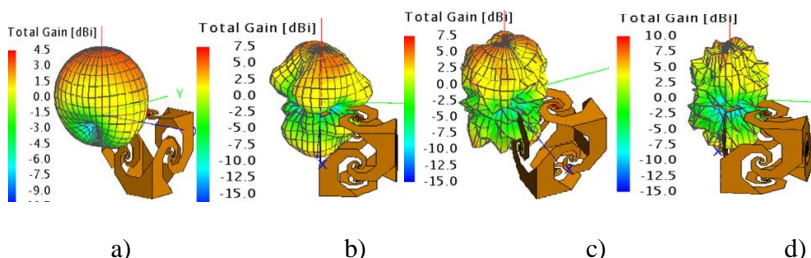


Fig. 3 – Antenna gain coefficient with open sides for frequencies: 0.48 GHz (a), 2.0 GHz (b), 6.0 GHz (c), 10.0 GHz (d).

The final results of the modeling of the overall gain coefficient of the spiral antenna with shorted and open sides are shown in Fig. 4.

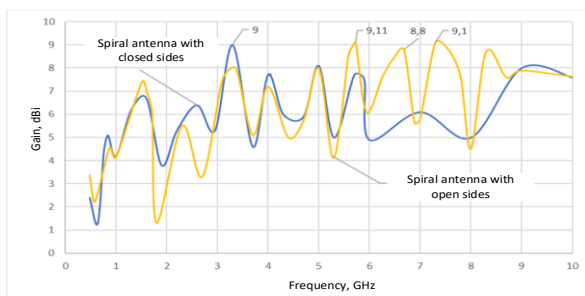


Fig. 4 – Gain coefficient of the spiral antenna with closed and open sides.

From the graphs, it is evident that the gain coefficients of the antenna increase with frequency for both the antenna configurations with closed sides and open sides. The maximum gain coefficient for the antenna with closed sides

sides is 9.0 dBi at a frequency of 3.3 GHz. The maximum gain coefficient for the antenna with open sides is 9.11 dBi, which corresponds to a frequency of 5.73 GHz.

Conclusion.

Thus, the cubic spiral antenna with both open and shorted sides forms a linearly polarized field in the lower part of the frequency range up to 2.0 GHz. Subsequently, from 2.0 GHz to 10.0 GHz, an elliptically polarized field is actively generated along the Z-axis. The antenna with closed sides achieves its maximum gain of 9.0 dBi in the lower part of the frequency range. Meanwhile, the antenna with open sides reaches its maximum gain values of 8.8 dBi, 9.1 dBi, and 9.11 dBi in the upper part of the studied frequency range.

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ANALYSIS OF INPUT CHARACTERISTICS OF A SPIRAL ANTENNA WITHOUT MATCHING IN VARIOUS CONFIGURATIONS

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Аннотация. Проведено исследование входных характеристик спиральной антенны без согласования в различных конфигурациях. На основе анализа полученных данных рассчитано волновое сопротивление для согласования входных характеристик. Оценка проводилась с помощью программы электромагнитного моделирования, при расчетах использовался метод моментов.

Ключевые слова: спиральная антенна, входные характеристики, согласование волнового сопротивления.

Annotation. A study of the input characteristics of a spiral antenna without matching in various configurations has been conducted. Based on the analysis of the obtained data, the wave impedance was calculated for matching the input characteristics. The assessment was carried out using an electromagnetic modeling program, with the method of moments employed in the calculations.

Keywords: spiral antenna, input characteristics, wave impedance matching.

Introduction.

Modern communication systems and radio engineering devices widely utilize spiral antennas due to their unique characteristics and capabilities. However, for these antennas to function effectively, proper matching of the input impedance must be ensured. The lack of input impedance matching can lead to serious consequences, such as significant power loss, reduced efficiency, and degraded signal quality. This article presents an analysis of the voltage standing wave ratio (VSWR) for a cubic spiral antenna with shorted and open sides at a characteristic impedance of $50\ \Omega$ in the frequency range of 0.48 – 10.0 GHz. The average value of the input impedance has been calculated to perform matching and improve the antenna's input characteristics.

Main Part.

In [2], research was conducted on a broadband hybrid log-periodic dipole antenna designed to operate in the frequency range of 50 MHz to 1 GHz. Methods for matching the antenna in the low-frequency region were considered, and the impact of three types of matching devices on the longitudinal dimension of the antenna under comparable matching characteristics was demonstrated.

The possibility of using a mobile antenna made from fluorinated ethylene-propylene material in combination with strontium hexaferrite $\text{SrFe}_{12}\text{O}_{19}$ for modern fifth-generation communication systems was investigated. Broadband matching of the proposed antenna was performed. The average VSWR (voltage standing wave ratio) without a matching device was 19.6, while with the implementation of a broadband matching device, the VSWR value decreased to 4.7 [3].

Additionally, a method for obtaining a stable toroidal radiation pattern over a wide frequency range for a compact antenna based on an asymmetric printed dipole was proposed. The method involves the use of a broadband rectangular radiator matched to a 50-ohm input connector via a quarter-wave transformer based on a microstrip transmission line and a specially shaped counterpoise. The matched antenna generates a toroidal field in the frequency range of 1500–4000 MHz with a gain of no less than 2 dBi in the direction of maximum radiation. The radiation pattern shape remains stable across the entire frequency range, with maxima oriented perpendicularly to the antenna axis [4].

Calculations used in this work were performed using the FEKO CAD system [1].

The structure of the spiral antenna represents a cube with edge length $L = 170$ mm, featuring fractal structures on its faces. The excitation point is located on the top face. The presence of spiral fractal elements on the cube faces is a key factor determining its characteristics. During the study, two versions of the antenna design were examined: in the first version, fractal elements on each face of the cube are connected at the central point by bridges, effectively creating closed loops. This affects current distribution and, consequently, the radiation pattern and antenna gain. In the second version, there are no bridges between the fractal elements, resulting in open loops. In both versions, the antenna is made from copper foil 0.3 mm thick, ensuring good conductivity and minimal losses. The interior of the cube is hollow, and the substrate of the faces is made from polystyrene foam.

Figure 1 shows the graphs of the real part of the input resistance for antennas with shorted and open sides. It was determined that the maximum real resistance for the antenna with shorted sides is $602.0\ \Omega$ at a frequency of 0.62 GHz, while the minimum real resistance is $100.0\ \Omega$ at a frequency of 0.8 GHz. In the range from 1.0 to 10.0 GHz, fluctuations in resistance remain within the bounds of 150–350 Ω , and with increasing frequency from 6.0 to 10.0 GHz, the value of the real resistance gradually increases within the range of 222.0–268.0 Ω . For the antenna with open sides, the maxima of the real resistance are $302.0\ \Omega$ at a frequency of 0.77 GHz and $310.0\ \Omega$ at a frequency

of 1.4 GHz, while the minimum real resistance is 125.0 Ω at a frequency of 0.63 GHz.

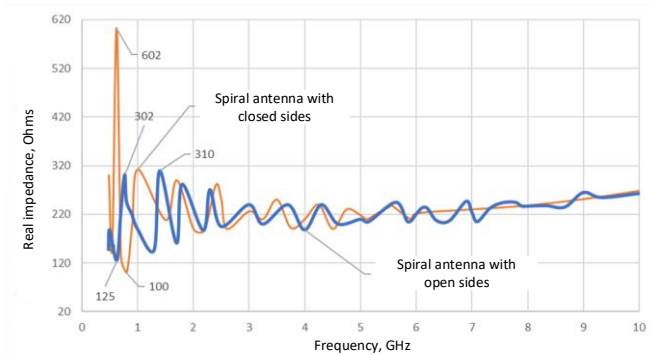


Fig. 1 – Real part of the antenna's input resistance

Fig. 2 shows the graphs of the reactive part of the antenna's input impedance. The maximum reactive impedance for the antenna with closed sides is 425.0 Ω at a frequency of 10.0 GHz and 220.0 Ω at a frequency of 0.58 GHz. The minimum reactive impedance is -280.0 Ω at a frequency of 0.65 GHz. Meanwhile, the maximum reactive impedance for the antenna with open sides is 205.0 Ω at a frequency of 10.0 GHz. The minimum reactive impedance is -80.0 Ω at a frequency of 0.57 GHz.

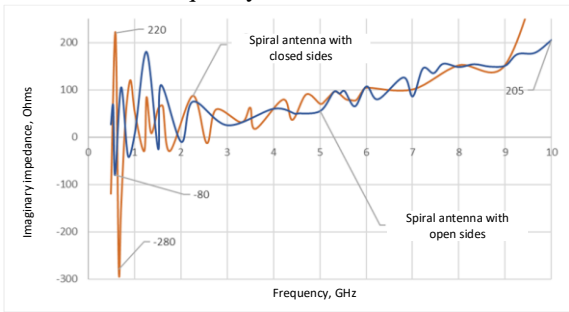


Fig. 2 – Reactive part of the input impedance

Fig. 3 shows the voltage standing wave ratio (VSWR) for a characteristic impedance of 50.0 Ω of the spiral antenna with shorted and open sides. The largest VSWR variations for the antenna with shorted sides occur in the range of 0.48 – 1.0 GHz. The VSWR variation limit in this range is from 12.7 at a frequency of 0.64 GHz to 1.8 at a frequency of 0.77 GHz. In the range from 1.0 GHz to 7.0 GHz, the VSWR variations are within 4.2 – 5.55. Starting from

7.0 GHz, the VSWR value gradually increases from 5.53 and reaches its maximum value of 19.7 at a frequency of 10.0 GHz. For the antenna with open sides, the VSWR values increase with frequency. The VSWR minimum is 2.5 at a frequency of 0.63 GHz, and the VSWR maximum is 8.5 at a frequency of 10.0 GHz.

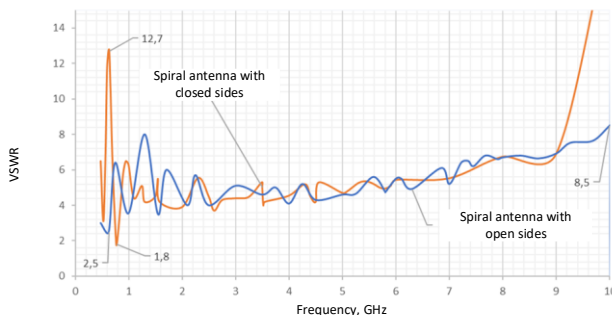


Fig. 3 – Voltage Standing Wave Ratio of the antenna

Conclusion.

Thus, the maximum real impedance for a characteristic impedance of 50.0Ω for the spiral antenna with shorted sides is 602.0Ω at a frequency of 0.62 GHz. The minimum real impedance of this antenna is 100.0Ω at a frequency of 0.8 GHz. The maximum real impedances for the spiral antenna with open sides at a characteristic impedance of 50.0Ω are 302.0Ω at a frequency of 0.77 GHz and 310.0Ω at a frequency of 1.4 GHz. The minimum real impedances of this antenna are 125.0Ω at a frequency of 0.63 GHz and 147.0Ω at a frequency of 1.3 GHz. The average value of the real impedance for antennas in different configurations is 240.0Ω across the entire studied range of 0.48 – 10.0 GHz.

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INVESTIGATION OF THE VOLTAGE STANDING WAVE RATIO OF A SPIRAL ANTENNA WITH MATCHING

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Аннотация. Проведен анализ коэффициента стоячей волны по напряжению (КСВН) спиральной антенны с согласованием в различных конфигурациях. На основе полученных данных выполнена оценка каждой конфигурации антенны. Работа выполнена с использованием программы электромагнитного моделирования, в расчетах использован метод моментов.

Ключевые слова: спиральная антенна, входные характеристики, согласование волнового сопротивления.

Annotation. An analysis of the voltage standing wave ratio (VSWR) of a spiral antenna with matching in various configurations has been conducted. Based on the obtained data, an assessment of each antenna configuration was

performed. The work was carried out using an electromagnetic modeling program, with the method of moments employed in the calculations.

Keywords: spiral antenna, input characteristics, wave impedance matching.

Introduction.

Broadband spiral antennas possess versatile characteristics that make them indispensable in various areas of radio and telecommunications. They are used in satellite communication systems, radars, radio astronomy, and other high-tech fields due to their wide frequency range and stable signal quality. Research in the field of broadband spiral antennas focuses on optimizing their design and improving performance to meet the growing demands of modern communication systems. This article presents an analysis of the voltage standing wave ratio (VSWR) of a cubic spiral antenna with shorted and open sides at a characteristic impedance of $240\ \Omega$ in the frequency range of 0.48 – 10.0 GHz.

Main Part.

In [4], an electrodynamic modeling of the input characteristics of a hemispherical spiral antenna was conducted. It was determined that in such an antenna, there exists an active region equal to the wavelength. The antenna is broadband with an overlap factor of 1.84 and radiates a rotating polarization field. In the frequency range of 0.325 – 0.6 GHz, the antenna gain varies by no more than 1 dB.

In [2], the emission characteristics of a broadband spiral antenna using a Gaussian pulse are examined. The paper presents an algorithm for calculating the frequency characteristics of a spiral antenna when transmitting a broadband signal using the method of moments. Using the developed algorithm based on numerical methods, the frequency characteristics of the spiral antenna for ultra-wideband radio signal transmission in the range of 0.1 to 3.7 GHz were obtained. To confirm the effectiveness of the proposed methodology, numerical simulations were carried out using the FEKO software. The results indicate the high potential of the considered broadband spiral antenna for ultra-wideband signal transmission.

In [3], multi-band antennas based on fractal structures are investigated. An electrodynamic analysis, design, and modeling of fractal-type antennas were performed. Experimental studies of the radiation and matching characteristics of the fabricated antenna prototypes were carried out. Comparative results of modeling and experimentation are presented. The practical applicability of these antennas in communication systems and RFID (Radio Frequency Identification) systems is demonstrated.

The calculations used in this study were performed using the FEKO CAD system [1].

The work presents the construction of a spiral antenna in the form of a cube with edge length of 170 mm. A key feature of this antenna is the presence of spiral fractal elements located on each of the six faces of the cube. The excitation point is placed on the top face, which is a standard solution for similar constructions (Fig. 1). However, the fractal design of these elements changes the antenna's characteristics compared to traditional spiral or wire counterparts. Two versions of the design were studied during the research. The first version features closed fractal loops, where the spiral fractal elements on each face are connected at the center of the cube by thin bridges. The second version consists of open fractal loops, where the absence of bridges between the fractal elements on the faces leads to the formation of open circuits. Both versions of the antenna are made from copper foil 0.3 mm thick, ensuring low resistive losses and high conductivity. The interior of the cube is hollow, and polystyrene foam is used as a substrate for increased rigidity and reduced weight of the faces. Polystyrene was chosen due to its low dielectric permittivity, which has minimal impact on the radiation characteristics.

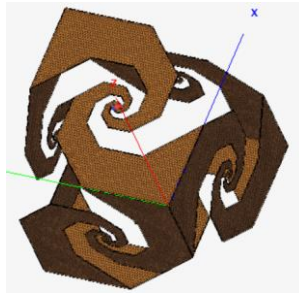


Fig. 1 – Spiral antenna

Fig. 2 shows the VSWR (voltage standing wave ratio) of a cubic spiral antenna with shorted sides for a characteristic impedance of $240\ \Omega$ in the frequency range of 0.48 – 10.0 GHz.

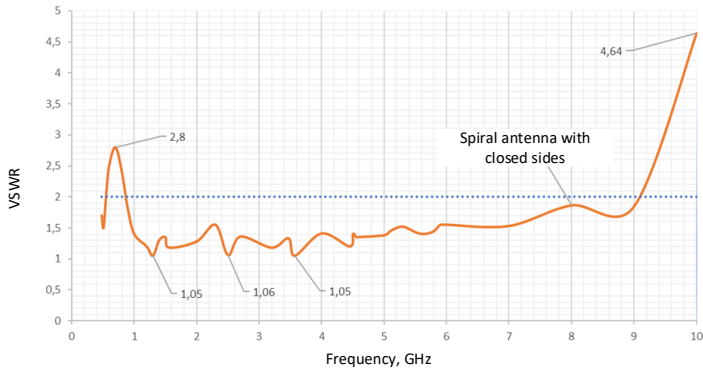


Fig. 2 – VSWR of the spiral antenna with shorted sides

For the spiral antenna with shorted sides, at a frequency of 0.72 GHz, the VSWR reaches its maximum value of 2.8 within the range of 0.48 – 1.0 GHz. Afterward, the VSWR gradually decreases and reaches a value of 1.05 at a frequency of 1.0 GHz. In the frequency range of 1.0 – 5.0 GHz, the minimum VSWR values of 1.05 and 1.06 correspond to frequencies of 1.6 GHz, 2.57 GHz, and 3.67 GHz. In the range of 6.0 – 10.0 GHz, the minimum VSWR value of 1.53 occurs at a frequency of 7.0 GHz, while the maximum VSWR value of 4.64 corresponds to a frequency of 10.0 GHz.

Figure 3 shows the VSWR of the cubic spiral antenna with open sides for a characteristic impedance of 240 Ω in the frequency range of 0.48 – 10.0 GHz.

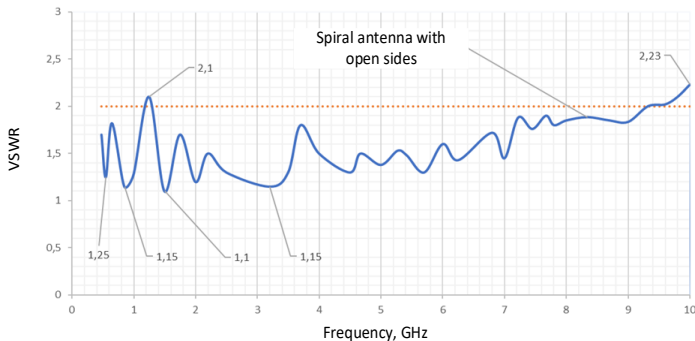


Fig. 3 – VSWR of the spiral antenna with open sides

For the spiral antenna with open sides, within the range of 0.48 – 1.0 GHz, there are two VSWR minima equal to 1.25 and 1.15, corresponding to

frequencies of 0.55 GHz and 0.86 GHz, respectively. The frequency range of 1.0 – 5.0 GHz also contains two VSWR minima equal to 1.1 and 1.15 for frequencies of 1.5 GHz and 3.55 GHz. For the frequency range of 5.0 – 10.0 GHz, the VSWR minimum of 1.47 corresponds to a frequency of 7.0 GHz. The VSWR maxima equal to 2.1 and 2.23 occur at frequencies of 1.25 GHz and 10.0 GHz.

Conclusion.

An investigation of the voltage standing wave ratio (VSWR) of a cubic spiral antenna with shorted and open sides for a characteristic impedance of 240Ω in the frequency range of 0.48 – 10.0 GHz has been conducted. It was determined that, overall, the VSWR for both antenna variants does not exceed a value of 2.0. The VSWR minima for the antenna with closed sides, equal to 1.05 and 1.06, correspond to frequencies of 1.6 GHz, 2.57 GHz, and 3.67 GHz. The VSWR minima for the antenna with open sides, equal to 1.25, 1.15, 1.1, and 1.15, correspond to frequencies of 0.55 GHz, 0.86 GHz, 1.5 GHz, and 3.55 GHz.

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ANALYSIS OF UNIFORM-STEP SPIRAL CONICAL ANTENNAS

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Аннотация. Проведен анализ характеристик двухвитковых конических равноугольных спиральных антенн с различными значениями высоты конуса. Представлены результаты расчетов входных характеристик и характеристик излучения антенн.

Ключевые слова: спиральная антенна, входные характеристики, согласование волнового сопротивления.

Anotation. An analysis of the characteristics of two-turn conical equiangular spiral antennas with different cone height values has been performed. The results of the calculations of the input characteristics and radiation characteristics of the antennas are presented.

Keywords: spiral antenna, input characteristics, wave impedance matching.

Introduction.

For the implementation of communication in mobile systems, it is necessary to ensure a wide radiation pattern in the upper hemisphere with elliptical polarization of the emitted field. Such field radiation can be created using conical spiral antennas [1, 2]. In this case, different methods of antenna excitation with multiple turns can be employed, which significantly affects the input characteristics and radiation characteristics of such antennas.

Main Part.

Conical spiral antennas represent a specialized type of antenna within the class of spiral antennas. They possess unique characteristics such as wide

bandwidth and circular polarization, which make them indispensable in various radio engineering systems. These antennas are capable of operating over an extremely wide frequency range, enabling their use in radar systems, communication systems, and radio detection applications. Additionally, they provide circular polarization — either left-handed or right-handed — which reduces the impact of reflections and enhances signal stability when the orientation of the receiver or transmitter changes.

Geometrically, a conical spiral antenna consists of two or more metallic spirals arranged along the surface of a cone [3, 4]. Typically, a double-spiral configuration is used, where each spiral forms one of two phase-shifted lines that constitute the antenna. When an electromagnetic signal is fed into the antenna, currents flow along the spirals, generating a rotating electromagnetic field. This field corresponds to circular polarization, which is particularly useful for detecting objects in space regardless of their orientation.

Moreover, conical spiral antennas have a radiation pattern concentrated along their axis of symmetry, ensuring high efficiency in transmitting and receiving signals. They also exhibit low levels of secondary radiation, making them suitable for environments with stringent isolation requirements between antennas.

The applications of these antennas span a wide range of fields. For instance, they are used in radar systems for target detection at long distances. In aviation systems, they serve purposes such as navigation, communication, and detection of other aircraft. In satellite communications, their ability to operate across a wide frequency band and provide reliable connectivity with moving objects makes them essential. Additionally, modified versions of these antennas are employed in mobile devices and wireless networks to ensure stable communication links.

In this work, two-turn conical antennas of varying lengths were investigated using an electromagnetic analysis program [5]. For the excitation of the two-turn antennas, an antiphase excitation method was used. The antennas, with a wire radius of 0.5 mm, were positioned on cones with an initial radius of 2 mm, a final radius of 47.5 mm, five turns per winding, and a height of 47.5 mm.

Figure 1 shows the dependencies of the standing wave ratio on frequency after matching for various antenna heights.

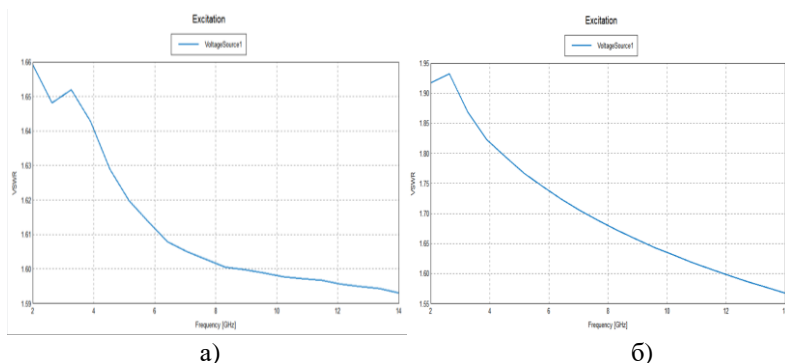


Fig. 1 — Dependence of the standing wave ratio on frequency: a) $h = 47.5$ mm, b) $h = 95$ mm

From Fig. 1, it can be seen that the antenna is matched with the feed line in the frequency range of 2–14 GHz, with $VSWR < 1.66$ for $h = 47.5$ mm and $VSWR < 1.95$ for $h = 95$ mm. The standing wave ratio decreases with increasing frequency and is 1.59 at the high-frequency edge of the band.

Figures 2 and 3 show the dependencies of the real and imaginary parts of the antenna's input impedance on frequency.

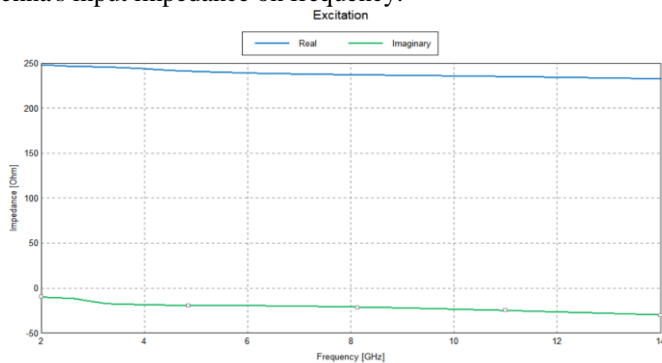


Fig. 2 — Dependence of the standing wave ratio on frequency for $h = 47.5$ mm

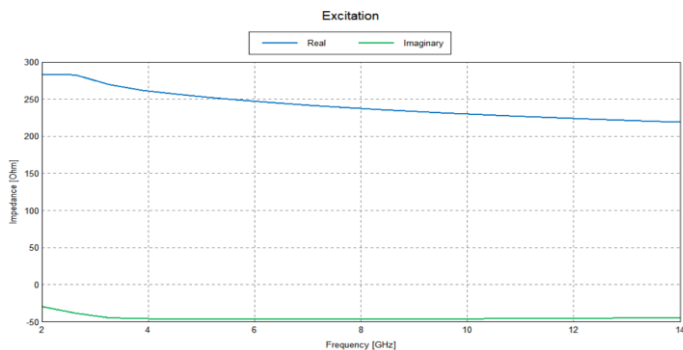


Fig. 3 — Dependence of the standing wave ratio on frequency for $h = 95$ mm

Fig. 4 shows the radiation patterns of the antenna for a height of 47.5 mm.

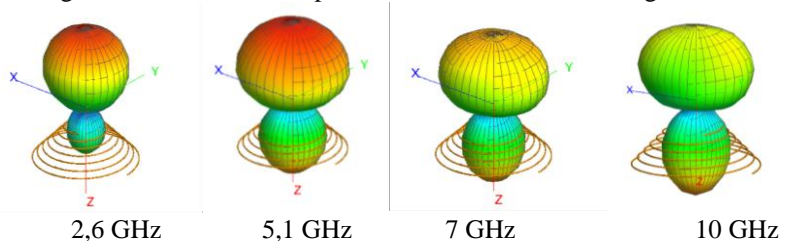


Fig. 4 — Radiation patterns of the antenna for a height of 47.5 mm

Fig. 5 shows the radiation patterns of the antenna for a height of 95 mm.

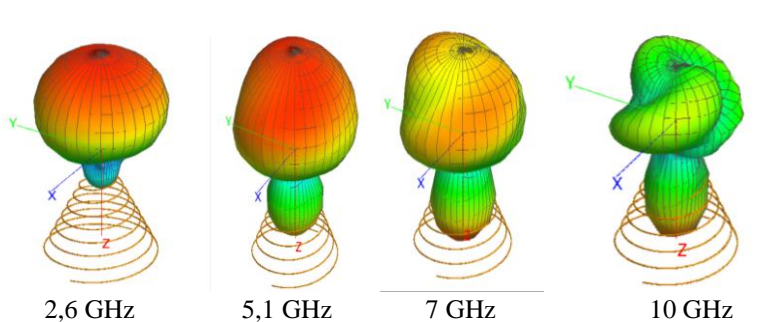


Fig. 6 — Radiation patterns of the antenna for a height of 95 mm

Fig. 7 shows the vertical plane slices of the antenna's radiation pattern; for these slices, the apex of the cone is directed downward.

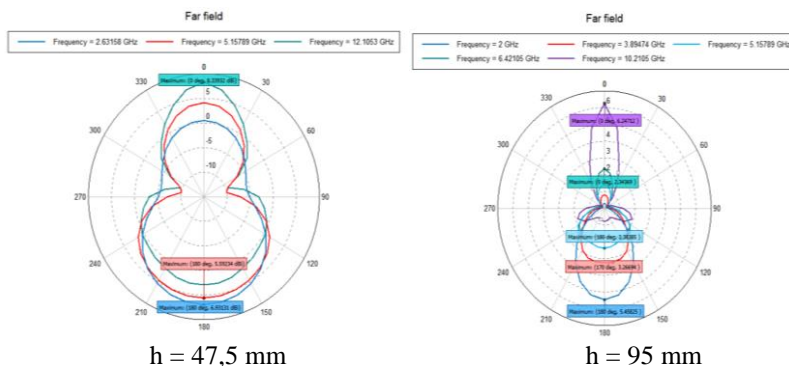


Fig. 7 — Vertical plane slices of the antenna's radiation patterns

From Fig. 7, it follows that the antenna gain for $h = 47.5 \text{ mm}$ is 6.9 dBi at 2.63 GHz, 5.6 dBi at 5.15 GHz, and 3 dBi at 12.1 GHz. The antenna gain for $h = 95 \text{ mm}$ is 5.45 dBi at 2 GHz, 3.26 dBi at 3.89 GHz, and 2.38 dBi at 5.15 GHz. With increasing frequency, the radiation into the backward hemisphere increases.

Conclusion.

The width of the radiation pattern of the two-turn conical antenna changes only slightly within the operating range of 2–14 GHz. At frequencies from 2–6 GHz, the radiation is directed toward the apex of the cone, with the width of the radiation pattern varying from 79° to 102° . At frequencies from 6–14 GHz, the radiation is directed toward the base of the cone, and the width of the radiation pattern varies from 34° to 47° .

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SECTION 2: INFORMATION SYSTEMS AND TECHNOLOGIES



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DEVELOPMENT OF A SMART MASSAGE DEVICE

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Аннотация. В статье предлагается прогрессивная концепция разработки уникального массажера, основанного на стандартах трехмерного принтера. Этот гаджет представляет собой устройство, которое воздействует на поверхность тела с помощью уникальных сдвигающих факторов, соответствующих печатающей головке трехмерного принтера. Благодаря этому механизму массажер способен выполнять глубокий и точечный массаж, адаптируясь к особым формам и особенностям корпуса. Это делает его гибким и мощным устройством для отдыха и восстановления мышечного тонуса.

Основная идея заключается в применении технологий, которые обычно используются в трехмерной печати, для создания инструмента, который, на мой взгляд, удовлетворил бы желания каждого потребителя. Это позволяет максимально повысить эффективность обработки, учитывая анатомические особенности и возможности человека. Массажер может быть настроен на различные режимы и интенсивность,

что делает его подходящим для людей с уникальным в своем роде уровнем физического здоровья и физической подготовленности.

Кроме того, один из таких массажеров можно использовать не только для отдыха, но и для профилактики и лечения мышечных болей и беспокойства. Благодаря своей адаптивности, он способен воздействовать на уникальные участки тела, усиливая кровообращение и способствуя быстрому заживлению после физических нагрузок. В основном это актуально для спортсменов, людей, ведущих энергичный образ жизни, а также для тех, кто любит постоянное напряжение во время занятий живописью.

Современный способ изготовления массажера открывает новые возможности в сфере медицины и здравоохранения. Этот инструмент может стать незаменимым помощником для тех, кто стремится вести здоровый образ жизни и поддерживать свое тело в отличной форме. Простота использования и высокая эффективность делают его доступным для широкого круга потребителей, независимо от их возраста и состояния здоровья.

Ключевые слова: 3D-принтер, экструдер, двигатели, оси X, Y, Z, датчики, встроенный контроллер, G-код, вибрационный массажер, координата, инфракрасные датчики.

Annotation. The article offers a progressive concept for developing a unique massager based at the standards of a three-d printer. This gadget is a device that actions along the ground of the body with the assist of unique shifting factors corresponding to the printhead of a three-d printer. Thanks to this mechanism, the massager is capable of provide deep and acupressure, adapting to special frame shapes and features. This makes it a flexible and powerful device for rest and recovery of muscle tone.

The main idea is to apply technology which might be generally applied in three-d printing to create a tool that would for my part meet the desires of every consumer. This permits you to maximize the effectiveness of rub down, considering the anatomical features and alternatives of someone. The massager can be configured for various modes and intensities, which makes it suitable for people with one of a kind ranges of physical health and fitness conditions.

In addition, one of these massager can be used no longer most effective for rest, but also for the prevention and treatment of muscle pain and anxiety. Due to its adaptability, it is able to have an effect on unique areas of the frame, enhancing blood move and selling rapid healing after physical exertion. This is mainly actual for athletes, folks that lead an energetic lifestyle, as well as for folks who revel in consistent pressure and strain at paintings.

The contemporary method to growing a massager opens up new possibilities inside the subject of medical era and the wellbeing enterprise. The tool can emerge as an essential assistant for those who try for a wholesome way of lifestyles and need to hold their body in notable form. Its ease of use and immoderate performance make it available to a giant range of customers, regardless of their age and health degree.

Keywords: 3D printer, extruder, motors, X, Y, Z axes, sensors, integrated controller, G-code, vibration massager, coordinate, infrared sensors.

Introduction

In modern society, there is a developing hobby in professional back and neck rub down. This is due to a growth in strain levels, a sedentary lifestyle and the unfold of sicknesses of the musculoskeletal system. However, conventional methods, along with contacting a certified chiropractor or the usage of high-priced rubdown gadgets, are not usually accessible or handy for everybody.

Many people face inconveniences whilst touring an expert: This may be because of lack of time, monetary charges, or geographical remoteness. In addition, expensive rub down devices regularly require special capabilities to use them, making them inaccessible to a wide target market.

In reaction to those demanding situations, a revolutionary idea became proposed for the development of a brand new rubdown tool that combines current era and simplicity of use. This tool can be prepared with an automatic manage device for the depth and trajectory of the rubdown effect. It will recall the person anatomical features and preferences of the user, so that you can permit all and sundry to personalize the massage system consistent with their needs.

This manipulate system will make certain maximum massage performance, allowing you to achieve the exceptional consequences within the shortest viable time. The person will be able to independently alter the rub down parameters, deciding on the ultimate depth and period of the system. This is in particular essential for human beings with chronic ache or bodily disabilities who find it tough to receive professional help on a regular basis.

In addition, the innovative device could be compact and clean to use. It will be capable of run on battery power, which makes it cell and convenient to be used at domestic. This will allow human beings to get hold of expert massages anytime, everywhere, with out leaving their houses.

The main part

In modern world, characterised by means of pressure, a sedentary way of life, and exposure to damaging environmental elements, the improvement of progressive healthcare technologies has end up crucial. Among those,

vibrating massagers have emerged as brilliant innovations. This device no longer best offers relaxation but additionally has multifaceted advantageous outcomes at the human frame, contributing to normal well-being and physical fitness.

In this newsletter, we explore the mechanisms in the back of vibration massagers, delve into their layout elements, and explore the ability benefits and programs of this generation. The effectiveness of a vibrating massage is based on its potential to generate vibrations that have an effect on the pores and skin and underlying tissues, stimulating sensory receptors, activating blood move and the lymphatic device, in addition to nerve networks. These physiological reactions make contributions to the various benefits for the body.

Different vibration frequencies have a profound impact at the contraction of muscle fibers, growing their tone and flexibility. This, in flip, makes them more elastic, lowering the chance of sprains and accidents. In addition, those fluctuations make a contribution to the acceleration of metabolism within cells, contributing to the removal of dangerous materials and waste products. Additionally, they improve the supply of oxygen and essential nutrients to tissues.

The structural additives of the tool are crucial for its effective functioning. The vibration module serves because the heart of the system, producing vibrations. This module may be implemented using piezoelectric materials, electromagnetic systems, or superior technologies. Modern models often have modules that permit users to modify the frequency and depth of vibrations in keeping with their possibilities.

The manage gadget of the rubdown tool is based totally on a microcontroller, which controls the operation of the device and regulates its vibration parameters. It may include various sensors, such as infrared sensors, which accurately determine the position of the tool on the subject of the consumer's frame. This function guarantees a safe and snug user experience by using preventing the massager from straying outdoor the certain massage location. The use of infrared sensors in these devices demonstrates the significance of precision in improving security measures.

In the context of rubdown devices, infrared sensing generation plays a vital role in providing correct guidance. These sensors allow the device to as it should be deciding the bounds of the rub down area, which makes it particularly beneficial for influencing positive regions of the frame in the course of rubdown. This characteristic is particularly treasured for stopping accidental accidents, which include those that can occur throughout facial or neck massages.

Some contemporary models of vibration massagers are prepared with a completely unique tool called an extruder. This progressive element is a

miniature mechanism that moves along predefined trajectories. This design lets in for more centered and unique effects on various elements of the body, making the rub down as powerful and snug as viable.

The extruder can be geared up with a variety of nozzles, every designed to perform precise responsibilities. For example, there are attachments that sell deep muscle relaxation, enhance blood stream and reduce swelling. Thanks to this versatility, users can personalize the massager consistent with their wishes and dreams. The use of an extruding mechanism in vibrating rub down devices significantly increases their effectiveness. The tool no longer only massages the surface of the pores and skin but additionally penetrates deeper into muscle tissues, accomplishing deeper layers, that's specifically critical for humans stricken by muscle tension, ache or harm. An extruder helps relax muscle groups, relieves cramps and improves the overall circumstance of the body. An example of a massage nozzle that will be used instead of an extruder is shown in Fig. 1.



Fig. 1 – An example of a massager, instead of an extruder

In addition, nozzles that can be mounted on an extruder can help you tailor the massage to individual needs. For instance, individuals who want stepped forward blood movement can choose a nozzle with stronger vibrations. Those who need to reduce swelling can use a nozzle that gives a mild, relaxing impact.

Thus, vibrating massagers with extrusion become a flexible device for health and wellbeing. They are beneficial for each expert therapists and people who wish to care for our bodies independently. Due to their effectiveness and flexibility, these devices are getting more popular amongst the ones searching for a healthy life-style.

Regular vibration rubdown offers numerous health advantages, selling universal properly-being. These blessings consist of:

Secondly, the tool correctly relieves muscle anxiety, relieving ache and promoting rest. This benefit is specifically beneficial for athletes and individuals whose paintings includes lengthy durations of sitting or standing

in a single position. In addition, the consistent use of a rub down tool allows to increase flexibility and mobility, boost the pliancy of muscle mass and optimize joint mobility. This now not only prevents injury, however also accelerates recuperation after bodily exertion.

In addition, vibrations emitted by using the tool have a high-quality impact on the nervous machine, stimulating it and increasing ordinary power. As a result, mood improves and performance increases, the person feels greater active and attentive. Using a vibrating rub down not simplest improves blood move however also promotes lymphatic drainage, strengthening the immune device and making the body better able to withstand infections and disease.

The multifaceted use of vibration massagers extends beyond medicinal drug and cosmetology to the fields of sports and rehabilitation. In the field of sports activities, those devices are proving to be worthwhile, supporting athletes get over accidents and enhance their performance. They additionally play an important function in rehabilitation after operations and diseases of the musculoskeletal machine, accelerating restoration by using improving blood move and decreasing muscle anxiety.

In cosmetology, vibro massagers are used to improve pores and skin condition and reduce cellulite, as well as to boost muscle tone and promote ordinary well-being. Their use also improves pores and skin texture and hydration.

In the field of sports medication, vibration massagers have attracted good sized attention due to their potential to boost up restoration after training, prevent injury, and decorate athletic performance. By correctly relieving muscle fatigue, growing muscle elasticity, and boosting the frame's ordinary staying power, those devices have come to be invaluable equipment for both athletes and health lovers.

In addition, the popularity of vibration massagers has spread to the house, wherein humans have a tendency to include them of their day by day weight loss program to keep fitness and well-being. These less expensive devices offer a realistic answer for keeping physical health and ordinary wellbeing, making them a valuable addition to any self-care regimen.

Modern vibration massagers frequently have sophisticated control structures that permit customers to regulate the complex extruder movement paths and thoroughly control the vibration parameters. To gain such accuracy, a specialized programming language referred to as G-code is used. G-code serves as a preferred language used in numerical manipulate gadget equipment, which allows users to exactly software moves of the extruders alongside unique trajectories and adjust vibration parameters to get favored outcomes. Here is an instance of a G-code application for a vibrating massager:

1. Start moving to beginning position with acceleration.
2. Move linearly alongside X-axis with pace of 1,000 cm/min.
3. Do circular motion clockwise.
4. Then do round motion counter-clockwise.
5. Apply force of 3 mm on surface.

The advantages of using a vibrating rub down system are multifaceted. Regular use of any such device can lead to a massive development inside the trendy circumstance of the frame. By stimulating nerve endings, growing blood circulate, facilitating lymphatic drainage, and activating cell metabolic methods, the body turns into more green in its features. Consequently, the general properly-being of someone improves, muscle tone will increase, and tension and pain decrease. Improved blood flow promotes expanded elimination of toxins and metabolic waste, which has a positive impact on pores and skin condition and normal nicely-being. Moreover, steady use of a vibrating massager strengthens the immune system, making the body greater proof against infection and sickness. This is specifically crucial in mild of contemporary environmental conditions and elevated degrees of pressure.

Conclusion

The basics of programming have been studied and a test code for the address LED strip has been written. In the future, using the example of this year, it is planned to add a Bluetooth module to the lamp to control it from the phone.

Thus, a lamp was manufactured, which currently has the following characteristics: 4 strips of address tapes; the brightness of the lamp is 1300 lumens per meter; power supply is 5 Volts.

It is planned: the introduction of an Arduino board; the embedding of touch buttons for adjusting saturation and light direction.

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OVERVIEW OF MODERN VEHICLE MONITORING SYSTEMS

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Аннотация. В последние годы системы мониторинга автотранспорта стали неотъемлемой частью логистических процессов во многих компаниях. Актуальность использования таких систем обусловлена несколькими факторами. Точное планирование и контроль процесс доставки грузов, это исключает возможность простоев и задержек. Анализ времени в пути, простои и частоту доставок, что ускоряет процесс доставки и повышает удовлетворённость клиентов. Так же отслеживание маршрута и условий перевозки гарантирует сохранность продукции и соблюдение стандартов доставки. В современной экономике, где эффективность и снижение издержек являются ключевыми факторами успеха, использование систем мониторинга становится неотъемлемой частью бизнес-процессов.

Ключевые слова: Система мониторинга, автотранспортные средства, логистика, оптимизация маршрутов, безопасность перевозок, угоны, Global Tracer, Mobitel, GPS, спутниковая навигация, диспетчерский центр, бортовое оборудование, путевые листы, CDMA, GSM, THURAYA, Bluetooth, низкоорбитальные спутниковые системы, Гонец.

Annotation. In recent years, vehicle monitoring systems have become an integral part of logistics processes in many companies. The relevance of using such systems is due to several factors. Precise planning and control of the cargo delivery process, which eliminates the possibility of downtime and delays. Analysis of travel time, ease and frequency of deliveries, which speeds up the delivery process and increases customer satisfaction. Tracking the route and conditions of transportation also guarantees the safety of products and compliance with delivery standards. In today's economy, where efficiency and cost reduction are key success factors, the use of monitoring systems is becoming an integral part of business processes.

Keywords: Monitoring system, vehicles, logistics, route optimization, transportation safety, hijackings, Global Tracer, Mobitel, GPS, Satellite navigation, Control center, on-board equipment, waybills, CDMA, GSM, THURAYA, Bluetooth, low-orbit satellite systems, Messenger.

Introduction

In recent years, vehicle monitoring systems have become an integral part of logistics processes in many companies. The relevance of using such systems is due to several factors. Firstly, vehicle monitoring can improve the efficiency of logistics operations. Thanks to them, it is possible to optimize delivery routes, reduce transport downtime and fuel costs. This is especially important for large companies with a large fleet and engaged in long-distance transportation. Secondly, monitoring systems enhance transportation safety. They allow you to track vehicles in real time and quickly respond to changes in traffic. For example, if a driver encounters an unexpected situation on the road, they can contact the dispatcher for help. Thirdly, vehicle tracking helps prevent theft and unauthorized access. Let's look at some similar systems.

The main part

Global Tracer Vehicle Monitoring System

This vehicle tracking system includes:

1. on-board equipment;
2. dispatch center.

On-board equipment is a "black box", which contains a central processor, GPS receiver, memory unit, and GSM communication unit. This "black box" is installed unobtrusively in the car and does not reveal itself visually or acoustically. The dispatch center is based on the client's personal computer and consists of: — special "Tracer" modems for both fixed and mobile telephone networks; — software that monitors vehicles in automatic mode and generates waybills; — a set of electronic cards. The Tracer system uses an integrated GPS receiver to locate the vehicle. GPS (Global Positioning System) is a satellite radio navigation system developed by the US Department of Defense. It consists of GPS receivers that receive signals from satellites [2].

Radio navigation satellites determine the coordinates of objects with high accuracy in any weather. Satellites transmit navigation information free of charge. The received coordinates are stored in the non-volatile memory of the "black box", which can be controlled from a control panel. The interval for recording can be selected from 1 second to several hours. If an interval of 3 minutes is chosen, then the memory will last for 400 hours, so the Tracer system records the entire route traveled by the vehicle continuously. Coordinates can be transmitted in two ways: remotely or directly. The Tracer allows you to locate a car at any time and show its position on an electronic map while connected remotely [1].

The system communicates with the "black box" at a preset frequency and requests information about the current location of the car or route traveled. A network is used for remote communication with the dispatcher. The dispatch center can get information about a car's route for a certain period of time.

A GSM 900/1800 mobile phone is used to communicate with the control panel. A regular SIM card from any GSM network is installed in the "black box". After the connection is established, the control center automatically switches to the next car. After all cars have been called sequentially, it returns to the first car and the process starts again.

The Global Tracer system has several advantages:

1. Difficult to access installation reduces the likelihood of unauthorized access.
2. Ability to remotely change recording interval.
3. a large amount of internal memory in the device, allowing you to read the route traveled by the car during a trip when returning to base;
4. data transmission to control panel in online mode;
5. ability to use any GSM operator during trip thanks to Roaming function;
6. acceptable technical specifications for the system.

The main disadvantages of Global Tracer are:

1. use of GSM mobile phone as voice communication channel leading to low immunity and higher probability of signal interception;
2. lack of information on vehicle movement if it leaves coverage area of GSM operator;
3. no transmitted info about vehicle systems.

Mobitel remote vehicle monitoring system. Mobitec's remote vehicle monitoring solution is designed to collect & transmit info about location & condition of remote mobile objects.

Mobitel Remote Vehicle Monitoring Controller

It is installed in a car and allows receiving operational information about its location (using GPS satellite navigation) and the status of sensors connected to the device. Data can be transmitted over a radio channel (CDMA, GSM, Thuraya) in real time or upon request (Teletrack modification), or stored in non-volatile memory for subsequent transmission to the control system via wireless connection (radio modem, Bluetooth, or using a cable). A combination of these modes is also possible. The device is intended for dispatching services by public and private passenger fleets, security services, and individual clients.

Functions of the Mobitel dispatching system include:

1. operational control of routes and schedules;
2. automatic warning of deviations from set routes;
3. The ability to control passenger traffic;
4. Cost savings through route analysis and planning;
5. Dispatcher's help in choosing the optimal route for a taxi.

One should evaluate the advantages and disadvantages of the Mobitel system.

The advantages of Mobitel include:

1. A wide range of features for each application;
2. A large number of possible installed sensors and control channels;
3. Various methods of data transfer; Acceptable technical specifications;
4. Ability to use SMS to transmit data;
5. Transmission of information from automotive systems' sensors and linking them to coordinates.

Disadvantages of Mobitel:

1. Low accuracy in determining coordinates;
2. Lack of information about a car's movement when it leaves the GSM coverage area;

Satellite systems

Since the 1990s, there has been a new trend in satellite technology.

Communications have been developing based on low-orbit spacecraft. LEO (Low Earth Orbit) satellites include spacecraft with orbits ranging from 700 to 1,500 kilometers high. A low-orbit constellation may include from one to several dozen small satellites weighing up to 500 kilograms. Orbits are used to provide communication over a large area of Earth, which may contain several spacecraft in different planes. The increased interest in low-orbit satellite communications is explained by the possibility of providing personal communication services, including radiotelephone exchange, using relatively cheap small-sized satellite terminals. Low-orbit systems allow for uninterrupted communication with terminals located anywhere on Earth and have virtually no alternatives when organizing communications in regions with underdeveloped communication infrastructure and low population density.

One of the main advantages contributing to the development of low-orbit satellite communication systems is the biological factor. So, to ensure biological protection of humans from UHF radiation, the recommended continuous radiation power level of a radiotelephone is no more than 50 MW. The effective reception of a signal of such power by a geostationary satellite is associated with significant spacecraft complexity, deployment of large antennas, and their precise positioning. For low-orbit satellites, there are many fewer radio lines and the problem of multipath antennas is less acute. These systems include Iridium and Globalsat, which were created by foreign consortia led by large manufacturing companies such as Motorola/Lockheed and Qualcomm/Loral.

Several low-orbit systems were created over the past decade, but for limited applications, mainly related to the transmission of short and relatively rare messages (for example, the first project of Russian Gonets-D systems). Only the tempting idea of global personal communication based on modern technology has revived interest in low-orbit satellite systems. Satellite radio navigation systems Multifunctional personal satellite communication system Gonets-DM (MSPCC) The Gonets low-orbit communication system has passed through all stages

The development and deployment of the Gonets-D1M MSPCC is currently underway. The main purpose of this system is to transmit data and provide mobile satellite communications services to subscribers globally using a constellation of low-orbit communication spacecraft. The orbital grouping of Gonets-M spacecraft is 12 low-orbit satellites.

Conclusion

Transport monitoring systems such as GlobalTracer and Mobitel help to make transportation more efficient and safer. They also help you choose the best route and save on fuel. These systems monitor the movement of cars.

Each system has its own pros and cons. GlobalTracer is difficult to install, but it has a lot of memory and transmits data at once. But it has a weak signal, and it does not transmit information about cars.

Mobitel transfers data quickly, stores it in memory and transmits it wirelessly. It transmits information about cars, but it has a weak signal, it does not transmit data about cars outside the signal area and does not transmit data about the condition of cars by radio.

The choice of system depends on what the company needs and how much money it has. It is important to know the pros and cons of each system in order to choose the right one.

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DEVELOPMENT OF THE STRUCTURAL SCHEME OF THE VEHICLE CONTROL SYSTEM

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Аннотация. В этой статье рассматривается разработка системы слежения за транспортным средством, которая отслеживает местоположение, скорость, уровень топлива и ошибки в электронных модулях управления транспортным средством, а также другие параметры. Ключевые компоненты системы включают в себя источник питания, сенсорную систему, микроконтроллер, дисплей, клавиатуру, GPS, Ethernet-соединение, спутниковую связь и регулятор напряжения.

Особое внимание уделено протоколу CAN для передачи данных и протоколу NMEA 0183 для работы с GPS. Кроме того, выделено использование протокола Ethernet для мониторинга параметров транспортного средства в режиме реального времени. Система позволяет владельцам получать информацию о состоянии транспортного средства и принимать меры по оптимизации его использования.

В процессе разработки учитывается взаимодействие между компонентами системы посредством различных протоколов связи для обеспечения надежности и эффективности.

Ключевые слова: Система контроля, местоположение, скорость, уровень топлива, параметры транспортных средств, мониторинг, электронные блоки управления, микроконтроллер, индикаторы режимов работы, клавиатура, система GPS, терминал спутниковой связи, питание, датчики, CAN-шина, NMEA 0183, UART, MAC-адрес, Ethernet.

Annotation. The article discusses the development of a vehicle tracking system that monitors the location, speed, fuel level, and errors in electronic control modules of a vehicle, as well as other parameters. The key components

of the system include a power supply, a sensor system, a microcontroller, a display, a keyboard, GPS, an Ethernet connection, satellite communication, and a voltage regulator.

Special attention is paid to the CAN protocol for transmitting data and the NMEA 0183 protocol for working with GPS. Additionally, the use of the Ethernet protocol for real-time monitoring of vehicle parameters is highlighted. The system allows owners to obtain information about the vehicle's condition and take measures to optimize its use.

The development process considers the interaction between the system components through various communication protocols in order to ensure reliability and efficiency.

Keywords: Monitoring system, location, speed, fuel level, vehicle parameters, monitoring, electronic control units, microcontroller, operating mode indicators, keyboard, GPS system, satellite communication terminal, power supply, sensors, CAN bus, NMEA 0183, UART, MAC address, Ethernet.

Introduction

This article discusses in detail the development of a structural scheme for vehicle control systems. This system is an innovative solution to ensure efficient vehicle management and monitoring. It has a wide range of functions that allow you to track the location, speed, fuel level and various technical parameters of the car in real time.

The main components of the system include a GPS tracker for determining coordinates, speed and fuel level sensors, as well as modules for data collection and transmission. Modern wireless communication technologies such as GSM/GPRS or satellite communications are used to ensure reliable operation of the system.

The vehicle control system is widely used in various fields, including logistics, transportation and cargo transportation, taxi and carsharing services, as well as private cars. It allows you to optimize routes, reduce fuel and maintenance costs, as well as ensure safety and control over the movement of vehicles.

The main part

The main components of the system are: power supplies, sensors, microcontrollers, displays, keypads, Global Positioning System (GPS) and Ethernet. These components work together to effectively monitor and control the operation of the vehicle. A diagram of these components is shown in Figure 1.

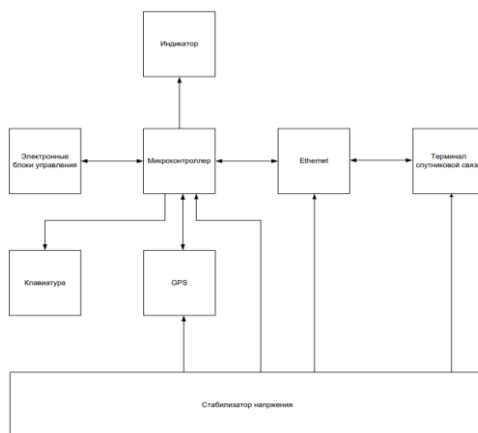


Fig.1 - Structural diagram of the vehicle control system

The "Voltage Stabilizer" unit provides stable power to the units that need it: the "Microcontroller", "GPS", "Messenger", and "Ethernet". All necessary information is read from Electronic Control Units, which is transmitted via CAN bus to Microcontroller for further processing using ISO11898(CAN) and ISO15765(CAN). The Microcontroller receives information from Electronic Control Unit and processes and transmits the received data to other units. The Operation mode indicators warn about various problems with the car, such as low fuel level or low pressure. The Keyboard is used to enter data, control monitoring functions, and enter commands. The GPS System determines the location [1].

Using satellites, it also performs navigation functions and monitors the route. The "Ethernet" block is responsible for the interaction between the "Microcontroller" blocks and "Satellite communication terminal". The Satellite Communication Terminal collects data on the vehicle's location, speed, distance traveled, departure and arrival times, fuel level and other parameters. This data is transferred to a central server where it can be analyzed and used for decision making. Description of protocols used to receive and process data from electronic control units. The CAN (Controller Area Network) communication protocol is a popular protocol used in the automotive industry for exchanging data between various vehicle components. The choice of the CAN protocol for intra-car communication has several justifications: - Reliability: The CAN protocol ensures reliable data transmission using an error correction algorithm which avoids [2].

Loss or distortion of information; Scalability: CAN supports a large number of devices connected to the network and provides efficient data traffic

management to avoid network congestion; Easy to use: CAN provides a simple and intuitive interface for programming and configuring devices, making the process easier for development and debugging of automotive systems. The CAN bus, being a digital communication and control system for electronic devices, allows the exchange of information between control units. The network has three main operating modes - active when the ignition is on, dormant when the ignition off, and finally, wake-up and sleep mode when the ignition turned on and off. The CAN Bus performs a number of tasks including speeding up the transmission of signals to different systems, mechanisms, and devices, reducing the number of wires and simplifying the connection and operation of additional devices.

According to CAN standards, it is assumed that there is a twisted pair of insulated conductors to which sensors of all other systems are connected. A CAN bus device consists of two wires that form a twisted pair. They are used to communicate between vehicle systems. These wires connect to the router, where different busses exchange data. The compact bus housing has a variety of connectors for cables. Signals from all devices travel through the CAN bus and are processed instantly. If no signal is received from a sensor, the system notifies the driver about a malfunction in any device. There are three main types of buses: power, comfort, and information and command. The power bus connects engine and transmission units, and the software signal is transmitted at a maximum speed of 500 Kbps.

Comfort connects the control units of the systems responsible for maintaining conditions in the cabin: heating, lighting, air conditioning, etc. The signal speed on this bus is 100 Kbps.

The information and command room provides communication with navigation systems and third-party devices at a speed of up to 10 Mbps.

CAN bus is located in a rectangular plastic case under the hood of the vehicle, under the dashboard or directly in the passenger compartment with direct access from the driver's seat. Its location is usually specified in technical documentation and operating instructions.

Operation of CAN bus: each device installed in the car transmits and receives data using CAN controllers. Information is read in order of priority, so the device with higher priority automatically turns off the transmission of a device with lower priority after a certain period of time.

The time interval between packet transmissions to the device resumes.

The CAN bus operates according to the following principle:

- The CAN bus wires connect to the control units of each system and connect the blocks.
- The bus receives voltage from the blocks and the blocks control the voltage level.

- The difference in voltage on the wires is detected by the bus and if there is a deviation, an error is reported to the onboard computer.

- Data is sent and received in an encoded form with each message having a unique identifier.

- Decrypted information is received by a person (operator or car driver). This information can be used to analyze car operation in the future.

So, the CAN bus is a network for information exchange between devices. This means that information is exchanged between different parts of the vehicle. For example, the engine control unit has not only one main function.

A microcontroller, but also a CAN device that generates and sends pulses over the H (CAN-high) and L (CAN-low) buses, which are called a twisted pair.

The signals are sent over a twisted pair by a transceiver or a transceiver. It is needed for a number of tasks - signal amplification, line protection in case of damage to the CAN bus, creating noise immunity conditions for transmitted pulses and adjusting their transmission rate. In the automotive industry, two types of transmitters are used - High Speed and Fault Tolerant. The first one provides high-speed data transmission up to 1 megabit per second. The second one is not so fast, but it transmits up to 120 kilobits per second and is error-tolerant, allowing deviation from the parameters, while the CAN bus is less sensitive to its quality.

CAN bus operates in several modes.

The background sleep mode is activated when the engine is turned off, but the bus is still powered by the on-board network, maintaining the functioning of systems and safety. The minimum voltage applied to it is 2.5 V. In wake-up mode, the tires start when the start/stop button is pressed in the car interior. In this mode, main instruments and sensors are started. The active mode is a full-fledged exchange of information between all mechanisms and tires. At the same time, up to 85 mA of voltage is consumed. This system, like any other, has pros and cons. Some advantages include the speed of message transmission, automatic distribution of broadcast speed based on priority of nodes, simplicity of information exchange channel, high compatibility with diagnostic devices and, consequently, possibility of rapid diagnosis. Additionally, the CAN bus makes it easy to install an anti-theft system. Disadvantages include increased

In response to increased channel load, machines with numerous electronic devices can experience delays. In addition, the breakdown of one electronic control unit can disable the entire system.

The NMEA 0183 protocol, developed by the National Marine Electronics Association, defines a text communication standard for navigation equipment and has become popular due to the widespread use of GPS receivers. It

provides for transmitting text commands and messages using ASCII characters, allowing them to be sent directly to a computer via the COM port. However, it is important to remember that the signal levels must be converted before transmission. The GPS module sends messages in various formats containing different data sets, such as latitude and longitude, speed, course, and time of satellites, etc., messages are transmitted sequentially and divided into several types, the format of each type of message contains strictly defined information in its fields. Let's take a closer look at the general structure of the messages that the GPS module outputs. Every message begins with this symbol, followed by an identifier of five text characters. The first two letters indicate the type of navigation system, for example "GP" - GPS or "GL" - Glonass etc. The next three characters are the identifier for the message format which fully defines the content of subsequent transmitted data. For example, "RMC" is the recommended minimum amount of data containing information about time, date, latitude, longitude, speed, course and magnetic deviation in degrees (it may be missing). "GSA" satellite data will be transmitted here, and the structure of main message types will be discussed below.

This is followed by a ",", a comma that follows directly after the message body, with various data separated by the same comma. If the transmitted number is not an integer, then the separator between the integer and fractional parts is a dot. The end of the message is indicated by "*". This is then followed by the checksum of all characters between "\$" and "*" - that is, the entire message body, including data and identifiers at the start of the message - which is calculated as the XOR of all

Conclusion

A structural diagram of the vehicle control system has been developed. It describes the interaction of the system's components. The main blocks and functional elements of the system have been identified.

The functionality of the device includes the ability to monitor and control various vehicle parameters, such as speed, fuel consumption, battery level, and others. This allows the owner of the vehicle to receive information about their vehicle's condition in real time and take appropriate measures to maintain and optimize its use.

A hierarchical structure has been developed within the project. It includes various modules and components that interact with each other using communication protocols. These protocols allow the system to function as a single unit and ensure reliable and efficient vehicle control.

Communication protocols provide data transfer between system components, allowing them to exchange information.

The condition of the car and making appropriate decisions increases the efficiency of the system and ensures the accuracy and reliability of the

received data. Thus, the development of a structural scheme for the control system, taking into account the functionality and communication protocols of vehicles, is an important step in creating an effective and reliable monitoring and management system by road.

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CREATION AND TRAINING OF A NEURAL NETWORK FOR SPOT DETECTION IN A PHOTO

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Аннотация. Теперь технологии быстро развиваются, и цифровые прорывы интегрируются в наше существование. Люди действительно хотят сделать новые способы выяснить вещи для различных проблем. Эти технологии уже используются в медицинских, образовательных, промышленных и транспортных областях.

Автоматическое обнаружение и категоризация знаков на изображениях является одной из важнейших обязанностей. Это важно в различных областях, таких как здравоохранение для определения неровностей в образах, сельскохозяйственных условий для управления здоровьем растений и в производстве для быстрого обнаружения недостатков.

Для этой задачи была разработана специальная нейронная сеть. Это помогает анализировать изображения и заметить даже небольшие

отклонения. Компьютерный мозг учится от больших групп информации, чтобы отделить различные виды точек и сортировать их по типам.

Усовершенствованные технологии повышают точность и быстроту идентификации маркеров, тем самым снижая продолжительность анализа данных и минимизируют ошибки. Это повышает надзор за различными областями и создает шансы на новые научные исследования.

Ключевые слова: Нейронная сеть, определение пятен, фотографии, YOLO (You Only Look Once), архитектура нейронных сетей, обнаружение объектов, набор данных, разметка данных, обучение модели, скорость обучения (learning rate), эпохи (epochs), тестирование модели, метрики качества, точность (precision), полнота (recall), F1-мера, оценка качества.

Annotation. Now technology is developing rapidly, and digital breakthroughs are being integrated into our existence. People really want to make new ways of figuring things out for various problems. These technologies are already being used in medical, educational, industrial, and transportation fields.

Automatic detection and categorization of signs in images is one of the most important responsibilities. This is important in various fields such as healthcare to identify irregularities in images, agricultural conditions to manage plant health, and in manufacturing to quickly detect deficiencies.

A special neural network has been developed for this task. It helps to analyze images and notice even small deviations. The computer brain learns from large groups of information to separate different kinds of points and sort them by type.

Advanced technologies increase the accuracy and speed of marker identification, thereby reducing the duration of data analysis and minimizing errors. This increases the oversight of various fields and creates chances for new scientific research.

Keywords: Neural network, spot detection, photographs, YOLO (You Only Look Once), neural network architecture, object detection, dataset, data markup, model training, learning rate, epochs, model testing, quality metrics, precision, completeness, F1 is a measure, a quality assessment.

Introduction

Due to all the technological advances that are taking place these days and the increasing number of digital tools used in everyday life, we can use them to solve various problems. One of these tasks is the automatic detection and classification of spots in images. To solve this problem, we have created a unique neural network that is designed to analyze images with different spots.

The main part

The process of developing a neural network for spot detection in a photo includes several important steps. To begin with, a suitable neural network architecture is selected. For this task, the choice fell on the YOLO architecture, because, as everyone who is interested in it knows, it is designed to detect objects in images and videos, and it is effective and works quite quickly.

Step 1: Data Preparation in the first stage of training, we need to prepare a dataset. The dataset should consist of images containing spots. It is very important that the images differ in size, shape, and color of the spots, as this allows the model to learn from different examples. Data is collected from various sources: personal photos or images taken by specialized devices, such as surveillance cameras. It must be remembered that the data must correspond to the specified task and cover several spots. After collecting the data, they need to be analyzed. Data annotation includes specifying the location and characteristics of objects in each image. This can be done manually or automatically. Manual annotation requires a lot of effort and a lot of time, but it gives high-quality results.

To create annotations manually, you can use special programs such as LabelMe, Labelbox or VGG Image Annotator. With their help, users can quickly add captions to images, noting the location and nature of objects. Semi-automatic annotation uses machine learning systems that automatically identify certain parameters of objects. This optimizes the time spent on annotating the data. However, even in this case, a person needs to check and edit the data in order to increase accuracy.

Step 2: Pre-processing

The stage following the data collection with annotation requires preprocessing. This step is composed of a few core actions.

1. **Data normalization:** Uniformly scaling all images to set bounds improves values convergence which assists with training the neural network.

2. **Data Extension:** The transformation of an image by rotating, zooming, or reflecting it to develop new images from existing models augments the data set and improves the generalizing ability of an image model.

3. **Data Separation:** Partitioning data into a training set, validation set, and test set helps estimate model performance. The training set allows the model to learn, the validation set assists in adjusting the model's hyperparameters, and the test set finally determines how good the model is.

4. **Model Training:** A neural network is trained with the training data to enable the model makes future predictions. In this work, after the data has been preprocessed, the model should be trained. Training the model includes several important steps, including.

Picking out an object detection model is critical attention to detail since it has the ability to make or break the success of the project. Because the YOLO model is well known for being extremely reliable in object detection, we opt to use it in this case.

The following items are part of the YOLO architecture:

1. Backbone: The backbone is the main section of the object detection model that image object detection. The backbone of the YOLO model is built with CNN frameworks such as ResNet, VGG or EfficientNet.

2. Neck: The neck section retrieves all of the relevant information that was processed at different layers of the base and uses it for final prediction. The \concatenation of the object method was employed for this in YOLOv3.

3. Head: The head takes the constructed objects and translates them into the predictions vis-a-vis object location and dimensions. This is done using the prediction engine (detection head).

A well defined process of optimizing the learning of a machine learning model is a well calibrated definition of the hyperparameter boundaries. These are such as learning rate, total number of periods for training, and size of one group of a given batch.

The loss function plays a crucial role in figuring out how well the model can predict the labels of various objects. When we talk about tasks that involve detecting features, we often lean on loss functions such as Intersection over Union (IoU) or Average Accuracy. These help gauge how accurate the model's predictions are. On the other hand, the optimizer is key in deciding how to adjust the model's weights based on the errors it makes. Popular choices for optimizers in object detection are Adam and Stochastic Gradient Descent (SGD).

Once we've trained the model, it's time to see how well it performs on new data. For this, we need to gather a dataset that hasn't been touched during training. This new data should reflect the issue at hand and include images featuring objects that the model hasn't seen before.

To truly assess how good the model is, we look at different metrics like accuracy, precision, and the F1 score. Accuracy simply tells us what percentage of the predictions were correct. Precision, on the other hand, measures how many of the predicted positives were actually true positives. The F1 score gives us a combined view of accuracy and precision, acting like a balance between the two.

After we take a look at these numbers, it's a good idea to figure out what they tell us. We want to spot any chances to make the model better. This means checking out where the model made mistakes and seeing if there's any pattern there. We should also pay attention to the parts where the model didn't do as

well. This way, we can figure out what areas we need to work on to see better outcomes.

Next, once we've gone over the test results, we can get started on making the model better. This usually includes a few important steps: first, we'll look closely at what worked well and what didn't. Some changes are figure out. Finally, we'll take another round of testing to check if our updates are hitting the mark.

1. First off, boosting the amount of training data can really help the model generalize better and cut down on errors. We can do this by using data augmentation techniques or simply gathering more data.

2. Another good approach is to tweak the model's architecture. Sometimes just making it deeper or wider can yield better results.

3. Adjusting hyperparameters can also lead to improvements. To find the best settings, we can use processes like grid search or random search to look for optimal values.

4. There are also advanced techniques like bagging and boosting that can significantly improve performance. These methods work by combining multiple models to produce more reliable outcomes. Figure 1 shows the process of training a neural network to detect objects from a prepared database.

One should consider the concept of spot detection using neural networks.

Spot recognition on different surfaces is basically a smart way of spotting and categorizing stains with the help of neural networks. When the system sees a new spot, it can figure out what it is based on what it has already learned.

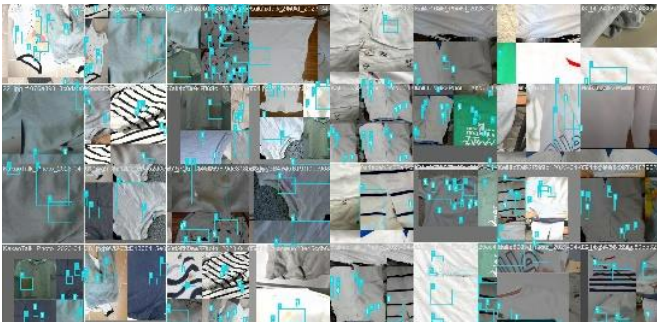


Fig.1 - The learning process of neural networks

There are some benefits of using neural networks for this kind of work.

- they can be really accurate. This kind of accuracy can be super useful, especially in fields where getting things right the first time is crucial. When

the system has a lot of examples to learn from, it can get pretty spot on with recognizing stains.

- these neural networks are flexible. One can train them to recognize all sorts of stains on all kinds of surfaces, making them fit for various jobs.

- it makes the whole process a lot easier. Since the neural networks can automatically detect stains, it cuts down on the need for human workers to do that job. This not only speeds things up. There's less manual work involved.

As for where this technology is applicable, there are loads of areas where it could really help out. For instance, companies could use it to check the quality of their products by making sure there are no unwanted stains before items get shipped out. Or it could even be utilized in sorting processes, ensuring that items are categorized correctly based on whether they're clean or stained.

Conclusion

Today, this neural network can be used in various fields where fast and accurate spot detection is required in photographs. For example, in industry for product quality control, in agriculture for the detection of plant diseases, and in many other fields.

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ARTIFICIAL INTELLIGENCE IN HUMAN PERSONAL AND SPIRITUAL DEVELOPMENT: CHALLENGES AND RISKS

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Аннотация. Распространение искусственного интеллекта благоприятствует человеческому развитию, но существуют скрытые угрозы для духовности и нравственности, что является серьезной социально-культурной проблемой современности.

Представлены преимущества и риски использования искусственного интеллекта для личностного развития. Описана этическая сторона использования нейросетей и потенциальные угрозы в духовном развитии личности.

Ключевые слова: нейросеть, духовность, нравственность, этика, ответственность, творчество, личностное развитие.

Annotation. The spread of artificial intelligence provides human development, but there are hidden threats to spirituality and morality, which is a serious socio-cultural problem of our time. The advantages and risks of using artificial intelligence for personal development are presented. The ethical aspect of using neural networks and potential threats to the spiritual development of the individual are described.

Keywords: neural network, spirituality, morality, ethics, responsibility, creativity, personal development.

Introduction

Artificial Intelligence (AI) has become an integral part of the modern world, transforming almost every sphere of human life. “In an era where digital transformation and technological innovation are pivotal to economic growth, Artificial Intelligence (AI) has unquestionably progressed alongside many other cutting-edge technologies such as RISC-V architecture promises to fundamentally alter the business landscape” [3, p.188].

AI shows incredible potential to optimise processes, analyse data and create new forms of interaction. “These advancements offer enterprises novel opportunities for operational optimization, enhanced decision-making, and the development of innovative products and services, thereby strengthening competitive edge and fostering sustainable growth” [3, p. 188]. But, on the other hand, AI is beginning to impact deeper aspects of human existence, including personal and spiritual development [1].

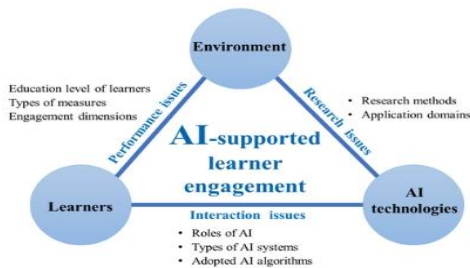
The relevance of the study is that, on the one hand, digitalization has led to serious transformations of the social structure, which has simplified our lives, but, on the other hand, artificial intelligence has a contradictory impact on modern society [7]. “AI arose to overcome the “human factor” as, in particular, a manifestation of the spiritual and moral assessment of the surrounding reality” [2, p. 170].

Materials and methods

The ethical issues of the influence of artificial intelligence on humans have been studied in sufficient detail by scientists: the danger of violating the boundaries of personal social space [4, 5], the negative consequences for spiritual and moral development [2], and the rethinking of the capabilities of human intelligence (using ChatGPT as an example) [6] are emphasized.

Artificial Intelligence role in personal and spiritual development was considered by Bodong Chen Xinran Zhu [4], Lee H.-Y., Cheng Y.-P., Wang W.-S., Lin C.-J., Huang Y.-M. [6], Chen X., Xie H., Qin S. J., Wang F.L. Yinan Hou [5], E.G. Popkova [2].

This article is aimed at considering how AI is affecting human spiritual growth, the challenges it presents, and the opportunities it offers for self-discovery, self-realisation and the search for meaning in life. One should discuss how to maintain a balance between technological progress and preservation of human essence in the era of digital transformation (pict. 1).



Picture 1. AI-supported learner engagement

Source: [4].

Artificial intelligence role as a tool for self-knowledge and personal growth is presented in table 1.

Table 1. Artificial intelligence as a tool for self-knowledge and personal growth

AI contribution	Features
Emotion and behaviour analysis	AI can determine a person’s emotional state. This enables the creation of tools that help people better understand their feelings, manage stress and develop emotional intelligence.
Personalised learning	AI is used in educational platforms, where it creates personalised learning programmes for appliction not only to academic knowledge, but skills related to personal growth, such as time management, communication and critical thinking.
Access to spiritual practices	AI makes spiritual practices. Virtual assistants can offer guided meditations or even analyse the user’s progress.

Despite its benefits, artificial intelligence poses a number of serious challenges to humanity that can hinder personal and spiritual growth (table 2).

Table 2. Challenges of AI's impact on spiritual development

Risks	Serious challenges to humanity
Risk of losing the depth of human experience	AI is unable to understand the true nature of spiritual experiences, which often transcend logic and rationality, that cannot be fully described or replicated by technology.
Dependence on technology	The risk of technology dependency increases. People may begin to rely on virtual assistants and algorithms even to make decisions related to their personal lives.
Erosion of human values	AI can be programmed to perform tasks that contradict ethical or spiritual principles.
AI and ethical issues of spiritual development	The development of artificial intelligence raises a number of complex ethical issues that are directly related to human spiritual development.
Cultural and religious sensitivities	AI should take into account the cultural and religious characteristics of users. This requires AI developers to have a deep understanding of and respect for the diversity of human beliefs.
Free will and individual autonomy	The use of AI to make decisions raises the question of free will. This is particularly important in the context of spiritual development
Manipulation of consciousness	AI can be used to manipulate people's consciousness. This poses a threat to spiritual development, as a person can become the object of external influence.
AI as a catalyst for spiritual development	Despite the challenges, artificial intelligence can be a powerful catalyst for new forms of spiritual enquiry
Philosophical issues	The development of AI is forcing humans to think about their uniqueness, the nature of consciousness and free will.

A key aspect of AI's impact on spiritual development is finding a balance between technological advancement and the preservation of humanity. Artificial intelligence must remain a tool that serves human beings rather than replacing them. For this purpose, it is important to develop awareness, critical thinking and the ability to reflect (table 3).

Table 3. A balance between technological advancement and the preservation of humanity

AI in personal development	Consequences
Conscious use of technology	Humans must be able to disconnect from technology to make time for inner dialogue and spiritual practices
Developing critical thinking	It is especially important to develop critical thinking so as not to fall prey to manipulation or false information.
Preserving human values	Technology should not replace human values. It requires to develop ethical standards that will guide the development of AI in a direction that promotes spiritual and personal growth

Conclusion

Artificial Intelligence has a profound impact on human personal and spiritual development. It opens up new opportunities for self-discovery, learning and interaction, but it also presents us with significant challenges. To harness the potential of AI for good, it is important to stay connected to our inner values, develop mindfulness and strive for harmony between technological advancement and spiritual growth.

Ultimately, it is up to us whether AI will become a tool for deepening human wisdom or will lead to the loss of spiritual depth. In the era of digital transformation, it is important to remember that technology is only a means, and the true meaning and purpose of life must be sought within oneself.

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AN EXPLORATION OF THE STATE INFORMATION SYSTEM IN RUSSIA

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Аннотация. В статье подробно рассматривается Государственная информационная система (ГИС) в России, комплексная структура, предназначенная для управления и распространения информации в различных секторах, включая правительство, здравоохранение, образование и государственные услуги. Обсуждение начинается с обзора структуры и функций ГИС, в котором выделяются ключевые компоненты. В статье подчеркивается значение ГИС в улучшении

управления, прозрачности и эффективности. Также обсуждаются меры по преодолению этих проблем.

Ключевые слова: Россия, электронное управление, Государственная информационная система, кибербезопасность, конфиденциальность данных, цифровая трансформация.

Annotation. This article provides an in-depth exploration of the State Information System (SIS) in Russia, a comprehensive framework designed to manage and disseminate information across various sectors, including government, healthcare, education, and public services. The discussion begins with an overview of the structure and functions of the SIS, highlighting key components. The article emphasizes the significance of the SIS in improving governance, transparency, and efficiency. Measures to overcome these challenges are also discussed.

Keywords: Russia, e-governance, State Information System, cybersecurity, data privacy, digital data.

A state information system (“SIS”) as a cornerstone of the country’s digital transformation, was being created where anonymised personal information would be collected to organize datasets and where this information would be processed. SIS was formed according to “Federal Law No. 233-FZ “On Amending the Federal Law On Personal Data and the Federal Law On Conducting an Experiment to Establish Special Regulation to Create the Necessary Conditions for the Development and Implementation of Artificial Intelligence Technologies in the Constituent Entity of the Russian Federation — the City of Federal Significance Moscow — and Amending Articles 6 and 10 of the Federal Law On Personal Data” (“Law”)” [1] which was signed by the President of the Russian Federation on the 8th of August 2024. It is expected that the implementation of the Law will contribute to reducing the turnover of processed personal data and improving its security [3].

The State Information System (SIS) in Russia is serving as a comprehensive framework for managing and disseminating information across various sectors, including government, healthcare, education, and public services. SIS in Russia is a critical component of the country’s digital infrastructure, designed to streamline the management and dissemination of information across various sectors.

The SIS includes a wide range of subsystems for healthcare, education, taxation, and public administration. In Russia it is a multi-layered system that integrates various subsystems to ensure the efficient management of information [4]. It plays a role in modernizing governance and improving public service delivery in Russia (table 1).

Table 1. The SIS as a multi-layered system

Benefits	Features
Enhanced Transparency	By digitizing government operations, the SIS increases transparency and reduces opportunities for corruption. Public access to government data and decision-making processes fosters trust and accountability [6].
Improved Efficiency	The SIS streamlines administrative processes, reducing paperwork and speeding up service delivery. For example, the Gosuslugi portal allows citizens to access a wide range of services online [5].
Increased Accessibility	“The SIS makes public services more accessible to citizens, particularly those in remote and rural areas. Online platforms eliminate the need for physical visits to government offices...” [2, p. 19].

Despite its benefits, the SIS in Russia faces several disadvantages:

1. Technological Modernization
2. Cybersecurity Threats
3. Data Privacy Concerns

Disadvantages of the SIS in Russia

Interoperability Issues.

The Russian government has to implement some measures to overcome these challenges.

The future of the SIS in Russia will be shaped by several key trends:

1. Increased Use of AI and Machine Learning [6].
2. Expansion of E-Governance.
3. Adoption of Blockchain.
4. Enhanced Citizen Engagement.
5. Focus on Sustainability.

Under the “Federal Law No. 233-FZ control and supervision over the implementation of organizational and technical measures to ensure the security of personal data established in accordance with this article, when they are processed in state information systems of personal data [1].

Conclusion. SIS in Russia is a critical component of the country’s digital infrastructure, designed to streamline the management and dissemination of information across various sectors. As Russia moves towards a more digital future, the SIS will play a crucial role in shaping the country's governance and public service delivery. Despite the challenges it faces, the SIS continues to evolve, driven by technological advancements and government initiatives.

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EDUCATIONAL AND RESEARCH STAND BASED ON MOBILE NETWORK EMULATOR

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Аннотация. В статье рассмотрены вопросы реализации учебно-исследовательского стенда на основе эмулятора мобильной сети второго поколения. В качестве эмулятора опорной сети определен вариант инсталляции открытого программного обеспечения с исходным кодом. Определены возможности мобильной связи, которые доступны для тестирования надежности, задержек и многих других параметров. Возможно использование созданного эмулятора мобильной сети при обучении студентов телекоммуникационного направления.

Ключевые слова: мобильная связь, базовая станция, 2G/GSM, SDR, эмуляция мобильной сети.

Annotation. The article considers issues of implementation of educational and research stand on the basis of a second-generation mobile network emulator. An open-source software installation option has been defined as the emulator of the host network. Defined mobile capabilities that are available for testing reliability, delays and many other parameters. It is possible to use the created mobile network emulator when teaching telecommunication students.

Keywords: mobile communication, base station, 2G/GSM, SDR, mobile network emulation.

Introduction. Despite the availability of regulatory documentation on mobile networks, when it is necessary to deploy a mobile network for research purposes, significant financial and time costs are required to create and deploy your network. With the advent of open-source projects for mobile network emulation, it allows you to implement a mobile network for research tasks without attracting significant investments with a minimum amount of equipment used.

Main part. To deploy a mobile network emulator, elements such as software that emulates the operation of a mobile network within the framework of the GSM protocol stack, the hardware on which this program is to be executed, as well as interfaces connecting the mobile network to users' devices are required. The system should also include a radio signal generation node based on a software-defined SDR radio. During the implementation of the mobile network emulator, a training and research stand was developed, the block diagram of which is shown in Fig. 1, where an Osmocom-based solution was chosen as the software [1], a computer was used as the hardware and a LimeSDR with a panel antenna was used as a radio path.

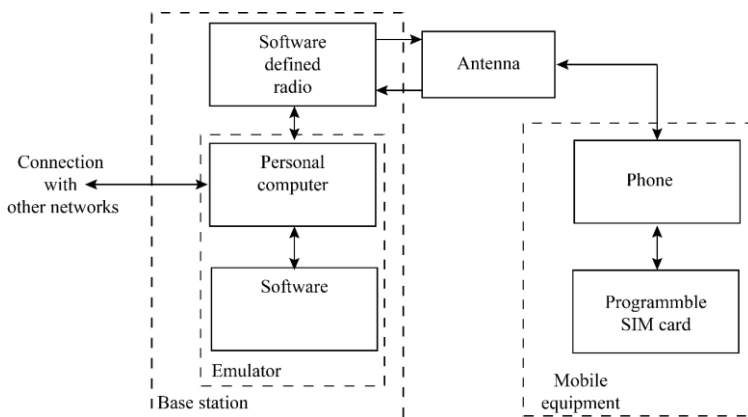


Fig. 1 — Structural diagram of the educational and research stand

The educational and research stand consists of a base station and user equipment. The base station includes an emulator, external wired and wireless communication interfaces, SDR and antennas. The user equipment includes a phone with a programmable SIM card.

The key element enabling the implementation of a mobile network is software-defined radio technology, which allows complex signal processing to be transferred from the hardware to the software, using Lime Microsystems' LimeSDR platform. LimeSDR itself provides an intelligent and flexibly configurable device for generating and processing radio signals, which allows for research and development of new mobile communication systems. The relevance of second-generation network research is explained by its use in the foreseeable future [2]. The conducted estimates [3, 4] show that it is possible to implement the operation of a 2G/GSM mobile network radio path based on LimeSDR.

A computer based on an x86-64 processor and an i5-9400 processor with an Internet connection and an antenna connected to the LimeSDR unit were used as hardware for software deployment.

The software part of the mobile network is implemented using the Linux operating system based on the Ubuntu distribution, using additional libraries — SQLite, libfftw3-dev, build-essential, libscdp-dev, ethtool, libzmq3-dev, libmbedtls-dev and others, as well as open-source software from Osmocom that implements the operation of the mobile 2G/GSM networks.

Osmocom's software package consists of libraries, modules, and interfaces that implement elements of a mobile network system and communications between them. The system generates a second-generation mobile network that meets the requirements of the 3rd Generation Partnership

Project (3GPP). Figure 2 shows a block diagram of the emulator software [1], consisting of modules and communication interfaces that are functionally related to a radio access network or a reference network.

The radio access network is responsible for the wireless connection of mobile subscribers via a radio interface to the network and consists of such elements as:

- OsmoBTS — the base transmitting station, which is the interface between the Um radio interface towards the phone and the A-bis wired interface towards the BSC;
- OsmoBSC — the base station controller, which is the interface between the A-bus interface towards BTS and the A-interface towards MCS;
- OsmoPCU — package management element;
- OsmoMGW — A media gateway that provides processing of user (voice) traffic in cellular networks, as well as transmission and processing of voice stream between various network elements such as BTS and external SIP facilities;
- OsmoSMCLC — A location center that allows you to calculate the location of mobile stations (phones) based on the network.

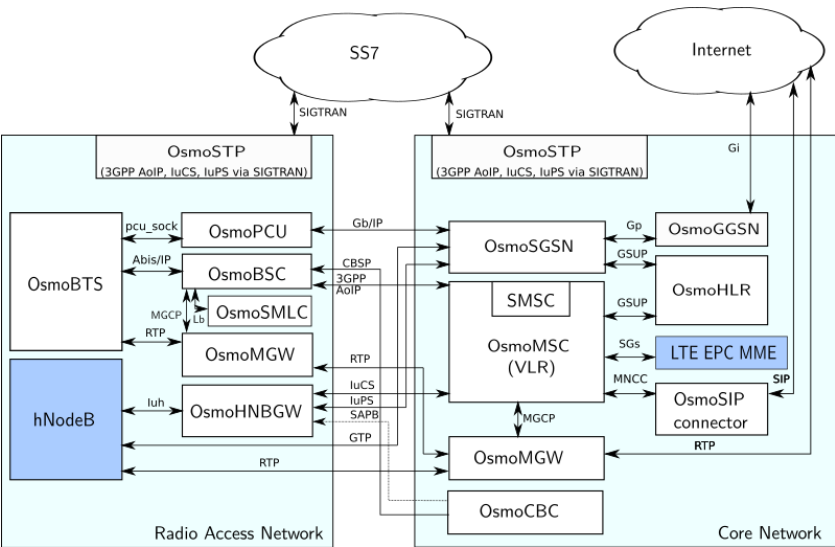


Fig.2 — Block diagram of the mobile network emulator software

The backbone network is responsible for call switching, subscriber management and mobility, as well as data transmission outside and consists of:

— OsmoHLR — Home Location Register (HLR), providing storage of information about subscribers;

— OsmoMSC — Mobile Switching Center (MSC), connecting the backbone network to the radio access network;

— OsmoCBC — Cell Broadcast Centre (CBC), providing broadcast management within the network;

— OsmoSIP connector — provides communication between Mobile Network Call Control (MVCC) and external IP telephone services;

— OsmoGGSN — Gateway GPRS support node, which is a connecting element between a mobile and an external network via packet data transmission;

— OsmoSGSN — Serving GPRS Support Node, a GPRS support node;

— OsmoSTP — Signal Transfer Point, which implements MTP routing, as well as SIGTRAN SG (Signaling Gateway) functionality.

The fact that the mobile network consists of separate modules allows you to create networks with different functionality. In the basic network, only voice and text communication between subscribers is possible. Packet transmission is possible in an extended network, and it is possible to work with third and fourth generation networks. Regardless of the selected module configuration, there are the following options for launching a mobile network:

1) Sequential execution code with configuration of each network element;

2) Sequential Run of Daemons with configuration of each network element;

3) Launch the bash script of all demons.

Before starting the mobile network, you need to determine its configuration and configure the selected configuration, for which there are the following options:

1) Use of built-in VTY interfaces in each of the modules;

2) Pre-configure configuration files before starting the network.

Built-in interfaces such as telnet VTY and Control interface allow:

— to examine the current state of the system, including its configuration parameters, and to view the status and statistics of execution time;

— view current (working) configuration;

— performing interactive configuration changes (for those elements that do not require a program restart);

— store the current configuration in a configuration file;

— enable or disable logging, for the VTY itself or for other purposes.

The mobile network is launched in several steps, requiring configuration files to be pre-configured:

- 1) Services are launched in the host network using STP, MSC, HLR, CBC and MGW modules;
- 2) The SDR is connected to the computer and the TRX module is started from the radio access network;
- 3) The BSC module is launched in the backhaul;
- 4) The BTS-Trx module is to be started.

After starting one of the base station configurations, it is required to manually connect the phone to the mobile network with the selection of the appropriate network in the settings of the phone's SIM cards. To do this, scan the available mobile networks and select the network Test PLAN 1-1 2G, SkolTech IoT Lab 2G or VKR Research 2G. The name of the network displayed may vary depending on the type of phone you are using. The process of finding and connecting the phone is shown in Fig. 3

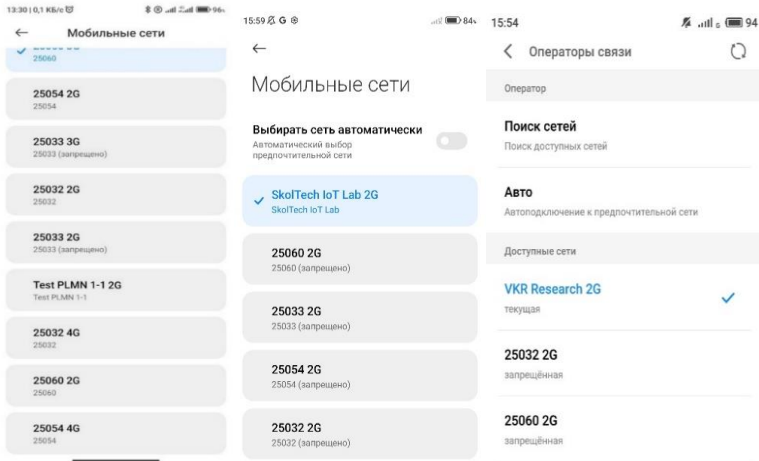


Fig. 3 — The phone's SIM card settings menu in the mobile network search and selection mode

As can be seen from Figure 3, the list of detectable networks includes the Test PLMN 1-1 2G network, which means PLMN (Public Land Mobile Network) or public land mobile network. The name of the network, such as Test PLMN 1-1, SkolTech IoT Lab, arises from the combinations of MCC (Mobile Country Code) and MNC (Mobile Network Code) used in the MSC settings, which distinguish the operator's radio access networks from each other. At the same time, the first three digits in the network name are MCC or the country code, and the next two digits are MNC, or the telecom operator's code, the values of which were set to 001 and 01, respectively, to eliminate

conflicts with commercial networks. It is also possible to set a different network name, for example, VKR Research.

In the case of network configuration with automatic registration, when the SIM card is initially connected to the network, the subscriber is initially registered in the home registry (local SQL database in the hlr.db file). In addition to automatic registration, there is the possibility of manual registration. For manual registration, you need to access the OsmoHLR module through one of the interfaces, which will allow you to set basic parameters such as a phone number (MSISDN), SIM card identifier (IMSI), authentication algorithms (comp128v3 for 2G and milenage for 3G) and other parameters. The process of adding subscribers to the database [5] is shown in Fig. 4.

```
$ telnet localhost 4258
OsmoHLR> enable
OsmoHLR# subscriber imsi 123456789023000 create
% Created subscriber 123456789023000
  ID: 1
  IMSI: 123456789023000
  MSISDN: none

OsmoHLR# subscriber imsi 123456789023000 update msisdn 423
% Updated subscriber IMSI='123456789023000' to MSISDN='423'

OsmoHLR# subscriber msisdn 423 update aud3g milenage k deaf0ff1ced0d0dabbeddlcedlcef00d opc ←
cededefacedacefacedbadfadedbeef
OsmoHLR# subscriber msisdn 423 show
  ID: 1
  IMSI: 123456789023000
  MSISDN: 423
  3G auth: MILENAGE
           K=deaf0ff1ced0d0dabbeddlcedlcef00d
           OPC=cededefacedacefacedbadfadedbeef
           IND-bitlen=5

OsmoHLR# subscriber msisdn 423 update aud2g compl28v3 ki beefedcafaceaceadeddecadefee
```

Fig. 4 — Working with the subscriber base when connecting using telnet

After registering with the HLR SIM card, the subscriber can make calls and send SMS messages to other subscribers within the network. In addition to audio and text communication, it is possible to packet information inside and outside the network, which will require access to SIM card information such as an authentication algorithm, international mobile subscriber identifier (IMSI), secret key (KI), and operator code or derived operator code (OP/OPc), which in turn, it can only provide a programmable or an open SIM card.

To conduct research on the network and its operability, there are a number of possible options, which include logging the operation of each individual element of the emulator with subsequent analysis of the information received, implementing packet interception techniques using Wireshark packet analyzers, using the Titan TTCN3 testing kit [1], using a spectrum analyzer to study the frequency range in the communication channel, and other options.

Consider a mobile network research option, such as packet interception with the help of Wireshark, for which we will send a test sms and set the `gsm_sms` filter. The result of the study is shown in Figure 5.



The image shows a Wireshark packet capture window titled "Wireshark - Packet 3881 - 3". The packet list on the left shows a packet of 81 bytes on wire (648 bits), 81 bytes captured (648 bits) on interface 0. The packet details pane on the right shows the following structure:

- Frame 3881: 81 bytes on wire (648 bits), 81 bytes captured (648 bits) on interface 0
- Ethernet II, Src: 00:00:00:00:00:00 (00:00:00:00:00:00), Dst: 00:00:00:00:00:00 (00:00:00:00:00:00)
- Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
- User Datagram Protocol, Src Port: 56309 (56309), Dst Port: 4729 (4729)
- GSM TAP Header, ARFCN: 734 (Downlink), TS: 1, Channel: SDCCH/8 (5)
- Link Access Procedure, Channel Dm (LAPDm)
- GSM A-I/F DTAP - CP-DATA
- GSM A-I/F RP - RP-DATA (Network to MS)
- ▼ GSM SMS TPDU (GSM 03.40) SMS-DELIVER
 - 0... .. = TP-RP: TP Reply Path parameter is not set in this SMS SUBMIT/DELIVER
 - .0... .. = TP-UDHI: The TP UD field contains only the short message
 - ..0... .. = TP-SRI: A status report shall not be returned to the SME
 -0... .. = TP-LP: The message has not been forwarded and is not a spawned message
 -1... .. = TP-MMS: No more messages are waiting for the MS in this SC
 -00... .. = TP-MTI: SMS-DELIVER (0)
 - ▶ TP-Originating-Address - (11 11 11 11)
 - ▶ TP-PID: 0
 - ▶ TP-DCS: 0
 - ▶ TP-Service-Centre-Time-Stamp
 - ▶ TP-User-Data-Length: (6) depends on Data-Coding-Scheme
 - ▼ TP-User-Data
 - SMS text: zzz

Fig. 5 — Packet interception and analysis result

As it can be seen from Fig. 5, the TP-Originating-Address field contains the sender's number, and the TP-User-Data field contains the text of the SMS message. This method of controlling the transmitted information can be applied to other interfaces.

Next, we will perform a frequency and energy analysis of the mobile network signal. To control the composition of the electromagnetic spectrum, it is necessary to use a spectrum analyzer. For example, when implementing the system in the GSM-900 range, the frequencies of 881 and 936 MHz in the uplink and downlink, respectively, can be selected. The process of spectral analysis is shown in Fig. 6.

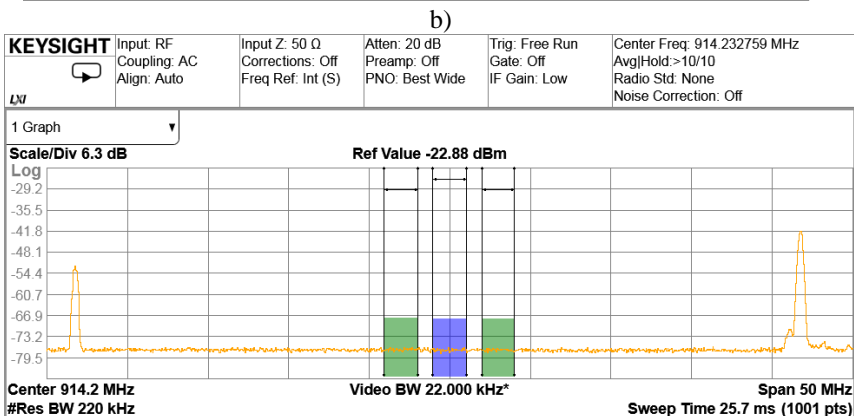
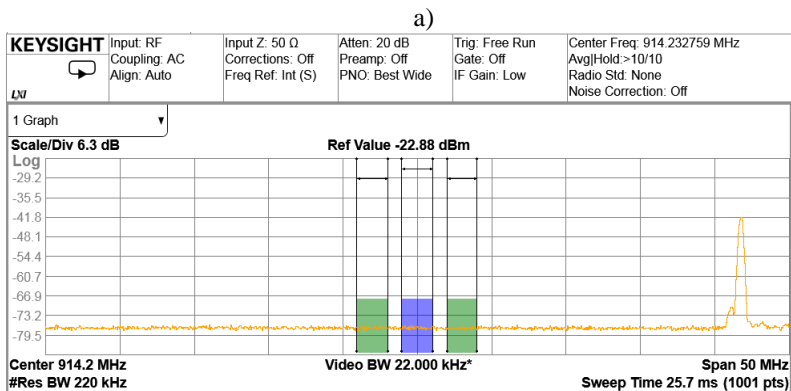


Fig. 6 — Image of the signal spectrum of ascending and descending line:
a) No SMS communication; b) SMS transmission

As shown in Fig. 6, when no data is transmitted from the telephone, the signal of the rising line is absent from the spectrum. When transmitting SMS messages, the power of the ascending line is less than the descending line and is -54 dB, while in the descending line it is -42 dB.

The developed educational and research stand provides an opportunity to deploy a second-generation mobile network with the possibility of flexible configuration, both before the network is launched and during its operation, providing students with practical and theoretical experience in working with a second-generation base station. Due to the possibility of automatic subscriber registration, the need for specialized equipment such as a programmable SIM card to access the network is reduced. With the use of such SIM cards, packet

transmission of information becomes possible, both inside and outside the network.

Conclusion. During the review of the deployment option of the 2G/GSM base station with a support network, features of operation of hardware and software parts were identified, as well as demonstrated the results of functioning of 2G/GSM cellular communication in different modes. In the course of a further study, it is planned to carry out load testing of network operation for several subscribers with an assessment of bandwidth.

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DESIGN APPROACHES RESEARCH FOR WEB APPLICATIONS USING XR TECHNOLOGIES

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Аннотация. В этом исследовании изучаются современные методы создания веб-приложений, использующих технологии XR, в том числе

расширенную, дополненную и виртуальную реальность. Приводится тщательное сравнение различных инструментов и фреймворков, используемых при создании интерфейсов XR в настройках браузера. Основной акцент этого исследования делается на организации стратегий дизайна, которые актуальны в веб-ландшафте XR, а также на оценке потенциала включения элементов XR в обычные веб-приложения.

Ключевые слова: XR, WebXR, виртуальная реальность, дизайн интерфейса, WebGL, Three.js, A-Frame, дизайн UX, иммерсивные технологии

Annotation. This study investigates contemporary methods for crafting web applications that leverage XR technologies, which include extended, augmented, and virtual reality. A thorough comparison of various tools and frameworks utilized in the creation of XR interfaces within browser settings is provided. A key emphasis of this research lies in organizing design strategies that are relevant within the XR web landscape, alongside evaluating the potential for incorporating XR elements into conventional web applications.

Keywords: XR, WebXR, virtual reality, interface design, WebGL, Three.js, A-Frame, UX design, immersive technologies

Introduction

Recently there has been an increase in Extended Reality (XR) technologies through multiple industries. XR encompasses a range of technologies: virtual reality (VR), augmented reality (AR), and mixed reality (MR). They have been used in healthcare, education, industrial design, and online shopping.

It is clear that the introduction of the WebXR API has created the opportunity to integrate immersive experiences right into web apps along with its related JavaScript frameworks, which eliminates the need for native applications for mobile or desktop devices. **The purposes** of our study are to examine the current methods used in the design of XR web applications; highlight their strengths and weaknesses; present significant areas for future development in this field.

Creating web applications that incorporate XR features requires unique architectural and interface approaches that contrast markedly with standard frontend development methods. Notable challenges arise in aspects like adaptability, performance, user experience design, and ensuring compatibility across various platforms when building XR interfaces in a browser setting.

Overview of Technologies

The advancement of XR capabilities relies mainly on the WebXR API within web browsers Chrome, Edge, and Firefox Reality. It enables seamless

communication between web applications and VR or AR hardware, eliminating the necessity for separate native applications [2].

Developers can generate and display three-dimensional graphics directly in web browsers through the use of WebGL. It offers programmers direct access to fundamental 3D rendering capabilities, such as geometry, materials, lighting, cameras, animation, shaders, and textures. Additionally, the large community and surrounding ecosystem have reinforced its reputation as a popular choice for creating tailored WebXR experiences [1].

A-Frame is a paternt created by Mozilla that simplifies the development of WebXR applications through an HTML-like syntax [3, 4]. It is based on Three.js, which helps manage much of the intricate details by utilizing a component-based approach. As a result, it becomes user-friendly for developers who may not have a deep background in 3D programming. A-Frame works well with VR and AR headsets for both desktop and mobile devices. It includes many plugins and components that make it easy to create prototypes quickly, develop educational tools, and craft interactive stories.

The existing frameworks differ significantly regarding their level of abstraction, performance, and ease of learning. A-Frame is especially advantageous for quick development and prototyping tasks. On the other hand, Three.js grants developers extensive control and options for customization. In contrast, Babylon.js strikes a good balance between visual tools and strong performance, making it appropriate for both creative individuals and technical experts working on advanced XR applications.

Comparative Analysis of Approaches are presented in table 1.

Table 1. Three main approaches of XR web application design

Approach	Description	Advantages	Disadvantages
Declarative (A-Frame)	Uses tags and components in HTML-like format	Fast development, low entry threshold	Limited flexibility, challenging customization
Imperative (Three.js)	Scene managed via JavaScript and WebGL	High flexibility, precise scene control	Higher complexity, requires knowledge of 3D graphics

Approach	Description	Advantages	Disadvantages
Hybrid (Babylon.js)	Combines visual editor and code	Balance between simplicity and functionality	High learning curve for API

WebXR enables automatic detection of device type (HMD, smartphone with ARKit/ARCore, desktop).

Implementation and Testing Example

To evaluate the applicability of different approaches, a prototype XR web application was developed — an interactive 3D tour of a virtual exhibition hall. Three versions of the application were implemented:

1. A-Frame: minimal code, basic navigation and interaction;
2. Three.js: manual camera setup, lighting, and user input;
3. Babylon.js: added realistic materials and motion physics [5-7].

Testing was conducted on Meta Quest 2, iPhone 13 Pro (via Safari + WebXR Viewer), and a Windows PC (via Chrome). Main evaluation criteria included performance (FPS), loading time, and user interaction convenience

The results showed that:

- A-Frame provides the best performance and accessibility but is limited in customization;
- Babylon.js demonstrates the highest scene quality but requires more resources;
- Three.js offers maximum control but involves greater development effort.

Future Development Prospects

The advancement of XR on the web is tied to several important trends:

Standardization of UX for XR: Creating a set of best practices and guidelines for user interaction in VR and AR settings is essential. This will help ensure smooth integration and improve how users engage with these technologies.

Integration with React/Vue: Connecting XR interfaces to popular UI frameworks is vital. This will increase the range of available options and make it easier for users to interact with virtual spaces.

Cloud-based XR platforms: Utilizing server-side rendering, or XR streaming, allows for the running of intricate scenes on devices with limited power. This approach ensures that XR experiences remain accessible and efficient for a wider audience.

AI + XR: The use of AI, particularly generative models for creating content in real time, is set to revolutionize how XR experiences are made and shared. For instance, transforming text descriptions into 3D models can greatly enhance the creative process in this field.

Conclusion

The incorporation of XR technologies within web applications presents exciting opportunities for interactive content and enhances user engagement. Although there are challenges related to technology and the complexity of implementation, current frameworks and WebXR standards allow for the development of effective and cross-platform immersive experiences.

The design strategy selected will vary based on the goals of the project, the resources available within the team, and the intended platform.

Looking ahead, advancements will aim for a more profound integration of XR into the web environment, enhancements in user experience, and broadened design possibilities for XR, particularly in collaboration with AI and cloud technologies

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CLOUD-BASED ACCESS CONTROL SYSTEMS

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Аннотация. В статье анализируются облачные системы контроля доступа (ACS) и их роль в современных инфраструктурах. Обсуждаются основные преимущества, такие как масштабируемость, интеграция с IoT и экономическая эффективность. Практические примеры из корпоративного сектора и умных городов иллюстрируют практические реализации. Также освещаются риски, включая киберугрозы и правовые ограничения.

Ключевые слова: облачные ACS, интеграция с IoT, Zero Trust, SaaS, кибербезопасность, GDPR.

Annotation. The article analyzes cloud-based access control systems (ACS) and their role in modern infrastructures. Key advantages such as scalability, IoT integration, and cost efficiency are discussed. Case studies from the corporate sector and smart cities illustrate practical implementations. Risks, including cyber threats and legal restrictions, are also highlighted.

Keywords: cloud-based ACS, IoT integration, Zero Trust, SaaS, cybersecurity, GDPR.

Introduction. The digital transformation of enterprises has redefined the requirements for security infrastructure. Traditional access control systems, which rely on on-premise servers and physical credentials (e.g., keycards), struggle to meet the demands of distributed workforces, multi-site operations, and smart building ecosystems. Cloud-based ACS address these challenges by centralizing data storage and access management in secure remote servers, enabling real-time control via web or mobile interfaces.

According to Gartner, 70% of organizations will transition to cloud-based security solutions by 2025, driven by the need for cost efficiency and agility [2]. This shift is further accelerated by advancements in IoT, AI, and blockchain, which enable cloud ACS to deliver unprecedented levels of automation and security. However, the adoption of these systems introduces

risks, such as API vulnerabilities and compliance complexities, which require strategic mitigation.

Main part.

AI-powered cloud ACS leverage machine learning algorithms to analyze historical access patterns and detect anomalies. For instance:

Kisi Predictive Access identifies suspicious behavior, such as repeated failed login attempts, with 92% accuracy, automatically triggering alerts or access denials [3].

Facial Recognition with Liveness Detection: Systems like Hikvision DeepinView use AI to distinguish between real faces and spoofs (e.g., photos or masks), reducing impersonation risks [13].

Blockchain technology ensures transparency and tamper-proof record-keeping. IBM’s Hyperledger Fabric integrates with cloud ACS to create decentralized audit logs, which are critical for industries requiring strict compliance (e.g., healthcare, finance) [4]. Each access event is timestamped, encrypted, and stored across multiple nodes, eliminating single points of failure.

Smartphones have replaced physical keycards in many cloud ACS deployments (table 1).

Table 1. Cloud ACS deployments

Replacements	Features
QR Code Access	Hotels such as Marriott issue time-limited QR codes to guests, streamlining check-ins and reducing front-desk congestion [6].
NFC and Bluetooth	Solutions like Salto KS allow users to unlock doors via mobile apps, with credentials stored securely in Apple Wallet or Google Pay [5].

Cloud ACS act as a hub for smart building technologies (table 2).

Table 2. Cloud ACS and smart building technologies

Cloud ACS	Features
Energy Optimization	Integration with HVAC and lighting systems ensures resources are activated only when authorized personnel are present.
Dynamic Access Policies	Doors unlock only when IoT sensors confirm safe conditions (e.g., air quality within norms, fire alarms inactive) [12].

3. Case Studies and Industry Applications

Siemens employs cloud ACS to manage access for 5,000+ employees across global R&D facilities. Role-based permissions ensure engineers access only relevant labs, while contractors receive temporary credentials. The system reduced administrative costs by 40% and eliminated physical keycard losses [7].

Hyatt’s cloud ACS, powered by Brivo, enables guests to access rooms via mobile apps. The system integrates with property management software to automate check-ins and align access rights with reservation timelines. Post-implementation, Hyatt reported a 30% increase in guest satisfaction scores [10].

Singapore’s Land Transport Authority uses cloud ACS to manage access to metro control rooms and maintenance zones. IoT sensors monitor passenger flow, while AI algorithms predict peak times and adjust staff access permissions dynamically. This reduced operational delays by 25% [9].Challenges and Risks are presented in the table 3.

Future cloud ACS Prospects

AWS IoT Greengrass enables cloud ACS to function autonomously during outages, ideal for remote oil rigs or manufacturing plants [11].

Table 3. The major risks of cloud ACS

Challenges	Features	Example
Data Leaks	Misconfigured cloud storage (e.g., public S3 buckets) can expose sensitive access logs.	Encryption (AES-256) and regular penetration testing are essential [5].
API Vulnerabilities	Cloud ACS rely on APIs for integration, which hackers often target.	In 2022, a breach in Verkada’s cloud platform exposed 150,000 security camera feeds, underscoring the need for Zero Trust policies [1].
Cybersecurity Law (CSL)	Mandates local data storage and government access to encryption keys	Federal government agencies and departments that handle sensitive personal data must use FIPS-certified cryptographic modules.

General Data Protection Regulation	Requires data localization	Cookies are an important tool that can give businesses a great deal of insight into their users' online activity.
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Ericsson’s pilot project at SoFi Stadium (USA) demonstrated seamless crowd management during events with 70,000+ attendees [8]. Microsoft’s ION project enables self-sovereign access credentials, reducing reliance on third-party providers [3]. It connects resource-constrained end devices to Azure, using innovations in VHF narrowband wireless technology. ZTA mandates continuous verification of users and devices, even within trusted networks. Gartner predicts that 60% of enterprises will adopt ZTA by 2025, making it a cornerstone of future ACS.

6. Conclusion

Cloud-based ACS represent a paradigm shift in security infrastructure. It provides system maintenance and health monitoring features that help increase uptime and improve productivity.

Cloud-based ACS’ advantages are assessing the operational status of cameras and servers from a central location and prioritizing maintenance. offering unparalleled flexibility, scalability, and integration capabilities. However, their successful implementation hinges on addressing cybersecurity risks, ensuring regulatory compliance, and investing in employee training. Future advancements in 5G, edge computing, and decentralized identity frameworks will further enhance their capabilities, positioning cloud ACS as indispensable tools for secure, smart, and sustainable environments. Organizations must prioritize partnerships with certified providers and adopt a phased implementation strategy to maximize ROI and minimize disruptions.

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**RESEARCH ON THE IMPACT OF IMAGE RESOLUTION
REDUCTION AND THE APPLICATION OF SUPER-RESOLUTION
MODELS FOR RESTORATION AND FINE-TUNING OF PRE-TRAINED
MODELS TO IMPROVE IMAGE CLASSIFICATION ACCURACY**

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Аннотация. В этой статье рассматривается влияние уменьшения разрешения изображения на производительность классификаторов на основе глубоких нейронных сетей с акцентом на архитектуры ResNet и MobileNet V3 при агрессивном сжатии входных данных. Предлагается методология, которая объединяет трансферное обучение и передовые методы восстановления изображений, такие как Real-ESRGAN и U-Net, для компенсации потери информации, вызванной уменьшением разрешения. Исследование также применяет методы тонкой настройки к предварительно обученным моделям ResNet и MobileNet путем замораживания верхних слоев для предотвращения переобучения. Сравнительный анализ стандартизированного набора данных образца ImageNet показывает значительное снижение точности классификации при сниженном разрешении изображения и оценивает эффективность подходов с суперразрешением для восстановления утраченных деталей.

Ключевые слова: изображения с низким разрешением, классификация изображений, восстановление изображений, трансферное обучение, MobileNet, ResNet.

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n Keywords: low-resolution images, image classification, image restoration, transfer learning, MobileNet, ResNet.

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t Modern computer vision systems often encounter imperfect input data in practice, which may contain image distortions or low resolution. Training deep neural networks on datasets like COCO or ImageNet, where images are of relatively high quality, creates a disconnect between controlled lab conditions and real-world applications.

This work focuses on investigating the impact of image resolution downscaling, resulting from up to 8x compression, on classification accuracy and methods to mitigate the decline in performance. The hypothesis to be tested in this article is that even the best models lose a significant amount of information when faced with low-resolution input data. To compensate for these losses, two main approaches are proposed: fine-tuning of pre-trained models and methods for restoring input images, where restoration refers to applying super-resolution algorithms and possible post-processing techniques to improve the quality of the visual information.

The relevance of this study is driven by the need to adapt computer vision systems to real-world conditions, where image quality may be suboptimal and

computational resources are limited.

The following neural network architectures were selected as classifiers: The ResNet network with large number of layers (ResNet101 and ResNet152 versions were chosen) [2] and MobileNet V3, a minimalist architecture specifically designed for operation under limited resources, while demonstrating good classification quality [3]. Both neural networks show high performance on the ImageNet dataset [6]. Each classifier was considered in two versions – a larger and a smaller model.

Two popular architectures were chosen as classifiers, which showed high efficiency on the standard ImageNet dataset but are potentially vulnerable to reduced input image quality. The first one is the ResNet family, known for its deep structure and ability to extract complex spatial features. The second one is MobileNet, designed for operation under limited computational resources, making it attractive both for mobile and embedded systems.

The Sample ImageNet dataset was chosen, containing random images from each class of the ImageNet dataset and consisting of 1000 images [7]. While the classifiers were provided with input images from the dataset they were tested on, the dataset size was comparable to that of a niche domain dataset.

Each image in the dataset was preprocessed: first, all images were resized to a fixed size of 224x224 pixels. Next, reduced versions were created with 2x, 4x, and 8x downscaling. When inputting into the neural network, all images (regardless of their original resolution) were resized to 224x224 pixels, and pixel values were normalized so that the mean values for each channel were (0.485, 0.456, 0.406), with standard deviations of (0.229, 0.224, 0.225), respectively.

Classification quality was evaluated using the following metrics: TOP 1 Accuracy (the correct label corresponds to the highest output value of the classifier percentage) and TOP 5 Accuracy (the correct label corresponds to one of the 5 highest output values of the classifier percentage).

The downscaled versions of the images were passed to the classifiers both directly and after resolution enhancement by neural networks trained to solve this task. Real-ESRGAN [5] and U-Net [4] models were selected for this purpose. Pre-trained models with weights were used for the study.

All experiments were conducted on a local workstation. Inference was performed using an NVIDIA GeForce RTX 4050 GPU. The source code for the experiments was written in Python version 3.11.4 using the PyTorch 2.5.0 library. The auxiliary torchvision library version 0.20.0 was also used. The source code for the experiments is available in the repository [1].

Tables 1 and 2 show the results of the experiment where low-resolution versions of images, initially interpolated using the nearest neighbor method to a size of 224x224, were input into the classifier. It can be concluded that even a 2x reduction in resolution noticeably impacts classification quality, while a 16x downscaling brings the accuracy close to random guessing. It can be hypothesized that with resolution reduction, local features, on which the classifier builds high-level representations, are lost.

Table 1. Top 1 Accuracy for Original and Reduced-Resolution Images

Size\Model	ResNet152	ResNet101	MobileNet V3Large	MobileNetV3 Small
original	76.7	75.9	72.6	63.8
downsampled_2x	66.8	67.0	63.5	52.1
downsampled_4x	46.4	46.1	36.8	31.4
downsampled_8x	14.8	16.0	11.7	9.8

Table 2. Top 5 Accuracy for Original and Reduced-Resolution Images

Size\Model	ResNet152	ResNet101	MobileNetV3Large	MobileNetV3Small
original	92.5	92.8	90.5	85.5
downsampled_2x	88.9	87.3	85.4	76.8
downsampled_4x	70.4	70.2	62.6	56.5
downsampled_8x	30.6	34.2	25.9	22.7

Images downsampled by 2x, 4x, and 8x were passed through the Real-ESRGAN model, generating a new dataset with images upsampled by 2x, 4x, and 8x, respectively. The restored images were then input into the classifiers.

The results of the experiment are shown in Tables 3 and 4 (with the percentage for the original resolution metric provided in parentheses).

Table 3. Top 1 Accuracy for Original and Real-ESRGAN Restored Versions of Reduced Images

Size\Model	ResNet152	ResNet101	MobileNetV3Large	MobileNetV3Small
original	76.7 (76.7)	75.9 (75.9)	72.6 (72.6)	63.8 (63.8)
downsampled_2x	66.3 (66.8)	65.1 (67.0)	61.2 (63.5)	53.0 (52.1)
downsampled_4x	42.4 (46.4)	40.7 (46.1)	37.6 (36.8)	35.6 (31.4)
downsampled_8x	13.5 (14.8)	12.6 (16.0)	13.0 (11.7)	13.5 (9.8)

Table 4. Top 5 Accuracy for Original and Real-ESRGAN Restored

Versions of Reduced Images

Size\Model	ResNet152	ResNet101	MobileNet V3Large	MobileNetV3Small
original	92.5 (92.5)	92.8 (92.8)	90.5 (90.5)	85.5 (85.5)
downsampled_2x	87.2 (88.9)	87.7 (87.3)	83.3 (85.4)	77.5 (76.8)
downsampled_4x	67.1 (70.4)	66.7 (70.2)	60.9 (62.6)	59.7 (56.5)
downsampled_8x	28.5 (30.6)	27.9 (34.2)	28.1 (25.9)	28.6 (22.7)

As seen in the table, resolution restoration does not always lead to improved classification quality (in fact, slight improvements in quality occur only in some cases for MobileNet, while for ResNet, accuracy decreases). Below are examples of resolution restoration results for some images. As we can see, the restoration model generates artifacts and poorly restores fine details, such as facial features (which is especially noticeable on the left, when the image is upsampled by 8x).

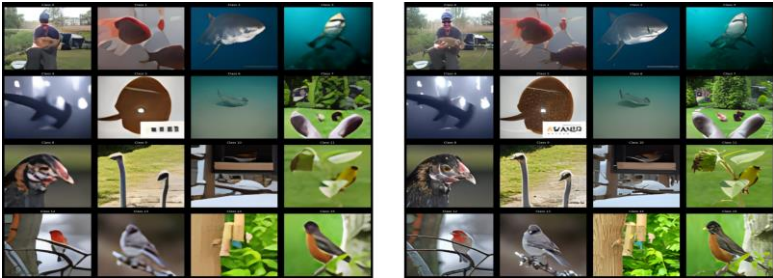


Figure 1 – Images with Restored Resolution (Left – 8x, Right – 4x)

In a similar manner, low-resolution images were passed through U-Net, and the restored versions were then fed into the classifiers. The results of the experiment are summarized in the table below. Unfortunately, the implementation used allows for resolution enhancement only by 4x.

Table 5. Top 1 Accuracy for Original and U-Net Restored Versions of

Reduced Images

Size\Model	ResNet152	ResNet101	MobileNetV3Large	MobileNetV3Small
original	76.7 (76.7)	75.9 (75.9)	72.6 (72.6)	63.8 (63.8)
downsampled_4x	71.7 (46.4)	68.8 (46.1)	64.6 (36.8)	58.6 (31.4)

Table 6. Top 5 Accuracy for Original and U-Net Restored Versions of Reduced Images

Size\Model	ResNet152	ResNet101	MobileNetV3Large	MobileNetV3Small
original	92.5 (92.5)	92.8 (92.8)	90.5 (90.5)	85.5 (85.5)
downsampled_4x	90.3 (70.4)	89.9 (70.2)	87.4 (62.6)	82.9 (56.5)

A significant improvement in classification quality is observed after image restoration for all considered classifiers – the results for the restored images are almost identical to those for the original images when calculating Top 5 Accuracy. The models were even able to restore facial details, something that Real-ESRGAN completely failed to do.

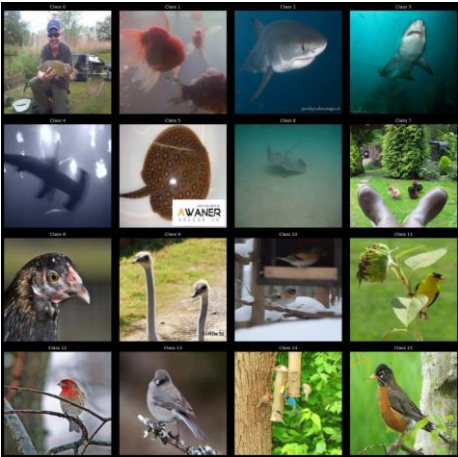


Figure 2 – Images with Restored Resolution Using U-Net
(the original image was "compressed" by 4x)

Another approach used was the fine-tuning method for pre-trained classifiers MobileNet. The main idea was to train first layers on extraction of low-level features from downsampled images. During the fine-tuning process, the upper layers of the network were "frozen." "Freezing" layers refers to the process where the weights of certain layers of the neural network remain unchanged during training. Imagenet Samples dataset has been splitted to train (600 samples), validation (100 samples for early stopping implementation purposes) and test (300 samples). ResNet has a bigger count of parameters, so fine tuning on small train split has been found to be inefficient. The results of the experiments are shown in the tables below. Max epoch count has been set to 20. Table contains results with the best scores on the test split.

Table 7. Test results for Mobile Net fine tuning (in brackets - score before fine-tuning)

Model Type	Unfrozen Layers	Has Augmentations	TOP 1 (test)	TOP 5 (test)	Down scaled on
mobilenet_v3_small	3	No	43.00 (31.4)	67.33 (56.5)	4
mobilenet_v3_small	5	No	40.33 (31.4)	68.00 (56.5)	4
mobilenet_v3_large	4	No	44.33 (31.4)	68.67 (56.5)	4
mobilenet_v3_large	5	No	44.67 (36.8)	71.00 (62.6)	4
mobilenet_v3_large	5	Yes	41.67 (36.8)	65.00 (62.6)	4
mobilenet_v3_large	6	No	42.67 (36.8)	69.67 (62.6)	4

Table 8. Test results for Mobile Net fine tuning (in brackets - score before fine-tuning)

Model Type	Unfrozen Layers	Has Augmentations	TOP 1 (test)	TOP 5 (test)	Down scaled on
mobilenet_v3_small	4	Yes	12.67 (9.8)	29.00 (22.7)	8
mobilenet_v3_small	5	Yes	16.33 (9.8)	37.00 (22.7)	8
mobilenet_v3_small	6	No	13.00 (9.8)	28.33 (22.7)	8
mobilenet_v3_small	6	Yes	14.67 (9.8)	34.67 (25.9)	8
mobilenet_v3_large	5	No	15.33 (11.7)	33.67 (25.9)	8
mobilenet_v3_large	5	Yes	14.33 (11.7)	29.33 (25.9)	8

Table 9. Test results for Mobile Net fine tuning (in brackets - score before fine-tuning)

Model Type	Unfrozen Layers	Has Augmentations	TOP 1 (test)	TOP 5 (test)	Down scaled on
mobilenet_v3_small	2	No	52.33 (52.1)	76.33 (76.8)	2
mobilenet_v3_small	3	Yes	53.00 (52.1)	77.33 (76.8)	2
mobilenet_v3_large	2	No	65.33 (63.5)	85.33 (85.4)	2
mobilenet_v3_large	3	No	62.33 (63.5)	83.33 (85.4)	2
mobilenet_v3_large	4	No	63.00 (63.5)	84.33 (85.4)	2
mobilenet_v3_large	5	No	60.33 (63.5)	84.33 (85.4)	2

As we can see, mobile net fine tuning has better results (it depends on trainable layers count, augmentation usage and model size) than Real-ESRGAN, but worse than U-Net upsampler and better results than classifier without fine tuning for x4 and x8 downsampled images (but a bit worse than classifier without fine tuning for x2 downsampled).

But it is important that the train dataset is small for machine learning purposes, and fine tuning results may be better if the train dataset is increased or by using semi-supervised learning.

The article examined the impact of image resolution reduction on the classification quality of ResNet and MobileNet V3 models, as well as methods for improving the classification quality of low-resolution images using pre-trained deep resolution enhancement models and the application of the "fine-tuning" approach to the models used.

It can be concluded that the result depends both on the architecture of the initial classifier and the resolution enhancement model. Moreover, the "direct" approach to solving the problem does not significantly improve the quality of highly "compressed" images or requires the use of a deep pre-trained model; the presence of an additional deep neural network itself is a disadvantage – computational and time costs may prevent the use of such solutions in real-time systems. This highlights the relevance of searching for alternative methods to adapt pre-trained classifiers to low-resolution images.

Furthermore, similar research is planned for other computer vision tasks, such as object detection, semantic segmentation, and instance segmentation.

In addition, future plans include analyzing other computer vision model architectures, including modern architectures like Swin Transformer. It should be noted that issues with "real-world" images are not limited to low resolution – images may be incomplete, corrupted, or contain artifacts from capture and/or data transmission. All of this points to the potential for further research in this area.

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CRITICAL INFORMATION INFRASTRUCTURE: SAFEGUARDING THE BACKBONE OF MODERN SOCIETY

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Аннотация. В этой статье рассматривается концепция критических информационных структур, которые являются важнейшими фреймворками для управления, хранения и защиты жизненно важных

данных в современных организациях. Рассматриваются проблемы, связанные с управлением этими структурами, такие как угрозы кибербезопасности, проблемы конфиденциальности данных, проблемы масштабируемости и интеграция новых технологий. Статья завершается обсуждением будущих тенденций, подчеркивая растущую важность ИИ, блокчейна, конфиденциальности данных, IoT, квантовых вычислений и периферийных вычислений в эволюции критически важных информационных структур.

Ключевые слова: критически важная информация, целостность данных, информационная безопасность, управление данными, кибербезопасность.

Annotation. This article explores the concept of critical information structures, which are essential frameworks for managing, storing, and protecting vital data in modern organizations. It also addresses the challenges associated with managing these structures, such as cybersecurity threats, data privacy concerns, scalability issues, and the integration of emerging technologies. The article concludes with a discussion of future trends, emphasizing the increasing importance of AI, blockchain, data privacy, IoT, quantum computing, and edge computing in the evolution of critical information structures. Keywords: critical information, data integrity, information security, data management, cybersecurity.

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Introduction. In the modern digital age, the concept of critical information structure has become increasingly important.

Critical information structures refer to the organized frameworks that manage, store, and protect essential data within an organization or system. These structures are vital for ensuring the availability, integrity, and confidentiality of information, which is crucial for decision-making, operational efficiency, and compliance with regulatory requirements. In an era where data breaches and cyberattacks are on the rise, the importance of robust critical information structures cannot be overstated. This article delves into the components of these structures, their significance, and the challenges associated with their management [4].

So, I. Ellefsen, S. von Solms proved that “the development of a national critical information infrastructure protection (CIIP) structure is essential to safeguard critical systems from cyber attacks and other threats” [3, p. 17]. Myriam Dunn [1, 2] described Critical information structures as “urgency which is due to their invaluable and growing role in the economic sector, their interlinking position between various infrastructure sectors, and their essential

role for the functioning of many of the critical services that are essential to the well-being of developed societies” [1].

The aim of the article is to explore components of critical information structures, focusing on their role in ensuring data integrity, security, and accessibility.

Critical information structures consist of several key components that work together to ensure the effective management and protection of data (table 1).

Table 1. Components of Critical information structures

Components	Features
Data Management Frameworks	These frameworks govern how data is collected, processed, and utilized. They include policies, procedures, and tools for data governance, ensuring that information is accurate, consistent, and available when needed [2]
Monitoring and Analytics Tools	Continuous monitoring and analysis of data flows help detect anomalies, potential threats, and performance issues. These tools provide insights that enable proactive management of critical information structures [3].
Data Storage Systems	These are the physical or virtual repositories where critical information is stored. Examples include databases, cloud storage, and on-premises servers
Backup and Recovery Systems	To ensure data availability in case of system failures or disasters, backup and recovery systems are essenti.
Security Measures	“Security measures include encryption, firewalls, access controls, and regular security audits” [3, p. 2].

Critical information structures play a pivotal role in modern organizations. They ensure that essential data is available, accurate, and secure, which is crucial for decision-making and operational efficiency [5].

Despite their importance, managing critical information structures presents several challenges:

1. Cybersecurity Threats.
2. Data Privacy Concerns.
3. Scalability Issues.
4. Integration with Emerging Technologies [3].

To address these challenges, organizations can implement several strategies (table 2).

Table 2. Strategies of critical information structures

Strategies	Features
Regular Security Audits and Updates	Conducting regular security audits and updating systems
Leveraging AI and Machine Learning	Enhance the monitoring and analysis of critical information structures
Adopting a Multi-Layered Security Approach	Combining encryption, firewalls, and access controls
Employee Training and Awareness	Educating employees about cybersecurity best practices and the importance of data protection

Conclusion. In the event of a system failure or cyberattack, Critical information structures are crucial for decision-making, operational efficiency, and compliance with regulatory requirements. The importance of robust critical information structures cannot be overstated.

Critical information structures are essential for disaster recovery and business continuity. These structures enable organizations to recover quickly and minimize the impact on operations and support innovation by providing a reliable foundation for the development of new technologies.

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ANALYSIS OF PERFORMANCE AND APPLICATION OF WIREGUARD TECHNOLOGY FOR LOCAL NETWORK INTEGRATION WITH ADVANCED OPTIMIZATION TECHNIQUES

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Аннотация. В этой статье представлено углубленное исследование реализации и производительности протокола WireGuard VPN в контексте объединения локальных вычислительных сетей (LAN) в распределенной инфраструктуре. Особое внимание уделяется анализу ключевых показателей производительности (KPI), таких как задержка, пропускная способность и использование процессора, а также изучению методов оптимизации для настройки конфигурации и мониторинга системы. Для измерения практического влияния оптимизации на производительность был проведен лабораторный эксперимент с использованием физических и виртуальных тестовых стендов. В заключение исследования даны рекомендации, направленные на повышение эффективности развертывания и надежности WireGuard в корпоративных средах.

Ключевые слова: WireGuard, VPN, оптимизация производительности, сетевая интеграция, мониторинг, безопасность.

Annotation. This article presents an in-depth study of the implementation and performance of the WireGuard VPN protocol in the context of uniting local area networks (LANs) across distributed infrastructure. Emphasis is placed on analyzing key performance indicators (KPIs) such as latency, throughput, and CPU usage, as well as exploring optimization methods for configuration tuning and system monitoring. A laboratory experiment was conducted using both physical and virtual testbeds to measure the practical performance impact of these optimizations. The study concludes with recommendations aimed at improving the deployment efficiency and reliability of WireGuard in enterprise environments.

Keywords: WireGuard, VPN, performance optimization, network integration, monitoring, security.

INTRODUCTION

Virtual private networks (VPNs) are fundamental tools in modern IT infrastructure, ensuring secure communication between distributed network segments. As organizations scale geographically and rely increasingly on cloud-based services, the importance of low-latency, high-throughput, and secure VPN solutions continues to grow. WireGuard, a next-generation VPN protocol, distinguishes itself from traditional alternatives such as OpenVPN and IPsec through its compact codebase, in-kernel operation, and modern cryptographic design.

Despite its advantages, the performance of WireGuard in large-scale deployments can vary significantly depending on configuration, load, and network conditions. This paper investigates not only the protocol's raw performance but also strategies for tuning its parameters to achieve optimal results. Particular attention is paid to real-time monitoring approaches, as proactive maintenance is critical to maintaining performance and security in long-lived VPN infrastructures.

THE MAIN PART

1. Performance Analysis of WireGuard

WireGuard is designed for simplicity and performance, yet its behavior under load or in enterprise settings needs detailed examination. Our evaluation focused on three primary metrics:

- Packet encryption and decryption introduce computational overhead. Testing showed that, under typical encryption loads, WireGuard maintains sub-10ms latency and can saturate a 1Gbps link, outperforming OpenVPN by up to 30%.

- as WireGuard operates in kernel space, it reduces the overhead of context switching. However, multiple concurrent tunnels can tax the CPU. Profiling revealed a linear relationship between tunnel count and CPU usage, highlighting the need for threading optimizations;

- real-time applications require predictable delivery. Under simulated high-load conditions using iPerf3, WireGuard displayed lower jitter values compared to IPsec, indicating stable packet timing [1].

A comparative analysis with OpenVPN and IPsec was carried out in identical test environments. Each setup used the same hardware, traffic generators, and test durations. The results confirmed that WireGuard has a lower processing overhead, enabling more efficient use of hardware resources.

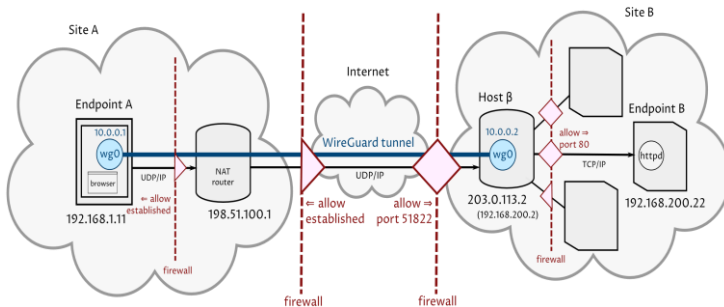


Figure 1— Network Topology Diagram with WireGuard VPN Application

2. Optimization Techniques for WireGuard Deployment

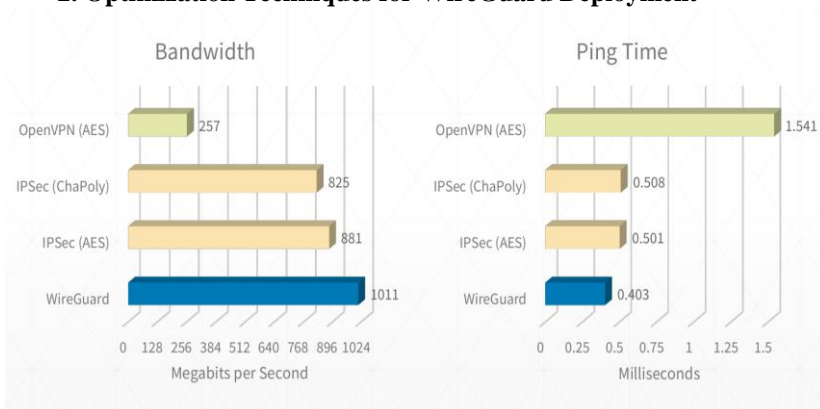


Figure 2— Comparative diagram of throughput and response time

To fully leverage WireGuard’s capabilities, several optimization strategies were tested:

- we conducted MTU sweep tests to determine the optimal packet size. The results indicated that adjusting MTU to values just below the typical fragmentation threshold (~1420 bytes) minimized retransmissions and improved throughput;
- while WireGuard itself is not multi-threaded per peer, deploying multiple independent tunnels across CPU cores achieved better parallelization. Tests showed a 20% improvement in packet handling with core pinning;
- enabling Linux flow offloading and BPF-based traffic shaping further reduced latency under congestion.

Redundancy is crucial for corporate VPNs. Two failover mechanisms were tested:

- Using ECMP (Equal-Cost Multi-Path routing), WireGuard traffic was split across multiple links [2]. This improved stability during link failure without interrupting ongoing sessions;
- scripts triggered by Prometheus alerts adjusted routing tables in real time, demonstrating WireGuard's agility under failure conditions.

3. Monitoring and Maintenance

4.

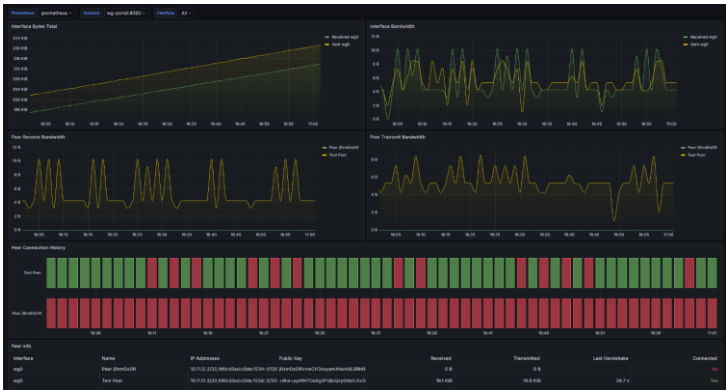


Figure 3 — Grafana dashboard for WireGuard monitoring

Performance without visibility can lead to undetected failures. Thus, a monitoring stack was developed:

- Metrics such as handshake times, packet rates, and CPU load were collected in real time. This provided insights into performance bottlenecks;
- using Fail2Ban in conjunction with systemd journal, we identified suspicious traffic patterns, which triggered automated firewall responses;
- regular key rotation and restricted access to configuration interfaces were enforced using cron scripts and ACLs (Access Control Lists).

4. Laboratory Validation

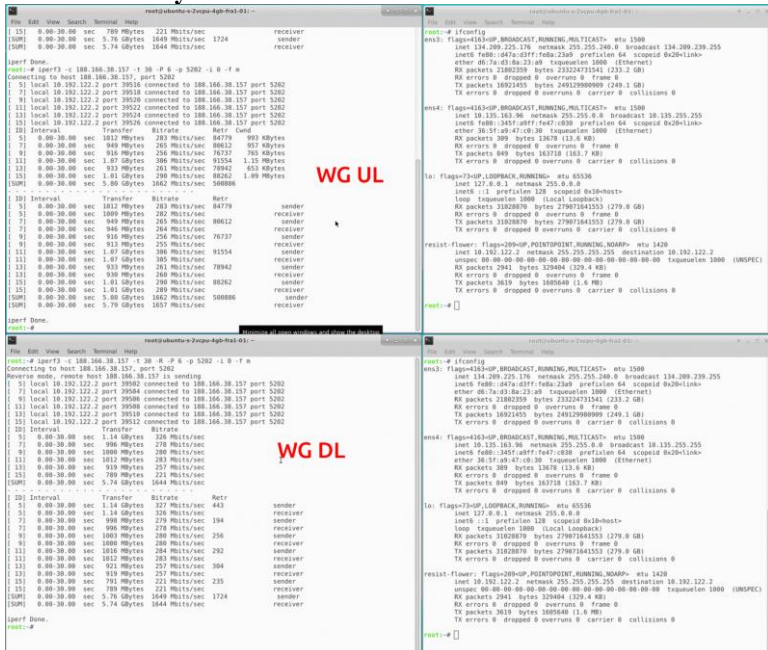


Figure 4 — Measurement results of real server-client throughput testing through the WireGuard tunnel

Speedtest CLI and perf3 tools were used to perform throughput measurements. The measurements were carried out in several stages to obtain a more reliable result. The measurement results are shown in Figure 4 and Figure 5. Following from the measurements, it can be seen that WireGuard is superior to OpenVPN [31].

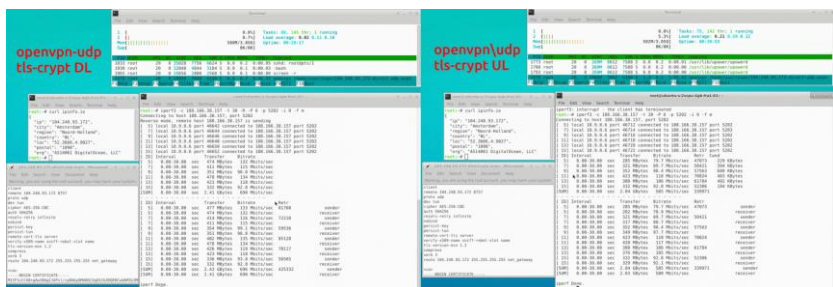


Figure 5 — Measurement results of testing the throughput of a real server-client through the OpenVPN tunnel

CONCLUSION

This study demonstrates that WireGuard can be significantly optimized for enterprise-scale network integrations by fine-tuning configurations, implementing load balancing, and enhancing real-time monitoring. Experimental analysis highlights key areas for performance improvement and provides practical recommendations for deploying WireGuard efficiently. Future work will focus on AI-driven automation for adaptive VPN configuration tuning.

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UDC 004.912

SOLVING THE PROBLEM OF AUTOMATING THE FORMATION OF THE DISCIPLINE'S WORK PROGRAM

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Аннотация. В статье рассматривается разработка веб-приложения «Конструктор рабочих программ дисциплин» (КРП), предназначенного для автоматизации создания учебной документации в соответствии с требованиями образовательных стандартов. В статье представлен основной функционал приложения, включающий: добавление и структурирование тем, лекций, лабораторных и практических занятий, а также привязку к ним соответствующих компетенций. Рассмотрены алгоритмы автоматического формирования структуры РПД на основе ФГОС и профессиональных стандартов. Предусмотрена возможность сохранения черновиков РПД, что позволяет пользователям вернуться к

работе в любое удобное время. Внедрение предлагаемого решения позволит существенно оптимизировать процесс разработки РПД, повысить его качество и соответствие современным требованиям.

Ключевые слова: веб-приложение, информационная система, рабочая программа дисциплины, автоматизация.

Annotation. The article discusses the development of a web application, the Discipline Work Program Designer (RPD), designed to automate the creation of educational documentation in accordance with the requirements of educational standards. The article presents the main functionality of the application, which includes: adding and structuring topics, lectures, laboratory and practical classes, as well as linking relevant competencies to them. Algorithms for automatic generation of the RPD structure based on the Federal State Educational Standard and professional standards are considered. It is possible to save drafts of the DWP, which allows users to return to work at any convenient time. The implementation of the proposed solution will significantly optimize the DWP development process, improve its quality and meet modern requirements.

Keywords: web application, information system, work program of the discipline, automation.

1. Introduction

In the modern educational process, the discipline's work program (DWP) is a key document defining the content, structure and methodological support of the training course [1, p. 2]. At the moment, at Sevastopol State University (hereinafter – SevSU), the process of forming the DWP is mainly manual input of a significant amount of data by the teacher. This entails significant time costs on the part of the teaching staff, distracting from other important activities such as scientific work and interaction with students. Moreover, manual data entry significantly increases the likelihood of errors and inconsistencies in the design of the document.

The urgency of the task of automating the process of DWP [6] formation is due not only to the need to optimize the time and resources of teachers, but also to the requirement to constantly maintain the relevance of information about disciplines, hours and topics. The curricula at SevSU, like at any other university, are subject to adjustments at the beginning of each academic year, which requires rapid adaptation of the curriculum.

Existing solutions for automating the formation of DWP presented on the market, including developments from other universities and online designers, have a number of disadvantages. These disadvantages range from incorrect formatting and formatting of the generated document, which requires additional manual refinement, to limitations in access and functionality. In

particular, in some DWP designers from other universities, it is possible to ensure that documents are processed correctly in accordance with the requirements of the university and provide flexible editing and customization options.

2. An overview of information systems of similar purpose

An analysis of existing solutions for automating the creation of DWP, such as those developed by ITMO Research Institute [3], TUSUR [4] and publicly available online constructor [5], revealed a number of functional limitations and inconsistencies with the requirements for the design of a DWP document at SevSU. Thus, the solutions of ITMO and TUSUR Research Institutes, having the ability to fill out the DWP by sections and save it in docx format, do not provide SevSU employees with access to create documents and do not take into account the specific design requirements adopted at the university. Online designers, although they provide the opportunity for SevSU employees to create a DWP and fill it out by sections, also do not meet the design requirements and, often, do not have sufficient adaptability.

Unlike the alternatives considered, the developed SevSU DWP constructor has a number of significant advantages. It provides the opportunity for SevSU staff to create and fill in the DWP in all sections, fully complies with the requirements for document design adopted at the university, allows you to save the document in docx format and has a high degree of adaptability. This makes it a more effective and convenient tool for SevSU teachers, allowing them to significantly reduce the time and resources spent on developing the DWP and ensure that the document meets all necessary requirements.

3. Information system design and development

The process of designing and developing an information system (IS) for automated DWP generation at SevSU will begin with the requirements analysis stage. This stage includes a thorough collection of information about the current process of forming the DWP, carried out through interviews with teachers, administration and staff of the educational and methodological department, as well as identifying the basic needs of users (teachers) and requirements for the functionality of the system. An important aspect is the analysis of current Federal State Educational Standards (FSSES) [7] and internal standards of SevSU, which regulate the structure and content of the DWP, as well as taking into account various levels of training and user experience when designing the interface and functionality of the system. The requirements analysis stage ends with the formulation of the goals and objectives of the system that clearly define the functionality of the IP, for example: reducing the time required to develop a DWP, improving the quality

of documentation, reducing the likelihood of errors, and ensuring compliance with the Federal State Budget and internal standards.

The next stage is the design of the system, which includes the development of a conceptual model that defines the main entities of the system (discipline, topic, lecture, competence, etc.) [2, p. 5] and the relationships between them. System architecture design involves choosing the appropriate architecture (for example, a three-level architecture: client level, business logic level, data storage level), and database design involves developing a database structure for storing information about disciplines, curricula, topics, competencies, and other data necessary for the formation of a DWP. The design of the user interface (UI) is aimed at developing an intuitive and user-friendly interface that provides easy access to all system functions and takes into account the principles of usability and adapts the interface to various devices (computers, tablets). The stage also involves designing algorithms for automatic DWP generation, which will automatically form the structure and content of the DWP based on selected parameters (discipline, curriculum, Federal State Educational Standard), and developing detailed specifications for each module of the system describing its functionality, input and output data, operating algorithms and interface requirements.

This is followed by the system development stage, which includes the selection of programming languages, frameworks, database management systems (DBMS) and other technologies used (for example: Frontend - React, Backend - Node.js, Database - PostgreSQL), the development of individual system modules in accordance with the specifications and their integration into a single system. In Figure 1, you can see the design of the authorization window.

Авторизация

Электронная почта*

Введите e-mail

Пароль

Введите пароль

ВОЙТИ

ЕЩЕ НЕТ АККАУНТА?

Figure 1 – Authorization window design

Figure 2 shows the design of the discipline addition screen, which provides for the input of fields such as the full and abbreviated name of the discipline, department, field of study, and discipline code.

Добавление дисциплины

Название дисциплины*

Сокращенное название дисциплины*

Кодификатор*

Направление подготовки*

Шифр дисциплины*

ДОБАВИТЬ ДИСЦИПЛИНУ

Тема*

ДОБАВИТЬ ТЕМУ

Лекция*

ДОБАВИТЬ ЛЕКЦИЮ

Figure 2 – Design of the discipline addition page

After logging in and filling in all the necessary fields, the user can create a DWP in the form of a document with the docx extension, which will be filled in with the data entered earlier. A part of the generated document can be seen in Figure 3.

РАБОЧАЯ ПРОГРАММА ДИСЦИПЛИНЫ	
Б1.О.19	УПРАВЛЕНИЕ ДАННЫМИ
<i>(шифр и наименование дисциплины в соответствии с учебным планом)</i>	
09.03.02	Информационные системы и технологии
<i>(код и наименование направления подготовки / специальности)</i>	
Интеллектуальные веб-ориентированные информационные системы и технологии	
<i>(наименование профиля / специализации)</i>	
бакалавриат	
<i>(уровень высшего образования)</i>	
очная, заочная	
<i>(форма обучения, год набора)</i>	

Севастополь
2022

Figure 3 – Part of the generated document

The final stage is the maintenance and development of the system, which involves constant monitoring of the system to identify and eliminate problems, prompt correction of identified errors and shortcomings, the release of new versions of the system with the addition of new functions and improvements, regular collection of feedback from users to improve the system and timely adaptation to changes in the Federal State Budget and internal standards of SevSU.

4. Conclusion

There are systems of similar purpose that generate a DWP document based on data entered by the user, but they have a number of disadvantages, one of which is most often present on university websites – the inability to create a DWP document by a user who is not authorized as an employee of this university. Also, on some websites there are problems with the compliance of the final DWP document with the rules of registration of the DWP document in SevSU.

The development of the system is designed to eliminate all of the above disadvantages. DWP is a document representing the curriculum of a training course. The DWP contains a detailed description of the goals, objectives, requirements, content and methods of teaching, as well as the main stages and forms of control of students' knowledge. This document describes not only the content of the course, but also methodological recommendations for its study, as well as a list of literature and resources needed to complete the tasks.

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EVOLUTION OF LANGUAGE MODELS: WHAT AWAITS US BEYOND GPT AND GROK?

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Аннотация. Рассматривается эволюция больших языковых моделей (LLM) от GPT (OpenAI) и Grok (xAI) к перспективам их развития после 2025 года. Описаны исторические этапы становления LLM, основанные на архитектуре трансформеров, и текущие достижения GPT-4 и Grok 3, включая их сильные стороны и ограничения, такие как энергопотребление и интерпретируемость. Основное внимание уделено будущим направлениям: оптимизации через "спарсенные" трансформеры, мультимодальности, интеграции с квантовыми вычислениями, самообучению и этическим аспектам. Рассмотрены сценарии применения, включая космос, медицину и образование. Вывод подчеркивает переход LLM к интеллектуальной автономности и их роль в будущем технологий, при условии решения текущих вызовов.

Ключевые слова: GPT, Grok, большие языковые модели, трансформеры, искусственный интеллект, мультимодальность, квантовые вычисления, энергоэффективность, самообучение, ИИ.

Annotation. The evolution of large language models (LLMs) from GPT (OpenAI) and Grok (xAI) toward their future development beyond 2025 is examined. The historical milestones of LLMs, based on the transformer architecture, are described, along with the current achievements of GPT-4 and Grok 3, including their strengths and limitations, such as energy consumption and interpretability. Primary attention is given to future directions: optimization through "sparse" transformers, multimodality, integration with quantum computing, self-learning, and ethical considerations. Application scenarios, including space exploration, medicine, and education, are explored. The conclusion highlights the transition of LLMs toward intellectual autonomy and their role in shaping the future of technology, contingent on addressing current challenges.

Keywords: AI, GPT, Grok, transformers, artificial intelligence, multimodality, quantum computing, energy efficiency, self-learning.

Introduction

Large Language Models (LLMs) have emerged as one of the defining technologies of the 21st century, revolutionizing natural language processing (NLP), text generation, and human-machine interaction. Since the introduction of GPT (Generative Pre-Trained Transformer) by OpenAI in 2018 and its subsequent iterations like GPT-3 and GPT-4, alongside models such as Grok from xAI, launched in 2023, LLMs have demonstrated remarkable progress. Built on the transformer architecture, these models excel at generating coherent text, answering questions, and tackling complex tasks.

By April 2025, it is evident that the evolution of LLMs is far from over, with new breakthroughs on the horizon. This article explores the key stages of LLM development, the current achievements of GPT and Grok, and the future prospects of their evolution.

Historical Context and LLM Architecture

The debut of GPT in 2018 marked a shift from specialized NLP models to versatile systems capable of learning from vast text datasets [1, p. 15]. The transformer architecture, introduced in the 2017 paper "Attention is All You Need" [2, p. 3], became the foundation for GPT and its successors. Its core component—the attention mechanism—enabled efficient processing of long text sequences while preserving context.

GPT-3, released in 2020, scaled up to 175 billion parameters, delivering a qualitative leap in text generation [3, p. 27]. Grok, unveiled by xAI in 2023, advanced further by focusing on computational optimization and integration with scientific data to enhance response accuracy [4, p. 12]. By 2025, both models have become benchmarks in their domains: GPT dominates mainstream applications, while Grok excels in research-oriented tasks.

Current Achievements and Limitations

As of April 2025, GPT-4 and its derivatives from OpenAI lead in text generation for commercial use cases, including chatbots, automated translation, and content marketing. With 1 trillion parameters, GPT-4 has improved reasoning capabilities and reduced "hallucinations"—fabricated facts in responses [5, p. 34]. However, energy consumption and training costs remain significant challenges: training GPT-4 consumed energy equivalent to powering a small city for a month [6, p. 9].

Grok 3, the latest iteration from xAI, is optimized for scientific computation and data analysis. Its ability to integrate with knowledge bases and verify facts makes it invaluable in academic research [4, p. 15]. Yet, Grok

lags behind GPT in conversational flexibility due to its lesser focus on general-purpose scenarios.

Key limitations of current LLMs include dependence on training data quality, high computational costs, and insufficient interpretability of decisions. These challenges set the stage for the next phase of evolution.

Future Prospects of LLMs

Optimization and Energy Efficiency, by 2025, research indicates that simply increasing parameter counts does not always yield proportional quality gains [7, p. 22]. Future models are likely to adopt "sparse" transformer approaches, activating only parts of the network for specific tasks. This is exemplified by the experimental SparseLLM, which cut energy use by 40% compared to GPT-4 [8, p. 18].

Multimodality, the next frontier is integrating text with other data types—images, audio, and even sensory inputs. OpenAI's DALL-E 3 (2023) showcased success in text-to-image generation [9, p. 11], and future LLMs, such as a hypothetical GPT-5, may combine these capabilities into a unified system capable of real-time multimodal content processing.

Integration with Quantum Computing, quantum computers promise to accelerate LLM training, particularly in optimization and big data tasks. In 2024, IBM reported the first successful training of a small language model using a quantum processor [10, p. 25]. By 2030, this could become standard for next-generation LLMs.

Intelligent Adaptation and Self-Learning Grok 3 already exhibits adaptive traits, updating its knowledge without full retraining [4, p. 16]. Future models may advance further with "active learning," autonomously requesting data to refine skills and minimize human intervention.

Ethics and Interpretability, as LLMs expand into critical domains like medicine and law, the demand for "explainable AI" grows. Researchers propose embedding interpretability modules to clarify decision-making processes [11, p. 31], potentially becoming a mandatory standard by the late 2020s.

Application Scenarios

New use cases across diverse domains can be unlocked by future large language models (LLMs). LLMs enable real-time data analysis from telescopes and mission management in space exploration, building on xAI's innovative approaches, as well as personalized medicine.

LLMs power adaptive learning systems customized to the unique needs of individual students, collectively demonstrating their potential to transform critical fields through advanced intelligence and adaptability.

LLMs facilitate the treatment plans creation by means of leveraging textual medical records and genomic data, and education.

Conclusion

The evolution of large language models beyond GPT and Grok is trending toward greater multimodality, efficiency, and intellectual autonomy.

By 2030, new systems can be presented. They will generate text and also interact with the physical world, leveraging quantum computing and novel architectures. However, success depends on addressing ethical and technical challenges. These are energy use and interpretability. LLMs will be active participants in human endeavors, opening new frontiers in technology and science.

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**APPLICATION OF SIMPLE DISTANCE CALCULATIONS AND
OSRM FOR GEOSPATIAL ANALYSIS IN SELECTING
EXECUTORS IN CMMS SYSTEMS FOR SMALL AND MEDIUM-
SIZED ENTERPRISES**

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Аннотация. В работе рассматривается задача автоматического подбора исполнителей для заявок в системе управления техническим обслуживанием и ремонтом (CMMS) для малых и средних предприятий. Первый подход использует метод «птичьего» расстояния, вычисляемого по формуле Хаверсина, что упрощает интеграцию и снижает вычислительные затраты. Второй подход опирается на реальную дорожную сеть, загруженную в Open Source Routing Machine (OSRM), обеспечивая более точный расчёт маршрутов, но требуя отдельный сервер и дополнительное время вычисления. В ходе эксперимента на условных данных (город Севастополь, 10 исполнителей, 20 заявок) показано, что «прямой» метод работает практически мгновенно, но иногда недооценивает сложность пути, тогда как OSRM выдает точные маршруты, однако отсекает больше заявок за пределами радиуса или недоступностями маршрута. Выбор метода зависит от приоритетов компании: если важна скорость решения, достаточно метода Хаверсина; при необходимости учёта реальной уличной топологии стоит использовать OSRM.

Ключевые слова: CMMS, Haversine, OSRM, геопространственный анализ, маршрутизация, OpenStreetMap, оптимизация дистанции, расстояние.

Annotation. This work addresses the problem of automatic assignment of executors to work orders in a Computerized Maintenance Management System (CMMS) for small and medium-sized enterprises. The first approach uses a «crow-fly» distance method, calculated via the Haversine formula, simplifying integration and reducing computational cost. The second approach relies on the real road network loaded into the Open Source Routing Machine (OSRM), enabling more accurate route calculations but requiring a dedicated server and additional computation time. An experiment on synthetic data (city of Sevastopol, 10 executors, 20 orders) showed that the «direct» method works almost instantly but may underestimate path complexity, while OSRM provides precise routing but filters more orders due to radius or route unavailability. The method choice depends on company priorities: for fast resolution, Haversine is sufficient; for real-world topological assessment, OSRM is recommended.

Keywords: CMMS, Haversine, OSRM, geospatial analysis, routing, OpenStreetMap, distance optimization, distance.

A Computerized Maintenance Management System (CMMS) is a software complex that accumulates a database of an organization's service activities and helps personnel perform their tasks more efficiently. One of the key functions of a CMMS, especially in the context of field services, is the assignment of work orders to the most suitable executors.

As the number of orders increases, a company's financial and time expenditures for their allocation rise significantly, making the issue of automatic optimal assignment critical. This problem can be solved through the application of a recommendation system [5].

Large companies use specialized modules or external routing services that are integrated with expensive mapping APIs to evaluate travel time to service locations, taking into account traffic and other factors (e.g., Yandex Maps API). However, for small and medium-sized enterprises, the use of paid mapping services imposes an additional financial burden, necessitating a more cost-effective solution.

In a resource-constrained environment, it is crucial for enterprises to strike a balance between the accuracy and cost of logistics automation and the selection of personnel for order execution. An example of such a solution is the system under development, «Geo Maintenance», focused on operating with a limited budget and designed for automatic assignment of work orders in maintenance organizations. This system requires a budget-friendly recommendation mechanism for selecting executors that can take into account both personnel skills and the geographical distance of objects [3]. In this

regard, the present work analyzes two approaches for route construction and determining the optimal executor for each order.

The first approach evaluates the distance between executors and orders in a simplified manner – it calculates the shortest distance over the Earth's surface using the Haversine formula [4]. The second approach uses the Open Source Routing Machine (OSRM) – a high-performance shortest-path calculation engine operating on OpenStreetMap data and distributed as free software [2].

The goal is to assess how the results of executor assignment and related metrics – total distance to all orders, time spent on calculations, and other parameters – differ depending on the chosen method. In particular, it is necessary to compare the accuracy of results when using OSRM versus simple coordinate-based calculations and evaluate the computational resource costs and implementation complexities. The influence of considering employee skills is also studied: how the limitation by competencies affects task distribution and distances.

Problem Statement

A simplified module for managing orders in a CMMS system is considered, in which there is a set E of executors (employees) and a set T of work orders (maintenance tasks).

For each executor e , the following are known.

1. Geographic location (x_e, y_e) , e.g., base or current position coordinates.
2. Set of competencies $Skills(e)$ – a list of types of work the executor is capable of performing (e.g., electrician, plumber).
3. Maximum service radius $Radius(e)$ in kilometers.

For each order t , the following are known:

1. Geographic location (x_t, y_t) – coordinates of the facility requiring service.
2. Required skill set $Skills(t)$ – competencies needed for completion.

It is required for each incoming order to automatically assign an executor e who satisfies the following two prioritized conditions:

1. Skill match $Skills(t) \subseteq Skills(e)$, i.e., the executor possesses all necessary skills for the assigned task.

2. Geographical availability. In addition to meeting professional requirements, the executor must be within their maximum allowable service radius. Given the executor's coordinates (x_e, y_e) and maximum radius $Radius(e)$, and the order's coordinates (x_t, y_t) , the distance must satisfy:

$$d((x_e, y_e), (x_t, y_t)) \leq Radius(e),$$

where the distance d can be calculated, for example, either using the Haversine formula or with consideration of road infrastructure.

If multiple executors satisfy the conditions (in terms of skills and radius), the most suitable one is selected based on the shortest distance, i.e., the one for whom the distance to the order is minimal. It is assumed that each executor can take on one task (at least at a single point in time), so tasks are considered individually, and the problem of multi-task route planning is not addressed.

Distance Estimation Methods

The key difference between the compared approaches lies in how the distance $d(e, t)$ между исполнителем between executor e and order t is computed for the purpose of assignment.

1. **Direct or «as-the-crow-flies» distance.** In the simplest case, this allows estimation of the distance in a straight line, «as the crow flies». To compute the shortest arc between two points on the Earth's sphere, given as latitude and longitude, the Haversine formula is used. The only required external data are the coordinates of the executor and the service object. Thus, the time and space complexity of such an operation is $O(1)$. On the other hand, the actual road situation and terrain may differ significantly from a straight line: roads may wind, obstacles (rivers, buildings, restricted areas) may exist between points, and the actual route may be much longer.

2. **Route via OSRM.** In this approach, a road graph is used, along which the executor travels. The distance $d(e, t)$ is defined as the length of the shortest path through the road network from point e to point t . The road graph data are taken from the free open map OpenStreetMap, and shortest path calculation is performed using the OSRM engine. Thanks to routing algorithms based on contraction hierarchies, OSRM can quickly return the distance and route in *GeoJson* format between specified points. However, this requires preprocessed data: a regional map and computed indices of the road structure. Subsequently, route calculation requests take only milliseconds. This method accounts for the actual road network, directionality, and existing infrastructure (bridges, etc.), so the final OSRM distance is usually longer than the «as-the-crow-flies» distance [1].

Order Assignment Algorithm

1. For an incoming order t , a list of candidate executors is formed:

$$C_t = \{e \in E \mid Skills(t) \subseteq Skills(e) \wedge d(e, t) \leq R_e\},$$

i.e., executors possessing the required competencies and located within service radius to the client.

2. If C_t is not empty, the executor with the minimum distance to the order is selected:

$$e^* = \operatorname{argmin} d(e, t), \quad e \in C_t$$

3. The order is assigned to executor e^* . If C_t is empty, the order remains unassigned or is sent for manual processing.

The only difference between the two system variants under consideration lies in the method of calculating $d(e, t)$. It is expected that in the general case, the results of assignments using both approaches may coincide if the road network is sufficiently uniform, but in individual cases, executor selection may differ.

Experiment Execution

To quantitatively compare the methods, an experiment using a program module in the Python language was conducted. Input data: the locality is the city of Sevastopol, the coordinates of the location of executors and requests for service are set in geographic coordinates.

Randomly generated 10 executors and 20 requests distributed in the area of the city. Each executor has one core competency from the set {A, B, C} and a service radius of 5 km; each request requires one of these competencies.

Two ways of estimating distances were compared:

1. The direct distance method using the Haversine formula.
2. Calculation using the Open Source Routing Machine – a Docker image of OSRM was deployed locally on a personal computer [7], and road data were loaded from open sources [6].

The following indicators were evaluated:

1. Number of cases where the two methods selected different executors for the same order.
2. Total distance that all assigned executors must travel to their tasks using the corresponding estimation method.
3. Average distance to an order (in km) and the maximum distance across all assignments.
4. Approximate calculation time for all assignments for each method.
5. Number of orders for which no executor was assigned.

Experiment Limitations

It should be noted that this study considers a simplified scenario that does not take into account many aspects of real-world planning.

Assignments are made independently for each order, without considering competition for executors or the possibility of simultaneous incoming orders. In a real-world environment, it would likely be necessary to distribute orders optimally among multiple executors, leading to more complex scheduling problems.

The arrival time factor was not considered, i.e., it was assumed that distance directly correlates with time, whereas in practice, traffic and time of day affect travel speed. OSRM can take into account road types and even traffic conditions if additional data are available, but this was not addressed in the present work.

Executor competencies were limited to one required competency per order, whereas in practice, requirements may be composite or more flexible (e.g., different qualification levels).

The road topology in OSRM is based on the available OpenStreetMap map. If actual information is missing in the open dataset (e.g., closed courtyards, secure facilities), the real route may differ from the calculated one.

Experiment Results

The results of the experiment are presented in Table 1.

Figure 1 shows the route construction on the map using the direct method, and Figure 2 – using OSRM. Pins represent executors, flags – target service objects.

Using the «direct» method, the average distance to an order was 1.40 km, and the maximum was 2.66 km. The total calculation time for all assignments was near zero, and all orders were successfully assigned (the nearest skilled executor was within 5 km «as-the-crow-flies»).

For the OSRM method, the average distance was 2.44 km, and the maximum reached 4.24 km. Route calculation took approximately 0.19 seconds, and 2 orders remained unassigned because the real road route exceeded the radius or was unavailable.

Assignments matched in 14 cases (70%) and differed in 6.

Table 1 – Experiment Results

Metric	Direct (Haversine)	OSRM (Routing)	Metric
Matching assignments, %	70%	70%	Matching assignments, %
Total distance, km	27.90	44.00	Total distance, km
Average distance, km	1.40	2.44	Average distance, km
Maximum distance, km	2.66	4.24	Maximum distance, km
Calculation time, sec	~0.00	~0.1897	Calculation time, sec
Orders without assignment	0	2	Orders without assignment

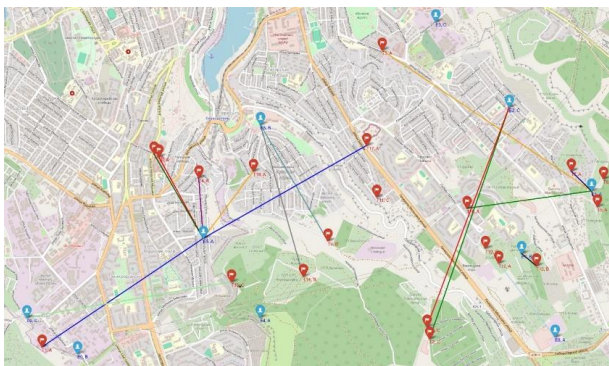


Figure 1 – Route construction on the map using direct method

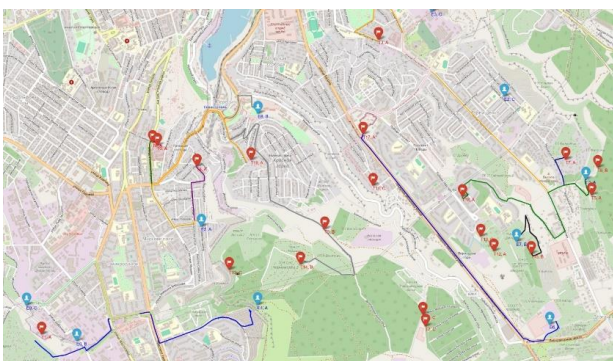


Figure 2 – Route construction on the map using OSRM

As seen from Table 1, the direct method results in shorter distances and lower computation time but may overestimate availability. The OSRM method more accurately reflects the real road situation and can filter out orders outside the radius (2 orders remained unassigned) while yielding greater total route lengths due to the actual road being longer than the «as-the-crow-flies» path.

Therefore, if simple implementation and fast approximate calculations are a priority, the direct method is sufficient. If realistic route assessment is important and improved selection is desired, it is reasonable to use OSRM despite additional infrastructure and increased computational cost. In the context of the «Geo Maintenance» system, where rapid automation of

executor assignment is crucial to reduce time and financial costs for extra personnel, it is advisable to initially use the «direct» method, since it requires no additional resources and minimal implementation effort. When scaling the system, a transition to integration with OSRM – a free solution based on OpenStreetMap – is appropriate.

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TECHNICAL MAINTENANCE SERVICE SYSTEMS: APPROACHES TO DATA ISOLATION

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Аннотация. В данной статье рассматривается проблема изоляции данных различных организаций при создании платформ технического обслуживания, где финансовые и организационные отношения между участниками строятся на основе модели подписки. Рассматриваются возможные подходы к сегментации и защите данных в условиях использования единой базы данных, общих сервисов и сервера идентификации Keycloak. Особое внимание уделяется схеме «много Realms, один Client», которая позволяет легко обеспечить уникальность учетных записей пользователей и надежную изоляцию данных.

Ключевые слова: модель подписки, Keycloak, многопользовательская архитектура, изоляция данных, техническое обслуживание и ремонт, сегментация данных, жизненный цикл организации, разделение данных организации.

Annotation. This article addresses the problem of isolating data from different organizations when creating technical maintenance service platforms in which financial and organizational relationships between participants are built on a subscription-based model. Possible approaches to data segmentation and protection are considered under the conditions of a single database, common services, and a Keycloak identity server. The emphasis is on the «multiple realms, single client» scheme, which makes it easy to ensure the uniqueness of user accounts and reliable data segregation.

Keywords: subscription model, Keycloak, multi-tenant architecture, data isolation, technical maintenance and repair, data segmentation, organizational lifecycle, organizational data separation.

In the context of the development of cloud technologies and technical maintenance and repair (TOMRO) systems, the subscription business model has shown impressive growth: according to Zuora, the use of subscriptions in the global market has increased by 436% over the last nine years, and by 2025, UBS forecasts that the volume of the subscription economy will exceed \$1.5 trillion. These trends are supported by Gartner research indicating that by 2023 about 75% of companies will already be offering subscription products [2].

However, when simultaneously servicing numerous independent organizations within a single infrastructure, the challenge of securely separating (isolating) their data arises. Consequently, the question ‘How can we guarantee that the records and user data of one technical maintenance and repair company will not be accessible to another?’ becomes paramount in the development of such platforms. Another crucial issue is the cost of developing such a software solution. As demonstrated by the departure of SAP from Russia, the problem of migrating from foreign products to local solutions requires thorough consideration, including preserving functionality, data integrity, and minimizing implementation costs [1].

Often, to reduce development costs, ready-made solutions are used. For instance, an identity server like Keycloak may be employed for authentication and access control, while all actual operations – such as working with orders, generating recommendations, and maintaining user accounts – are performed in a single database. In this situation, it becomes necessary to choose the optimal data isolation scheme.

There are several main ways to separate data when using Keycloak [4]:

1. Single realm, multiple clients. Suitable for scenarios where different clients (Clients) are used within one “space” (realm), but the organizations often do not have strict data boundaries. In certain circumstances, users from one organization may easily access the data of another.

2. Single realm, separation by groups. This approach stores all users and companies in one place. However, with a lot of organizations, it becomes more difficult to maintain a “branching” structure of groups and roles. This can make the system challenging to scale.

3. Multiple realms, single client. Under this approach, each organization is allocated its own realm (Realm), while the client (Client) is created alongside each realm. The realms are isolated from each other by default: a user from one realm cannot accidentally «penetrate» another.

As a result, for the technical maintenance and repair system, the third scheme, «multiple realms, single client», was chosen.

Rationale for the «Multiple Realms, Single Client» Approach

For startups, evolving systems, and even established solutions that serve multiple clients via subscription, it is critical to prevent both the leakage of confidential data and any confusion with user accounts. The chosen option appears most justified for the following reasons:

1. **Uniqueness of user accounts.** Each organization (realm) can have a user with the same login, for example, the same email or phone number, without conflicting with another organization. An exception, if required, is the account of the organization's creator, which must be globally unique throughout the system as the subscription owner.

2. **Clear data segregation.** Since realms do not intersect by default, the risk of accidentally granting access to an “outside” user is minimized. The administrator of one organization cannot peek into another realm that contains the user accounts and settings of another company. If necessary, intentional access among certain organizations can be provided via IdP and other services. For storing unstructured data – such as logs and multimedia objects – an S3-compatible cloud can be used, which scales in line with the “multiple realms, single client” architecture [3].

3. **Flexibility in subscription settings.** A specific subscription plan and its associated functionalities can be assigned to each realm. If one company needs advanced tools and another only the basics, this is handled in the realm settings and does not affect the global rules.

4. **Convenient management of an organization's lifecycle.** If necessary, an entire realm can be easily suspended or deleted without affecting other tenants. As a company grows, its realm can be scaled by adding new roles and policies. If required by a company, additional clients (Clients) can be created within its realm at any time to implement more secure authentication methods (e.g., separate protocols such as SAML or OAuth) or specialized authentication mechanisms for particular subsystems of the company. This does not affect the global platform structure.

Additional Considerations: One Database – One Schema

Although a single physical database instance is used for all organizations, their records are logically separated. Each object (order, user, setting) contains an attribute indicating its affiliation with a particular organization (realm). Such systems scale well in startup projects when the number of clients is still relatively small.

In more complex scenarios, there are also “one organization – one database” or “one organization – one schema” approaches, where each company receives a fully separate data structure. While this increases the level

of isolation, it significantly complicates infrastructure management (especially if there are dozens or hundreds of organizations). The departure of SAP has shown that physical data isolation at the database level may be justified for large corporate clients, but as mentioned earlier, for startups it remains less practical due to cost considerations.

In the context of a subscription model and the need for reliable data segregation among different organizations, the “multiple realms, single client” approach in Keycloak proves to be the most appropriate for startups and medium-sized companies. It offers transparency in configuring access policies, ensures ease of administration, allows compliance with the requirement for a unique organization owner, and retains flexibility in business logic.

Alternative options (a single realm for everyone or separation by groups) may be optimal in specific cases; however, they often face challenges with account uniqueness and security as the system scales. Concerning databases, it is most cost-effective at the initial development stage to use “one database – one schema,” and later, for specific clients, scale up to the “one organization – one database” scenario to achieve physical-level isolation.

Thus, the key takeaway is that “multiple realms, single client” strikes a reasonable balance between reliability, ease of administration, and scalability, which is especially important in the early stages of developing a subscription-based technical maintenance platform.

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**SOFTWARE IMPLEMENTATION OF WEIGHTED MEDIAN
ALGORITHMS FOR ESTIMATING THE CENTER OF
PROBABILITY DISTRIBUTION**

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Аннотация. В статье рассматриваются особенности программной реализации алгоритмов нахождения оценки центра распределения вероятностей в виде взвешенной медианы (ВМ). Оценка широко используется в методе наименьшего абсолютного отклонения при решении простых или множественных задач регрессии. Рассмотрены четыре алгоритма нахождения ВМ и приведены результаты их сравнения по времени выполнения.

Ключевые слова: мера центральной тенденции, оценка центра распределения, взвешенная медиана, временная сложность алгоритма

Annotation. The article discusses peculiarities of software implementation of algorithms for finding an estimate of the probability distribution center in the form of weighted median (WM). The estimate is widely used in the least absolute deviation method when solving simple or multiple regression problems. Four algorithms for finding the WM are considered and the results of their comparison in terms of execution time are presented.

Keywords: measure of central tendency, distribution center estimation, weighted median, algorithm time complexity

Introduction

The *weighted median* (WM) is the 50% weighted percentile. It is used as an estimate of the measure of central tendency (center of distribution) of data of various natures. In particular, the WM is often used in solving simple or multiple regression problems in the least absolute deviation method, which provides high reliability (robustness to outliers) in contrast to the popular least squares method [2, 4, 7].

For a given sample of n ordered elements x_1, x_2, \dots, x_n with positive weights w_1, w_2, \dots, w_n (such that the sum of weights is equal to one), the weighted median is the element x_k that satisfies the condition [4]:

$$\sum_{i=1}^{k-1} w_i \leq 0,5 \text{ и } \sum_{i=k+1}^n w_i \leq 0,5. \quad (1)$$

In the case of even n , condition (1) will be satisfied for two values of x , in the interval between which there are infinitely many weighted medians. Then it is common to choose the smallest of these values as the WM estimation. Such median is called the *lower weighted median*.

Table 1 shows an example of a sample of five elements x_i with weights w_i . For this sample, the weighted median is element x_3 because it is the only element that satisfies condition (1). Figure 1 illustrates the process of determining the weighted median for the sample from Table 1, where W_{sum} is the values of the weights sum of the previous elements for the current x . For element x_3 , the current weights sum W_{sum} reaches a value of 0.53, exceeding the threshold value 0.5 from condition (1) for the first time.

Table 1. Example of dataset values and weights for calculating the WM

Value x	1	2	3	4	5
Weight w	0.19	0.24	0.1	0.18	0.29

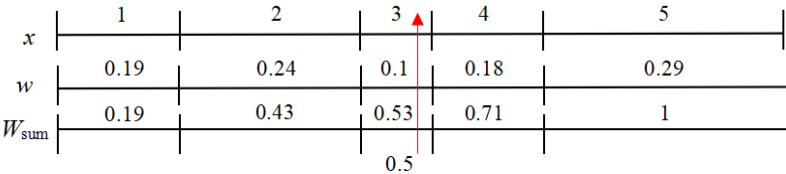


Figure 1. Visualization of the *introsort* (see next Section) procedure for determining the weighted median for the example from Table 1

Description of algorithms for finding the weighted median

All algorithms are programmed to work with the same data format. The input is an unordered array of objects consisting of a value x and its weight w . The output of all programs is the weighted median. Normalization of the weights, if required, is performed outside of the main functions. Let us consider four different variants of WM calculation, implemented on the basis of different approaches to sorting of elements.

Partial pyramidal sorting [7] defines the weighted median as the point on the real axis where the derivative changes its sign. If the data points are checked in order, then by successively adding weights to the left sum and subtracting the right sum, an index can be found that moves the balance from the right side to the left side. Obviously, the data points do not have to be

completely sorted, as not all points will be accessed. Below is a snippet of the main part of the algorithm code.

```
while (!minHeap.empty() && leftWeightSum < rightWeightSum) {
    median = minHeap.top();           // take the minimum element
    minHeap.pop();                   // remove this item from the heap
    leftWeightSum += median.weight;   // add the element
weight to the left sum of weights
    rightWeightSum -= median.weight;  // subtract element
weight from the right sum of weights }
```

Quick sorting method [2] organizes the data by pyramidal sorting if $n < 64$, otherwise the array is split into groups of five elements. Each group is then sorted and a WM is determined for each. The median of the medians is recursively determined. The code fragment has the following form.

```
for (const auto& point: dataPoints) {
    if (point.value < medianOfMedians.value) {
        leftPart.push_back(point);
        leftWeightSum += point.weight;    }
    else if (point.value > medianOfMedians.value) {
        rightPart.push_back(point);
        rightWeightSum += point.weight }
    else {
        equalPart.push_back(point);
        equalWeightSum += point.weight }
    }
    if (leftWeightSum + balance >= equalWeightSum + rightWeightSum) {
        return weightedSelect(leftPart, balance - equalWeightSum -
rightWeightSum);
    }
    else if (leftWeightSum + equalWeightSum + balance >=
rightWeightSum) {
        return medianOfMedians;
    }
    return weightedSelect(rightPart, balance + leftWeightSum +
equalWeightSum);
}
```

The introspective sorting method uses the *introsort* algorithm [6], after applying which it starts summarizing the weights until conditions (1) are satisfied. The code fragment has the following form.

```
std::vector<DataPoint> sortedData = dataPoints;           // copy the data
to sort
```

```

std::sort(sortedData.begin(), sortedData.end(), [](const DataPoint& a,
const DataPoint& b) {
    return a.value < b.value; });
double WeightSum = 0.0;
const double halfWeight = 0.5;

for (const auto& point : sortedData) {
    WeightSum += point.weight;
    if (WeightSum >= halfWeight) {
        return point.value; }          // output the result if the value is
greater than the threshold
    }
}

```

Partial quicksort method [2] applies the *Find* algorithm [3], which partially sorts the array, bringing the selected element to its place as if the array were fully sorted. In this case, the array will be partially sorted in such a way that all elements to the left of the selected element will be smaller in value than it, and to the right – larger. The code fragment has the following form.

```

while (true) {    rightIndex++;          // move on to the next
item on the right
    int currentIndex = rightIndex;
    double currentFunctionValue = functionValues[currentIndex];
    medianIndex = currentIndex;          // memorize the current
value of the function
    while (currentIndex < n - 1) { currentIndex++;      // search for
the minimum value in the right part
        if (functionValues[currentIndex] < currentFunctionValue) {
            currentFunctionValue = functionValues[currentIndex];
            medianIndex = currentIndex; } }          // update the value
    // add the weight of the selected element to the sum of the left part
    leftWeightSum += weights[medianIndex];
    if (leftWeightSum >= pivotWeight) break;          // if the
threshold is exceeded, the element is found
    functionValues[medianIndex] = functionValues[rightIndex]; //
moving elements
    weights[medianIndex] = weights[rightIndex];
    indices[medianIndex] = indices[rightIndex]; }

```

Computational experiment

To evaluate the four methods of finding the weighted median described above, a comparative experiment was conducted, during which the solution time was recorded for 1000 individual problems (sets of pairs “value x – weight w ”) of different size $n = 5, 15, \dots, 95$ with a step of 10. Table 2 shows

the values of the average running time of the algorithms for 100 individual problems at each value of n .

Table 2. Average running time of the algorithms in milliseconds for $n = 5, 15, \dots, 95$

n	Introspective sorting	Partial pyramidal sorting	Quick sorting	Partial quicksort
5	3.357	4.563	3.521	1.419
15	6.479	9.458	5.701	2.301
25	10.946	9.509	7.961	3.318
35	13.868	12.957	10.628	4.208
45	18.259	16.333	12.937	5.597
55	20.984	16.392	15.036	6.528
65	25.256	57.68	19.379	7.988
75	29.188	62.297	20.717	8.597
85	33.028	67.58	26.757	10.746
95	37.308	71.767	25.905	12.438

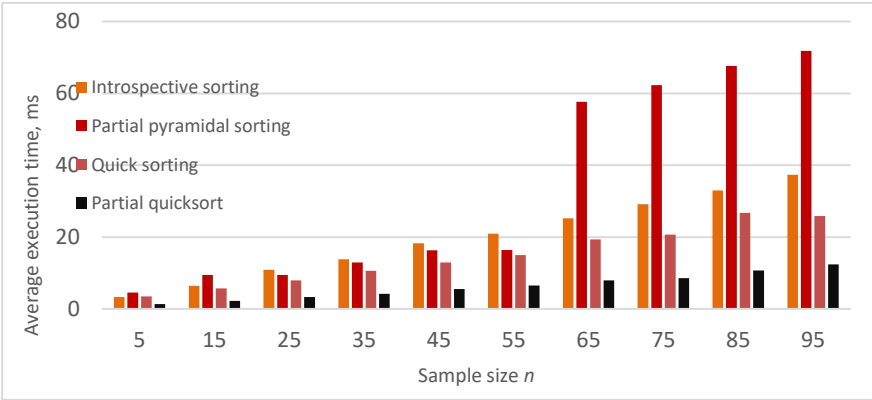


Figure 2. Average running time of algorithms depending on the number n of elements in a sample

Figure 2 shows the general performance trend of different algorithms. The average execution time of the partial sorting method is always less than that of any other method, even though in rare cases the quick sorting method may run faster (see Figure 3). The partial pyramidal sorting method always shows the most negative results, but it is often used as part of the quick sorting method, and can therefore be helpful.

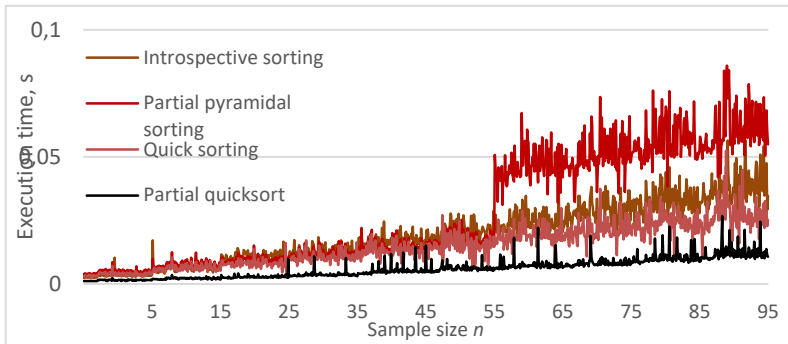


Figure 3. Running time of algorithms depending on the sample size n

Based on the experimental data shown in Figure 2 and Table 1, we can draw a number of conclusions. First, the method of partial pyramidal sorting sharply increases the execution time at $n > 64$, which makes its application inexpedient. Second, in all cases, the partial sorting method appeared to be the most performant, and exhibited the lowest runtime. Most likely, this is due to the fact that, unlike other methods, it requires almost no time for array sorting.

Conclusion

Thus, the analysis of the data obtained in the framework of the computational experiment allows us to recommend a promising algorithm for calculating the weighted median to be used in estimating the probability distribution center, namely, the method of partial sorting. This method is faster than other algorithms considered by about 2.1-2.5 times, depending on the dimensionality of the analyzed sample.

In the near future, the paper authors plan to conduct comparative studies of the weighted median estimate and the estimate found by the method of *interval fusion with preference aggregation* [5] to be applied in tasks of regression analysis.

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COMPARATIVE EVALUATION OF LSTM, CNN, AND MLP ARCHITECTURES TO STOCK PRICE FORECASTING

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Аннотация. В данной статье рассматривается применение нейросетевых алгоритмов для прогнозирования цен на фондовом рынке. Основное внимание уделяется использованию рекуррентных нейронных сетей (RNN) с архитектурой Long Short-Term Memory (LSTM), способных эффективно учитывать временные зависимости и нелинейные взаимосвязи в динамике финансовых активов. Предложенный подход включает формирование обучающих последовательностей с использованием оконной функции, позволяющей модели предсказывать цену закрытия следующего торгового дня на основе истории предыдущих значений. В работе проведено сравнение различных архитектур, таких как базовая LSTM, стековая LSTM, сверточная нейронная сеть (CNN) и многослойный персептрон (MLP), с использованием метрик, включая среднеквадратичную ошибку (MSE), корень из MSE (RMSE), среднюю абсолютную ошибку (MAE) и процентную ошибку (MAPE). Результаты экспериментов демонстрируют, что предложенный метод имеет высокий потенциал для повышения точности прогнозирования и может быть успешно применен в системах поддержки принятия инвестиционных решений.

Ключевые слова: нейросетевые алгоритмы, прогнозирование цен, фондовый рынок, LSTM, CNN, MLP, рекуррентные нейронные сети, глубокое обучение, временные ряды, машинное обучение.

Annotation. This paper considers the application of neural network algorithms for price forecasting in the stock market. The primary focus is directed towards the utilization of recurrent neural networks (RNN) with Long

Short-Term Memory (LSTM) architecture, which has been demonstrated to be capable of effectively accounting for temporal dependencies and nonlinear relationships in the dynamics of financial assets. The proposed approach involves the establishment of training sequences employing a window function, thereby enabling the model to predict the closing price of the subsequent trading day based on the historical values of preceding periods. The proposed approach is evaluated by comparing different architectures, including basic LSTM, stacked LSTM, CNN and MLP, using metrics such as mean square error (MSE), root of MSE (RMSE), mean absolute error (MAE) and percent error (MAPE). The experimental results demonstrate that the proposed method has the potential to improve forecasting accuracy and can be successfully applied in investment decision support systems.

Keywords: neural network algorithms, price forecasting, stock market, LSTM, CNN, MLP, recurrent neural networks, deep learning, time series, machine learning.

1. Introduction

Price forecasting on the stock market is one of the most critical and complex tasks of modern financial analytics. Conventional statistical methods, such as ARIMA and GARCH models, “are often limited by high volatility and nonlinear market dynamics” [2, p. 8553]. In recent years, machine learning methods have experienced active development, enabling the extraction of hidden dependencies from large volumes of data and substantially enhancing forecasting accuracy [1].

In this paper, the following model architectures will be considered: Multi-layer Perceptron (MLP), Convolutional Neural Networks (CNNs), Long short-term memory (LSTM). MLP is a regular fully connected network where the input data is represented as a one-dimensional vector. While MLP does not incorporate a specialized mechanism for handling temporal dependencies, it is often used as a baseline model in comparisons due to its capability to uncover hidden dependencies on a sufficient number of input features. By employing this architecture in comparisons, we can evaluate the significance of temporal structure processing in architectures specifically designed to handle sequences [4].

CNNs represent a specific implementation of feedforward neural networks, that demonstrate robust performance both in image and natural language processing. This architecture can be successfully applied for time series forecasting. The local perception and weight sharing of CNN can significantly reduce the number of model parameters, which improves the model training efficiency. CNNs are primarily composed of key elements: convolution layer and pooling layer. The convolution layer performs convolution operation, that extracts features from data, while the pooling layer

is utilized for feature size reduction due to significant amount of data passed from the previous step. “This results in smaller feature maps that reduce the network training costs” [3, p. 528].

LSTM is a type of recurrent neural network designed to work efficiently with sequential data. Compared to traditional RNNs, LSTM utilizes special structural units - memory cells, each with three gates: an input gate, a forgetting gate, and an output gate. The input gate determines what new information should be stored in the memory cell. The forgetting gate controls what portion of the already accumulated information should be discarded. The output gate controls which information from the memory cell should be used to generate the output at each time step. This allows the LSTM to preserve long term dependencies and avoid both vanishing and exploding gradient problems that characterize traditional RNNs [5].

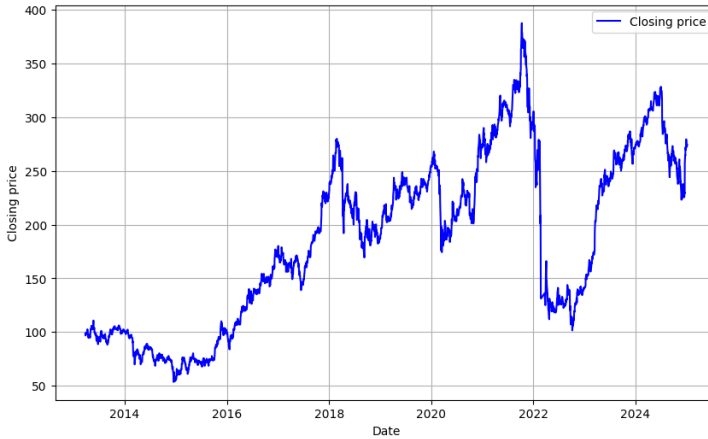
2. Data

This article examines Sberbank common stock from 2013-03-25 through 2025-01-06. The data for each date consists from:

- 1. Opening price;
- 2. Minimum price;
- 3. Maximum price;
- 4. Closing price;
- 5. Trading volume.

Table 1 - Dataset

Trade date	Open	Low	High	Close	Volume
25.03.2013	96.0	96.0	101.14	98.79	593680.0
26.03.2013	98.58	97.08	99.31	97.2	1283550.0
27.03.2013	97.9	95.39	98.0	96.75	1261950.0
28.03.2013	96.38	95.72	98.66	98.59	1971410.0
29.03.2013	98.6	98.32	99.09	98.76	782000.0
01.04.2013	98.37	97.55	99.43	98.07	2279650.0
02.04.2013	98.12	98.04	99.45	98.93	3555020.0
03.04.2013	98.9	98.69	99.71	99.59	3757240.0
04.04.2013	98.86	98.5	101.13	99.91	5172930.0
05.04.2013	99.88	98.4	100.84	99.38	5229210.0



Picture 1 - Historical quotes

Training and test samples were formed from a sliding window: at each step window generates two parameters: a sequence consisting of 30 prior observations and a target value based on a closing price from the next trading day. This approach the model's ability to consider the price history when forming the forecast.

3. Methodology

The following model architectures were selected to investigate the price forecasting capability:

1. LSTM: a single-layer recurrent neural network with 50 neurons, incorporating a Dropout layer to reduce overfitting, and an output full-link layer for regression;
2. Stacked LSTM: A two-layer LSTM architecture where the first layer outputs a sequence for subsequent processing by the second layer, thereby enabling the model to extract more complex temporal dependencies;
3. CNN: This architecture employs univariate convolutional filters to detect local dependencies in the time series. The application of MaxPooling and Flatten layers facilitate feature pooling and dimensionality reduction;
4. MLP: a traditional full-link network applied to pre-transformed input data, serving as a benchmark for comparing neural network methods that do not consider explicit temporal dependencies.

Every neural network architecture used Adam as an optimizer and RMS error as a loss function. The data was divided into training (80%) and test (20%) samples. Training was performed for 100 epochs with a batch size of 32. The

following metrics were used to evaluate the quality of the models: MSE, RMSE, MAE, MAPE.

4. Experimental comparison and analysis of results

Experiments were conducted on three types of datasets:

- 1. A set containing only the closing price.
- 2. A set containing the opening, minimum, maximum and closing price.
- 3. A set containing all available indicators, including trading volume.

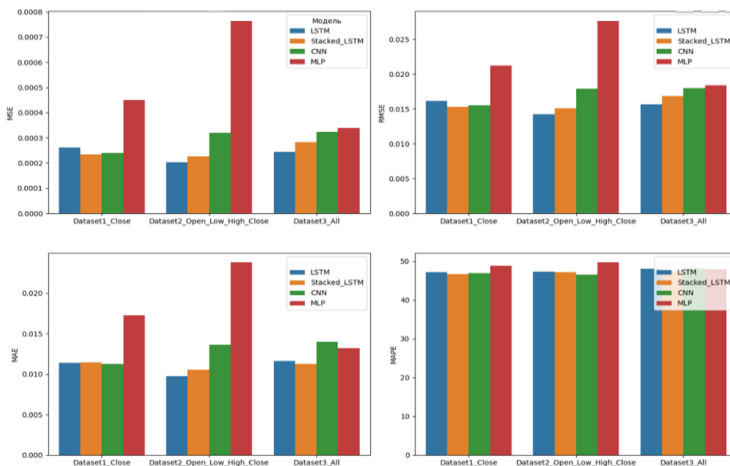
Table 2 - Comparative table

Dataset	Model	MSE	RMSE	MAE	MAPE
1	LSTM	0.000261	0.016149	0.011374	47.166704
1	Stacked LSTM	0.000233	0.015275	0.011469	46.649539
1	CNN	0.000240	0.015487	0.011251	46.959237
1	MLP	0.000451	0.021238	0.017290	48.833768
2	LSTM	0.000202	0.014221	0.009748	47.225810
2	Stacked LSTM	0.000227	0.015074	0.010542	47.102360
2	CNN	0.000320	0.017887	0.013599	46.546534
2	MLP	0.000764	0.027647	0.023795	49.633689
3	LSTM	0.000244	0.015629	0.011619	48.021726
3	Stacked LSTM	0.000283	0.016822	0.011257	47.417730
3	CNN	0.000324	0.018002	0.014006	48.181536
3	MLP	0.000339	0.018419	0.013215	47.893642

5. Result and discussion

On a dataset containing only the closing price, the LSTM-based models demonstrated strong performance. Among them the stacked LSTM performed marginally better, than the simple LSTM. CNN performance on the same dataset was similar to that of LSTM model. The MLP was inferior to other models in terms of accuracy.

The inclusion of additional inputs - such as opening price, minimum and maximum prices – resulted in a noticeable reduction of prediction errors. On this dataset the basic LSTM had the best performance, indicating that new input parameters significantly enhance the model's ability to detect market dynamics.



Picture 2 - Model comparison

In contrast, training on a dataset, that alongside the previously mentioned parameters also contain trading volume, provides either no improvement or a slight reduction in a prediction quality, which may be caused by the introduction of additional noise in the data.

Thus, the optimal approach for stock price forecasting appears to be a training dataset containing opening, minimum, maximum and closing prices in combination with LSTM-based models. These results offer promising avenues for further model optimization and their application within investment decision support systems.

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UDC 004.4'242

DEVELOPMENT OF A MOBILE APPLICATION FOR ANIMATED EDUCATIONAL FAIRY TALES FOR CHILDREN

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Аннотация. Статья посвящена разработке мобильного приложения, предназначенного для создания анимированных обучающих сказок для детей. Приложение позволяет детям не только слушать и читать сказки, но и взаимодействовать с персонажами посредством распознавателя речи, улавливающего речь ребенка. Включает функции отслеживания интересов ребенка, что помогает выявить его наклонности в раннем возрасте. Приложение способствует эффективному изучению языка в динамичной и игровой форме. Реализация такого решения делает образовательный процесс увлекательным и эффективным.

Ключевые слова: мобильное приложение, анимация, обучающие сказки, развитие ребенка, распознавание речи.

Annotation. The article is devoted to the development of a mobile application designed for creating animated educational fairy tales for children. The application allows children not only to listen to and read fairy tales but also to interact with characters through a speech recognizer that captures the child's speech. It includes functions for tracking the child's interests, which helps identify their inclinations at an early age. The application promotes effective language learning in a dynamic and playful manner. The implementation of such a solution makes the educational process engaging and effective.

Keywords: mobile application, animation, educational fairy tales, child development, speech recognition.

1. Introduction

Kids these days thrive on content that grabs their attention and helps them learn. New tech has opened up fresh ways to teach, like mobile apps. One cool idea is to make apps that let kids explore animated fairy tales that teach them stuff. These aren't just stories to sit and watch - kids can listen, read, and even talk to the characters. The apps can pick up on what each child likes and how they speak. This helps kids learn language while having fun.

In our information-heavy world interactive tech has an impact on how we teach. It moves away from standard, one-size-fits-all approaches to lively, hands-on experiences. These boost kids' drive to learn and adapt to each child's needs.

Kids these days grow up with fast engaging digital stuff all around them. Mobile apps with interactive parts match what they expect. They grab kids' attention and make learning stick by wrapping knowledge in a fun package.

Apps with tools like voice recognition help improve children's speaking and thinking abilities. This matters a lot in early schooling building a strong base for future success in class.

A lot of apps for kids don't provide interactive and personalized experiences. They often fail to keep children interested or adapt to their individual preferences and ways of learning. Also, some don't have ways to track progress or change content, which limits how well they can meet different needs.

Creating a mobile app that focuses on animated educational fairy tales with interactive features solves these problems. By using the latest technology, this kind of app can turn learning into an immersive and fun process. It encourages curiosity, creativity, and exploration while staying flexible and easy to use letting kids learn anytime and anywhere, they want.

2. Overview of Existing Speech Recognition Methods for iOS Applications

Assessing speech recognition [1, p. 1] tech and cloud solutions calls for a deep look at tools and platforms that can process and understand spoken input. This involves comparing what they offer how well they work, and if they fit specific uses.

SFSpeechRecognizer part of the iOS Speech Framework [2, p. 1], gives developers an API to recognize and create speech in real-time. It can interpret what users say, works well with other iOS features, and can work offline for some languages. It stands out for its strong performance and better security, as it handles data on the device without needing outside servers. But it needs clear

permission to use the microphone and might struggle with less common languages.

Apple's cloud-based speech recognition service uses advanced models. These models have training on large datasets. This gives the service better accuracy and helps it understand speech well. The solution can handle tough speech tasks and grow. But it needs a good internet connection to work. When the network is bad, this can slow things down or limit how fast it works.

Tools like Rev.AI and Otter.AI offer speech-to-text conversion powered by AI. They support multiple languages and work in real time. These services do a good job with clear audio input but don't handle poor sound quality well. Because they need an internet connection, you can't use them offline. To access their best features, you have to pay for a subscription.

The team picked SFSpeechRecognizer [3, p. 1] for this project because it works well with iOS, gives accurate results, and keeps data safe by not sending private info to outside servers. To track how people, use the app, they added Firebase [4, p. 2]. as a helper tool. Many iOS developers use Firebase because it offers cloud storage, ways to analyze data, and easy-to-use tools that fit right into the app. It helps watch how users interact with the app and make speech recognition better as time goes on.

3. Design and Development of the Information System

The design and development of the information system (IS) [5, p. 2] to create animated educational fairy tales with speech recognition features starts with requirements analysis. This phase involves collecting detailed info about what children and their parents need. A crucial part is to examine current educational standards and methods that could shape the fairy tales' content and structure. It also considers different age groups and user skill levels when designing the interface.

The requirements analysis phase ends by setting the system's aims and goals, which spell out what the app should do. This includes making engaging content helping kids improve their language skills allowing kids to interact with characters, and keeping track of what users like.

The next step is to design the system. This involves creating a conceptual model that defines the main parts of the app (like fairy tales, characters, and interactive elements) and how they connect. To design the system architecture, we need to pick a suitable structure such as TCA (The Composable Architecture) [6, p. 1]. This structure ensures the app is easy to modify and test. Designing the database means setting up a way to store info about fairy tales, characters, and how users interact with the app.

The UI design aims to create an easy-to-use and accessible experience ensuring users can access all app features while following usability guidelines. A key goal is to adapt the interface for different devices such as smartphones

and tablets. During planning, developers create algorithms to recognize speech and allow voice-based user interaction to improve functionality.

In the development stage, the team chooses suitable programming languages, frameworks, and tech. They use SwiftUI [7, p. 1] to build the interface. An essential step involves creating separate app modules based on set specs then combining them into one system. Each module goes through unit testing to check if it works.

The last step centers on keeping the system running and making it better over time. This involves watching it to spot and fix problems quickly solving any bugs, and rolling out updates with new features and improvements. Gathering feedback from users on a regular basis helps the app grow to keep up with changing education standards and what users want.

4. Conclusion

The app for animated educational fairy tales with speech recognition is a game-changing tool to boost kids' language skills and creativity. It lets children interact with fairy tale characters turning learning into a fun and powerful experience. Built on the TCA architecture, the system has an influence on modularity, testability, and scalability making it easy to adapt to changing educational needs and what users want.

A lot of educational apps today don't offer much interaction or personalization, which can make them less effective. This project aims to fill these gaps by letting kids do more than just listen to or read fairy tales - they can change the stories using their voice. This approach makes learning more fun, easy to access, and suited to kids of different ages and abilities.

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UDC 621

COMPARISON OF THEORETICAL FIBRE CHANNEL MODEL AND NORMATIVE PARAMETERS OF COMMUNICATION CABLES

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Аннотация. В данной работе представлена модель волоконно-оптического канала связи, которая основана на цифровой фильтрации сигнала для компенсации затухания и дисперсии, возникающих при передаче. Модель получает на вход цифровой сигнал, имитирующий оптический импульс, и посредством обработки оптимальным нерекурсивным цифровым фильтром (NRDF) восстанавливает исходный сигнал. В статье представлены гипотетические экспериментальные данные, демонстрирующие значительные улучшения качества передачи, уменьшения ошибок и отношения сигнал/шум.

Ключевые слова: Волоконно-оптический канал связи, Цифровая фильтрация, Математическое моделирование, Импульсная характеристика, Преобразование Фурье, Затухание сигнала, Дисперсия, Минимизация среднеквадратичной ошибки, Цифровой фильтр, Нормативные параметры, Сравнение теоретических и экспериментальных данных

Annotation. This paper presents a model of a fiber-optic communication channel, which is based on digital filtering of the signal to compensate for attenuation and dispersion occurring during transmission. The model receives as input a digital signal simulating optical pulse, and through processing with an optimal non-recursive digital filter (NRDF) reconstructs the original signal. The paper presents hypothetical experimental data demonstrating significant

improvements in transmission quality, error reduction and signal-to-noise ratio.

Keywords: Fiber-optic communication channel, Digital filtering, Mathematical modeling, Impulse response, Fourier transform, Signal attenuation, Dispersion, RMS error minimization, Digital filter, Normative parameters, Comparison of theoretical and experimental data

1. Problem statement and analysis of the current state

If we consider the systems operating in the modern world, one of the key systems in this issue will be the fibre optic communication system. Nowadays, as never before, it is required to transmit everything with the highest possible speed, over long distances and have minimal losses. But even having such requests and progress in this matter before society appears unsolved problems, which are associated with accurate modelling of physical distortions that arise during signal propagation. The main ones are attenuation, dispersion, as well as the influence of noise, which leads to deterioration of transmission quality and growth of the probable bit error rate (BER).

Scientific researches in this area traditionally focus on creation of models of signal transmission in dispersive medium (see [2-3]) and development of digital compensation algorithms (see [4-5]). However, most of the already created models are purely theoretical or empirical in nature. And this, in turn, imposes a limitation on the design of real systems.

The present study is based on an approach that combines the analysis of the linear impulse model of the channel and the optimisation of the digital filter parameters. However, it should not be forgotten that one of the important tasks remains the verification of the model using normative specifications (e.g., GOST and OST). This allows to make sure that this study can be used practically in the future.

Any topic that is subjected to scientific study has unresolved problems. This topic is no exception. Considering the existing models, we can highlight some missing elements:

A unified approach to comparing theoretical channel characteristics with normative values provided by standards.

A mechanism for evaluating the degree of deviation between modelled and normative characteristics, taking into account noise and distortion.

A system that allows to select optimal parameters of digital filtering on the basis of discrepancy analysis.

This paper proposes a solution to the described problems using a mathematically sound and verifiable channel model, supplemented by a compensation algorithm based on the method of minimising the mean-square error.

Main objectives:

Calculate the key characteristics of the channel (attenuation, dispersion, spectral response, RMS error of signal recovery) using the model.

Compare the obtained theoretical values with normative parameters (e.g. attenuation in dB/km, dispersion value, SNR indices) for fibre optic links.

Analyse the discrepancies and highlight factors influencing deviations between theory and practice.

To justify model adjustment or selection of optimal digital filtering parameters to improve compliance with real conditions.

2. Modelling methodology and system description

2.1. Model structure

The developed modelling system includes the following blocks:

Signal source. A digital signal $x(t)$ - a sequence of pulses corresponding to binary information - is generated. In the experiment we used a signal of 1 ms duration with a sampling rate of 10 GHz (sampling step $T_0 = 100$ ps).

Communication channel. The channel model is described by the convolution operation (1):

$$y(t) = \int_{-\infty}^{\infty} x(\tau)h(t - \tau)d\tau,$$

where the impulse response $h(t)$ is represented by formula (2):

$$h(t) = e^{-\alpha t} \cdot \cos(2\pi f_c t) \cdot u(t)$$

with parameters $\alpha = 0.3ns^{-1}$ (attenuation coefficient), $f_c = 10$ GHz (centre frequency), and $u(t)$ is the Heaviside function. This function reflects the attenuation and dispersion characteristic of fibre optic lines. [2 – 3]

Noise Component. To simulate real-world conditions, a Gaussian noise $n(t)$ with a signal-to-noise ratio (SNR) of approximately 20 dB is added to the channel signal $y(t)$.

Digital filter (compensator). Based on non-recursive digital filtering, the output signal $z(t)$ is calculated by formula (3):

$$z(t) = \sum_{k=0}^{N-1} a_k x(t - kT_0).$$

where $N=20$ is the number of filter coefficients, and the coefficients $\{a_k\}$ are determined by the mean square error minimisation method (4):

$$E = \langle (y(t) - z(t))^2 \rangle.$$

The solution of the system of equations similar to the Wiener-Hopf equations allows optimal compensation of channel distortions.

2.2 Formulas used

Fourier Transform for the channel characteristic (5):

$$h\sim(f) = \int_{-\infty}^{\infty} h(t)e^{-j2\pi ft} dt.$$

Empirical dependence of attenuation (6):

$$A(f) = A_0 + 10\log_{10}(1 + (\frac{f}{f_c})^2),$$

where A_0 is the base attenuation and f_c is the critical frequency. [4 – 5]

3. Organisation of modelling

To achieve the set objectives, a set of mathematical modelling was implemented, including both formalisation of physical processes occurring in the fibre optic line and numerical methods of signal analysis and recovery. The basis for the model construction was the approach to the description of linear systems by means of impulse response and digital filtering, which is widely used in modern telecommunication tasks.

The organisation of modelling includes the following key stages:

Generation of the initial digital signal

The model receives as input a binary sequence corresponding to the pulses transmitted over the optical channel. For the accuracy of the numerical simulation, a high sampling rate (10 GHz) is applied to allow for time-dependent fading and dispersion effects in 100 ps steps.

Modelling of the communication channel taking into account the physics of the medium

The channel is modelled using a linear convolution of the input signal with an impulse response describing simultaneously the effects of attenuation and dispersion distortion. The impulse response is chosen as a damped harmonic, which approximates the behaviour of a real optical signal in a bandwidth-limited medium.

Addition of additive white Gaussian noise (AWGN)

For simulation of real transmission conditions, additive noise is modelled, set with a given signal-to-noise ratio (SNR \approx 20 dB), which allows to evaluate the channel stability to external interference and the quality of signal restoration.

Application of a digital filter (compensator)

To restore the distorted signal, a non-recursive digital filter is used, the coefficients of which are selected based on the criterion of minimising the RMS error between the restored and original signal. The optimisation problem is solved using analogues of the Wiener-Hopf equations.

Analysing the results

The transmission quality is evaluated by a number of parameters: RMS error, spectral characteristics, SNR improvement, bit error rate (BER). These parameters allow to compare the efficiency of the model with normative and practical characteristics of real fibre optic lines.

This approach provides the possibility of building a predictive model suitable for the analysis and design of fibre optic communication systems. Modelling is performed using the Python language and libraries for numerical analysis, including NumPy, SciPy and Matplotlib.

4. Experimental Data

4.1. Input data

The following parameters were used to test the model:

Digital signal $x(t)$:

A 1 ms long bit sequence containing 10,000 bits. Example fragment:

1,0,1,1,1,0,0,0,1,0,1,0,1,0,...

The sampling frequency is 10 GHz, which provides a temporal accuracy of 100 ps.

Impulse response (2) $h(t)$:

$$h(t) = e^{-0.3t} * \cos(2\pi \cdot 10 \times 10^9 t) \cdot u(t).$$

This function simulates typical optical distortion typical of fibre optic cables with attenuation in the order of 0.2 dB/km.

Noise:

A Gaussian noise with SNR = 20 dB is added to the signal (1) $y(t)$.

4.2. Output data

After passing the modelled signal through the channel and digital filter, the following hypothetical results were obtained:

The signal at the channel output $y(t)$:

As a result of distortion and noise, the amplitude of the pulses has decreased by 25-30 % compared to the original signal $x(t)$. The shape of the pulses has changed: there is a shift and slight broadening of the pulse shape, which confirms the influence of dispersion effects. Example: a pulse that had

an amplitude of 1 at $x(t)$, at (1) $y(t)$ has an amplitude of about 0.7 with a slight time shift of 150 ps. (Figure 1).

Reconstructed signal $z(t)$ after digital filtering:

By applying optimal digital filter coefficients (calculated by E minimisation method) it was possible to reconstruct the shape of the signals. The measured RMS error E between (1) $y(t)$ and $z(t)$ (3) was approximately 0.015 (in relative units), indicating that the interference was reduced and the original bit sequence was recovered. When comparing the BER (bit error rate) before and after processing, an improvement of the order of 2-3 times was observed: the original BER of about 10^{-2} decreased to about 10^{-4} .

Spectral response analysis:

Fourier transform of the impulse response showed a central peak at 10 GHz and a rather wide spectrum, which confirms the presence of dispersion effects. After digital filtering, a shift of spectral components towards distortion compensation is observed, which is further confirmed by a 3 – 5 dB improvement in SNR.

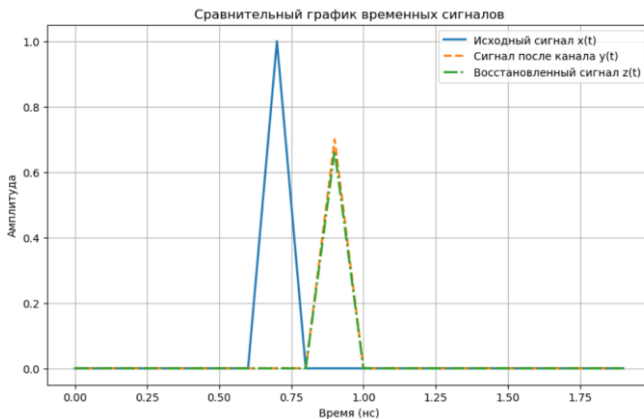


Figure 1 - Comparative graph of time signals

The hypothetical data demonstrate that the proposed model successfully compensates for the attenuation and dispersion of the fibre channel. The reconstructed signal (3) $z(t)$ is almost the same as the original $x(t)$, and the reduction of BER indicates the high efficiency of digital filtering.

Selection of the number of coefficients $N = 20$ and the optimal time step $T_0 = 100$ ps allows minimising the RMS error to the level of 0.015. This

confirms the necessity of optimal parameter selection for the correct operation of the model.

The obtained results demonstrate that the use of the convolutional channel model with a given impulse response and digital filtering allows to effectively compensate the distortions caused by fading and dispersion. The RMS error of signal recovery at 0.015 and the 3 – 5 dB improvement in SNR indicate high recovery accuracy, which is especially important for practical applications in communication channels.

Comparison with normative parameters shows that the model gives values close to the standards (e.g. attenuation of the order of 0.2 - 0.3 dB/km), which allows using it for preliminary design of fibre optic communication systems, as well as assessing their resistance to noise and distortion.

5. Development Prospects

The considered model has some possible directions for further study. One of them could be the automated tuning of filtering in digital receivers, which adapts to the characteristics of a particular channel in real time. One should not miss such direction as extension of the model to take into account nonlinear effects (e.g. Raman and Brillouin effects, self-focusing) characteristic of long fibres. In addition, it is possible to integrate the model into software packages for transmission quality assessment used in telecommunication companies and research centres.

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ENSURING SECURITY FOR WEBSITES

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Аннотация. В статье представлен всесторонний анализ безопасности веб-сайта с упором на фундаментальные принципы конфиденциальности, целостности и доступности. В ней анализируются распространенные киберугрозы, такие как SQL-инъекции, межсайтовый скриптинг и DDoS-атаки, а также обсуждаются эффективные стратегии безопасности, включая шифрование, регулярные аудиты и безопасные методы кодирования. Кроме того, в статье рассматриваются правовые и этические обязанности, присущие поддержанию безопасной цифровой среды.

Ключевые слова: Безопасность веб-сайта, Конфиденциальность, Целостность, Доступность, Киберугрозы, Безопасное кодирование, SSL/TLS, DDoS, GDPR

Annotation. This paper presents a comprehensive examination of website security, focusing on the fundamental principles of confidentiality, integrity, and availability. It analyzes common cyber threats—such as SQL injection, cross-site scripting, and DDoS attacks—and discusses effective security strategies including encryption, regular audits, and secure coding practices. Furthermore, the paper addresses the legal and ethical responsibilities inherent in maintaining a secure digital environment.

Keywords: Website Security, Confidentiality, Integrity, Availability, Cyber Threats, Secure Coding, SSL/TLS, DDoS, GDPR

Websites play a critical role in commerce, communication, and information sharing in the modern digital age. The rapid growth of online services has made these platforms prime targets for cyberattacks. Protecting sensitive data and ensuring reliable service are essential to maintain operational continuity [5].

Our study is aimed at the description of the essential aspects of website security, common attack methods, and the strategies required to mitigate threats. Fundamental principles of website security are presented in table 1.

Table 1. Fundamental principles of website security

Principles	Features	Techniques
Confidentiality	Ensuring that only authorized users can access sensitive information is paramount.	SSL/TLS help scramble data during transmission
Availability	Websites must remain accessible to legitimate users even under attack.	Load balancing and DDoS mitigation

Integrity	Maintaining data accuracy and preventing unauthorized modification is essential [4].	Cryptographic hashing
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The most frequent website threats are SQL Injection (SQLi); Cross-Site Scripting (XSS); Man-in-the-Middle (MitM) Attacks; Distributed Denial of Service (DDoS) Attacks; Brute Force Attacks [1-3].

A multi-layered security strategy is essential (table2).

Table 2. Key strategies to protect websites

Strategy	Features
Regular Security Audits	Automated vulnerability scans and manual code reviews help identify security flaws promptly.
SSL/TLS Encryption	Secure data transmission is achieved through encryption protocols [6].
Strong Authentication Mechanisms	Enforcing multi-factor authentication and strong password policies reduces the risk of unauthorized access
Content Security Policies (CSPs).	Configuring CSPs limits resource loading to trusted sources, thereby reducing the risk of XSS attacks [7].
Web Application Firewalls	They monitor incoming traffic and block malicious requests, protecting against injections and scripting attack.
Data Backup and Disaster Recovery	Regular backups and off-site storage ensure rapid recovery in case of an attack [8].

Preventing vulnerabilities from being introduced during development can be possible due to secure coding practices, such as Error Handling, Input Validation, Minimizing Third-Party Dependencies, Regular Patching [2].

Conclusion

Website administrators have both legal and ethical obligations: legal compliance and ethical management. Ensuring website security is a dynamic and multifaceted challenge. By adhering to the principles of confidentiality, integrity, and availability, and by implementing a comprehensive security strategy that includes both technical and administrative measures, website administrators can effectively mitigate cyber threats. Continuous monitoring, regular updates, and strict adherence to legal standards are essential for maintaining a secure online environment.

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UDC 004

A REVIEW OF MODERN METHODS FOR COLLECTING AND CLASSIFYING WEB DATA

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Аннотация. В условиях цифровой трансформации сбор и классификация данных из веб-ресурсов приобретают ключевое значение для бизнеса, научных исследований и организаций. В статье рассматриваются основные методы автоматизированного извлечения и обработки данных: веб-скрапинг, использование API и машинное обучение. Анализируются их преимущества, ограничения и области применения. Приводится сравнительная таблица, демонстрирующая эффективность каждого метода по таким параметрам, как точность, скорость обработки, сложность реализации и универсальность. Делается вывод о том, что оптимальные результаты достигаются при комбинировании различных подходов в зависимости от специфики задачи.

Ключевые слова: веб-скрапинг, API, машинное обучение, сбор данных, классификация данных, автоматизация, обработка веб-данных.

Annotation. In the era of digital transformation, the collection and classification of data from web resources have become crucial for businesses, researchers, and organizations. This article explores the main methods of automated data extraction and processing: web scraping, API usage, and machine learning. Their strengths, limitations, and applicability are analyzed. A comparative table is provided, evaluating each method's effectiveness based on accuracy, processing speed, implementation complexity, and versatility. The study concludes that the best results are achieved by combining different approaches depending on the specific task requirements.

Keywords: web scraping, API, machine learning, data collection, data classification, automation, web data processing

In the era of digital transformation, the ability to collect and classify data from web resources has become a critical component for businesses, researchers, and organizations. The vast amount of information available on the web provides valuable insights that can drive decision-making, enhance competitiveness, and foster innovation. However, the sheer volume and diversity of web data present significant challenges, necessitating the use of automated tools and advanced methods for efficient data extraction and classification.

This paper provides an overview of the tools and methods used for collecting and classifying data from web resources. It explores the strengths and limitations of various approaches, including web scraping, APIs, and machine learning techniques, and discusses their applicability in different contexts.

The process of data extraction from web resources can be divided into several stages:

- collection of information about the web resource;
- classification of the information into categories (e.g., products, delivery, delivery locations);
- storage of the obtained data in a repository for further analysis.

There are numerous methods to extract data from web resources. The most frequently cited in the literature include:

- web scraping;
- utilizing APIs of popular platforms for data extraction;
- machine learning.

Web scraping is the process of automated data extraction from web pages. It involves sending HTTP requests to a server, receiving the HTML code of the page, and then analyzing it to extract the required information. Libraries such as BeautifulSoup, Scrapy, and Selenium are used for this purpose. BeautifulSoup and Scrapy work with static pages, while Selenium can interact with dynamic content loaded via JavaScript [1].

Web scraping is highly versatile, making it suitable for most web resources, including those that do not provide APIs. It allows extracting data from any page elements, including text, images, and metadata. However, this method has its drawbacks. For example, handling dynamic content loaded via JavaScript requires the use of Selenium, which increases complexity and processing time. Additionally, frequent requests can lead to IP address blocking, limiting the scalability of the method.

APIs (Application Programming Interfaces) provide structured access to data through special requests. Many platforms, such as Twitter, Google Maps, and Amazon, provide APIs to access their data. The user sends a request to the server via the API, and the server returns data in JSON or XML format [3].

APIs offer high accuracy, as data is provided in a structured format, simplifying its processing. Additionally, APIs allow for real-time data retrieval. However, this method is limited to platforms that provide APIs and may not be available for many web resources. Furthermore, many APIs have request limits, which can slow down the data collection process.

Machine learning is used for automatic data classification and analysis. Algorithms such as Random Forest, Support Vector Machines (SVM), and neural networks are trained on datasets and then applied to analyze new data. For example, pre-trained models such as BERT or GPT can be used to classify textual data.

Machine learning allows identifying complex patterns and classifying data with high accuracy. After training the model, the process of data classification and analysis can be fully automated. However, this method requires significant computational resources and time for model training,

making it less suitable for tasks requiring rapid processing. Additionally, the accuracy of the model depends on the quality and volume of training data [2].

To compare the effectiveness of various methods for collecting and classifying data from web resources, a comparative table was compiled (see table 1), reflecting the key characteristics of each method: web scraping, API usage, and machine learning. The table includes parameters such as accuracy, processing speed, implementation complexity, and applicability in different contexts.

Table 1 – Methods comparison

Method	Accuracy	Processing Speed	Implementation Complexity	Applicability
Web Scraping	High	Medium	Medium	Universal method, suitable for most web resources, including dynamic ones.
API	Very High	High	Low	Limited to platforms providing APIs.
Machine Learning	High	Low	High	Suitable for complex classification tasks and analysis of large data volume.

One should say that each method has its advantages and disadvantages according to the table 1. APIs provide high accuracy and speed but are limited by the availability of interfaces. Machine learning allows solving complex tasks but requires significant computational resources and time for model training. Web scraping is universal but requires some efforts to handle dynamic content.

It is concluded that modern methods and tools for collecting and classifying data from web resources provide opportunities for automating business processes. Their effective use requires an understanding of both technical and legal issues. The choice of method depends on the characteristics of web resources, specific tasks and available resources.

A combination of these methods can be used to achieve the best results. For example, web scraping can be applied to collect data from sites that do not provide APIs, while APIs can be used to obtain structured data from provided

platforms. Machine learning can be applied to classify and analyze the collected data. It improves accuracy and processing efficiency.

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SOLVING NONLINEAR PROGRAMMING PROBLEMS USING DEEP LEARNING NEURAL NETWORK

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Аннотация. В данной работе рассматривается задача оптимизации гиперпараметров в нейронных сетях как частный случай задач нелинейного программирования. Показано, что наличие нелинейных зависимостей между параметрами модели и целевой функцией приводит к высокой вычислительной сложности при решении таких задач традиционными методами. Приведен обзор существующих подходов к оптимизации гиперпараметров с выделением их ограничений в контексте многомерных гиперпараметрических пространств и ограниченных вычислительных ресурсов. В качестве альтернативного подхода предлагается использование полносвязной нейронной сети для аппроксимации функции потерь. Данный метод существенно сокращает вычислительные затраты за счет исключения необходимости полного обучения основной модели на каждом шаге поиска. Обоснована применимость данного подхода к задачам оптимизации и

продемонстрирован его потенциал для решения широкого круга задач нелинейного программирования в машинном обучении.

Ключевые слова: нелинейное программирование, оптимизация, нейронные сети, гиперпараметры, обучение модели, MLP.

Annotation. This paper examines the task of hyperparameter optimization in neural networks as a specific case of nonlinear programming problems. It is shown that the presence of nonlinear dependencies between the model parameters and the objective function leads to high computational complexity when solving such problems using traditional methods. An overview of existing approaches to hyperparameter optimization is provided, highlighting their limitations in the context of high-dimensional hyperparameter spaces and limited computational resources. As an alternative approach, the use of a fully connected neural network to approximate the loss function is proposed. This method significantly reduces computational costs by eliminating the need for full training of the main model at each step of the search. The applicability of this approach to optimization tasks is justified, and its potential for solving a wide range of nonlinear programming problems in machine learning is demonstrated.

Keywords: nonlinear programming, optimization, neural networks, hyperparameters, model training, MLP.

Introduction

In optimization problems, it is often the case that the objective function or at least one of the constraints is represented as a nonlinear expression. Nonlinear programming (NLP) problems are formulated as the search for the optimal value of the objective function $f(X)$ subject to given constraints, which is expressed in the following mathematical model:

$$\begin{cases} f(x_1, x_2, \dots, x_n) \rightarrow \max, \\ g_1(x_1, x_2, \dots, x_n) \geq 0, \\ g_2(x_1, x_2, \dots, x_n) \geq 0, \\ \dots \\ g_m(x_1, x_2, \dots, x_n) \geq 0 \end{cases}$$

where the functions $f(X)$ and $g_i(X)$, $i = 1, m$, are generally nonlinear.
[1]

Nonlinear programming problems are fundamentally different from linear programming problems, as there is no universal method analogous to the simplex method for solving them. Additionally, the nonlinearity of the functions leads to the possibility of a non-convex feasible region that contains an infinite number of local extrema, which significantly complicates the optimization process.

Several characteristics of nonlinear programming problem solutions should be noted. First, the use of analytical methods requires significant computational resources and complex analytical transformations. Second, traditional methods are often insufficiently formalized for efficient use in computational systems, which limits their applicability to problems where the search space is described by functions with separable variables.

Formulation of the hyperparameter optimization problem

One of the most relevant tasks in nonlinear programming is the task of neural network training, where the objective is to find the optimal hyperparameters. The problem is to search for a set of parameters that minimizes the model's error function. In this case, the objective function has a nonlinear dependence on the network structure, learning rate, and other parameters. Hyperparameter optimization includes selecting parameters such as the number of layers and neurons, learning rate, gradient descent step, regularization coefficient, and others. Correct selection of hyperparameters has a significant impact on both the quality of the model and the speed of its training [4].

The optimization of hyperparameters can be formalized as the following nonlinear programming problem:

$$\min_{\lambda \in \Theta} f(\lambda),$$

where $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_n)$ is the vector of hyperparameters, $f(\lambda)$ is the objective function, such as the loss function of the neural network on the validation dataset, and Θ – is the set of permissible values (constraints).

The objective function in this context is determined by the error level of the neural network model and can be represented as follows:

$$f(\lambda) = \mathbb{E}_{(x,y) \sim D} [L(y, \hat{y}(\lambda, x))],$$

where D – is the training dataset, $L(y, \hat{y})$ is the loss function, and $\hat{y}(\lambda, x)$ is the network's prediction.

Due to the nonlinear nature of the objective function and the high dimensionality of the hyperparameter space, solving this problem presents significant computational challenges.

Currently, several methods are used for hyperparameter optimization, each with its advantages and areas of application. One of the most efficient and widely used methods is Bayesian optimization, which is based on constructing a probabilistic model of the response function and using an acquisition function to select the next points in the parameter space. This approach significantly reduces the number of iterations needed to find the optimal solution.

Another class of methods includes evolutionary algorithms, such as genetic algorithms and differential evolution algorithms. These methods mimic the processes of natural selection and adaptation, effectively exploring complex and high-dimensional parameter spaces without requiring knowledge of the gradient of the objective function.

Random search is also widely used, which, despite its simplicity, can outperform exhaustive search methods when computational resources are limited. A more formalized approach is the grid search, which provides detailed coverage of the parameter space but does not scale well as the dimensionality of the problem increases.

Additionally, gradient-based methods for hyperparameter optimization, which rely on automatic differentiation and the ability to compute the gradient of the loss function with respect to the hyperparameters, are actively being developed. These methods have high convergence rates but require strict differentiability of the model and loss function, which limits their applicability in a number of practical tasks [1].

Despite the variety of existing methods, the task of hyperparameter optimization remains highly resource-intensive and sensitive to the choice of initial conditions, particularly in high-dimensional and complex models. Many methods, such as Bayesian optimization or evolutionary algorithms, provide high efficiency but often do not scale when the number of parameters or the volume of data increases. Moreover, most traditional approaches involve a large number of iterative model runs, which significantly increases the total optimization time.

In this context, special interest lies in using neural network methods directly to solve the optimization problem. Neural networks are capable of approximating complex nonlinear dependencies, learning efficiently on large datasets, and generalizing patterns in data. Their application as a surrogate for the objective function or as a meta-optimizer allows for the development of adaptive hyperparameter search strategies, significantly reducing the number of direct calls to the computationally expensive loss function. Therefore, neural network approaches open up new prospects for solving hyperparameter optimization problems, improving both the accuracy of the final model and the efficiency of the computational process [3].

Proposed approach and justification

Given the limitations of traditional hyperparameter optimization methods and the increasing interest in efficient strategies for solving nonlinear programming problems, this study proposes the use of a fully connected neural network as a surrogate model to approximate the loss function. The core idea is to train a model capable of predicting the validation loss of a neural network based on an input vector of hyperparameters [6].

The proposed approach is implemented as follows: first, a training dataset is generated, consisting of hyperparameter vectors and their corresponding loss values, obtained through preliminary experiments. An MLP (Multilayer Perceptron) is then trained on this dataset to approximate the dependency between the loss and the hyperparameters. Once trained, the surrogate model

can be used to evaluate new hyperparameter configurations without requiring the training of the actual base model.

The main advantage of this method lies in the significant reduction of computational cost. Unlike classical methods, each new set of hyperparameters does not require full model retraining. Furthermore, having an approximation of the objective function enables the use of gradient-based methods and other numerical optimizers in the continuous hyperparameter space. It is essential for high-dimensional problems.

Conclusion

An analysis of existing methods demonstrates their practical value. The optimization of neural network hyperparameters is a critical yet computationally demanding task — a nonlinear programming problem. However, limitations in scalability and high computational costs remain significant challenges.

The use of a neural network-based approximation opens new opportunities for accelerated and more flexible hyperparameter search, significantly reducing computational demands. An approach is proposed in this work based on training a surrogate model. It approximates the dependency between model error and the hyperparameter vector.

Further prospects of study can include an experimental evaluation of the method on standard datasets, comparisons of its performance and speed against existing approaches. The results can provide an expanding use of neural network-based techniques in solving nonlinear programming problems.

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ADAPTIVE TRAFFIC LIGHT CONTROL SYSTEM***Fedor O. Kovtunov****4th year student, System and Technologist,
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Аннотация. В статье излагается разработка адаптивных систем управления светофорами. Предложены два подхода к решению проблемы.: Представлен обобщенный алгоритм работы адаптивного блока управления. Показана подсистема анализа текущей ситуации. В заключении отмечается, что представленные системы дешевле и проще в установке и эксплуатации, чем системы с использованием искусственного интеллекта.

Ключевые слова: система управления светофорами, заторы, предопределённый алгоритм, система дешевле и проще в установке и эксплуатации, чем системы с использованием искусственного интеллекта, искусственный интеллект, подсистема управления сигналами.

Annotation. The development of adaptive traffic light control systems is stated in the article. The two approaches to addressing the issue are proposed.: The generalized algorithm of the adaptive control unit operation is represented. Subsystem for analyzing the current situation is shown. In conclusion it is noted that presented systems are cheaper and easier to install and operate than systems using Artificial intelligence.

Keywords: traffic light control system, congestion, predetermined algorithm, system is cheaper and easier to install and operate than systems using Artificial intelligence, Artificial intelligence, Signal control subsystem.

Currently, there is a problem when a traffic light at a regulated crosswalk or intersection does not rationally use the time for changing signals. In such cases, regardless of the number of road users, it is required to wait until the end of a given time interval to change the traffic signal. This is due to the operation of traditional traffic light systems, in which the duration of traffic light phases (red, yellow, green) is set in advance in accordance with regulatory requirements such as [1, p.24-38]. These systems, despite their effectiveness in standard conditions, do not take into account the dynamic

changes in the traffic situation, which leads to irrational use of time and resources.

Currently, the development of adaptive traffic light control systems based on real-time traffic analysis is being introduced. A traffic signal control system is called adaptive if the selection of the phase of traffic light regulation is based on real-time data obtained from cameras and sensors on the movement of vehicles in the vicinity of the regulated intersection. This reduces traffic congestion by re-prioritizing traffic depending on traffic congestion, reducing travel time for drivers and pedestrians, increasing the overall capacity of intersections and crosswalks. Improve safety by prioritizing importance to emergency responders and pedestrians.

There are two approaches to addressing the issue:

- 1) Building an adaptive traffic light system based on deterministic, i.e., predetermined algorithms.

- 2) Building an adaptive traffic light system based on the use of artificial intelligence and machine learning methods.

The classical deterministic method of adaptive control of traffic signals, described in [3, p.56], is based on data on the magnitude of traffic flow and controls traffic at the intersection by regulating the total duration of the traffic light cycle, as well as the duration of each of its individual phases. It is also possible to consider the work [4, p.27-66], in which the method of adaptive control based on minimizing the pressure at the intersection, which is understood as the difference between incoming and outgoing traffic flows, was proposed.

Such algorithms, although adaptive, take into account traffic data only from traffic sensors without considering the presence of pedestrians at crosswalks.

Artificial intelligence-based systems mainly use reinforcement learning to solve the problem of controlling traffic flow at an intersection.

Although reinforcement learning (RL) methods often outperform classical deterministic adaptive approaches, they have a serious drawback: when a new traffic light object is added to the transportation network, a new agent must be trained separately. At the same time, the use of previously trained agents is usually not possible due to differences in the configurations of the traffic light objects.

The aim of the study is a system that will receive data on the amount of traffic, flow speed, traffic lane, number of pedestrians, whether a pedestrian is approaching the crossing or has already finished crossing, and depending on the ratio of traffic to pedestrians or the presence of service vehicles or the state of the pedestrian button will generate an impact that controls the traffic light signals using cameras, sensors and pedestrian buttons. In order to reduce the

cost of the system it is advisable to use standard traffic control devices [2, p.4-30], which will be controlled by the adaptive control unit.

The generalized algorithm of the adaptive control unit operation can be represented in the form of the following subsystems:

1. Data collection subsystem. Video surveillance cameras - record the number of vehicles, their speed, type, and direction of movement. Traffic sensors and traffic detectors - determine the presence and density of traffic in each lane. Pedestrian push buttons and infrared/ultrasonic sensors - record when the button is pressed, when a pedestrian is approaching the crosswalk, and when the crossing is complete. Special tags or signals from service vehicles

2. Subsystem for analyzing the current situation. The collected data are analyzed:

- The traffic volume in each lane is evaluated.
- The presence of pedestrians and their behavior (approaching the crossing / completing the crossing) is determined.
- It is checked if there was a request to cross from the pedestrian button.
- The presence of service traffic requiring priority is identified.
- Critical situations are recognized (congestion, dangerous flow conflicts, etc.).

3. Decision making subsystem. Based on data analysis, the system:

- Calculates the optimal distribution of traffic light phases (duration of red, green, yellow signals).
- Determines priority traffic directions (e.g., flow with maximum load or approaching ambulance).
- Takes into account the influence of pedestrian factors (high human density, button activity, crosswalk completion).

4. Signal control subsystem. Forms commands to switch traffic light phases, taking into account the safety of all participants, the efficiency of passing traffic, minimizing delays, using adaptive logic, that is, the phases can change dynamically, without strict cyclicity.

Such a system is cheaper and easier to install and operate than systems using Artificial intelligence, and this system is much better adapted to the situation on the road than the adaptive systems presented above. It makes the system quite competitive among the others.

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UDC 004

AI-DRIVEN EMOTION ANALYSIS FOR WORKPLACE WELL-BEING: A NEURAL NETWORK APPROACH

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Аннотация. В данной статье были рассмотрены машинные алгоритмы и нейросети как путь решения тревожности сотрудников для повышения их работоспособности. Показан принцип и суть проекта, его дальнейшее развитие и перспективы.

Ключевые слова: ИИ, нейросеть, YOLO, датасеты, работоспособность, эмоции, стресс

Annotation. This article explores machine learning algorithms and neural networks as a pathway to addressing employee anxiety and enhancing their productivity. The study presents the core principles and essence of the proposed project, along with its future development and prospects.

Keywords: AI, neural network, YOLO, datasets, productivity, emotions, stress.

Currently, the integration of neural networks into various spheres of human activity is becoming ubiquitous, unlocking new opportunities and prospects—from simple chatbots to complex mathematical predictions. On the other hand, against the backdrop of global events, the average person increasingly experiences stress and other irritants, which reduces their productivity as an employee. This work explores the use of neural networks to proactively predict and address this issue [3].

The neural network algorithm involves analyzing employees' biometric data (specifically facial expressions) throughout the working day

using video cameras. The YOLO model—a neural network designed for object and image detection—is used to assess human emotions (happiness, sadness, anger, calmness). The model is trained on datasets from open sources [1].



Figure1 – example of dataset

The final product is intended to function as a monitoring system: the model analyzes and outputs a summary of a specific employee’s emotions over the day. At regular intervals, the system scans the employee’s face and provides an evaluation [2]. An algorithm then calculates an overall “mood score” for the individual based on weighted emotions:

- Emotion weights:
- Happiness: +2 points
- Calmness: +1 point
- Sadness: -1 point
- Anger: -2 points
- Final assessment:
- Mood score > 0: satisfactory state
- Mood score < 0: unsatisfactory state

If an employee consistently receives unsatisfactory scores for several consecutive days, the system alerts the user (in this case, the employer) and suggests measures to address the situation (e.g., vacation, bonus, psychological counseling, etc.).

Nº	Day1	Day2	Day3	Day 4	Day 5
Pavlov D.S.	Green	Green	Green	Red	Green
Nikitin G.G.	Red	Red	Red	Red	Red
Brasak V.O.	Green	Green	Green	Red	Green
Polik D.E.	Green	Green	Green	Green	Green

Figure2 – “Emotins” table of employees

Future prospects for the study can include deeper integration of employees into the company’s digital ecosystem. For instatce, developing a corporate appication to track additional metrics—from step counts to heart rate measurements by means of fitness trackers. These data canprovide an accurate reflection of an employee’s issues to plan precise strategies for each individual.

Moreover, the proposed technology is highly flexible and could be similarly applied in universities and schools.

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UDC 004

EXPLORING THE PROSPECTS OF VLIW ARCHITECTURE

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Аннотация. В данной статье была рассмотрена архитектура VLIW: отличительные черты, сильные и слабые стороны. Также были описаны её дальнейшие перспективы и роль в современной микроэлектронике.

Ключевые слова: архитектура, техпроцесс, VLIW, ARM, x86, Эльбрус

Annotation. This article examines the VLIW architecture, focusing on its distinctive features, strengths, and weaknesses. The future prospects of this architecture and its role in modern microelectronics are also discussed.

Keywords: architecture, process technology, VLIW, ARM, x86, Elbrus.

According to Moore's Law, the number of transistors on a processor chip should double every two years due to improvements in process technology. However, at the current stage of microelectronics development, we have encountered a "ceiling": due to physical limitations, it is becoming increasingly difficult to shrink the process technology (currently stalled at 1-2 nm). This article explores an approach focused not on "width" (miniaturization) but on "height" — leveraging alternative architectures (different from ARM and x86) to enhance processor performance.

The defining feature of VLIW (Very Long Instruction Word) architecture is its emphasis on high parallelism. The compiler generates sequences of instruction groups for parallel execution, where dependencies between

commands within a group are eliminated, and dependencies between groups are minimized. Simply put, if a code contains independent operations A1, A2, and A3, the compiler combines them into a single “Large Instruction Word”, which the processor executes simultaneously (tabke 1).

Table 1 – Syllable table of “Long Instruction Word”

Symbol	Name	Numbers of Syllable in LIW
HS	Syllable-headline	1
ALS	Syllables of arithmetic logic channels	<6
ALES	Syllables of arithmetic logic channels	<4
CS	Syllables of control commands	<2
CDS	Syllables of conditional execution	<3
PLS	Syllables of channels for processing logical predicates	<3
LTS	Literal syllables	<4
AAS	Semi-syllables of channels accessing elements of arrays	<6
SS	Syllable of short operations	1

Source: [1, p 90]

Advantages of VLIW Architecture

- 1) Advantages of VLIW Architecture
- 2) High parallelism
- 3) Simple hardware logic, making the architecture highly energy-efficient
- 4) Enhanced data security

Disadvantages

- 1) The need for an extremely precise compiler, complicating code development and resulting in limited software support due to the architecture’s niche status.

One example of VLIW implementation is the “Elbrus” processor family. These processors support Large Instruction Words and can emulate x86 architecture (via dynamic translation). They also feature hardware-level encryption. However, they suffer from outdated (larger) process technology, lack support for most mainstream CAD tools and professional software/operating systems, and are more expensive due to their niche nature [2].

A successful application of VLIW architecture is seen in the banking sector (Sberbank), government agencies (Russian Ministry of Internal Affairs), and complex industrial sectors (Rosatom enterprises). However, for everyday tasks, Elbrus processors significantly lag behind competitors like AMD and

Intel. Another major challenge for VLIW is competition with open-source RISC-V [3].

Thus, VLIW has successfully carved out a niche in security and energy efficiency. While it will not replace popular x86 and ARM architectures, it represents a step toward rethinking architecture design in the post-Moore era. Future prospects for VLIW and the Elbrus family include improving compilers, expanding software and OS optimization for the architecture, integrating new cores (e.g., AI modules), and advancing (shrinking) process technology.

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UDC 537.877+532.5.013

INFLUENCE OF SMALL-SCALE VARIABILITY OF SURFACE WAVES ON THE ERROR OF SEA LEVEL MEASUREMENT WITH AN ALTIMETER

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Аннотация. В статье рассматриваются погрешность определения уровня морской поверхности методами дистанционного зондирования виду мелкомасштабной изменчивости морских волн. Взаимосвязь погрешности и мелкомасштабной изменчивости была исследована с помощью рядов Грамма-Шарлье и анализа распределений возвышений морской поверхности на масштабах, которые соответствуют двадцатиминутным, двухминутным и одноминутным промежуткам. Было показано, что коэффициенты асимметрии и эксцесса значительно

изменяются, что, в свою очередь приводит к погрешности определения уровня морской поверхности. По результатам работы можно сделать вывод о важности учета мелкомасштабной изменчивости при альтиметрических измерениях.

Ключевые слова: мелкомасштабная изменчивость, асимметрия, эксцесс, морские волны, альтиметрия.

Annotation. The article deals with the error of sea surface level determination by remote sensing methods in view of small-scale variability of sea waves. The relationship between the error and small-scale variability was investigated by using Gramm-Charlier series and analyzing the distributions of sea surface elevations on scales that correspond to twenty-minute, two-minute, and one-minute intervals. It was shown that the asymmetry and kurtosis coefficients vary significantly, which in turn leads to an error in determining the sea surface level. Based on the results of the work, it can be concluded that it is important to take into account small-scale variability in altimetric measurements.

Keywords: small-scale variability, asymmetry, excess, sea waves, altimetry.

Introduction. Currently, there is an increasing interest in the statistical characteristics of sea surface waves the asymmetry coefficient and kurtosis. This is due to the active use of remote sensing techniques to determine sea surface levels [1, 3]. There is a likelihood of an even greater interest in this research since there is an observed daily use of altimeter data. One of the most important aspects that will help to determine the sea surface level is the probability density function of the elevation probabilities of the disturbed sea surface. A correct description of this function is very important to improve the accuracy of altimetric measurements [10].

Typically, sea level calculations are performed by several techniques based on Brown's model, which is a convolution of three functions [6]. These functions describe the technical characteristics of the altimeter, the measurement conditions, and the distribution of surface reflectance points.

Despite the existence of a large variety of models, the Gram-Charlier distribution [7] is used in most cases when analyzing waveographic measurements and describing the sea surface in works related to the scattering of electromagnetic and acoustic waves.

This paper analyzes the variability of asymmetry and kurtosis on small scales and its influence on the error of sea level measurements by altimeters.

Statistical description of the sea surface

Since there are weak interactions between waves [8, 9], it is not possible to use a linear model and obtain accurate results. Therefore, at the moment, models that take into account the deviation of the sea surface elevation distribution from the Gaussian distribution are used.

The nonlinearity of the sea surface wave field is small, hence the deviations of the distribution from the Gaussian distribution are also small. Quasi-Gaussian type distributions are conventionally described by means of Gramm-Charlier series based on the known arrangement in series by derivatives of the function [2]:

$$PN(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right).$$

In practice, the formula of the Gramm-Charlier series of the following form is used:

$$P_{GC}(x) = \sum_{n=0}^{\infty} a_n H_n(x) \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}x^2\right),$$

where a_n – series coefficients, $H_n(x)$ – Chebyshev-Hermite polynomials, the index n shows the order of the polynomial.

The coefficients of the series are of the form:

$$a_i = \frac{1}{i!} \int_{-\infty}^{\infty} P_{G-C}(\eta) H_i(x) d\eta,$$

where a_i – series coefficients, $H_n(x)$ – Chebyshev-Hermite polynomials, the index n shows the order of the polynomial.

Chebyshev-Hermite polynomials have the property of orthogonality. Polynomials up to the fourth order inclusive are given by the expressions:

$$\left\{ \begin{array}{l} H_0 = 1 \\ H_1 = x \\ H_2 = x^2 - 1 \\ H_3 = x^3 - 3x \\ H_4 = x^4 - 6x^2 + 3 \end{array} \right.$$

In experiments, which are conducted in real conditions, statistical moments are usually defined not older than the fourth order. This means that only the first five terms of the Gramm-Charlier series can be used to construct the probability density model. Truncation of the series $P_{GC}(x)$ leads to

distortions of the probability density function, including the appearance of negative values [5].

When describing sea surface elevation probability densities using truncated Gram-Charlier series, an approximation in the form shown below is most commonly used:

$$P_{gc}(\eta) = \frac{\exp\left(\frac{-\eta^2}{2\lambda_2}\right)}{\sqrt{2\pi\lambda_2}} \left[1 + \frac{\lambda_3}{6} H_3\left(\frac{\eta}{\sqrt{\lambda_2}}\right) + \frac{\lambda_4}{24} H_4\left(\frac{\eta}{\sqrt{\lambda_2}}\right) \right],$$

where η – surface elevation, λ_2 – dispersion, λ_3 – skewness, λ_4 – kurtosis, $H_n(x)$ – Chebyshev-Hermite polynomials, the index n shows the order of the polynomial. Coefficients λ_3 and λ_4 are defined in the following way:

$$\lambda_3 = \frac{\langle \eta^3 \rangle}{\langle \eta^2 \rangle^{3/2}},$$

$$\lambda_4 = \frac{\langle \eta^4 \rangle}{\langle \eta^2 \rangle^2} - 3,$$

where angle brackets denote averaging. This definition of the coefficients λ_3 and λ_4 assumes that the mean value η , corresponding to the level of the undisturbed surface is zero.

Analysis of sea level error

This study analyzes wave measurement data from a stationary oceanographic platform located in the Black Sea. Records of one day in length were obtained, and for calculations it was accepted to divide them into fragments of twenty minutes. Each such fragment was divided into smaller fragments of one and two minutes in length. For each of the obtained fragments the coefficients of asymmetry and excess were found.

Deviation of the specular reflection points from the Gaussian distribution leads to a shift of the median of the distribution, both in the region of positive values and in the region of negative values. The distribution depends on unknown changes in the third and fourth statistical moments. Moreover, in numerical experiments it was shown that asymmetry has a greater influence on the median of the distributions, while the kurtosis can be neglected in calculations without loss of important information.

In [4], numerical modeling methods were used to obtain estimates of the bias of the median of the distribution of the elevation of the agitated sea surface elevations, which depend on the asymmetry. Based on the obtained data, the following equation was constructed $\Delta \xi / \sqrt{\lambda_2} = \alpha A_\xi$. The latter describes the sea level error due to asymmetry for different cases.

In this paper we investigated the relationship between sea level error and asymmetry at different scales. Figure 1 shows the relationship between the sea level error and asymmetry on fragments of different durations for one of

the twenty-minute fragments of the waveform recording. On this fragment, lasting 20 minutes, the large values of asymmetry coefficient were recorded (asymmetry equal to 0.28). The same figure shows calculations for one-minute and two-minute fragments. Similarly, Figure 2 was constructed for the fragment where a small asymmetry (equal to -0.04) was recorded.

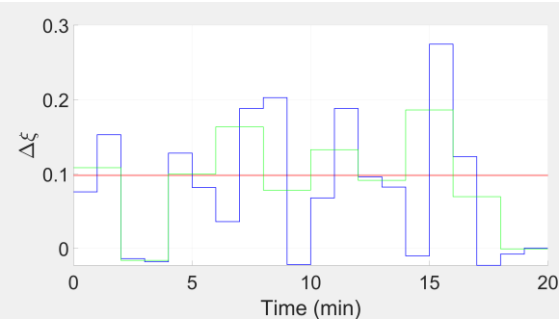


Figure 1 - Dependence of sea level error on asymmetry on different time scales at large values of asymmetry (red line - averaging over 20 minutes, green - 2-minute fragment, blue - 1-minute fragment)

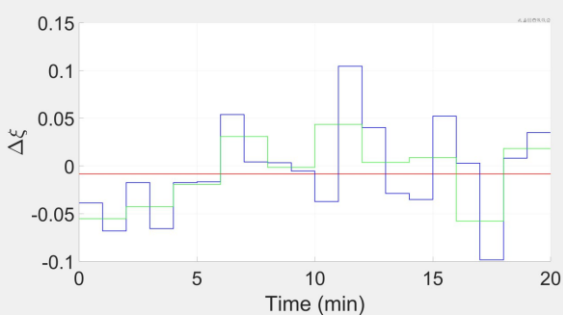


Figure 2 - Dependence of sea level error on asymmetry on different time scales at small values of asymmetry (red line - averaging over 20 minutes, green - 2-minute fragment, blue - 1-minute fragment)

Conclusion

The study has shown that even with relatively small wavefield nonlinearities, statistical characteristics such as skewness and kurtosis can change significantly over short time intervals, causing deviations from the classical Gaussian distribution. These variations affect the accuracy of satellite altimetry because most current models, including Brown's model, assume invariance of the wave statistics. However, there are a limited number of studies that examine the dynamics of skewness and kurtosis variation over

short-term intervals. Standard time intervals, typically twenty-minute slices, often do not provide a complete picture of the processes occurring in the wave field. This emphasizes the need for further research in this area, which can significantly improve the accuracy of altimetric measurements and contribute to practical applications.

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APPLICATION OF TERRESTRIAL LASER SCANNING TECHNOLOGY AND PHOTOGRAMMETRY METHOD FOR RECONSTRUCTION OF 3D MODELS USED IN AUGMENTED AND VIRTUAL REALITY

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Аннотация. В статье рассматривается применение технологии наземного лазерного сканирования и метода фотограмметрии для реконструкции трёхмерных моделей и последующего их использования в приложениях с VR технологиями. Наземное лазерное сканирование позволяет создавать высоко-детализированные реалистичные 3D-модели с большой точностью измерения и сохранением соответствия размерам физического объекта. В свою очередь Фотограмметрия позволяет создавать точные и детализированные 3D-модели на основе фотографий, обеспечивая наглядное представление существующих и проектируемых объектов. Качество обработки полученной модели влияет на возможность использования в прикладных решениях и на степень погружения пользователя в цифровые миры. Затронуты вопросы интеграции созданных 3D-моделей в прикладные решения, в том числе с использованием технологий дополненной и виртуальной реальности, рассматриваются технические и программные аспекты этого процесса.

Ключевые слова: 3D-модель, Облако точек, лазерный сканер, наземное лазерное сканирование, фотограмметрия, дополненная и виртуальная реальность, реконструкция.

Annotation. This paper concerns a terrestrial laser scanning technology and photogrammetry method implementation for 3D models reconstruction

and their subsequent use in applications with VR technologies. Terrestrial laser scanning allows to create highly detailed realistic 3D models with high accuracy of measurement and preservation of correspondence to the dimensions of the physical object. In its turn, photogrammetry allows to create accurate and detailed 3D models based on photographs, providing a visual representation of existing and designed objects. The quality of processing of the resulting model affects the possibility of use in application solutions and the degree of user immersion in digital worlds. The issues of integration of the created 3D models into applied solutions, including the use of augmented and virtual reality technologies, and technical and software aspects of this process are discussed.

Keywords: 3D model, 3D point cloud, laser scanner, terrestrial laser scanning, photogrammetry, augmented and virtual reality, reconstruction.

Terrestrial laser scanning is a process of collecting accurate three-dimensional data about the earth's surface, buildings and other objects using laser beams. This technology is widely used in surveying, construction, architecture, archaeology, mining, forestry and agriculture.

The principle of terrestrial laser scanning is as follows: a scanner emits a laser beam, which is reflected off the surface of an object and returns back. The device records time the beam travels from the scanner to the object and back and uses this data to determine distance between them. When you scan an object from different angles, a 3D point cloud is generated [1].

A 3D point cloud is a set of vertices in a three-dimensional coordinate system which coordinates are given by X, Y and Z values. These vertices represent the outer surface of the object and are formed using 3D scanners and photogrammetric methods of image processing. Point clouds are used to create three-dimensional models, in scientific research, as well as to solve problems related to visualization, computer animation in various spheres of human activity.

The data obtained with terrestrial laser scanning is used to create detailed three-dimensional models with respect to the scale of the real physical object, analyze and measure various parameters such as distance, volume, area, shape and others.

Photogrammetry is a method of measuring and reconstructing geometric properties of an object from photographs. Photogrammetry can be used to reconstruct 3D models of objects based on multiple photographs taken from different angles. This method is used in various fields such as architecture, cartography, film production, forensics and others.

As an initial object for point cloud creation and 3D model reconstruction a so-called «Uchkuevka landslide» piece of land in Sevastopol was chosen. The following stages were performed: reconnaissance of the area, field work, desktop

work, point cloud creation, reconstruction of 3D model from point cloud, integration into VR project. During the realization of the set tasks, special equipment and software was used, specifically, terrestrial laser scanner (TLS) Stonex X300, StonexReconstructor, CloudCompare, Unity Engine.

The optimal scanning points were determined at the reconnaissance stage. During field work, to simplify the point cloud stitching, 11 scans of the landslide slope were made using terrestrial laser scanner:

- 1) 360-degree scan at “Fast” survey quality - 2 scans;
- 2) 200-degree scan at “Standard” survey quality - 1 scan;
- 3) 180-degree scan at “Standard” survey quality - 8 scans [3].

In the course of cameral work, the point clouds obtained by terrestrial laser scanner were stitched together. StonexReconstructor software was used for point clouds stitching. For point cloud stitching we used the “Automatic pre-registration” algorithm. It consists of three steps:

- 1) pre-processing: removing noise and unwanted objects from each point cloud;
- 2) reducing the number of points for faster and more accurate registration;
- 3) registration: matching two or more point clouds.

Using this algorithm, two point clouds were stitched together, the rest were stitched manually using the “Manual positioning” tool, this process is the most time-consuming, since the point clouds are moved in different planes, the subsequent correction was performed using the “Cloud to Cloud registration” algorithm.

The stitched and corrected point cloud is shown in Figure 1.

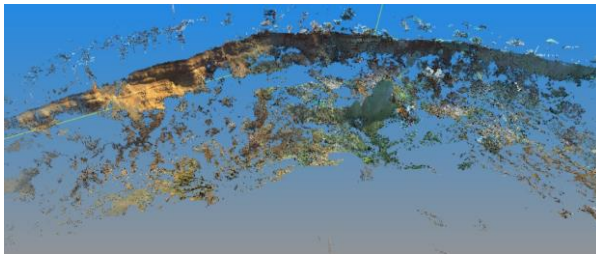


Figure 1 - The point cloud created with terrestrial laser scanner

The next step is to upload the obtained point clouds to the CloudCompare program, in which it is being created a united point cloud, as well as noise removal by removing from the cloud those points that can obstruct the 3D-model mesh surface creation. To create the mesh surface, we used the “Poisson Surface Reconstruction” tool, which uses the method of 3D

reconstruction based on the mesh and Poisson equation - Poisson Surface Reconstruction algorithm.

The advantage of using photogrammetry in reconstructing 3D objects is that there is no need to use special tools or equipment to create objects 3D models. The goal is achieved by processing images using special programs that analyze images geometric and brightness properties and then reconstruct the three-dimensional object shape [4].

As the basic software for 3D model reconstruction by photogrammetry method a program Agisoft Metashape was chosen. In the photogrammetry method of 3D model creation, firstly one should import photos into the software product “Agisoft Metashape”. For this purpose, it is necessary to use the tool “Add Photos”. A total of 73 photos were loaded. The next step is to align the photos. After alignment it is necessary to delete photos not suitable for further processing [5]. As a result, 55 photos remained after processing.

The next step is to create a dense point cloud. For this purpose, we used the “Build Dence Cloud” tool. Then the point cloud should be processed, specifically points should be removed to ensure the optimal cost of hardware resources when building a 3D model. After processing the point cloud, the “Build Mesh” tool is selected to create the mesh surface. The result of mesh surface generating is shown in Figure 2.



Figure 2 - The result of mesh surface generating

After obtaining a point cloud and generating a mesh, the obtained models can be integrated into 3D platforms. The chosen software is Unity 3D - a cross-platform development environment that allows creating interactive solutions using 3D content, that can be used then in augmented and virtual reality technologies. The camera view of the integrated 3D model into Unity 3D platform is shown in Figures 3, 4.



Figure 3 - A 3D model integrated into the Unity 3D platform (made with terrestrial laser scanner)



Figure 4 - A 3D model integrated into the Unity 3D platform (made with photogrammetry)

During the model integration, an automatic triangulation (polygon-to-triangle conversion of polygons) takes place [6]. Uncleaned models consist of millions of triangles, which is quite a lot for such a model when used in application solutions. There is a lot of noise, pieces of mesh left over on the model from vegetation and rocks. In contemporary applications, such models are separated and the vegetation in the form of a mesh is replaced by textured objects [7]. In order to optimize the use of the model in application solutions, the 3D model is divided into constituent parts. This approach allows rendering separately the part to which the camera is directed, resulting in load optimization. Unity Engine uses Occlusion Culling technology for this purpose, as well as static batching to reduce the number of rendering calls [8].

As a result, using laser scanning technology and photogrammetry, a work on creating point clouds and reconstructing a 3D model of the real terrain “Uchkuevka landslide” was pursued. The models are suitable for integration into application solutions, including projects with augmented and virtual reality.

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AUTOMATED PROCESS CONTROL SYSTEM

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Аннотация. Представлено исследование автоматизированных систем управления технологическими процессами (APCS). Подчеркиваются многочисленные преимущества APCS, такие как улучшенная эффективность, повышенная точность, повышенная безопасность, экономия средств и масштабируемость. Однако также рассматриваются проблемы, связанные с внедрением APCS, включая высокие первоначальные затраты, сложность, риски кибербезопасности, интеграцию с устаревшими системами и пробелы в навыках. Также обсуждается роль новых технологий, таких как искусственный интеллект (ИИ), Интернет вещей (IoT), машинное обучение (ML), периферийные вычисления и цифровые близнецы, в расширении возможностей APCS. Статья завершается обзором будущих тенденций.

Ключевые слова: критическая информационная инфраструктура (сii), кибербезопасность, киберугрозы, программы-вымогатели, распределенные атаки типа «отказ в обслуживании» (ddos), усовершенствованные постоянные угрозы.

Annotation. This article provides an in-depth exploration of Automated Process Control Systems (APCS), which are essential for modern industrial

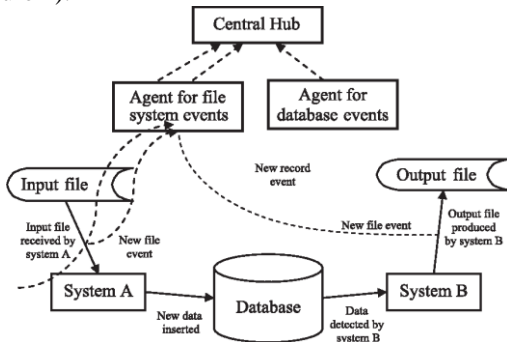
operations. The article highlights the numerous benefits of APCS. However, it also addresses the challenges associated with implementing APCS, including high initial costs, complexity, cybersecurity risks, integration with legacy systems, and skill gaps. The role of emerging technologies such as artificial intelligence (AI), the Internet of Things (IoT), machine learning (ML), edge computing, and digital twins in enhancing the capabilities of APCS is also discussed. The article concludes with a look at future trends, emphasizing the increasing adoption of AI and ML.

Keywords: critical information infrastructure (cii), cybersecurity, cyber threats, ransomware, distributed denial of service (ddos) attacks, advanced persistent threats.

Introduction. Automated Process Control Systems (APCS) have become a cornerstone of modern industrial and manufacturing processes. APCS are integral to modern industrial operations. These systems ensure efficiency, accuracy, and safety. They use a combination of hardware and software to monitor and control industrial processes where precision and reliability are critical.

Alan F. Blackwell argued that many scientists have spent “insufficient time understanding the mechanical ambitions of what AI engineers actually create” [2, p.3]. Farid Askary and Neal Sullivan wrote that precision was deemed the essential aspect of a measurement for process control. Claire dela Luna D.Mourtzis, J. Angelopoulos, N. Panopoulos presented the future of the Human-Machine Interface. They said that enterprises are encouraged to design frameworks capable of harnessing the power of human and technological resources to enhance the era of Artificial Intelligence (AI) [3, p. 162].

The Concept of Automated Process was presented by I. Oditis, J. Bičevskis (picture 1).



Picture 1. The Concept of Automated Process Control.
Source: Oditis I., Bičevskis J. [4]

The subjective of our article is to consider the numerous benefits of APCS.

The main part.

APCS are used in industries such as: manufacturing, pharmaceuticals, energy, oil and gas. s on their evolution.

Several key components of APCS are: Sensors and Actuators; Programmable Logic Controllers (PLCs); Human-Machine Interface (HMI); Supervisory Control and Data Acquisition (SCADA); Control Algorithms.

There are many benefits of APCS (table1).

Table1. The benefits of APCS

Benefits of APCS	Features
Enhanced Accuracy	APCS minimize human error, ensuring consistent and precise control of industrial processes. This is particularly important in industries such as pharmaceuticals
Improved Efficiency	By automating repetitive tasks and optimizing process parameters, APCS reduce waste and improve resource utilization
Cost Savings	APCS reduce labor costs and minimize downtime by enabling predictive maintenance and real-time monitoring
Increased Safety	Automated systems can detect and respond to hazardous conditions faster than human operators, reducing the risk of accidents

But APCS presents several challenges as well: High Initial Costs, Complexity, Integration with Legacy Systems, and Cybersecurity Risks.

“Security automation helps to streamline the numerous notifications that security professionals get regularly” [2].

APCS are used in:

- Manufacturing to optimize production lines.
- Oil and Gas industry to monitor and control drilling, refining, and distribution processes.
- Pharmaceuticals to ensure precise control of critical processes.
- Energy industry to manage power generation and distribution.
- Food and Beverage to control processes such as mixing, cooking, and packaging.

Emerging technologies are transforming the capabilities of APCS are Machine Learning (ML), Artificial Intelligence (AI), Digital Twins, Internet of Things (IoT). In a smart factory, IoT devices can communicate with each

other, allowing the entire production process to be monitored and controlled from a central location.

The future of APCS can be seen in:

1. Increased Adoption of AI and ML.
2. Integration of IoT.
3. Focus on Cybersecurity.
4. Development of Smart Factories.
5. Sustainability.

Conclusion. Automated Process Control Systems are essential for modern industrial operations, offering numerous benefits such as improved efficiency, accuracy, and safety. However, their implementation presents challenges, including high costs, complexity, and cybersecurity risks. The integration of emerging technologies such as AI, IoT, and ML is transforming the capabilities of APCS, enabling more advanced and efficient process control. As industries continue to evolve, APCS will play a crucial role in driving innovation, sustainability, and competitiveness.

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FEATURES OF USER AUTHENTICATION OVER WIRELESS NETWORKS IN IT COMPANY INFRASTRUCTURE

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Аннотация. В статье рассматриваются особенности идентификации пользователей по беспроводному каналу в сети IT-компаний, соответствующей требованиям законодательства Российской Федерации в области безопасного доступа к публичным Wi-Fi сетям. Представлена структурная схема устройства, основанного на микроконтроллере с поддержкой SIM-модуля для SMS-аутентификации и интерфейсом USB-UART для подключения к ПК.

Ключевые слова. captive portal, беспроводная аутентификация, SMS-идентификация, публичные сети Wi-Fi.

Annotation. The article examines the specifics of user identification over wireless channels in an IT company's network, designed to comply with the requirements of the Russian Federation legislation regarding secure access to public Wi-Fi networks. The study presents a structural diagram of a microcontroller-based device incorporating a SIM module for SMS authentication and a USB-UART interface for PC connectivity.

Keywords. captive portal, wireless authentication, SMS identification, public Wi-Fi.

1. Introduction

In 2017, our President Vladimir Putin presented the concept of "digital transition"[1]. During his speech at a meeting of the Council for Strategic Development and Priority Projects, the President emphasized the critical need for the development of the digital economy and the use of digital technologies to enhance the efficiency of public administration, education, healthcare, and other important sectors of society.

Moreover, the digital transition is not just a technological shift but a comprehensive transformation that requires systemic changes in policy, education, and infrastructure. By stimulating innovation and integrating digital solutions into everyday life, Russia aims to occupy competitive positions in the global digital arena. The proactive approach of the state to promote digitalization underscores the recognition that technological progress is the cornerstone of modern development, capable of addressing social issues and creating new opportunities for growth and prosperity.

The digital transition has enormous potential to improve the quality of life for people, increase business productivity, stimulate economic growth, and promote social progress. The successful implementation of this process and the full utilization of the advantages of digital technologies require close cooperation between the state, business, and citizens. One of the key aspects of the "digital transition" is accessibility and inclusiveness, reflecting the commitment to ensure access to digital technologies and services for all segments of the population. This includes expanding broadband internet infrastructure, creating public access points to digital services, and teaching digital literacy to equip citizens with the necessary skills to navigate the digital world. In this regard, organizing free and unlimited internet access through public Wi-Fi networks is a pressing task, which this work is dedicated to addressing.

2. Main part

Free internet access via Wi-Fi networks has become a common offering in most public places. This is especially important in IT companies, where most business processes are technically based on it. However, to ensure user security and comply with Russian laws, it is necessary to implement a specialized security mechanism known as wireless authentication. This system plays a crucial role in regulating access, adhering to legislative norms aimed at protecting users and maintaining order in the digital space. Wireless authentication functions as an authentication gateway, intercepting users before they gain full access to the internet and requiring them to verify their identity. This may include entering a phone number to receive an SMS code, providing social media credentials, etc. By implementing this additional level of authentication, the IT company's network gains the ability to actively monitor connections, creating a more secure environment that prevents unauthorized use and potential abuses. The necessity of the proposed solution in Russia is dictated by Federal Law No. 152-FZ "On Personal Data," [2] which establishes strict rules for the processing and protection of citizens' personal information. IT company owners are responsible for ensuring that only those users who have provided accurate and verifiable personal data have access to the internet. This requirement not only helps prevent unauthorized

access to the network but also allows tracking user actions during investigations of violations or other illegal activities.

From a technical standpoint, wireless authentication works by redirecting users to a login page at the moment they attempt to connect to the Wi-Fi network. The system keeps the connection in a limited state until the authentication process is completed, which may involve several verification stages depending on the network's security protocols. After successful authentication, the user gains full access, while the system logs the session for possible future use. The structural diagram of such a device is shown in Figure 1. The structural diagram represents an embedded system centered around a microcontroller that serves as the main control module for the entire scheme. A microcontroller with a Wi-Fi modem, such as those from the ESP family, has been chosen; these intelligent processing modules can coordinate all business logic of the device, ensuring seamless interaction between various components. A critically important element of this scheme is the built-in SIM module, which provides essential telecommunications and communication functions, allowing both sending and receiving SMS messages. For the SIM module, a SIM800 module can be used, which can provide cellular communication capabilities, forming the basis of the device's network functions. To exchange data and configure the system, the device establishes a reliable connection with personal computers through a USB-UART adapter interface. The CP2101 module can be used as a USB-UART adapter, enabling efficient serial communication while providing both programming and monitoring functions. Power supply issues have been resolved by implementing a battery-based system, with the built-in battery providing the necessary electrical energy for autonomous operation. This power solution ensures stable operation while maintaining the portability and flexibility of the device in various deployment scenarios. The battery can be charged from both the mains and solar energy, making this device overall more energy-efficient.

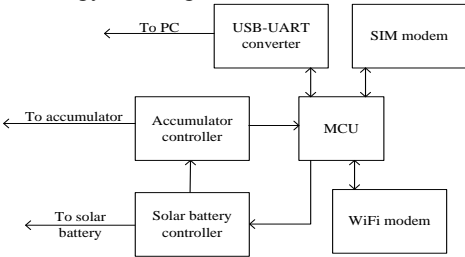


Figure 1 – The structural diagram enabling identification during wireless access.

The software on the microcontroller sets up an open WiFi network that users can connect to. The software listens on TCP port 80, and upon connection, generates an authentication page for the user. The authentication page contains several text fields, controls, and a button. The user can enter their phone number, confirm the user agreement, and click the "send message" button. After receiving the message, the user enters the code from the message in the corresponding field and clicks the "check" button. If the code matches, the device remembers the user's device ID and saves it to the database server, and the user gains full access to the internet. In addition to fulfilling legal obligations, the wireless authentication device significantly contributes to the overall security and performance of the network.

3. Conclusions

As a result of the conducted analysis, it has been established that there is both a technical and legal need for the implementation of wireless authentication functionality in full compliance with the current legislation of the Russian Federation. This necessity is driven by both regulatory requirements and practical security considerations in the context of access to the IT company's network. As a result of the analysis, two different but complementary scenarios for the application of the proposed device have been suggested, each addressing specific operational needs within a broader system for managing secure access to the internet.

In the first operational mode, the device serves as a specialized interface designed for transmitting SMS messages, primarily focused on user authentication processes. This configuration prioritizes simplicity and reliability in the identity verification procedure. The second, more comprehensive approach transforms the device into a complete solution for wireless authentication, including advanced features that cover the entire range of requirements for managing secure access. Thus, we have achieved adaptability of the system to various deployment contexts while adhering to all relevant legal norms governing access to public networks and user identification protocols.

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GAME ENGINE DEVELOPMENT AS A WAY TO GAIN PROFESSIONAL SKILLS

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Аннотация: Данная рассматривает создание игрового движка как способ получения профессиональных навыков в разработке высоконагруженных систем, выполняющих вычисления в реальном времени. Выделяются такие навыки, как умение проводить анализ требований и проектировать системы с большим количеством компонентов, умение выбирать подходящие сторонние средства разработки и работать с ними, определение необходимости использования абстракции для построения комплексных систем, а также умение разделять данные на независимые друг от друга потоки для повышения производительности. В ходе работы проведена декомпозиция общих систем игрового движка, рассмотрена архитектура среды исполнения игрового движка, были затронуты техники для разработки кроссплатформенных и многопоточных приложений.

Ключевые слова: программная инженерия, кроссплатформенные приложения, игровой движок, рендеринг, API рендеринга.

Annotation: This article examines game engine development as a way to gain professional skills as a software engineer of high load real-time applications. The following skills are highlighted: the ability to perform requirements analysis and to design a system with a large number of components, choosing and using third-party development tools, ability to determine the need of abstraction to build complex systems and the ability to separate data into independent threads to improve performance. The work includes a decomposition of the general game engine systems, a review of the game engine runtime architecture, and techniques of developing cross-platform applications and multithreaded applications.

Keywords: software engineering, cross platform applications, game engine, rendering, rendering API.

Game engine is a software that is extensible and can be used as the foundation for a huge variety of games without major modification. Game engines are complex applications, which include working with low-level operational system concepts, processing of sound, graphics and user input, and in some cases integration with network technologies. Moreover, most of the game engines are designed to be cross-platform, which greatly increases the complexity of development. Analysis of how such complex system operate is an excellent way to gain the competences of a cross-platform software developer.

Separation between the core engine and video game systems is not always clear. Some of the game engines are designed for creating one exact game and its modifications, such as id tech 3 engine for the Quake III Arena video game, while others provide functionality for developing video games of almost any genre, like Unity, Unreal engine and Godot. The latter are the most popular nowadays.

Figure 1 illustrates the components that are responsible for different levels of abstraction [1]. The first three levels (Hardware, Drivers and OS) describe a set of initial conditions that a game engine must satisfy. Hardware includes the target physical devices, such as mobile phones, a gaming console or a PC. Drivers are low-level software that directly interacts with the hardware devices. The Operating System, in turn, is the environment in which the game engine runs (Windows, MacOS, Linux, Android, Orbis, etc.).

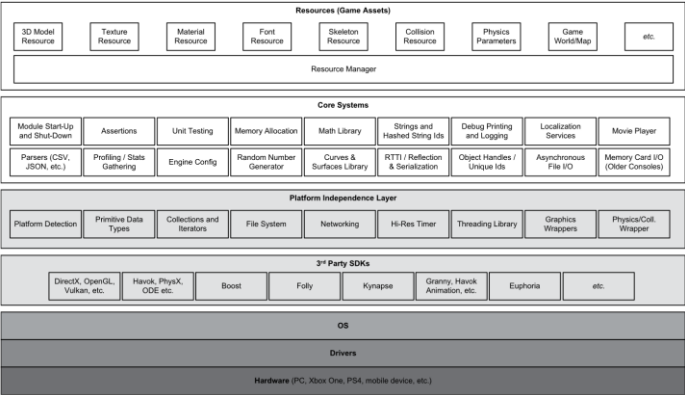
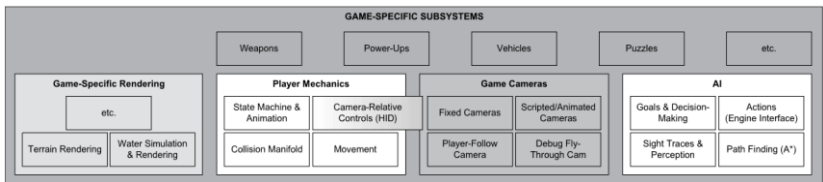


Figure 1. - Low-level game engine components

Third party SDKs¹ include some ready-made functionality that is necessary to implement components at the Core Systems level, like creating application windows and managing user input, rendering and so on. Sometimes these SDKs are used needed to create a Platform Independence layer. For example, window management and user input libraries (SDL and GLFW) use platform specific API² in order to provide an interface, which works the same way on different platforms. Since these using third party software affects how core components work and determine the list of supported platforms, selection of them should be approached with extreme responsibility.

Basically, game engine has a lot more specific components, which are too complicated to discuss them there (fig. 2). Starting from modular components that include rendering, physics, scripting, and ending with game-specific subsystems, such as agents AI, movement. Including game specific components as a part of a game engine may reduce the amount of reusability of the software, but can provide more consistent performance. The huge amount of these components and the fact that each of them can be implemented in enormous quantity of ways creates the variety of the game engines that we have now. For instance, only the rendering system has much more details than it looks like at first glance [2]. Furthermore, it is often noted by the developers [3] that in order to create an optimized game it is often required to change the core game engine systems. We can see this phenomenon in the latest games created using Unreal Engine 5. While famous companies are able to adapt the engine for their needs so games work as intended, lots of smaller studios' games are seen to have lots of «stutters», mostly connected with real-time shader management. The fact that these problems exist tells us that the industry has a demand of game engine developers that can enable creating more optimized games.



¹ SDK or software development kit is a collection of software development tools in one installable package

² API or application programming interface is a software interface for interaction with the core application system

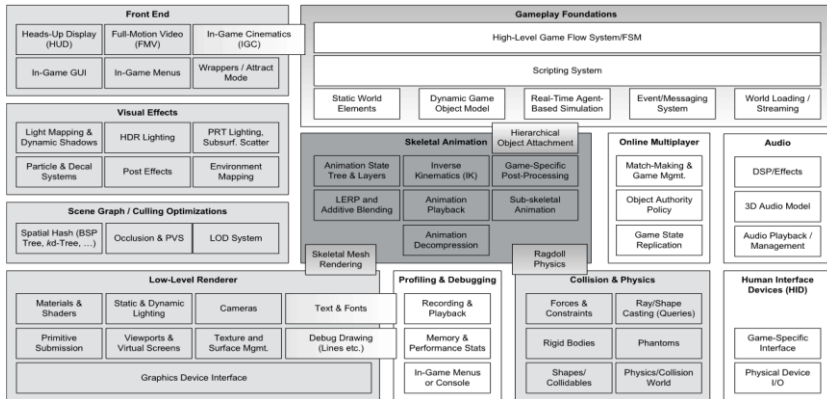


Figure 2. - High-level game engine components

Most often when developing a game engine, it is not possible to get by without using any external SDKs since they provide the basic functionality that would be unreasonable to implement ourselves. However, some details of the implementation of these external libraries may not be suitable for your game engine. There are multiple ways of overcoming this:

Using the copy of the library with the source code changed to fit your goals

Looking for additional external libraries that implement the required functionality or replacing the current one with the other. Doing that will likely require an API abstraction.

Creating your own implementation. There are some examples [4] proving that it is sometimes the best solution.

It was already mentioned that using multiple external dependencies that implement one and the same functionality requires interface abstraction. The main value of using this technique reveals when developing cross platform applications. Although using external libraries that are fully compatible with all the target platforms of your product may decrease the development difficulty, the compatibility compromises may result in poorer performance. This could be solved by using platform-specific APIs, like Windows window management and DirectX graphics API, when aiming for Windows OS. The best moment for integrating these platform-specific solutions is when the project already has an abstraction layer built on top of a fully compatible solution, like SDL for windows management and OpenGL for rendering. It is worth mentioning that abstraction principles should only be used when creating a software that needs to interact with different implementations of one and the same system. When creating a simple product which uses exactly one

dependency for one system it may not be adequate to use abstraction, since it will increase the difficulty of development.

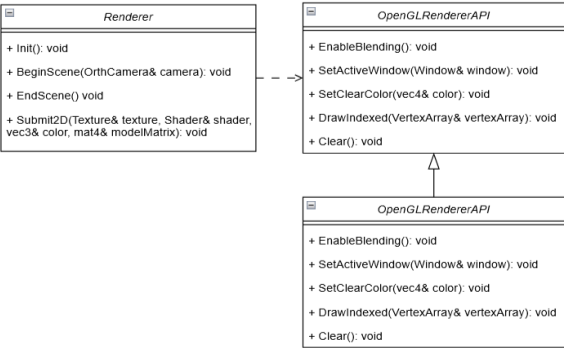


Figure 3. - Renderer API abstraction example

After fulfilling the basic layer of game engine functionality time comes for creating high-level systems such as game objects and scene management, graphics layers, and so on. Managing these systems without initial planning is almost impossible. The easiest way to show how systems interact with each other is to use a notation, such as UML, for creating diagrams. It helps to describe complicated processes so they can be understood by the people who are not even engaged in the development. For instance, Sequence UML diagram may help to describe how different systems interact with each other and also provide a clear view on the lifetime of the objects in the process (fig. 4). Component UML diagram is useful for stating the main components that each system has and the interfaces it uses to interact with other systems' components.

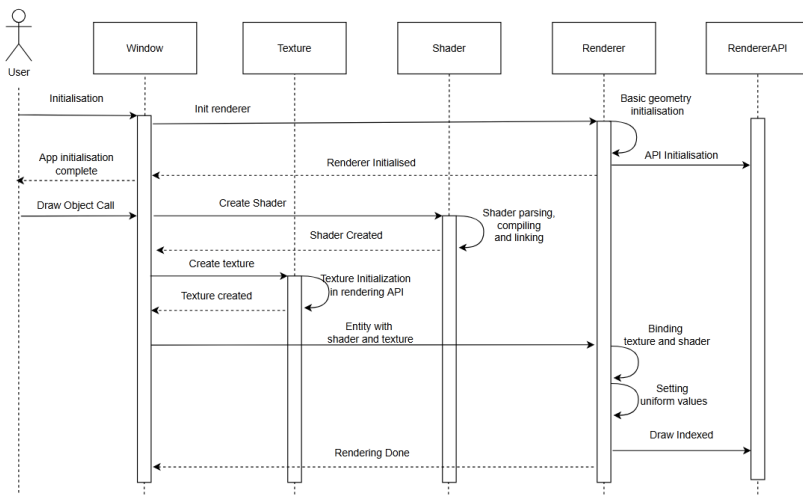


Figure 4. - UML sequence diagram example

In addition to the last paragraph, all the systems should be designed with a thought that game engine is a product that will be used by the target consumers. The users of the game engine are extremely diverse and can be:

1. Game mechanics engineers – development and integration of game-related systems
2. Game engine tool developer – creating additional tools for engine that will be used by the development team, such as visualized scene graphs.
3. Game designer – designing game mechanics, creating levels and environments for a video game.
4. Artist – creating assets, which may include animations, textures, sounds, music, and including assets into the game engine's resource manager.

In order for the game engine to be suitable for use by each of these roles, it is necessary to know the intricacies of these roles to create a convenient working environment for consumers.

Game engine is most often a complex desktop application that simulates objects in real time. High performance in such a case is almost impossible to achieve without multithreading. Additional threads will be needed at least for updating the user interface to avoid «freezing» when working with the game engine's editor. However, this alone will not be enough to create a viable game engine, because the video game itself will work using only one thread. This can cause not only performance issues, but also deprive of the opportunity to implement such basic functions as playing audio and video recordings along the main game loop. Most often, there are several concurrent threads. The

main thread is engaged both in calculating basic things, such as the state of game objects, and in redirecting tasks to other child threads when the state of game objects changes. The child threads may include an animation thread, a physics processing thread, and rendering. Implementation of these threads and a set of actions they perform is different with any game engine. However, separating concurrent data threads is the main key to reaching high performance.

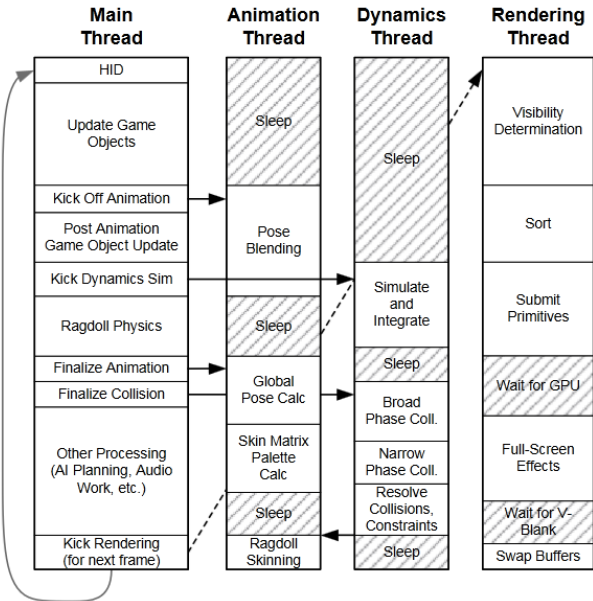


Figure 5. - Game engine multithreading example

Based on the points above, game engine development helps develop a wide variety of skills.

Requirements analysis helps to identify the business processes running in the game engine and understand the needs of different groups of consumers, which include other developers, game designers, and artists.

The requirements are used to determine the qualitative and quantitative characteristics of the product that must be achieved, such as supported operating systems and performance metrics. The ability to select third-party development tools (SDKs) that meet these requirements is also a key skill.

In order to work most effectively with third-party development tools, the following abilities are required: reading the source code to understand the

implementation details, changing the source code in case the existing implementation is not suitable for a specific product are required.

Creating such complex software as a game engine greatly strengthens cross-platform application development skills, since game engines have a variety of different systems, such as rendering and application windows management, that require the use of abstraction to provide a platform-specific implementation.

The next step after developing the base layer of platform independence is to design the high-level systems of the game engine. Basic knowledge of commonly used notations, such as UML, is necessary for designing high-level game engine systems and defining communications between them.

The resulting representation of the system at the design stage is used not only in building the project architecture, but also in separating the concurrent data of the internal processes into different threads, which is a necessary skill for reaching high-performance in real-time applications.

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EVOLUTION OF DECENTRALISED MOBILE NETWORKS USING ARTIFICIAL INTELLIGENCE

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Аннотация. В статье рассматривается концепция Follow-Me AI — инновационный подход к децентрализации мобильных сетей, основанный на интеграции искусственного интеллекта (ИИ) и технологий распределенных вычислений. Развивая идеи Follow-Me Cloud, предложенной в 2016 году, Follow-Me AI обеспечивает динамическую миграцию сервисов ближе к пользователю, снижая задержки, оптимизируя энергопотребление и повышая качество обслуживания (QoE). Проведен анализ архитектурных решений, включая взаимодействие ИИ-агентов, балансировку нагрузки и семантическую нарезку сети. Особое внимание уделено сравнению с традиционными подходами (SDN, OpenFlow) и перспективам внедрения в 6G. Результаты моделирования подтверждают эффективность Follow-Me AI для сценариев массового IoT, виртуальной реальности и телемедицины.

Ключевые слова: Follow-Me AI, Follow-Me Cloud, децентрализация, edge computing, ИИ, 6G, QoE

Annotation. This paper discusses the concept of Follow-Me AI, an innovative approach to decentralising mobile networks based on the integration of artificial intelligence (AI) and distributed computing technologies. Developing the ideas of Follow-Me Cloud proposed in 2016, Follow-Me AI enables dynamic migration of services closer to the user, reducing latency, optimising power consumption and improving quality of service (QoE). Architectural solutions including AI-agent interaction, load balancing and semantic network slicing are analysed. Special attention is paid to comparison with traditional approaches (SDN, OpenFlow) and implementation prospects in 6G. Simulation results validate the effectiveness of Follow-Me AI for massive IoT, virtual reality and telemedicine scenarios.

Keywords: Follow-Me AI, Follow-Me Cloud, decentralisation, edge computing, AI, 6G, QoE

Introduction. With the growth of traffic in mobile networks, traditional centralised architectures faced scalability challenges. In 2013, the Follow-Me

Cloud (FMC) concept was proposed, based on dynamic migration of services between data processing centres (DPCs), localisation of APN (Access Point Name) to link services to geographical zones, and the use of OpenFlow/SDN (in early versions) [1, 2].

However, FMC had limitations — high migration overheads, dependency on SDN infrastructure, load balancing issues when edge nodes are overloaded.

Follow-Me AI is a new paradigm that addresses these drawbacks by — integrating AI agents that in turn analyse user behaviour in real time, predict moves and migrate services in advance, help in optimising energy consumption through adaptive resource allocation. Also abandoning SDN in favour of semantic routing (based on ICN/CCN).

The aim of the work is to evaluate the effectiveness of Follow-Me AI for 6G networks.

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To avoid additional complexity in mobile networks, the use of OpenFlow and other SDN technologies is not presented in this paper [1, 2]. The network topology as shown in Figure 1 with additional components is shown. It is the FMC controller and the DC/GW (data centre/gateway) linking device.

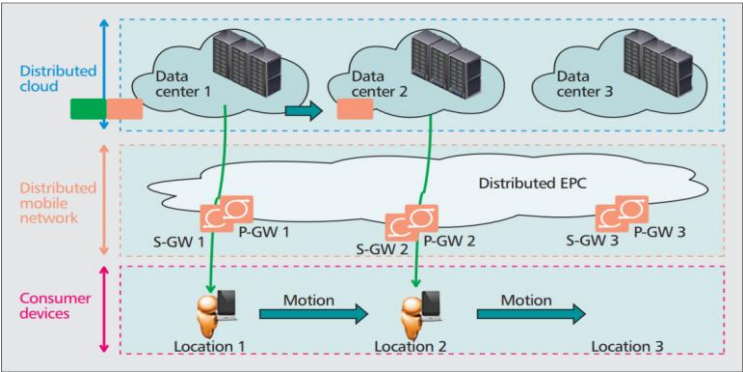


Figure 1 — Distributed mobile networks and clouds

The growth in the number of users is increasing annually at a steady rate. A graph of the projected user growth considering the collected statistics from 2010 to 2030 is shown in Figure 2.

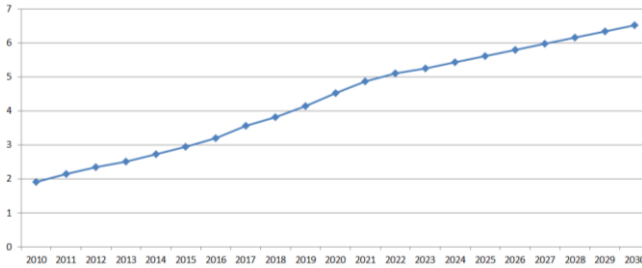


Figure 2 — The Number of Internet users projected from 2010-2030

As Figure 2 shows, the number of users will reach up to 7 billion by 2030.

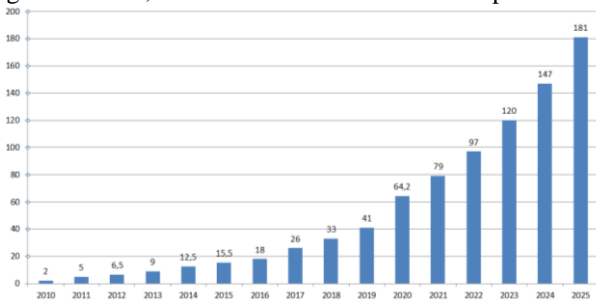


Figure 3 — Diagram of data traffic in zettabytes from 2010-2025

While Figure 2 shows a linear relationship, Figure 3 shows an exponential relationship.

The data traffic generated at the edge of the Internet has exceeded the operational limits of traditional centralised networks with the increasing use of intelligent applications for mobile devices and the influx of data from local devices. Bandwidth is required to handle the huge volumes of data being sent and received, as well as advanced processing capabilities to manage and analyse this information. Edge/fog computing aims to counter this development by dynamically allocating and moving resources and services closer to the user has become crucial in improving performance, minimising latency and improving the overall quality of user experience.

This shows that in order to optimise the load of the communication network, an approach is needed that can solve this problem without the need to build new data centres, which is risky for the environment.

The key technologies in Follow-Me AI are — dynamic load balancing, however there is a problem is that overloaded edge nodes increase the latency. To solve this problem Follow-Me AI has features such as — generative AI (GenAI) predicts peak loads, also large language models (LLM) optimise resource allocation [3]. For energy efficiency of this system is — 30%

reduction in energy consumption compared to FMC due to predictive migration (avoiding redundant moves), disabling unused edge nodes. And semantic network slicing allows to allocate virtual segments for specific services (for example, ‘telemedicine’ with priority on QoS).

The Follow-Me concept of Artificial Intelligence (AI) aims to improve user interaction with smart spaces, enhance user experience, reduce energy consumption and provide better control over the data collected by the smart environment [3].

Table 1 — Comparison of Follow-Me Cloud and Follow-Me AI

Parameter	Follow-Me Cloud (2016)	Follow-Me AI (2024)
Latency	50-100 ms	<10 ms
Power consumption	High	Optimised
SDN dependency	Yes	No
AI support	No	Yes (LLM, GenAI)

Follow-Me AI can be applied to 6th generation mobile communications. For example, for URLLC scenarios, it will guarantee latencies down to 1 ms for industrial IoT. For the mMTC scenario, it will allow scaling network capacity to 10⁷ devices/km². And for the eMBB scenario, it will help deliver speeds of up to 1 Tbps through local processing.

The approach involves the use of AI agents that accompany users and interact with AI agents of the surrounding smart environment, negotiating the management of collected data based on consent, directing the control of the environment to the user's preferences, and providing the smart environment with predictions of user behaviour (e.g. destination) for prescriptive control of the smart environment [3].

Conclusion. By helping to coordinate environmental management efficiently and adaptively, Follow-Me AI contributes to sustainability efforts as a step towards technology integration and environmental protection. Further research is focused on the feasibility of application in real 5G/6G networks.

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VOICE USER INTERFACES IN AUGMENTED AND VIRTUAL REALITY APPLICATIONS

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Аннотация. Интеграция голосовых интерфейсов пользователя (VUI) в дополненные и виртуальные среды (AR/VR) приобретает всё большую актуальность на фоне активного развития иммерсивных технологий. В данной статье рассматривается современное состояние разработки VUI для AR/VR-приложений, проводится обзор существующих инструментов и платформ, а также анализируются основные вызовы и перспективы данной области. Отдельное внимание уделяется потребности в интуитивно понятных, бесконтактных способах взаимодействия и роли искусственного интеллекта в повышении точности распознавания речи. Выделены ключевые выводы и предложены направления дальнейших исследований в этой области.

Ключевые слова: голосовой интерфейс, AR/VR, распознавание речи, взаимодействие с пользователем, иммерсивные технологии.

Annotation. The integration of voice user interfaces (VUI) into augmented and virtual environments (AR/VR) is becoming increasingly important amid the rapid development of immersive technologies. This article examines the current state of VUI development for AR/VR applications, reviews existing tools and platforms, and analyzes the main challenges and prospects in this area. Particular attention is paid to the need for intuitive, contactless interaction methods and the role of artificial intelligence in

improving speech recognition accuracy. Key findings are highlighted and directions for further research in this area are proposed.

Keywords: voice interface, AR/VR, speech recognition, user interaction, immersive technologies.

Augmented and virtual reality technologies are currently becoming increasingly popular for use in various areas of human life, in many of them, such as gaming, healthcare, education and many others, the need for more natural and user-friendly methods of interaction with applications is becoming more and more relevant and necessary. Traditional input methods, controllers, keyboards, are often impractical and cause inconvenience in immersive environments. Application developers are constantly looking for ways to improve user experience and reduce user inconvenience. One such example is the implementation of voice interfaces, which allows for a significant increase in accessibility for a wider audience, especially for people with disabilities.

The research presented in this article is based on a review of the existing literature, a comparative analysis and some case studies. Specifically, to assess the current state of voice user interface (VUI) development in AR/VR, a review of articles, white papers, and industry reports published over the past five years starting from 2020 was conducted, with priority given to peer-reviewed sources describing VUI implementation in immersive environments. A comparative analysis of platforms such as Google Speech-to-Text, Microsoft Azure Speech Services, and OpenAI Whisper was conducted based on some of the most important parameters, including speech recognition accuracy, support for a large number of languages, request processing latency, offline capability, and ease of integration with AR/VR application development frameworks such as Unity, Unreal Engine, ARKit, and Vuforia. The results of this work were used to describe technology trends, challenges, and explore possible future research directions aimed at improving this area of development. One of the main goals of augmented reality (AR/VR) technologies is to create a comfortable environment that promotes maximum user immersion in the process of using the product, and it is through the integration of speech recognition technologies and voice commands that users are able to interact with the virtual environment without being distracted from the process, which significantly increases engagement in games, various training simulations and many other scenarios. An example of a practical application of VUI is a virtual tour of a museum in a VR headset. Instead of using a controller to select an exhibit or get information about it, the user can simply voice the action they want. The system recognizes the command, and the relevant information immediately appears on the screen or an audio guide is launched. This interaction does not disrupt immersion in the environment

and significantly simplifies navigation, which is especially useful for people with disabilities.

The latest advances in artificial intelligence aimed at natural language processing have significantly increased the accuracy of human speech recognition and understanding. Neural network models such as transformers and recurrent neural networks are capable of analyzing sound signals to a significant degree of reliability, while taking into account the context of the utterance. The use of these models increases the accuracy of recognition even in the presence of background noise or the presence of an accent in a person.

Voice user interface (VUI) development is based on the use of specialized tools and platforms that provide tools for improving voice interaction between different technologies. Among the most widely used and used solutions by developers are Google Speech-to-Text, Microsoft Azure Speech Services (Speech SDK) and OpenAI Whisper. The products described provide the ability to process speech in real time, while supporting many of the most common languages, with high accuracy and ease of integration into various applications. Each of these platforms has its own strengths and conditions under which one is better than the other.

Based on the open data, some conclusions can be drawn about the strongest advantages of each of them. For example, Google Speech-to-Text is best used for applications that use cloud solutions with the need to support a large number of languages and high-speed transcription in real time. This makes Google Speech-to-Text ideal for solutions in the areas of online educational platforms or various conferences in virtual environments. Microsoft Azure Speech Services, in turn, is better suited for enterprise or industry solutions. It supports integration with existing Microsoft ecosystems, which makes it especially useful in production. It is not so dependent on an Internet connection and can work in a mixed mode. The last of them, OpenAI Whisper, can be called a leader in developments for various types of mobile and autonomous systems with augmented and virtual reality technologies. Its feature is autonomous processing and special resistance to background noise and various human accents. Another advantage for developers is the open-source code, which greatly helps to reduce the costs of development and further maintenance of the software.

With the development of technology, more and more tools and platforms for creating sophisticated virtual environments are becoming available to developers. One of the leading platforms for developing augmented and virtual reality is Unity. This cross-platform development environment provides many tools for developers, and cross-platform nature makes it possible to develop products for the most popular operating environments. Unreal Engine, another powerful open-source engine, is widely used to create

VR applications. Unreal Engine has gained the greatest popularity due to the ability to develop scenes with photorealistic graphics. It is worth mentioning that the development of augmented reality mobile applications relies on the ARKit and ARCore platforms created by Apple and Google respectively. Both platforms provide tools for tracking the environment, recognizing surfaces, evaluating lighting, and much more, which allows you to create applications of any kind.

According to researchers, the AR/VR market in the manufacturing sector alone is expected to grow from \$1.5 billion in 2024 to \$4.0 billion by 2030, at a compound annual growth rate of 17.8%. The growing adoption of these technologies is primarily in the entertainment, education, healthcare, and manufacturing industries, opening up new opportunities for digital interaction, operational efficiency, and process optimization.

A study published in the journal *Virtual Reality* presented a deep learning-based system for real-time silent speech recognition using facial electromyograms recorded around the eyes. This system enables hands-free interaction in VR, achieving an accuracy of 92.53% in classifying six different silently spoken words [1].

In another area of human activity, the medical field, VUIs are used to facilitate navigation in virtual environments. In a study conducted by the journal *Computers & Graphics*, VUIs were evaluated in three main categories: orientation, configuration, and analysis. The obtained results indicate that voice interaction serves as a possible way of communicating with visualization, increasing user satisfaction and usability [2].

Due to their capabilities, voice interfaces are becoming increasingly popular, however, despite all their potential, they have a number of problems that researchers and developers of these technologies from all over the world are working on. Some of the main problems are correct speech recognition through background noise surrounding the user, accurate speech recognition in different languages and accents, as well as problems with delays in processing commands. To address these issues, future research could focus, for example, on improving acoustic modeling for augmented reality and virtual reality environments, which in turn would improve the accuracy of speech recognition and commands in general. An example of such an approach is Google's research on using simulation data to train sound separation models [3]. Another important area for research is the development of user-centered design. In order to fully design a product, it is necessary to take into account user feedback, which in turn is necessary to understand how it meets the needs and preferences of different user groups.

There are a number of issues related to privacy and data security, since voice interfaces usually require continuous or frequent audio input. It can

potentially lead to the collection of sensitive user information and possible leakage of the collected data. This is especially relevant in healthcare and various industries, where the processed conversations of users and people around them may contain sensitive data.

That's why it is important to provide the secure transmission and processing of voice data, first of all, in cloud systems. Another challenge is stated to be limitations at the user device level, such as the microphone and other hardware. The effectiveness of VUI is influenced by the quality, placement, and integration of microphones in AR and VR headsets. For instance, it may result in poor audio recording quality, background noise, and reduced recognition accuracy, especially in noisy industrial environments if the microphone used is of poor quality or when users speak with different accents.

Users may experience discomfort when using voice commands in public or coworking spaces, i.e., collaborative work, and the cognitive effort required to remember and execute multiple commands in fast-paced scenarios may hinder intuitive interaction and immersion. Finally, one of the most important features and challenges of speech processing approaches is their dependence on an Internet connection, because many current solutions rely on cloud computing, and their performance can be significantly reduced in offline or low-bandwidth environments.

In conclusion, one should highlight that the integration of voice user interfaces (VUIs) into augmented reality and virtual reality (AR/VR) applications presents a transformative approach to traditional human-computer interaction. VUIs can significantly improve user experience by means of providing intuitive, hands-free controls in immersive environments. However, for these benefits to be fully realized, developers and researchers must address a number of critical challenges that have been outlined in this paper. Future research should focus on developing more robust, secure, and multimodal interaction systems that combine voice with gestures or gaze control, while optimizing offline and edge processing capabilities can reduce the reliance on cloud computing, thereby reducing the reliance on internet connectivity in products, improving their reliability and responsiveness. Although the technology is still in its infancy, voice interfaces have enormous potential to make AR/VR applications more accessible, effective, and immersive across a wide range of products and areas of human activity.

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APPLYING NEURAL NETWORKS IN GAME DEVELOPMENT WITH UNITY: METHODS, TOOLS, AND PERSPECTIVES

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Аннотация. В данной статье рассматривается применение нейронных сетей в современной разработке видеоигр с использованием игрового движка Unity. Подчеркивается значимость искусственного интеллекта (ИИ) для создания адаптивного поведения NPC, процедурной генерации контента и персонализированных игровых сценариев. Особое внимание уделено инструментам Unity Barracuda и формату ONNX, включая подробное описание установки, экспорта моделей и их интеграции в игровой проект. Представлены практические примеры и архитектурные подходы, способствующие эффективному внедрению ИИ. Также рассматриваются лучшие практики по управлению памятью и оптимизации производительности. Статья акцентирует внимание на доступности технологий машинного обучения в Unity и их растущем влиянии на игровую индустрию.

Ключевые слова: Unity, нейронные сети, искусственный интеллект, ONNX, Unity Barracuda, разработка игр, машинное обучение, ИИ в играх, процедурная генерация, адаптивный геймплей.

Annotation. This article explores the integration of neural networks into modern game development using the Unity engine. It highlights the importance of artificial intelligence (AI) in enhancing gameplay through adaptive NPC behavior, procedural content generation, and personalized experiences. The study focuses on the use of Unity Barracuda and the ONNX format, providing an overview of the installation, model exporting, and implementation processes. Practical examples and architectural considerations are discussed to help developers embed AI solutions. The paper emphasizes the accessibility of machine learning tools within Unity and outlines best practices for performance and memory management. As AI continues to reshape the game industry, understanding these tools is essential for future-ready development.

Keywords: Unity, neural networks, artificial intelligence, ONNX, Unity Barracuda, game development, machine learning, AI in games, procedural content, adaptive gameplay.

The video game industry was valued at over \$217 billion in 2023, and it continues to grow at a tremendous pace due to various technological innovations. For example, Artificial Intelligence (AI) has become the latest transformational force to create more advanced, immersive and adaptive games through neural networks and machine learning [3].

Previously difficult to research, AI is revolutionizing game development by offering many applications such as procedural content generation, dynamic behavior of NPCs (Non-Player Characters) and real-time player adaptation. These capabilities are becoming available to developers of all skill levels [7].

As one of the most popular game engines, Unity offers the potential to utilize neural networks through tools such as Barracuda, allowing direct and easy integration of neural networks into projects on many operating systems [9, 5]. This paper discusses practical applications of neural networks in Unity, key tools and integration techniques, processes for exporting ONNX models to Barracuda, current challenges and future potential.

The guide focuses on making AI techniques accessible for game development while maintaining performance and usability.

The purpose of this paper is to explore the application of neural networks in game development using Unity focusing on the integration of AI and Machine Learning (ML) Technologies to enhance the game experience. The aim of the paper is to provide a comprehensive overview of tools such as Unity Barracuda and the ONNX format, demonstrate their practical applications, and discuss potential applications, challenges, limitations, and future opportunities for AI-based game development.

The subject of the study is the use of Artificial Intelligence and Neural Network Technologies in Unity game development pipelines. The object of study is the broad field of modern game development with special emphasis on the revolutionary effect of Artificial Intelligence and Machine Learning Technologies.

Today, neural networks have become a key component of gaming AI, as they are able to learn complex patterns and make intelligent choices based on the information obtained. Unlike traditional rule-based systems and static scripts that developers write, neural networks allow making the gameplay more flexible and richer, with more advanced NPC behavior and the ability to create an interesting and dynamic game world.

In game design, reinforcement learning is used to train agents – enemies or non-player characters – by rewarding them for good behavior and punishing them for bad behavior, so that they can learn and adapt to certain rules, conditions or player strategies over time. Generative models, such as generative adversarial networks (GANs) and variational autoencoders (VAEs), are used to create game content, such as textures, levels, or even entire environments, with much less human effort. Convolutional neural networks (CNNs) are used for image and video processing, enabling tasks such as object detection, facial animation and graphics enhancement. Recurrent neural networks (RNNs) and their variants such as long-short-term memory (LSTM) process sequential data, making them ideal for dialogue systems, time series prediction or story continuation [2].

The use of neural networks in games has some significant advantages. NPCs and enemies become more responsive, reacting ‘intelligently’ to the player's actions and increasing the level of complexity and realism. Procedural content generation simplifies development by automating the creation of assets and levels. Last but not least, neural networks open the door to innovative mechanics – such as AI-driven storytelling and emergent gameplay - that were difficult or even impossible to realize in the old ways [4].

This research combines theory and practice in investigating the integration of neural networks in game development using Unity. The theory is based on analyses of tools such as ONNX and Barracuda. Practice involves data preparation, deployment and experimentation to find viable approaches. Theory and practice are combined to provide an overview of the application of AI in game development.

ONNX (Open Neural Network Exchange) is an open machine learning model representation format for inter-framework compatibility, which can support TensorFlow, PyTorch, and many others popular ML frameworks. ONNX can actually be viewed as a bridge that connects machine learning frameworks and execution environments. Thanks to ONNX developers can

bridge neural networks into Unity, from almost every framework. This section is a simple guide on the exporting process of a model to ONNX, highlighting its cross-platform compatibility and simplicity in game development.

The ONNX format offers several advantages for deploying AI models. Firstly, universal compatibility allows deployment of models that have been trained in any framework that supports ONNX export. This provides greater flexibility to the platform. ONNX models can run on Windows, macOS, iOS, Android, and even game consoles. However, some devices require significant performance optimization. ONNX models can be optimized using compression and acceleration techniques. This can make some large models viable on some less powerful devices or simply improve performance in a game. In addition, support for this format by many developers is expanding over time, making it a viable choice for many future development tools. ONNX is not perfect and can sometimes be outperformed by other formats. For example, if you are developing for IOS only. I suggest using the CoreML format. It is better suited for IOS, but can only run on Mac, IOS, and Linux.

The direct approach ensures that your AI models can go from a data exploration pad to a real-time game environment with minimal hassle. The exported ONNX file will retain all learned behaviors and will be ready to work with the Barracuda inference engine in Unity. Almost every tool available for ML supports exporting to various formats. Be sure to read the official documentation of your framework to better understand the export process [6].

Unity Barracuda is a neural network inference library built for Unity and designed specifically for game development. Unlike many generic ML frameworks, Barracuda is focused on real-time performance in games. It is lightweight and increases the build size by only 5-15 MB. This is especially important for mobile builds. Also, because Barracuda runs on the Unity engine, it can be used on all Unity-compatible devices. In addition, it does not require any external dependencies.

Now proceed to installing Barracuda. Unfortunately, since Barracuda has been removed from the Unity package manager, the installation requires some extra work. Firstly, you'll need to find the latest stable build on GitHub. Then you can manually download and import it or use this GitHub link in the package manager. Personally, I recommend the second option. It's simple and stable, you won't be able to mess it up. After adding the package from the GitHub link and installing it, you can verify that everything works fine by using the `Unity.Barracuda` namespace in your Unity project. If there are no errors, congratulations, you have successfully installed Barracuda. Now we can move on to implementation in Unity.

To better understand how to use barracuda we need to take a look at the core components: model representation, execution workers, tensor handling, and the standard workflow for model execution.

Barracuda supports processing models that are exported from ONNX. They are represented in two main classes. The `NNModel` and `Model`. The former is a Unity asset that wraps. onnx file to refer to it via Inspector. The latter is a runtime representation of a neural network, which is loaded from `NNModel` via `ModelLoader.Load()`. It contains the network structure, layers, weights and execution graph. The `IWorker` interface is essential to Barracuda. It controls the model execution. There are various types of Workers for a given task. `WorkerFactory.Type. Auto` can be the most general and easy choice because it chooses automatically the best backend (GPU or CPU). There are certain points on which it can be fine-tuned. `WorkerFactory.Type. ComputePrecompiled` will be ideal for desktop or gaming console GPU. For CPU the `WorkerFactory.Type. CSharpBurst` will be ideal especially for mobile platforms. For older hardware the Barracuda can still be used via `WorkerFactory.Type. PixelShader`. Its performance is not good and not recommended though. All of these workers can be instantiated via `WorkerFactory.CreateWorker()` and don't forget to dispose them to prevent large memory leaks. You can always keep an eye on your memory usage via Unity profiler.

Models in Barracuda operate on tensor objects – the multi-dimensional arrays to store the input and output data. Tensors can be created from different sources, like raw arrays, textures, or pre-allocated shapes. Same as for workers, don't forget to dispose tensor after use to save some memory [6].

A typical model execution workflow is actually quite simple. First, you need to load the model into memory. This is done by either importing the `NNModel` asset via the Unity Inspector or loading it via code, depending on which design works better for your project. The loaded asset is converted into an executable model using `ModelLoader.Load()` and is ready to actually work on the output.

After your model is set up, the next step is to set up what we call a "worker" – the object that will run your neural network. This `IWorker` object is created using your preferred backend configuration. In most cases, you will want to select GPU here, though Barracuda offers several backend options depending on your platform and performance needs. Last but not least, the data preparation step. Some of your game state data, textures, or other input data have to be reshaped into Tensor objects, which are the data form that Barracuda expects you to feed to neural networks. The conversion process in this step is 100% crucial because it reshapes your game data into the shape that your model will understand. When you're about to perform inference, a

simple call to worker. `Execute(inputTensor)` starts things off. For heavier models that can cause drops in the frame rate, there's an alternative in Barracuda: `StartManualSchedule()`. This clever method loads the computation over multiple frames so your game stays responsive even when processing heavy AI.

There are a few best practices for better stability and performance. Pay attention to memory usage as is critical in game development, especially with memory consuming neural networks. Always remember to dispose tensors and workers. Either manually with `Dispose()` or via using blocks for automatic cleanup. Do not rush the tensor dispose. If it is possible you can reuse tensors for frequent inferences. Additionally, use the Unity profiler to check memory usage and overall performance. To maximize performance, consider batch data entry to process multiple data points in a single call. Also consider quantizing the model. Reducing the precision from FP32 to INT8 significantly improves performance. This can be critical for mobile devices. Also try checking the output timing. If possible, try to make it as small as possible. Depending on the task, the time may vary, but in my experience, an output time of less than 65ms is sufficient for smooth operation.

Barracuda makes it possible to integrate the neural networks into Unity projects without relying on any external frameworks. Once you become familiar with its core components which include Model, IWorker, and Tensor, developers can efficiently deploy AI for NPCs, procedural content, and real-time analytics. Proper memory management and optimization will ensure smooth performance across all platforms. As Unity continues to enhance Barracuda, its role in game AI will only expand, making it a crucial tool for modern game development [1].

Now that we've covered the ONNX exporting process and Barracuda installation, let's discuss how to properly structure a Unity project for the best results. While implementation may vary depending on game design, here's a straightforward approach to get started.

When creating any project, it is necessary to take into account its architecture. The same is true for neural networks in Unity projects. In the process of research three main approaches have been identified. All of them have their advantages and disadvantages. The first pattern that comes to mind for many developers is a centralized system where there is a single game object that controls all processes with the AI. This simplifies the architecture, but can cause problems with system expansion and possibly dependency issues. If your scene is small and simple, this approach may be optimal. For larger projects, we can suggest a distributed system with multiple GameObjects handling their models with all the data. It is superior to the centralized approach, but creates even more dependency problems and requires careful

communication. One of the most viable approaches is to use a hybrid system, where you separate the models from the data to better manage the project and have good scalability. In most cases, we recommend using a single GameObject, especially when you are just figuring out how to implement a feature and make a test scenario. This will save a lot of time and give you the knowledge you need for more complex architectures [8].

Now one should consider the basic setup of a minimally functional neural network system. We will use a single GameObject approach. To get started, simply create an empty GameObject that will control the execution of the model and attach the following script to it. The script itself is simple, but it contains all the information you need to get started, see Figure 1.

```
public class NeuralNetworkRunner : MonoBehaviour
{
    public NNModel modelAsset;

    private IWorker _worker;

    void Start()
    {
        var model = ModelLoader.Load(modelAsset);
        _worker = WorkerFactory.CreateWorker(WorkerFactory.Type.Auto, model);
    }

    public float RunInference(float input)
    {
        using var tensor = new Tensor(1, input.Length, input);
        _worker.Execute(tensor);
        using var output = _worker.PeekOutput();
        return output.ToReadOnlyArray();
    }

    void OnDestroy()
    {
        _worker?.Dispose();
    }
}
```

Figure 1 – Code to run neural network

After that, import the ONNX model into the assets folder and assign it to the script component field. Then, call ProcessAI () to get the results from the model, after which you will have to interpret them depending on your task. The same goes for Python.

Although this approach is simple to implement, it has some drawbacks. If you have a very small model or don't use it that often, you'll be fine. But if you scale this approach up a bit, you will have performance issues. The basic idea of any game engine is to have everything happening at the same time. The player can't spend a couple of seconds waiting while the game thinks about what to do. Any significant operation that takes some time should be done separately from the main game loop or asynchronously. This will allow the game engine to move on to executing the next instructions in the code without waiting for the long operation to complete. Therefore, we strongly recommend using asynchronous programming for all time and resource consuming operations. This will improve performance on some older platforms as well. Example: see Figure 2.

```

public void PredictAsync(Texture2D input)
{
    StartCoroutine(RunAsync(input));
}

private IEnumerator RunAsync(Texture2D input)
{
    var processed = Preprocess(input);
    using var tensor = new Tensor(processed, 3);

    var op = _worker.StartManualSchedule(tensor);
    while (op.MoveNext())
        yield return null;

    using var output = _worker.PeekOutput();
    HandleResult(output);
}

```

Figure 2 – Asynchronous model runner code

Perspectives and Future Possibilities

Neural networks are dramatically transforming game development. Although most recent uses are focused on NPC behavior or procedural generation, the future is much farther out. Some leading trends are on the verge of reshaping the industry.

AI-Driven Dynamic Storytelling

One of the most interesting and game-changing trends is AI dynamic storytelling. Imagine an NPC that can react to player behavior and even have an interesting dialog on almost any subject without current limitations. This can create a new unique and unforgettable player experience.

Self-Improving Game Systems

Reinforcement learning can help to make games, that evolve alongside players. Game NPCs can adapt them to players' behavior. This will make game worlds “alive” challenging, fair, and interesting to explore.

Improved Procedural Content Generation

A new look on procedural generation can make game development easier and also personalize player experience making it more unique. As a result, interesting to explore.

Technical Challenges

While these opportunities are exciting, some significant struggles remain. Implementation of AI requires careful optimization, especially with current hardware limitations. Also, developers must learn to ensure that neural network outputs align with game design and can create a proper player experience. But as technologies become more advanced, the more possibilities we will have. In the coming years, we will likely see how neural networks will become a more common thing in our lives, in every sphere.

This article has demonstrated that neural networks are no longer theoretical concepts but practical tools for modern game development. Through Unity Barracuda, developers can implement complex AI systems

using familiar workflows, optimize models for real-time performance across platforms, and most importantly focus on innovational approaches.

Key findings include that ONNX standardization eliminates compatibility problems, Barracuda's lightweight architecture makes neural networks viable even for mobile games, and proper memory management and backend selection are critical for performance. The experimental results show that neural networks, despite current hardware limitations, can revolutionize game design. However, as this study reveals, their adoption requires some trade-offs between realism and performance – a key direction for future work. The challenge for developers will shift from implementing these technologies to proper creative application – discovering new ways that these technologies can enhance player experiences rather than simply imitating existing ones.

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FEATURES OF REMOTE SOFTWARE DEVELOPMENT FOR EMBEDDED SYSTEMS

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Аннотация. В статье рассматривается подход к минимизации проблем, возникающих при передаче разработки программного обеспечения для специализированных аппаратных платформ на аутсорсинг. В качестве решения предлагается схематичная реализация аппаратной части в среде моделирования Proteus 8. Такой подход позволяет: упростить формулировку технических требований и коммуникацию между заказчиком и исполнителем; организовать тестирование и отладку ПО без необходимости предоставления физического прототипа устройства; снизить зависимость от реального оборудования при оптимизации работы с ограниченными ресурсами микроконтроллеров; обеспечить защиту интеллектуальной собственности и ускорение процесса разработки.

Ключевые слова: встраиваемые системы, Proteus 8, виртуальное прототипирование, удаленная разработка, аппаратная симуляция.

Annotation. The article examines an approach to minimizing challenges in outsourcing software development for specialized hardware platforms. The proposed solution involves schematic implementation of hardware components in the Proteus 8 simulation environment. This methodology enables: simplified technical requirements formulation and improved communication between clients and contractors; software testing and debugging without physical prototype access; reduced hardware dependency while optimizing for microcontroller resource constraints; intellectual property protection and accelerated development cycles.

Keywords. embedded systems, Proteus 8, virtual prototyping, remote development, hardware simulation.

Introduction

In modern society the quality of life directly depends on the services available for everyday use. They represent hardware, embedded platforms, the functioning of which is directly affected by the software. There are not many specialists capable of developing such software.

A number of challenges arise when it comes to remote software development, when dealing with specialized devices, such as a shredder with an ATtiny2313 controller. The main problem is that a remote team of developers usually does not have a complete understanding of all the nuances of the equipment's operation and the specifics of software interactions with the actual device. This is particularly critical for such microcontrollers, as their programming requires not only knowledge of C or assembly language but also the architecture, limitations, and specific capabilities of the chip.

One should consider the difficulties which a remote team can have. The lack of access to the device itself for the remote team of developers is one of the key challenges [2].

The shredder has unique characteristics: processing signals from jam sensors, algorithms for the operation of the blades, motor control—all of this requires an understanding of how the device should function in real-world conditions. The final result will be unusable, if a clear technical specification is not formulated for the remote team.

A misunderstanding can still occur even with a detailed specification for the software being developed for the hardware platform. For instance, in case of communication between the client and the contractor is limited by time zones or language barriers. There is a high risk that the software will not work correctly under real conditions, if developers write code based on the technical specification. For instance, time delays that seemed optimal during development may turn out to be unacceptable for the actual mechanism. It can lead to failures or even breakdowns [1].

Since external developers do not have physical access to the device, debugging is often carried out on microcontroller simulators or development boards that only approximately mimic the behavior of the actual hardware platform. This means that some algorithmic errors may only manifest after integrating the software into the final product, which increases development time and costs. Therefore, choosing and justifying methods for more complete simulation of the hardware platform is a relevant task, which this work is dedicated to solving.

Main part

One of the main challenges of remote development of embedded software for specialized equipment, as previously noted, is the contractor's lack of access to the device itself. In the case of the shredder based on the ATtiny2313, this is particularly critical, as the system's behavior depends not only on the software but also on how the microcontroller interacts with mechanical components, sensors, and actuators. If the remote development team cannot physically test the software on real hardware, this significantly increases the risk of algorithmic errors, incorrect timing delays, and even potential equipment failures. However, if the hardware is accurately modeled in the Proteus 8 environment, these risks can be substantially reduced by providing developers with a virtual model of the device that allows them to perform initial debugging of the code under conditions close to reality.

The Proteus 8 software package is a powerful environment for simulating both analog and digital electronic circuits, supporting not only printed circuit board design but also microcontroller emulation. If the control circuit of the shredder is correctly designed in Proteus—taking into account all key components (motors, jam sensors, control buttons, etc.)—remote software developers gain the ability to dynamically test the embedded software while observing how the virtual system responds to commands. This is especially important for verifying critical functions such as fault signal processing or motor power management. Unlike abstract emulators, Proteus can model analog signals, electrical noise, and even mechanical loads, making testing much closer to that of a real device. The schematic implementation of the hardware platform in Proteus 8 can be an effective solution for minimizing issues related to transferring software development for remote development.

Figure 1 illustrates an example of a schematic emulation of the shredder's operation. Here, LDR1 is a paper presence sensor. The motor has unipolar activation and is connected without drivers to indicate only the direction of paper movement. D1 is an indicator for operational mode or fault. S1 and S2 are control buttons. This model allows for monitoring emergency situations; for example, when paper jams occur, the paper sensor remains activated for an extended period, and after a safe period ends, the motor reverses to push the paper back. As seen in the Proteus 8 environment, even non-standard situations can be modeled.

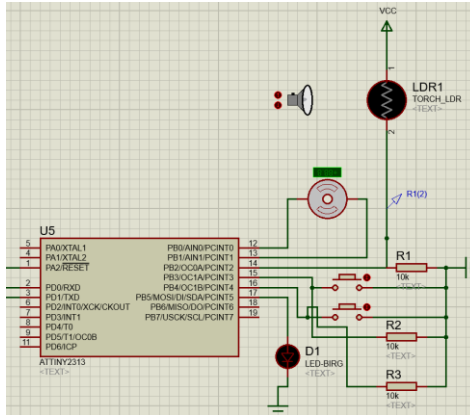


Figure 1 – Simplified hardware simulation of the shredder in Proteus 8 environment.

There is an assumption that using the Proteus 8 simulation package can significantly simplify interaction between the software customer and remote programmer. Even the most detailed technical specifications do not always account for all the features of software code execution on a specific hardware platform, especially in complex electromechanical systems where resonances caused by mechanical vibrations may occur, which in turn are caused by software code execution.

When the customer develops, approves, and transfers a completed Proteus schematic to the development team as part of the technical specifications, this provides clear understanding of the expected behavior of each hardware platform element, since the first development stage has already been completed, resulting in abstraction from all unnecessary hardware properties of the system being developed that are irrelevant to solving the specific task. For example, thanks to visual perception of the hardware model schematic, understanding emerges of how the microcontroller should process the signal from the jam sensor or how changing PWM duty cycle affects motor speed. This reduces the number of errors caused by incorrect interpretation of requirements.

This approach also allows reducing software debugging time. Considering that in the classical remote development scheme, programmers write code relying only on documentation, and only after transferring the software to the customer does its testing on a real device begin. This approach inevitably leads to multiple revisions, delays, and increased development timelines. However, when using the Proteus development environment, most software problems are identified at the design stage. Developers can immediately check, for example, how a timer configuration failure affects

actuator operation or whether sensor interrupts are processed correctly. This is especially critical for low-performance microcontrollers like ATtiny2313, where it is very important to efficiently use every byte of memory and processor time.

One should consider simulation limitations and attempt to reasonably select methods for their compensation.

In complex and integrated projects, simulation in the Proteus environment cannot fully replace testing on real equipment, as it does not account for mechanical vibrations, thermal effects, or production tolerances of component parameters. Nevertheless, this methodology allows filtering out most logical and algorithmic errors before prototype assembly, which saves development overhead costs and provides it with a competitive market advantage. It is also possible to further improve model accuracy if the customer provides device operation videos or oscillograms of key signals.

In other words, using the Proteus 8 environment to create a virtual prototype substantially simplifies the software development process. This method not only reduces risks associated with remote work but also accelerates the development cycle, makes interaction between all project participants more transparent, and reduces revision costs. Although testing on a real device is mandatory, preliminary simulation minimizes the number of algorithmic errors and increases the chances of successful project launch on the first attempt.

Conclusions

The proposed approach allows to: simplify the formulation of requirements and communication between the customer and the outsourcing team; provide the capability for testing and debugging without the need to supply a physical prototype; reduce dependence on the hardware platform and optimize development for the microcontroller's limited resources; protect intellectual property and accelerate the development process.

Thus, the use of Proteus 8 not only facilitates the transfer of development to remote development but also improves the quality and reliability of the final product.

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THE EVOLUTION OF CYBER THREATS IN THE ERA OF QUANTUM TECHNOLOGIES: CHALLENGES AND MITIGATION STRATEGIES

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Аннотация. Статья посвящена анализу трансформации киберугроз в условиях стремительного развития квантовых технологий. Рассмотрены ключевые риски, связанные с уязвимостью классических криптографических алгоритмов (RSA, ECC) перед квантовыми атаками, такими как алгоритм Шора, способный взламывать шифрование за полиномиальное время. Особое внимание уделено практическим ограничениям квантовой криптографии, включая проблемы реализации протоколов QKD, фотонные потери в оптоволоконных сетях и высокую стоимость инфраструктуры. В качестве решений предложены постквантовые алгоритмы (CRYSTALS-Kyber, SPHINCS+) и гибридные системы, совмещающие классические и квантово-устойчивые методы. Отдельно исследуются этические и политические аспекты: цифровое неравенство, милитаризация квантовых технологий и фрагментация стандартов безопасности. Статья подчеркивает необходимость глобальной кооперации, инвестиций в образование и разработку нормативных актов для устойчивого перехода в квантовую эру.

Ключевые слова: Квантовые вычисления, кибербезопасность, постквантовая криптография, алгоритм Шора, QKD (квантовое распределение ключей), гибридные системы, цифровое неравенство.

Annotation. The article examines the evolution of cyber threats in the context of rapid advancements in quantum technologies. It highlights critical risks posed by quantum attacks, such as Shor's algorithm, which can break RSA and ECC encryption in polynomial time. The study addresses practical limitations of quantum cryptography, including challenges in QKD implementation, photon loss in fiber-optic networks, and high infrastructure costs. Mitigation strategies include post-quantum cryptographic algorithms (CRYSTALS-Kyber, SPHINCS+) and hybrid systems combining classical and quantum-resistant methods. Ethical and political dimensions are also

explored, such as the digital divide, militarization of quantum technologies, and fragmentation of security standards. The paper emphasizes the need for global collaboration, investments in education, and regulatory frameworks to ensure a secure transition to the quantum era.

Keywords: Quantum computing, cybersecurity, post-quantum cryptography, Shor's algorithm, QKD (Quantum Key Distribution), hybrid systems, digital divide.

Introduction

The dawn of quantum technologies marks a paradigm shift in computational power and data security. Quantum computers, leveraging principles of superposition and entanglement, promise to solve problems intractable for classical systems, such as optimizing supply chains or simulating molecular structures. However, this technological leap also poses existential risks to existing cryptographic infrastructures [4]. For instance, Shor's algorithm, when executed on a sufficiently powerful quantum computer, could factorize large integers exponentially faster than classical methods, rendering RSA and ECC encryption obsolete. Simultaneously, quantum communication protocols like QKD, though theoretically secure, face practical implementation challenges [8].

The purpose of the study.

This article examines the dual-edged nature of quantum advancements, focusing on their implications for cybersecurity and proposing mitigation strategies.

A.I. Gazin and N.S. Diakov said that "successful digital transformation requires a heightened focus on security. Some of the world's largest companies have fallen victim to cyber attacks. IP, personal information, and finances are constantly under threat. In the content of the digital world of corporate networks, the past no longer exists" [1, p. 8]. So, V. Nikulchenkova states that "the existing system of preventive measures and criminal law measures in Russia is not capable of fully counteracting cybercrime, which justifies the relevance and necessity of conducting scientific research in this area for the purpose of criminological and criminal law prevention of cybercrime" [2, p. 96].

The main part.

Quantum Technologies: Capabilities and Applications

Quantum computing works very differently from standard computers. It uses special rules like superposition (being in multiple states at once), entanglement (linked particles), and quantum effects to tackle hard problems regular systems can't handle. A key part is the quantum bit (qubit), which can be both 0 and 1 at the same time, allowing many calculations to happen

together. This makes methods like Shor’s algorithm—which cracks RSA encryption by factoring large numbers much faster—and Grover’s search tool—which finds data quicker—possible [9].

Today’s progress includes three main types:

- Superconducting qubits (like IBM’s 433-qubit Osprey)
- Trapped-ion setups (IonQ’s 32-qubit Forte)
- Light-based systems (Xanadu’s Borealis)

Each type has strengths and weaknesses in how long they stay stable, how often errors happen, and how easy it is to build more qubits. In 2019, Google showed a quantum machine solving a problem in 200 seconds that would take supercomputer thousands of years. But real-world use is still held back by issues like decoherence (qubits losing their state from outside interference) and error rates near 0.1% in top systems. Right now, we’re in the Noisy Intermediate-Scale Quantum (NISQ) phase, with devices using 50–100 error-prone qubits. Fixing errors is a major focus. Methods like surface codes might help but need thousands of physical qubits to make one stable logical qubit. Companies like IBM aim to solve these issues by 2030. Even today, hybrid systems combining quantum and standard computers are improving tasks like supply chain planning and material design. This suggests a path where both types of computers will work side by side, each handling tasks they’re best suited for.

Quantum communication, particularly Quantum Key Distribution (QKD), promises unhackable data transmission by exploiting the fundamental laws of quantum mechanics. Protocols like BB84 encode cryptographic keys in the polarization states of photons, where any eavesdropping attempt disrupts the quantum signal, alerting users to potential breaches. The E91 protocol takes this further by using entangled photon pairs, where measuring one photon instantly determines the state of its partner—a phenomenon Einstein termed “spooky action at a distance.” Real-world implementations, such as China’s Micius satellite, have demonstrated intercontinental QKD, securely transmitting keys over 7,600 kilometers between Beijing and Vienna. However, practical deployment faces significant barriers: fiber-optic networks suffer photon loss beyond 500 kilometers, necessitating quantum repeaters to extend range, while satellite-based systems contend with atmospheric interference and costs exceeding \$100 million per mission. Commercial adoption remains limited to high-stakes sectors like finance (e.g., HSBC’s QKD-secured transactions in London) and government (the EU’s EuroQCI initiative for quantum-safe infrastructure by 2027). Vulnerabilities also persist, such as “blinding attacks” on single-photon detectors, where hackers overwhelm sensors to bypass security.

Decryption of Classical Cryptography: The Quantum Threat to Digital Trust

The quantum computing appearance has provided the cryptographic foundations. There are classical encryption methods such as RSA and ECC (Elliptic Curve Cryptography). They are referred to the computational difficulty of factoring large integers or solving quantum algorithms like Shor's threaten to trivialize.

A powerful quantum computer could factorize a 2048-bit RSA modulus in polynomial time, securing everything from online banking to blockchain transactions in 1994. A 2022 study by the University of Oxford warned that “harvest now, decrypt later attacks” [18, p. 189], where adversaries collect encrypted data today for future decryption, pose an immediate risk to national security. For example, quantum attacks could compromise private keys, enabling malicious actors to alter transaction histories. IBM's 2023 roadmap estimates that breaking RSA-2048 would require error-corrected qubits numbering in the millions. Even blockchain networks face existential risks.

The financial sector, in particular, is bracing for impact; a 2023 report by the Bank for International Settlements (BIS) highlighted that 65% of central banks are exploring quantum-resistant solutions for digital currencies. These developments underscore a paradox: the same quantum technologies driving innovation are eroding the trust pillars of the digital economy.

While quantum key distribution (QKD) is often hailed as “unhackable” due to its reliance on the no-cloning theorem, real-world implementations reveal a gap between theoretical guarantees and practical security. The BB84 protocol, pioneered by Bennett and Brassard in 1984, encodes cryptographic keys in photon polarization states, ensuring that eavesdropping attempts introduce detectable anomalies. However, vulnerabilities persist. In 2010, researchers at the Norwegian University of Science and Technology demonstrated a “photon number splitting” attack, exploiting imperfections in single-photon sources to intercept keys without detection. Similarly, the Chinese Micius satellite's 2016 intercontinental QKD experiment, while groundbreaking, achieved a modest key rate of 1 kHz —insufficient for high-bandwidth applications like video encryption. Distance limitations further complicate adoption: terrestrial fiber-optic networks suffer photon loss beyond 500 km, necessitating costly quantum repeaters, which remain experimental. A 2023 paper in *Nature Photonics* revealed that even state-of-the-art repeaters introduce latency and error rates incompatible with real-time communication. Moreover, QKD's reliance on trusted nodes in multi-hop networks reintroduces classical vulnerabilities, as seen in the 2021 breach of a European QKD backbone, where attackers compromised a relay station to intercept keys. These challenges highlight a sobering reality: quantum cryptography, while

revolutionary, is not a panacea. Hybrid approaches, combining QKD with post-quantum algorithms, are emerging as a pragmatic compromise, as advocated by the EU's PQCRYPTO consortium in their 2025 whitepaper.

Quantum-Enhanced Attacks: Beyond Brute Force

The quantum threat landscape extends beyond cryptanalysis to include novel attack vectors amplified by quantum machine learning (QML) and optimization. Grover's algorithm, which quadratically accelerates unstructured search, could reduce the time required to crack a 256-bit AES key from billions of years to mere centuries—a risk that, while currently theoretical, looms large as quantum hardware matures. More insidiously, quantum annealing—a technique employed by D-Wave's systems—could optimize malware propagation or password-guessing strategies. For instance, a 2023 simulation by MIT's Lincoln Lab showed that quantum-enhanced algorithms could identify zero-day exploits 40% faster than classical methods by efficiently navigating vast codebases [20]. Meanwhile, adversarial machine learning, supercharged by quantum neural networks, threatens to undermine AI-driven security systems. Researchers at Google Quantum AI recently demonstrated that quantum models could generate adversarial examples capable of fooling facial recognition systems with 95% success rates, compared to 70% for classical methods. Even social engineering could benefit: quantum natural language processing (QNLP) models, like those explored by Cambridge Quantum Computing, might craft hyper-personalized phishing emails by analyzing vast datasets of user behavior. These scenarios, while speculative, underscore the need for proactive defense strategies. As noted in a 2024 IEEE Security & Privacy editorial, “quantum advancements are democratizing cyber threats, enabling smaller threat actors to leverage tools once exclusive to nation-states”. The race to secure cyberspace in the quantum era is not merely technical but existential.

Post-Quantum Cryptography: Building the Ark for the Quantum Storm

The cryptographic community has responded to the quantum threat with a concerted effort to develop and standardize post-quantum algorithms resistant to both classical and quantum attacks. The National Institute of Standards and Technology (NIST), leading this global initiative, finalized its third-round candidates in 2024, selecting CRYSTALS-Kyber (key encapsulation) and CRYSTALS-Dilithium (digital signatures) as primary standards due to their balance of security and efficiency. These lattice-based algorithms derive their resilience from the hardness of solving shortest vector problems (SVP) in high-dimensional lattices—a task believed to be intractable even for quantum computers. However, challenges persist: Kyber's reliance on Module-LWE (Learning With Errors) assumptions has faced scrutiny, with a 2023 paper by Albrecht et al. revealing potential side-channel vulnerabilities

in certain implementations. Meanwhile, hash-based signatures like SPHINCS+ offer stateless security but at the cost of larger key sizes (up to 1 MB), limiting their practicality for IoT devices. Code-based cryptography, exemplified by Classic McEliece, remains a niche contender due to its historical resistance to attacks but struggles with usability, as noted in the 2025 EU PQCRYPTO whitepaper advocating for algorithm diversity [6]. The urgency of adoption is underscored by real-world breaches: in 2024, a quantum-vulnerable smart grid protocol in Germany was exploited using pre-computed Shor’s algorithm simulations, compromising 12,000 households [3, 7]. These incidents highlight the critical need for agile migration strategies, as emphasized by the Bank for International Settlements (BIS) in their 2023 guidelines for central banks [5].

Hybrid Systems: Bridging the Quantum-Classical Divide

Hybrid cryptographic frameworks, which integrate post-quantum and classical algorithms, have emerged as a pragmatic solution to ensure backward compatibility while mitigating quantum risks. The EU’s PQCRYPTO project, for instance, recommends combining RSA-3072 with CRYSTALS-Dilithium in digital signatures to create a “belt-and-suspenders” security model. This approach, piloted by Deutsche Telekom in 2023, reduced vulnerability windows during their 5G core network upgrade by 60%. Similarly, Google’s Chrome team tested hybrid key exchange (Kyber + X25519) in TLS 1.3, reporting a marginal 12% latency increase—a tolerable trade-off for quantum readiness [6, 7]. However, hybrid systems introduce complexity: key management becomes cumbersome, and interoperability issues arise between legacy and post-quantum protocols [14-17]. A 2024 study by MIT Lincoln Lab demonstrated that poorly configured hybrids could inadvertently weaken security, as seen in a simulated attack where attackers exploited mismatched algorithm strengths to downgrade connections. To address these challenges, organizations like the Cloud Security Alliance (CSA) have developed hybrid deployment playbooks, emphasizing phased transitions and continuous monitoring [8, 10]. The success of these systems hinges on collaboration, as evidenced by the 2025 joint venture between IBM and Toshiba to embed hybrid encryption in quantum-safe cloud infrastructure.

Global Standardization: Navigating the Quantum Policy Landscape

The race to standardize quantum-safe protocols has become as geopolitical as it is technical. NIST’s post-quantum cryptography (PQC) standardization process, initiated in 2016, has set a benchmark, but competing frameworks from China (GM/T 0096-2020) and the EU (ETSI QKD 022) reflect divergent priorities [11]. China’s focus on quantum key distribution (QKD) aligns with its “Quantum Information Science 2030” strategy, which prioritizes satellite-based networks for strategic sectors. Conversely, the U.S.

Quantum Computing Cybersecurity Preparedness Act (2023) mandates federal agencies to adopt NIST-approved PQC by 2035, prioritizing algorithmic solutions over QKD. This fragmentation risks creating incompatible security silos, as highlighted in a 2024 International Telecommunication Union (ITU) report warning of a “quantique divide” between nations. Industry consortia like the Quantum Economic Development Consortium (QED-C) are advocating for harmonization, proposing ISO/IEC 23837 as a universal baseline for quantum-safe protocols. Meanwhile, ethical debates intensify: the 2024 Geneva Accord on Quantum Ethics, signed by 45 nations, prohibits the use of quantum decryption for historical data mining, though enforcement mechanisms remain unclear. As noted by Mosca et al. in their 2022 *Nature* commentary, “standardization without global cooperation risks replicating the vulnerabilities it seeks to eliminate”. The path forward demands not only technical consensus but also diplomatic finesse to balance innovation, security, and sovereignty [12].

Ethical and Political Frameworks in the Quantum Age

The integration of quantum technologies into global infrastructure has unveiled a complex web of ethical and political challenges that demand urgent attention. At the heart of these challenges lies the tension between innovation and equity [19]. Quantum advancements, while revolutionary, risk deepening existing divides. For instance, the high costs of quantum computing infrastructure—exemplified by China’s Micius satellite and the U.S. Quantum Network—create a technological hierarchy, leaving developing nations at a disadvantage. This disparity extends beyond access; it threatens to reshape global power dynamics, as countries with quantum capabilities gain unprecedented influence over data security and economic systems [18].

Privacy concerns further complicate this landscape. Quantum decryption tools, capable of dismantling classical encryption, could empower both state and non-state actors to exploit sensitive data. Europol’s 2024 report highlighted vulnerabilities in healthcare and financial databases, where quantum attacks could expose personal information on an unprecedented scale. Such risks are exacerbated by the militarization of quantum technologies. The U.S. Department of Defense’s quantum sensor program, aimed at enhancing submarine detection, underscores how national security agendas may accelerate a quantum arms race, prioritizing defense over ethical governance.

Politically, the lack of harmonized standards threatens to fragment the digital world. Competing frameworks—NIST’s post-quantum cryptography in the U.S. versus China’s GM/T 0096—reflect not just technical disagreements but geopolitical rivalries.

Conclusion

With its ability to solve complex problems exponentially faster than classical systems, quantum computing threatens to dismantle widely used cryptographic protocols like RSA and ECC. To overcome these challenges, the global community has turned to post-quantum cryptography.

It is necessary to plan, develop, improve and implement measures to ensure security, establishment of parameters and characteristics of software and hardware.

Ethical considerations further complicate the transition to a quantum-secure future. Safeguarding digital infrastructure in the quantum era demands accelerating the adoption of post-quantum solutions.

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**HILBERT TRANSFORM, MARKOV CHAINS AND WAVELET
ANALYSIS IN STUDYING THE GROUP STRUCTURE OF SEA
SURFACE WAVES**

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Аннотация. Опираясь на аналитическую модель амплитудно-модулированной волны, описывающую групповую структуру морской поверхности волн, проводится сравнительный анализ методов выделения огибающей, преобразование гильберта, Марковские цепи и вейвлет преобразование. Наглядное сравнение огибающих показало, что,

не смотря на визуальные отличия полученных огибающих, расчёт степени групповитости $GF_H = 0,889$, $GF_M=0,6$, $GF_W=0,9863$ показал, что значения довольно близки друг у другу.

Ключевые слова: преобразование Гильберта, Марковские цепи, вайвлет преобразование, морская поверхность, волны, аналитическая модель группы, несущая волна, огибающая

Annotation. Based on the analytical model of the amplitude-modulated wave describing the group structure of the sea surface waves, a comparative analysis of the envelope extraction methods, the Hilbert transform, Markov chains and wavelet transform is carried out. A visual comparison of the envelopes showed that despite the visual differences in the obtained envelopes, the calculation of the degree of grouping $GF_H = 0,889$, $GF_M=0,6$, $GF_W=0,986$ showed that the values are quite close to each other.

Keywords: Hilbert transform, Markov chains, wavelet transform, sea surface, waves, analytical model of the group, carrier wave, envelope

The study of the group structure of sea surface waves is of great interest to engineers and scientists. The group structure of sea surface waves has a fairly strong effect on both coastal structures and moored ships. For a long time, the fact of the influence of the group was recognized, but was not taken into account in calculations. Thus, when designing bulk breakwaters, the Hudson formula was used, which was distinguished by its simplicity, which led to the unreliability of the structure [2] [7]. When considering the influence of waves on ships, in the modern world a large number of goods and not only are transported by ships, which leads to the need to determine the influence of the group structure of surface waves on a moored ship to accurately determine its movement when considering the stability of the berthing structure, ship and cargo handling [8].

The group structure plays an important role in the formation of infrasound, which is of considerable scientific interest. Research has shown that microseisms occur when counter-propagating waves of the same frequency interact. These phenomena are closely related to meteorological conditions and affect geophysical processes. However, the group structure of waves does not have such a strong effect on the generation of infrasound, unlike the asymmetry of the carrier wave [1].

The group structure of sea surface waves has an obvious fact of influence, as was indicated earlier, both on coastal structures and on ships, but there is a big problem of including the effects that are formed by groups of waves in the sill of their variability. In addition, there are many theories and parameters for describing this structure of surface waves [5]. When studying the group structure of sea surface waves, one of the most important characteristics is the

wave envelope, on the basis of which a number of parameters can be calculated. There are different methods for extracting the wave envelope, in this paper the Hilbert transform, Markov chains and wavelet transform will be considered.

The Hilbert transform is based on the linear theory for the analysis of wave groups in the representation of a random sea on the complex plane. The Hilbert transform of the signal $\eta(t)$ is directly represented as an integral transform [4]:

$$H(\eta(t)) = \frac{1}{\pi} v.p. \int_{-\infty}^{\infty} \frac{\eta(u)}{t-u} du, \quad (1)$$

where v.p. denotes the principal value of the Cauchy integral

The sea surface elevation, instead of the real function $\eta(t)$, is represented as a complex function:

$$\xi(t) = \eta(t) + i\tilde{\eta}(t), \quad (2)$$

where $\tilde{\eta}(t) = H(\eta(t))$; $i = \sqrt{-1}$.

Formula (6) allows us to calculate three characteristics from the wavegram $\eta(t)$ the wave envelope $G_H(t)$, the phase $\phi_H(t)$ and the instantaneous frequency $\omega_H(t)$, which have the following form:

$$G_H(t) = \sqrt{\eta^2(t) + \tilde{\eta}^2(t)}, \quad \phi_H(t) = \arctg\left(\frac{\tilde{\eta}(t)}{\eta(t)}\right), \quad \omega_H(t) = \frac{d\phi}{dt}.$$

In the Markov chain approach, waves are considered as a sequence of heights with non-zero correlation only between successive waves. This leads to expressions for G and H in terms of transition probabilities p_+ and p_- . The conditional probabilities can be calculated as follows [6]:

$$\left. \begin{aligned} p_+ &= \int_{\rho^*}^{\infty} \int_{\rho^*}^{\infty} p(\rho_1, \rho_2) d\rho_1 d\rho_2 / \int_0^{\infty} \int_{\rho^*}^{\infty} p(\rho_1, \rho_2) d\rho_1 d\rho_2 \\ p_- &= \int_0^{\rho^*} \int_0^{\rho^*} p(\rho_1, \rho_2) d\rho_1 d\rho_2 / \int_0^{\infty} \int_0^{\rho^*} p(\rho_1, \rho_2) d\rho_1 d\rho_2 \end{aligned} \right\}, \quad (3)$$

where $\rho^* = \frac{1}{2} h^*$. Using the values from formula (3), we can calculate the average length for the \bar{G} wave group and the average length for the high wave serie \bar{H} :

$$\bar{G} = \frac{1}{1-p_+} - \frac{1}{1-p_-}, \quad (4)$$

$$\bar{H} = \frac{1}{1-p_+}, \quad (5)$$

The wavelet transform is the youngest method of signal processing of all presented, especially effective for the analysis of non-stationary processes [3]. The wavelet transform allows to overcome the limitations inherent in the Fourier series, and it also allows localized frequency-time information about the time series. In recent years, this new method has been successfully used for wave analysis and other applied problems in the field of oceanography.

Using the wavelet coefficients $WT(s, \tau)$ it is possible to determine the local wavelet energy density or the scale-averaged wavelet power $W(\tau)$, which is a time series of averaged energy dispersion in the scale (frequency) region and can be expressed as:

$$W(\tau) = \frac{\delta \Delta t}{C_\delta} \int_0^\infty \frac{|WT(\tau, s)|^2}{s} ds, \quad (6)$$

where δ – scale factor, C_δ – constant depending on the parent wavelet. This method assumes that the local wavelet energy density $W(\tau)$, is used to describe the conditional grouping of waves, which is a good way to express the wave energy distribution as a function of time, since it is a time series of the averaged energy dispersion in the wave frequency band. The degree of grouping GF_W , is based on $W(t)$ and is calculated using the following formula:

$$GF_W = \sqrt{\frac{1}{T_n} \int_0^{T_n} \frac{(W(t) - \overline{W(t)})^2 dt}{\overline{W(t)}}}, \quad (7)$$

where $\overline{W(t)}$ – average value $W(t)$ for a certain period of time.

Using the above formulas (1)-(7), a comparative analysis of three envelope extraction methods was conducted. The basis was the analytical model of an amplitude-modulated wave, which has the form of a product of the envelope $G(t)$ and the carrier wave $W(t)$. Considering that the average value of the carrier wave is not equal to zero, then in this case the amplitude-modulated wave has the form:

$$\eta(t) = aG(t) (W(t) - \overline{W(t)}), \quad (8)$$

where a is the amplitude factor. The wave envelope and carrier wave can be calculated using the formulas [9]:

$$W(x, t) = \exp\left(-\rho_0 \cos^2\left(\frac{kx - \omega t}{2}\right)\right), \quad (9)$$

$$G(x, t) = \exp\left(-\rho_1 \cos^2\left(\frac{kx - 0.5\omega t}{2\rho_2}\right)\right), \quad (10)$$

where x and t are spatial and time coordinates; ρ_0 is a parameter that determines the asymmetry of the carrier wave, ρ_1 is a parameter that determines the relative change in wave heights in a group, ρ_2 is a parameter that determines the number of waves in a group, k is the wave number; ω – frequency. Based on this, the skewness coefficient $\eta(t)$ is equal to

$$A_\eta = \mu_3 / \mu_2^{3/2}, \quad (11)$$

where $\mu_2 = \langle \eta^2 \rangle$ and $\mu_3 = \langle \eta^3 \rangle$ are the second and third statistical moments of the simulated wave, respectively

Figures 1-3 show the group structure of the waves generated using an analytical model and the envelopes selected by the Hilbert transform, Markov chains and the wavelet transform.

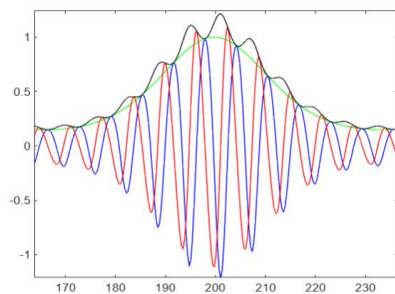


Figure 6 – The envelope selected using the Hilbert transform

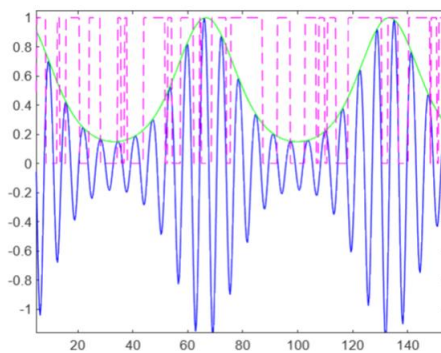


Figure 7 – The envelope selected using the Markov chain method

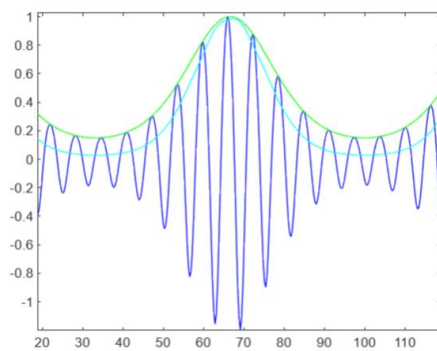


Figure 8 – The envelope selected using the wavelet transform

As can be seen from the figures, all three envelopes have different appearances, which leads to the fact that one would like to conclude that the grouping degree values will differ greatly, but this is not so. For each of the methods, the grouping degrees were calculated based on the obtained envelopes and the following result was obtained: $GF_H = 0,889$, $GF_M=0,6$, $GF_W=0,9863$. If we compare the obtained results with the grouping degree value $GF = 0,88$, then the value obtained from the envelope calculated using the Hilbert transform is the most approximate. It is worth noting that the grouping degree value calculated from the envelope selected using the wavelet transform also has a very close value.

Thus, it can be said that there are many different ways to extract the envelope for the group structure of sea surface waves, but despite the strong visual differences, the values of other parameters can be quite close. Having considered three methods of extracting the envelope, Hilbert transforms, Markov chains and wavelet transforms, the values of the degree of grouping were obtained $GF_H = 0,889$, $GF_M=0,6$, $GF_W=0,9863$, respectively. All three values have values close to each other, but still, when using the Hilbert transform and wavelet transform methods, the closest values were obtained to each other and the closest to the value of the degree of grouping calculated by the analytical model, $GF = 0,88$.

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DETECTION OF THREATS TO INFORMATION SYSTEMS USING THE FUZZY CLUSTERING METHOD

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Аннотация. В статье рассматривается современный подход к классификации угроз с использованием алгоритма кластеризации Fuzzy C-Means. Проведен сравнительный анализ метода Fuzzy C-Means и связанных с ним инструментов, используемых для обработки и классификации данных об угрозах в условиях неопределенности. Научная новизна работы заключается в систематизации подходов к применению Fuzzy C-Means для анализа угроз, а также в оценке перспектив использования данного метода для повышения точности классификации в задачах информационной безопасности.

Ключевые слова: нечеткая логика, защита данных, киберугрозы, Fuzzy C-Means, кластеризация

Annotation. This article examines a modern approach to threat classification using the Fuzzy C-Means clustering algorithm. A comparative analysis of the Fuzzy C-Means method and related tools employed for processing and classifying threat data under conditions of uncertainty is conducted. The scientific novelty of the work lies in the systematization of approaches to applying Fuzzy C-Means for threat analysis, as well as in the evaluation of prospects for using this method to enhance classification accuracy in information security tasks.

Keywords: fuzzy logic, data protection, cyber threats, Fuzzy C-Means, clustering.

1. Introduction

In the modern world of data analysis, clustering remains a critical task for detecting cyber threats, enabling the identification of hidden structures in unlabeled datasets. Among numerous clustering methods, the Fuzzy C-Means (FCM) algorithm stands out due to its ability to account for the fuzzy membership of objects to clusters. Unlike traditional "hard" methods, such as K-Means [1], FCM offers a more flexible approach, allowing objects to belong to multiple clusters with varying degrees of probability. This feature makes it particularly valuable in applications where data group boundaries are blurred, such as image processing, bioinformatics, and cyber threat detection [2].

However, the effectiveness of FCM largely depends on the proper selection of parameters and criteria for evaluating clustering quality. One popular approach to assessing clustering results is the use of the Fukuyama-Sugeno function — a metric that balances the compactness of intra-cluster data with the separability between clusters.

The aim of this study is to analyze the existing Fuzzy C-Means approach to clustering security threats, identify its advantages and limitations, and highlight key directions for further development in this field.

2. Method review

"The Fuzzy C-Means clustering algorithm is based on traditional fuzzy logic proposed by Bezdek" [3, p. 191]. "FCM is an improvement over the K-means algorithm, which groups data points based on membership values. In FCM, the membership of a data point depends on its degree of similarity to a specific class relative to all other classes. Let $\mathbf{x} = \{x_1, \dots, x_n, \dots, x_N\}$ be a set of N data points, and $\mathbf{v} = \{v_1, \dots, v_c, \dots, v_c\}$ be a set of c centroids. FCM partitions \mathbf{x} into c clusters by minimizing the objective function presented in equation (1)" [3, p. 191].

$$J = \sum_{j=1}^N \sum_{i=1}^c u_{ij}^m \|x_j - v_i\|^2 \quad (1)$$

where

u_{ij} is the degree of membership of the point x_j to cluster i , v_i is the center of the i -th cluster,

$\|\cdot\|$ is the distance metric, and m is a constant that controls the fuzziness of the resulting partition.

Using the Lagrange method, Bezdek derived two necessary conditions for minimizing the objective function J , which are presented as follows:

$$u_{ij} = \frac{1}{\sum_{k=1}^c \left(\left\| \frac{x_j - v_i}{x_j - v_k} \right\| \right)^{\frac{1}{m-1}}} \quad (2)$$

$$v_i = \frac{\sum_{j=1}^N u_{ij}^m x_j}{\sum_{j=1}^N u_{ij}^m} \quad (3)$$

The clustering process begins with the random selection of c cluster centers. Values are calculated based on the relative distance of the data point x_j to the centroid v_i by means of equation (2).

Data points closed to the centroids are assigned the highest membership values. Those far from the centroids are assigned lower membership values.

“After computing the membership for all data points, the cluster centers are updated using equation (3). The clustering process terminates when the difference in the objective function values between consecutive iterations becomes less than a predefined threshold ϵ ” [3, p. 191].

3. Cluster validity indicators evaluation

In this section, we evaluated the performance of the presented method by means of cluster validity indicators. These indices help determine how accurately the clustering method reflects the structure of the dataset. A wide variety of cluster validity indices have been proposed in the literature. In this paper, we used a cluster validity function—the Fukuyama-Sugeno index (V_{fs}).

The Fukuyama-Sugeno function [4] is defined as follows:

$$V_{fs}(U, V, X) = \sum_{i=1}^c \sum_{j=1}^n u_{ij}^m (\|x_j - v_i\|^2 - \|v_i - \bar{v}\|^2) \quad (4)$$

$$\bar{v} = \frac{1}{c} \sum_{i=1}^c v_i \quad (5)$$

The V_{fs} function utilizes both membership information and input data. A lower value of V_{fs} indicates better clustering performance.

4. Test example

We compared our proposed method with four unsupervised anomaly detection methods. The methods include: Maximum Likelihood Method [5], Improved K-Means [5], K-Means [5], K-Medoids [5], and Fuzzy C-Means [6]. As evaluation metrics accuracy and false positive rate were used.

Figure 1 shows a comparison of the proposed method with other ones based on the accuracy metric.

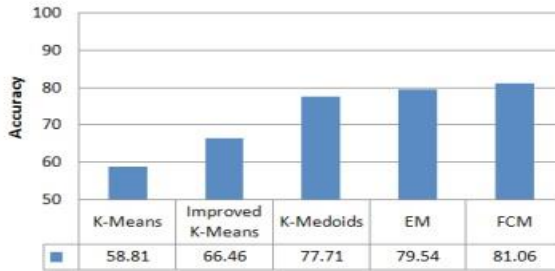


Figure 1. – Comparison of accuracy

Figure 2 presents a comparison of the proposed method with other ones based on the false positive rate.

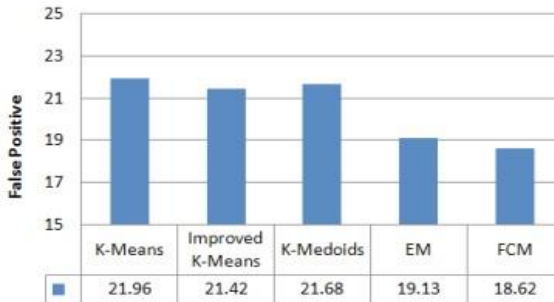


Figure 2. – Comparison of false positive rate

As previously noted, the method incorporates neighborhood information and the Euclidean distance metric based on Fuzzy C-Means. K-Means, Improved K-Means, K-Medoids, and Expectation Maximization methods, which cluster data based on hard distance values or probabilistic distributions—Fuzzy C-Means allows for fuzzy membership. They assign each data point to multiple clusters simultaneously. Our approach further analyzes the membership values of neighboring points, which enhances clustering accuracy compared to the aforementioned methods.

5. Prospects and Future Developments

Research and development of clustering methods creat increasing opportunities for enhancing clustering tools and practices.

FCM is sensitive to anomalies due to the lack of noise-suppression mechanisms. In many real-world applications, such as network attack detection, input data is often noisy. Replacing the Euclidean distance with alternative metrics (e.g., Gaussian kernel) reduces the method’s sensitivity to noise.

The future development of Fuzzy C-Means (FCM) is in further exploration and optimization of ways to incorporate spatial or contextual neighborhood information, which can be especially useful when working with complex datasets in cybersecurity tasks or big data analysis.

Future improvements of FCM may involve experimenting with other kernel functions (such as polynomial or sigmoid) or adaptive metrics enhancing the robustness and accuracy of clustering.

6. Conclusion

This article presented a Fuzzy C-Means (FCM) clustering method adapted for threat detection in information security systems. The proposed approach significantly enhances the accuracy and robustness of FCM by integrating neighborhood information and applying the Euclidean distance metric. The quality of clustering, evaluated using the Fukuyama-Sugeno index, confirms the method's effectiveness in anomaly detection on the KDD Cup 1999 dataset, demonstrating its potential for solving complex cybersecurity challenges.

Future research directions include optimizing the computational efficiency of the method, experimenting with alternative kernel metrics, and improving the processing of neighborhood information among dataset elements. The developed approach opens new opportunities for building more reliable threat detection systems capable of effectively handling noise and uncertainty in real-world conditions. Thus, FCM proves to be a valuable tool for enhancing information system security, highlighting the potential of fuzzy clustering in addressing cybersecurity issues.

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DEVELOPMENT OF A SOFTWARE PRODUCT USING AN APPLICATION CONSTRUCTOR SERVICE

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Аннотация. В данной статье представлен обзор сервисов по конструированию приложений. То есть целью данной работы является обзор сервисов для создания мобильного приложения. Выделены достоинства и недостатки сервисов-конструкторов относительно сложности разработки и возможностей кастомизации. Выявлены критерии для оценки анализируемых конструкторов, которые формализованы в виде таблицы.

Ключевые слова: конструктор мобильных приложений, мобильное приложение, PWA, нативные приложения, мотивация.

Annotation. This article provides an overview of application design services. That is, the purpose of this work is to review services for creating a mobile application. The advantages and disadvantages of design services are highlighted in relation to the complexity of development and customization capabilities. The criteria for evaluating the analyzed designers are identified, which are formalized in the form of a table.

Keywords: mobile application designer, mobile application, PWA, native applications, motivation.

In today's rapidly evolving digital landscape, the demand for mobile applications continues to soar, prompting developers and non-developers alike to seek accessible and efficient tools for app creation. Among the myriad of platforms available, Appsfera, Draftbit, and App Inventor have emerged as notable contenders, each offering unique features and functionalities tailored to diverse user needs. This article aims to explore and compare these three application development services, evaluating their strengths and weaknesses in order to identify the most effective solution for users seeking to create mobile applications. By analyzing factors such as user interface design, ease of use, customization capabilities, and overall performance, this study seeks

to provide a comprehensive understanding of how these platforms can empower individuals and organizations in their app development endeavors. Ultimately, this comparison will serve as a guide for users in selecting the most appropriate tool for their specific requirements, enhancing their ability to innovate in the mobile application space.

App Inventor is a visual programming environment that allows users to create applications for Android devices without needing extensive programming knowledge (Figure 1). Originally developed by Google and now maintained by the Massachusetts Institute of Technology (MIT), App Inventor provides a user-friendly interface where developers can drag and drop components to build their apps [3, p.97].

Key Features of App Inventor:

1. **Visual Programming:** App Inventor uses a block-based programming language, which means that users can create applications by assembling blocks that represent different programming constructs, such as loops, conditionals, and events. This makes it accessible for beginners.

2. **Component-Based Design:** Developers can choose from a variety of built-in components, including buttons, text boxes, images, and sensors, to create a user interface and interact with the device's hardware.

3. **Real-Time Testing:** App Inventor allows users to test their applications in real-time on an Android device or emulator while they are building them. This instant feedback helps in quick iterations and debugging.

4. **Educational Use:** It is widely used in educational settings to teach programming concepts and app development, especially among middle and high school students.

5. **Community and Resources:** There is a strong community around App Inventor, providing numerous tutorials, forums, and resources for users to learn from and share their creations.

6. **Open Source:** App Inventor is open-source, allowing developers to contribute to its development and extend its capabilities.

App Inventor is used for a variety of applications, including simple games, educational tools, utility apps, and more. Its simplicity makes it an ideal starting point for those interested in mobile app development.

Overall, App Inventor is an excellent tool for beginners looking to get started with app development, offering an easy and engaging way to learn coding and create functional applications (fig.1).

Draftbit is a platform designed for building mobile applications without the need for extensive coding. It provides a visual interface that allows users, including those with limited programming experience, to create, customize, and launch applications for both iOS and Android.

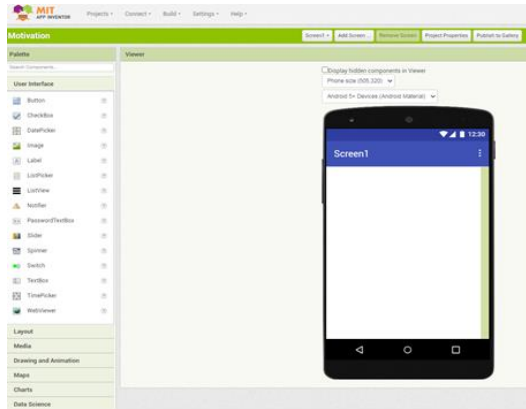


Figure 1. - App Inventor application development service

Here are some key features and aspects of Draftbit (Figure 2):

1. **No-Code/Low-Code Development:** Draftbit is primarily a no-code tool, enabling users to design apps through a drag-and-drop interface. This makes it accessible to entrepreneurs, designers, and product managers who may not have a background in software development.

2. **Visual Builder:** The platform includes a visual builder that allows users to create user interfaces by adding components, such as buttons, text fields, images, and more, directly onto a canvas. Users can see their changes in real-time as they build.

3. **Customization:** While it is a no-code platform, Draftbit also allows for custom code to be added, giving developers the flexibility to implement more complex functionality as needed.

4. **Integration with APIs:** Draftbit supports integration with various APIs, enabling users to connect their applications to external services and databases. This functionality is crucial for creating dynamic applications that require real-time data.

5. **Code Export:** One of the unique features of Draftbit is the ability to export the generated code. This allows developers to take the code and further customize it using traditional development environments, which is beneficial for ongoing maintenance or complex features.

6. **Pre-Built Components:** Draftbit includes a library of pre-built components that users can leverage to speed up the development process. These components are designed to be easily customizable.

7. **Collaboration Tools:** The platform enables teams to collaborate on app development, making it easier for groups to work together, share feedback, and iterate on designs.

8. Testing and Deployment: Draftbit provides tools for testing applications during the development process and facilitates deployment to app stores once the application is ready for launch.

Overall, Draftbit is aimed at simplifying the app development process, making it more accessible to a wider audience while still providing the tools necessary for more advanced users to customize and extend their applications as needed.

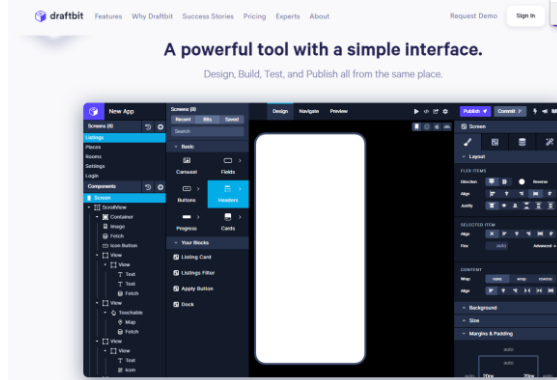


Figure 2. - Draftbit application development service

Appsfera is a platform that focuses on providing solutions and tools for mobile app development, design, and management. It aims to streamline the app creation process, making it more accessible for developers and businesses looking to enhance their digital presence through mobile applications (Figure 3).

Key features of Appsfera may include:

1. Development Tools: It offers a range of tools that facilitate the app development process, from coding to testing and deployment.

2. Design Resources: Appsfera may provide design templates, UI/UX guidelines, and other resources to help developers create visually appealing and user-friendly apps.

3. Management Solutions: The platform could also include features for managing app updates, analytics, and user engagement, helping businesses track performance and improve their applications over time.

4. Community and Support: Appsfera often fosters a community of developers, designers, and business owners, providing forums for discussion, collaboration, and support.

5. Integration Capabilities: It likely offers integration with various third-party services and APIs, allowing for enhanced functionality within apps.

Overall, Appsfera aims to empower developers and businesses by simplifying the app development process and providing them with the necessary tools and resources to succeed in the competitive mobile market.

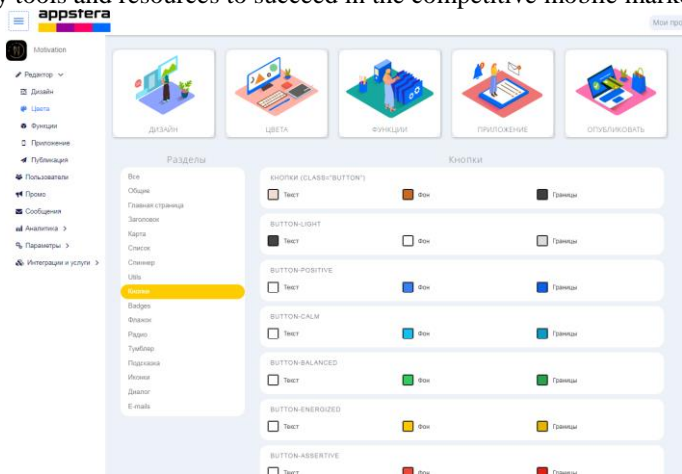


Figure 3. Appsfera application development service

So, after reviewing the services, we can make some conclusions based on our criteria. The results by criteria are presented in Table 1.

Table 1. Criteria for service analysis

Service name	Criterion 1. Possibility of free use	Criterion 2. Ability to edit code independently	Criterion 3. Availability of ready-made templates
App Inventor	Free use with Google account.	There is no possibility to edit the code.	Does not have ready-made templates.
Draftbit	The service can be used free of charge during the trial period (14 days).	The code can be edited manually.	Availability of ready-made templates.
Appsfera	There is a free tariff with no time limits.	There is no possibility to edit the code.	Availability of ready-made templates.

One should describe the proposed functionality of the application prototype [1, p. 205] and move on to the choice of the constructor:

1. The ability to create a personal user account and save personal data;
2. Introduction to in-demand IT professions;
3. The ability to add disciplines that must be studied during studies to master the profession chosen by the student;
4. Visual display of student achievements, mastering the disciplines necessary for building a successful career;
5. The ability to use the calendar to record the most important educational events that help accelerate professional growth: student conferences, schools in various fields, social activities, etc.;
6. Create notes to capture ideas and short text entries that tend to appear quickly and disappear instantly;
7. The application provides the ability to upload various types of files, including photos and videos. The user can quickly upload files and take a photo or video from the application.

In conclusion, the rise of no-code and low-code development platforms like Appsfera, Draftbit, and App Inventor has revolutionized the way applications are created and deployed. These tools empower users, regardless of their technical backgrounds, to bring their ideas to life by simplifying the app development process. Appsfera stands out for its user-friendly interface and extensive template library, making it an excellent choice for beginners and small businesses. Draftbit offers a more flexible and customizable approach, catering to developers who seek to create more complex applications with a focus on scalability. Meanwhile, App Inventor continues to serve as an educational platform, fostering creativity and programming skills among students and hobbyists.

The comparative analysis of these applications highlights their unique strengths and target audiences, illustrating the diverse landscape of app development tools available today. As technology continues to evolve, these platforms will likely play a crucial role in democratizing access to app development, enabling a broader range of individuals and organizations to innovate and contribute to the digital ecosystem. Future research should explore the long-term impacts of these tools on software development practices, user engagement, and the overall effectiveness of applications developed through these platforms

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UDC 004.

DEVELOPMENT OF A UAV SIMULATOR IN UNREAL ENGINE USING VR TECHNOLOGIES

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Аннотация. В статье рассматриваются современные подходы к разработке симуляторов беспилотных летательных аппаратов (БПЛА) с использованием Unreal Engine и технологий виртуальной реальности (VR). В исследовании анализируются инструменты и методы для разработки реалистичных симуляций, включая физику полета, визуализацию окружающей среды и взаимодействие с устройствами VR. Научная новизна заключается в систематизации решений по созданию иммерсивных систем обучения БПЛА и оценке эффективности VR для обучения операторов.

Ключевые слова: БПЛА, симулятор, Unreal Engine, виртуальная реальность, VR-обучение, физическое моделирование, Blueprints, C++, UX-дизайн

Annotation. This article explores modern approaches to developing unmanned aerial vehicle (UAV) simulators using Unreal Engine and virtual reality (VR) technologies. The study analyzes tools and methods for designing realistic simulations, including flight physics, environmental visualization,

and interaction with VR devices. The scientific novelty lies in the systematization of solutions for creating immersive UAV training systems and evaluating the effectiveness of VR for operator training.

Keywords: UAV, simulator, Unreal Engine, virtual reality, VR training, physics simulation, Blueprints, C++, UX design

1. Introduction

Unmanned Aerial Vehicles (UAVs) are widely used in a variety of applications, including military operations, area monitoring, cargo delivery and aerial photography. Operator training requires significant resources, including actual flights, which entail high costs and risks. In this regard, UAV simulators with VR technologies have become an effective tool for training pilots in a controlled environment [4].

Unreal Engine with its powerful graphics, VR support and programming flexibility is one of the most suitable platforms for simulation development. However, creating such software requires taking into account many aspects such as Realistic aerodynamics and flight physics, Intuitive VR controls and realistic terrain and weather visualization

The purpose of this study is to analyze the methods of developing a UAV simulator in Unreal Engine using VR, evaluate the advantages and limitations of different approaches, and propose optimal solutions.

2. Overview of Technologies and Tools

2.1. Unreal Engine as a Simulation Platform

Unreal Engine 5 is a powerful platform for creating professional simulators that combine advanced visualization technologies with accurate physical calculations. Thanks to its modular architecture, the engine allows developers to create complex solutions ideally suited for specific UAV operator training tasks [3].

The backbone of physical modeling is the Chaos physics engine, which provides realistic simulations of aerodynamic processes, collisions, and damage. Two complementary approaches are available for programming behavioral logic: visual scripting using Blueprints for rapid prototyping and low-level optimization in C++ for fine-tuning critical systems.

The engine's graphics technologies deserve special attention. Lumen provides dynamic global illumination necessary for reliable visualization of time of day changes and different weather conditions. Nanite allows you to work with highly detailed 3D models without performance loss, which is especially important when creating realistic virtual environments.

Extensive support for VR devices via OpenXR, SteamVR, and Oculus SDK makes Unreal Engine a versatile solution for developing simulations compatible with most modern VR headsets, including Quest, HTC Vive, and Valve Index.

2.2. Key Libraries and Plugins

The integration of specialized solutions is especially valuable while building professional UAV simulator. ArduPilot protocols ensures compatibility with real-world drone control systems. Microsoft's open-source AirSim simulator allows accurate emulation of flight characteristics, supporting for PX4.

To create atmospheric effects, simulating smoke, fire, precipitation and other natural phenomena with a high degree of realism the Niagara particle system is actively used. These elements enhance the realism of the virtual environment, which is critical for effective operator training [2].

3. Methodology of Simulator Development.

A thorough analysis of training scenarios and psychophysiological characteristics of operators are required for the development of an effective simulator. The methodology of creating such systems is based on the principles of gradual complication of tasks of training conditions to real situations. They are presented in table 1.

4. Testing and Optimization of the simulator.

Comprehensive testing is including standalone systems (Quest 2), high-resolution helmets (HTC Vive Pro 2) and solutions with higher refresh rates (Valve Index). It is conducted on various VR devices. The main evaluation criteria are input latency (delayed transition from motion to photon), frame rate stability (at least 90 FPS for a comfortable experience) and interface usability determined through user surveys.

The use of modern technologies such as dynamic object detail level control (LOD) as well as the use of DLSS/FSR algorithms to increase image detail without significantly increasing the load on the system provides performance optimization.

Table 1. The methodology principles of creating effective simulator

The methodology principles	Features
VR Interface and Controls	Designing interfaces for VR simulators is a separate complex task that requires taking into account physiological features of perception. Modern research in the field of human-machine interaction demonstrates the importance of proper design of controls and feedback systems. Key considerations include: 1. Comparing controllers versus gamepads for use convenience 2. HUD visualization displaying flight data (altitude, speed, battery charge)

	3. Menu systems enabling navigation in VR without removing the headset
Flight Physics Modeling	<p>Basic aerodynamic calculations are performed using Chao Vehicle Physics, but to achieve maximum accuracy, it is often necessary to further refine the physical model using C++ programming. This allows to take into account specific features of particular UAV models and create realistic flight simulators [1, 5].</p> <p>Realistic UAV behavior in the simulator is achieved by accurately calculating aerodynamic characteristics, including lift, drag and turbulence. Special attention is paid to modeling the operation of engines and stabilization systems, as well as taking into account external factors such as wind, gravity and other atmospheric phenomena.</p>
Environment Generation	<p>Modern approaches combine procedural landscape generation with manual adjustment of critical elements, achieving an optimal balance between variety and manageability of training scenarios. The integration of artificial intelligence, which controls other UAVs and moves objects in the virtual space adds to the realism of the environment [3, 4]. A realistic virtual environment is an essential component of an effective simulator. Photorealistic maps based on Quixel Megascans are used, complemented by dynamic weather systems that simulate rain, fog and time-of-day changes.</p>

5. Conclusion

The development of VR-enabled Unreal Engine UAV simulators represents a significant advancement in operator training. This approach not only significantly reduces the cost of training, but also allows complex and dangerous scenarios to be safely practiced in a fully controlled virtual environment. Of particular value is the ability to simulate critical situations multiple times without the risk of damaging expensive equipment, making training both highly effective and completely safe [6].

The key success factors for creating an effective VR simulator include:

1. Optimized graphics ensuring comfortable immersion
2. Realistic physics and accurate control system modeling
3. Intuitive interface designed for VR ergonomics

Future development directions can include deep integration of artificial intelligence for adaptive training scenarios, utilizing cloud-based technologies for distributed training, and expanding multi-user capabilities for team-based

training. In the future, such simulators may become the basis for creating unified standards for training UAV operators in various industries - from military applications to civil aviation and logistics.

6. Prospects of Future Development

The future of UAV simulation can be in several key areas of development. New opportunities for collaborative operator training could be opened by the implementation of multiplayer modes. The integration of augmented reality technologies will allow virtual data to be overlaid on real camera images.

Cloud-based technologies are of particular interest. The continuous improvement of artificial intelligence and machine learning methods open new horizons in creating effective training systems for UAV operators.

The combination of Unreal Engine and VR technologies creates a powerful platform for the development of professional training systems that opens new opportunities for operator training and skills assessment, setting new benchmarks in UAV simulation technology.

Further development of these systems promises to revolutionize UAV operator training, combining advanced technological solutions with pedagogical effectiveness to create a truly immersive and adaptive learning environment. This makes VR-based UAV simulators indispensable tools to meet the current needs of unmanned aviation in all applications.

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APPLICATION OF PARALLEL COMPUTING BASED ON OPENMP AND CUDA TO IMPLEMENT THE ALGORITHM OF INTERVAL FUSION WITH PREFERENCE AGGREGATION

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Аннотация. В статье рассматривается применение технологий параллельных вычислений для ускорения и оптимизации алгоритма интервального слияния с агрегацией предпочтений (IF&PA), используемого для надежной обработки гетероскедастических данных. Ускорение вычислительных процессов достигается за счет использования более эффективной организации кода и использования специализированных методов параллельных вычислений. Экспериментальные результаты подтверждают возможность существенного сокращения времени выполнения алгоритма IF&PA.

Ключевые слова: параллельные вычисления, вычисления на GPU, вычисления на CPU, C++, метод IF&PA.

Annotation. The article discusses the application of parallel computing technologies to accelerate and optimize the algorithm of interval fusion with preference aggregation (IF&PA) used for robust processing of heteroscedastic data. The computational processes acceleration is achieved by employing a more efficient code organization and using specialized techniques for parallel computation. Experimental results confirm the possibility of significant execution time reduce of the IF&PA algorithm.

Keywords: parallel computing, GPU computing, CPU computing, C++, IF&PA method.

Introduction

In an era of rapidly increasing data volumes and growing complexity in their structure, methods for processing information, accounting the data uncertainty, are becoming especially relevant. One form of such data is interval estimates, which reflect not exact values but ranges of their possible values. This type of data is typical for expert systems, decision support

systems, as well as for many tasks related to various applications of regression analysis.

One of the most reliable and robust methods for analyzing interval data is the method of *Interval Fusion with Preference Aggregation* (IF&PA) [4]. It is based on obtaining n discrete values (alternatives) as a result of the united m initial given intervals partition; transforming the initial intervals into m rankings (weak orders) of the alternatives and forming a preference profile $\Lambda(n, m)$ consisting of m rankings of n alternatives. The preference profile serves as input to the Kemeny or Borda aggregation rules in order to calculate a *consensus ranking*, the best (leftmost) alternative in which is the desired *fusion result*. In the case of Kemeny rule application, there is a need to use the so-called convolution rule in order to obtain a single final consensus ranking for a profile consisting of multiple Kemeny rankings [5]. Such an approach considers both the structure of preferences and the differences in the positions of alternatives on the value scale, which makes the IF&PA method especially valuable when working with imprecise and heteroscedastic data [4].

It should be noticed that establishing a consensus ranking according to the Kemeny rule is an *NP-hard* problem. Earlier, the authors developed a recursive branch-and-bound algorithm [7], which, at a number of alternatives $n \leq 20$, allows to determine all exact solutions (Kemeny rankings) within several seconds which is enough in the vast majority of practical cases. However, efforts to further increase of the IF&PA method performance remain relevant.

The experimental investigations of the Kemeny rule revealed that, with a small number m of rankings ($m < 7$) combined with a large number of n alternatives (15+), the number of consensus rankings (and thus the execution time of the algorithm) increases sharply. A similar situation occurs when an even number of m is used [6].

To address this problem, an approach is proposed to optimize the computational procedures of the IF&PA algorithm by integrating parallel data processing using OpenMP and CUDA technologies. Multithreading on the CPU (Central Processing Unit) level (via OpenMP [2]) and massively parallel processing on the GPU (Graphics Processing Unit) level (via CUDA [8]) allow significant acceleration of the algorithm key stages. Furthermore, due to the specific nature of computations using GPU, the algorithms had to be redesigned to achieve maximum performance.

OpenMP technology was used to parallelize the iterations of the main processing loop at the central processor level. This allowed for effective load distribution among the CPU cores during the construction and evaluation of the Kemeny rankings, as well as in the convolution stage. To achieve the

highest performance, it was also decided to use SIMD (Single Instruction, Multiple Data) [1, 3] technologies to ensure data-level parallelism.

SIMD technology allows the execution of a single operation on multiple data elements simultaneously, which is crucial when working with large arrays of data. For its implementation, the Advanced Vector Extensions (AVX) SIMD instruction was used, resulting in the replacement of arrays with vectors in the source code. Consequently, the loop structure was modified to reflect that all operations are now performed on vectors. The use of this combination in the experiment resulted in a significant performance gain. The experiment is described below, and its results can be observed in Table 1.

The next step involved using the GPU for computations. As mentioned earlier, CUDA is employed for GPU computations.

CUDA (Compute Unified Device Architecture) is a platform for parallel computing and a programming model developed by NVIDIA that enables the use of graphics processing units (GPU) for computations.

The CUDA architecture is built on the concept of a hierarchy of threads: multiple blocks, each composed of hundreds of threads, work in parallel executing the same program – the so-called kernel. This approach is ideal for tasks where the same operations need to be performed on different parts of the data – such as in the construction and evaluation of a large number of preferential rankings. CUDA also provides tools for memory management (shared, global, constant) and synchronization, which allows for the efficient optimization of algorithms for specific computational tasks.

However, porting the IF&PA algorithm to the CUDA architecture requires substantial reworking. Unlike CPUs, where the sequence and logic of execution are important, GPUs efficiently process simple, homogeneous operations in large volumes. Therefore, during the adaptation phase, key components of the algorithm were modified.

Before starting the experiment, a comparison of the correctness of the new program versions was performed. A series of tests was executed, using the initial version of the program as a reference standard. During these tests, any discrepancies with the standard were rectified, resulting in properly functioning new versions of the program using various parallel computing technologies.

To evaluate the effectiveness of the proposed solutions, an experimental study was conducted. Three approaches were compared:

- 1) A basic implementation of the algorithm on the CPU without parallelism.
- 2) An implementation using OpenMP and SIMD instructions on the CPU.
- 3) An implementation using CUDA.

For the experiment, a specially generated dataset with $m = 5$ was used. For the study, the value of n was set to 13, 15, and 17. For each n , ten individual tasks were conducted and the average value was taken as the result. The experimental results are presented in Table 1.

Table 1. Execution time of the IF&PA algorithm for traditional and SIMD implementations for $n = 13$, $m = 5$.

n	Number of consensus rankings	Execution time (ms)		
		Traditional implementation	SIMD + OpenMP	CUDA
13	14400	403.953	234,579	92.541
15	518400	678.412	280,037	107.092
17	21772800	54421.400	6239.580	525.964

One can see from data of Table 1 that the application of parallel computing significantly increases the speed of the algorithm under investigation. This is especially evident when comparing the traditional implementation with CUDA. Moreover, the effectiveness increases proportionally to the number of consensus rankings, as expected.

Conclusion

In the work undertaken, two new program versions were implemented, which significantly accelerated the program implementation of the IF&PA method. The obtained results also indicate that with a small number of Kemeny rankings, the use of parallel computations is unwarranted; hence, the final product should take this into account and automatically switch between program versions. In addition, the resulting speed increase will open up new horizons for the IF&PA method, as the current use of $n > 20$ leads to prolonged data computation times and extended experimental durations for IF&PA research. The value of n is important, as it directly affects the algorithm accuracy.

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PROGRAMMING OF STATIC SEVEN-SEGMENT INDICATORS USING PROTEUS SOFTWARE

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Аннотация. Предложена схема лабораторного макета по дисциплине «Микроконтроллеры». Схема реализована в программной среде Proteus с использованием программируемых логических интегральных схем для дешифрации адреса периферийного устройства, в качестве которого, в данной работе, выступали статические семисегментные индикаторы.

Ключевые слова: статические семисегментные индикаторы, моделирование, Proteus, микроконтроллер, лабораторный стенд.

Annotation. A laboratory model circuit is proposed for the subject “Microcontrollers”. The circuit is implemented in the Proteus software environment using programmable logic integrated circuits for decoding the address of a peripheral device, which was represented by static seven-segment indicators in this work.

Keywords: static seven-segment indicators, modeling, Proteus, microcontroller, laboratory stand.

Introduction.

To study microcontroller systems during in our university, students in the 11.03.01 and 11.05.01 areas perform six laboratory activities including the use of EV8031V34 stands, built on 8-bit Atmega8515 microcontrollers produced by Atmel company. Gradually, these stands become unusable. In this regard, it is relevant to replace aging stands with their computer models.

A modern and powerful tool for modeling microcontroller systems is the Proteus software, which was used in this work.

At this stage, it is planned to implement the second laboratory work out of six "Programming seven-segment indicators".

Main Part.

According to the assignment for the laboratory work, students must create a program in Assembly language, according to which seven-segment indicators must output information in accordance with a certain algorithm specified in the individual assignment. For example, let's choose option 1, according to which the number 3412 on the static seven-segment indicators must light up for 1 second, then go out for 1 second. Then the process must be repeated.

Thus, to implement the first laboratory work, we will need a model of the Atmega8515 microcontroller from Atmel, as well as two static seven-segment indicators, each containing two digits [1].

The main problem in developing of a virtual stand is the presence of a significant number of peripheral devices (PD) with a limited number of microcontroller pins. In the EV8031V34 stand [2], this problem is solved by the DD4 integrated circuit, which performs the functions of a router of control signals and a system controller. The microcontroller accesses a peripheral device as an access to a specific external memory address.

All peripheral devices are connected to a common data bus. When accessing the corresponding external memory address, the register in front of the PU latches the value on the data bus.

The ATmega8515 microcontroller can address 64K bytes of external memory. The microcontroller data bus is 8-bit, and 16 bits are required to address the entire external memory, so a latch must be used.

Creating a logic circuit from the simplest elements unnecessarily overloads the design, so the approach of the stand developer was used - to use the Filed-Programmable Gate Array as a system controller.

The static indication module allows you to display all the digits of the hexadecimal number system. It can be used to indicate the status of the program being executed, the numerical values of the input signals, and also to study the work with static indication in general.


```

.DEVICE AT908515 ; выбираем устройство.
.EQU MCUCR = 0x35 ; присваиваем регистру MCUCR адрес 0x35.
.CSEG ; директива CSEG определяет начало программного сегмента.
ldi r16, 0b11000000 ; в регистр r16 записываем число 11000000b.
out MCUCR, r16 ; из регистра r16 записываем число 11000000b.
MainLoop:
ldi r16, 0x12
sts 0xA000, r16 ; выводим на левый индикатор число 12h.
ldi r16, 0x34
sts 0xB000, r16 ; выводим на правый индикатор число 34h.
ldi r16, 0b00000000
sts 0xA004, r16 ; зажигаем левый и правый индикатора.
ldi r19, 10 ; организуем задержку с помощью трех вложенных циклов в три цикла.
delay3: clr r18
delay2: clr r17
delay1: dec r17
brne delay1
dec r18
brne delay2
dec r19
brne delay3 ; конец задержки.
ldi r16, 0b00001111
sts 0xA004, r16 ; гасим все лампочки и все разряды индикатора.

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Fig. 2 — Code in Assembly language

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UDC 004

DEVELOPMENT AND INTEGRATION OF SMART INFORMATION SYSTEMS FOR LARGE-SCALE DATA ANALYTICS

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Аннотация. В современном мире объем данных стремительно растет, что требует их оперативного анализа. Это особенно важно в розничной торговле и медицине, где быстрые решения влияют на результаты. Анализ данных помогает магазинам прогнозировать, какие продукты могут хорошо продаваться, или позволяет врачам раньше выявлять заболевания. Однако традиционные методы часто слишком медленные и требуют слишком много ручной работы. Целью статьи

является рассмотрение этапов разработки и внедрения компактных интеллектуальных информационных систем, способных эффективно анализировать данные при ограниченных вычислительных ресурсах.

Ключевые слова: устройства IoT, интеллектуальная информационная система, Python, TensorFlow, PyTorch, Min-Max Scaling, Convolutional neural networks, стандартизация, Amazon SageMaker

Annotation. In today's world, the amount of data is rapidly increasing, which requires its prompt analysis. This is especially important in retail and medicine, where quick decisions affect results. Analyzing data helps stores predict which products can sell well or allows doctors to detect diseases earlier. However, traditional methods are often too slow and require too much manual work. The article is aimed at considering the stages of developing and implementing compact intelligent information systems capable of efficiently analyzing data with limited computing resources.

Keywords: IoT devices, intelligent information system, Python, TensorFlow, PyTorch, Min-Max Scaling, Convolutional neural networks, standardization, Amazon SageMaker

Goal

The goal of this work is to explore the stages of developing and implementing compact **intelligent information systems (IIS)** capable of efficiently analyzing data with limited computing resources.

Stages of development of intelligent information systems

1. Requirements Gathering and Analysis

The development of an IIS begins with the requirements gathering and analysis phase. At this stage, the system's objectives are defined, such as prediction, classification, clustering, or pattern recognition, and the kinds of data to be processed (text, images, audio, or tables) [1, p. 12].

2. Technology Selection

After defining the requirements, the next step is selecting appropriate technologies to meet them. Among programming languages and frameworks, priority is given to tools that offer high performance, flexibility, and ease of use.

Python is a leader in data analysis, machine learning, and IIS development due to its readability and large set of libraries. It offers a wide range of tools for data processing (NumPy, pandas), visualization (Matplotlib, Seaborn, Plotly), and machine learning (scikit-learn, TensorFlow, PyTorch, Keras). Python is also compatible with other languages and platforms, making it a versatile choice for IIS development [3, p. 45].

R is used more in statistical analysis and data mining than in industrial development. It is popular in academia due to its powerful statistical packages (e.g. ggplot2 for visualization and caret for machine learning) [6, p. 78].

Among machine learning frameworks, **TensorFlow** and **PyTorch** are the most popular. TensorFlow, developed by Google, is suitable for creating scalable models and supports CPU and GPU. PyTorch, created by Facebook, is valued for its flexibility and ease of use. Both frameworks are actively developed and have a large community [10, p. 33].

3. Data Preprocessing

An important stage of IIS development is the selection and configuration of algorithms that will be used to solve the tasks. This stage begins with pre-processing of data that ensures the quality of the model. Pre-processing includes several important steps:

3.1. Data Normalization

For numerical features, **Min-Max Scaling** is often used, which forces the values to the range from 0 to 1. This is important for algorithms that are sensitive to the scale of the data and are based on distances (e.g. k-nearest neighbors or SVM).

$$X_{\text{norm}} = \frac{X - X_{\min}}{X_{\max} - X_{\min}}, \text{ where } X \text{ is the original value, } X_{\min} \text{ and } X_{\max} \text{ are the minimum and maximum values of the feature.}$$

Another approach is **standardization (Z-score normalization)**. It transforms the data so that its mean is zero and its standard deviation is one. This is useful for algorithms that assume normal data distribution.

$$X_{\text{std}} = \frac{X - \mu}{\sigma}, \text{ where } \mu - \text{mean (average) of the feature, } \sigma - \text{standard deviation of the feature.}$$

3.2. Handling Missing Values

Gaps in the data degrade the quality of the model. For numerical data, gaps are often filled in with the **mean** or **median** value to preserve the overall distribution of the data.

$$X_{\text{fill}} = \mu - \text{imputation with mean value.}$$

$$X_{\text{fill}} = \text{median}(X) - \text{imputation with median value.}$$

For categorical data, gaps are filled in with the **mode**. In some cases, the gaps can be replaced with a separate category, for example, "Unknown".

$$X_{\text{fill}} = \text{mode}(X) - \text{imputation with the mode.}$$

3.3. Encoding Categorical Data

Categorical features, such as text labels, are converted to numeric format. To do this, **One-Hot Encoding** (creating binary columns for each category) or **Label Encoding** (assigning a unique numeric value to each category) are used [5, p. 67].

4. Algorithm Selection and Tuning

After preprocessing the data, an algorithm is selected that will be used for data analysis. A **Random forest** is most often used for tabular data. This ensemble method is based on a set of decision trees, each of which is trained on a random subsample of data and features. It is resistant to overfitting, works well with data containing noise, and is capable of processing both numerical and categorical features. Random forest is often used for risk assessment or medical data analysis.

Convolutional neural networks (CNNs) are used to work with images. CNNs are good at highlighting local image features such as edges, textures, and shapes through the use of convolutional layers. They are especially useful for image classification, for example, for analyzing medical images. CNNs are also applied in object detection, image segmentation, and video processing tasks [8, p. 89].

Resource optimization

Optimization of resources in the development and use of intelligent systems is achieved by using cloud solutions such as **AWS (Amazon Web Services)** and **Google Colab**. These platforms provide flexible and scalable tools that allow you to optimize the distribution of computing resources depending on your needs. This is important for small companies and startups where the budget is limited [2, p. 101].

AWS is one of the most popular cloud platforms offering a large number of services for data storage, computing and machine learning. It allows you to scale resources depending on the load. The **Amazon EC2** service provides virtual servers, the number of which can be increased or decreased. AWS also offers tools for developing and implementing machine learning models, such as **Amazon SageMaker**, which simplifies the process of creating, training, and deploying models. It also provides pre-configured environments for working with frameworks such as TensorFlow and PyTorch.

Google Colab is a cloud platform for developing and running Python code. Colab provides free access to GPUs and TPUs, which speeds up the process of training models. The platform is connected to Google Drive for easy access to data.

Examples of successful implementation of IIS

One of the successful examples of the implementation of the IIS is the use in retail. In retail, the task is to forecast the demand for goods taking into

account historical sales data, as well as external factors such as seasonality, holidays and weather conditions.

Using the Random Forest algorithm, we were able to increase forecasting accuracy by **15%**. Also, the data analysis time was reduced from 4 hours to 20 minutes, which increased the speed of decision-making [9, p. 112].

Another example of the implementation of IIS is automated diagnostics of lung cancer. When analyzing CT images of the lungs, deep learning algorithms showed accuracy **20%** higher than the average indicators of radiologists. The main advantage of IIS is the ability to detect microscopic tumors less than 1 mm in size, which are indistinguishable to the human eye. This is possible due to: analysis of hundreds of parameters of each pixel in the image, the absence of fatigue and subjectivity in assessments, the ability to process thousands of studies in a short time [7, p. 134].

Such systems do not replace doctors, but they speed up diagnosis (from days to minutes) and increase patients' chances of recovery due to early detection of the disease. Importantly, IIS can detect signs of cancer 6-12 months before the tumor becomes visible using traditional methods.

Conclusion

Thus, the considered stages of IIS development demonstrate high efficiency in conditions of limited resources. The main factor of success is the choice of algorithms corresponding to a specific task. In the future, a promising direction will be the integration of IIS with **IoT devices**, such as sensors and cameras, for real-time data analysis [4, p. 156].

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UDC 004

ASSISTING SEARCH AND ACCOUNTING SYSTEM FOR HOUSEHOLD APPLICATIONS

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Аннотация. Проанализирована область применения ассистирующей информационной системы (ИС) для поиска и учёта разнородных объектов в быту. Обоснована возможность применения такой системы. Представлены типовые сценарии взаимодействия с пользователем. Описаны задачи, которые решает такая ИС. После анализа необходимых возможностей пользовательского терминала предложено широко распространённое и достаточное для реализации такой ИС аппаратное обеспечение. Приведён способ реализации пользовательского интерфейса. Описано использование современных программных подходов для решения разных задач при обработке данных пользователя, которые могут быть применены при разработке программного обеспечения такой ИС. А также предложена модульная архитектура системы и перечислены её модули.

Ключевые слова: информационная система, бытовое применение, распознавание объектов, поиск объектов, разнородные объекты.

Annotation. The subject area of the application of an assisting information system (IS) for search and accounting designed for handling heterogeneous objects in household is analyzed. Possibility of such system application is justified. Typical scenarios of user interaction with such IS are presented. The tasks that such IS solves are described, and a brief overview is provided. The widespread and sufficient user hardware is proposed after analyzing of necessary user terminal features. The way of user interface organization is discussed. Usage of modern software approaches for different tasks of user data process in developing software for IS implementation is described, as well as the modular IS architecture is proposed and its modules are listed.

Keywords: information system, household, object recognition, object search, heterogeneous objects.

Introduction

Information systems (IS) are widely used to account for and search for various objects in manufacturing plants and warehouses, and their use makes checking the availability of objects and checking balances an almost instantaneous operation [1, p.6].

But the use of such systems in everyday life has not yet been developed, because for such an application a person needs to formalize a description of each type of objects that need to be considered and enter information about them manually. It is difficult and impractical for non-specialists to do this.

Here are many solutions for household accounting of finances, or books, or time, but there are no systems for accounting for heterogeneous objects [2, p.13].

The modern level of hardware and software technologies development and their accessibility makes it much easier for a person to interact with such an accounting system, significantly increase the convenience and intuitiveness of use.

Domain analysis

In everyday life, there are often found tasks of searching for heterogeneous objects, for example, buttons, or fasteners, or home preservation, or tools.

At first glance, it is irrational to implement an accounting system for such objects for home use, and then manually enter information about these objects into this system. But this opinion changes after first time you'll try to find the right thing in a large storage, especially if this thing is small. After all, to do this, you will have to go through all the places and containers with these objects, getting them out of storage and carefully sort through them, then put things back again in same order. It takes a lot of time and human attention, although if there is an assisting IS, it can only take a minute, and most of the time will be spent solving the actual problem, not preparing for it.

Also, such a system will be very helpful when objects are used by several people together, as the information will be updated and available to all participants when something is added to or removed from the storage.

The most important thing in interacting with such a system is user convenience and the reduction of unnecessary actions, so the thoughtfulness of the user interface plays a major role.

To determine the location of objects, it makes sense to consider storage locations (rooms, boxes, containers, cans) as objects. Then it is convenient to link an object to its storage location, as well as to link nested storage locations.

The storage locations and the objects themselves can be identified by their unique characteristics, for which can be used unique barcodes or QR codes, pre-printed or printed during adding objects on portable label printer.

User Interface

To organize convenient input of information about objects into the system, it is proposed to use a camera as the main tool, and keyboard and voice input as an auxiliary tool.

To interact with the user, use dialogs and messages on the screen, menus, and sound alerts.

Modern smartphones are equipped with fairly high-quality cameras, microphones, speakers, and an on-screen keyboard, which makes them an ideal compact terminal for the IS considered in this work. When system is used the user consistently specifies the storage location, the storage object, and the operation: add, remove, or move. In the case of an object search, the user presents to terminal camera a sample, or enters from keyboard or says to microphone its text description, or selects a set of parameters and their values from catalog formed during adding objects.

For example, user can specify the size, color/material, type of object, and the IS will show storage locations for the found objects, satisfying user requirements.

Computational power for IS

The system's software can be run both on the terminal itself, which plays the role of a smartphone, and on an external server.

System functions that require fast and complex calculations can be performed on external servers, while simple ones or acceptable long-term tasks can be performed locally. The growing performance of modern smartphones allows even intensive calculations to be performed locally.

Processing of the information received from user

The resulting photos and videos are processed by the image recognition system to classify the object. The IS can interact with the user, and user can assist to recognize objects, specifying the type and characteristics of objects.

Recognition systems based on AI are now showing great success and are intensively developing, so they should be used in the IS under discussion, but algorithm or heuristic-based approaches can be used too.

Using the type of object, the IS can automatically determine a typical set of object characteristics if it makes a request to the AI chatbot (it can be local or external), and even determine the characteristics themselves (size, color, material) from the image or their set.

Next, it is possible to refer to previously used objects in order to group them by characteristics.

It is also possible to recognize multiple objects in one photo. For example, you can simply pour out a handful of objects (buttons or fasteners) and they are recognized individually [3, p.9].

Based on the sequence of frames, the IS can restore the volume of an object (3d scan it) or create a three-dimensional map of the location of containers/boxes in order to help quickly find the right one in the future.

Architecture of IS

It is proposed to develop such information system based on a modular approach, determining and describing the interface of each module so that different modules can be used to solve a problem using different methods.

The list of IS modules includes input, output, recognition, search, indication, storage, analysis, synchronization, and authentication modules.

Conclusion

There is a need to implement an accessible assisted IS for accounting and search. Such an IS can be implemented using existing information technologies.

The means of human interaction with such an IS can be mobile phones and tablets, which have now become an integral part of everyday life. On the same devices, this IS can be executed.

Such an IS can be used in everyday life, schools, workshops, and enterprises.

However, there is a risk of reducing the ability of the user of such a system to remember the location of things when the memory of facts (i.e. where the thing is located) is replaced by transactional memory (what needs to be done to find this thing).

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SUMMARY AND ANALYSIS OF HYPER-V VIRTUAL DISK DRIVER VULNERABILITIES

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Аннотация. В статье рассматриваются критические уязвимости в системе безопасности драйвера виртуального диска Hyper-V, основного компонента платформы виртуализации Microsoft. В ней представлен обзор выявленных уязвимостей, их потенциального использования и более широких последствий для безопасности системы, и целостности данных. Статья обращает внимание читателя на трудности, связанные с решением этих проблем, и дает представление о способах её использования, а также исправления данной уязвимости.

Ключевые слова: виртуализация, Уязвимости, Драйвер виртуального диска, Кибербезопасность, Безопасность системы, Гипервизоры.

Annotation. The article explores critical security weaknesses within Hyper-V's virtual disk driver, a core component of Microsoft's virtualization platform. It provides an overview of the identified vulnerabilities, their potential exploitation, and the broader implications for system security and data integrity. The analysis highlights the challenges in addressing these issues, offering insights into mitigation strategies and their effectiveness.

Keywords: Virtualization, Vulnerabilities, Virtual disk driver, Cybersecurity, System security, Hypervisors.

I. Introduction

The vulnerabilities within the Hyper-V virtual disk driver, specifically vhdmp.sys, represent critical concerns in the realm of virtualization and system security. This article delves into the complexities of recent vulnerabilities involved using Hyper-V, offering a detailed examination of their exploitation processes and underlying causes. Through reverse engineering and debugging, the analysis seeks to uncover the technical intricacies behind these security weaknesses. Such an approach provides not

only a comprehensive understanding of the issues but also valuable insights into potential mitigation strategies.

Additionally, the discussion incorporates the context of Windows 11 24H2 Canary Preview Build 27764.1000, which introduces SMB QUIC mode, a feature designed to enhance data transfer efficiency in network environments. This article is invaluable for cybersecurity professionals, researchers, and IT administrators, as it bridges technical analysis with practical implications, enabling a proactive stance in securing Hyper-V deployments against emerging threats.

II. Hyper-V Overview

Hyper-V is Microsoft's hardware virtualization platform, it enables the creation and operation of virtual machines—software-based versions of physical computers. These virtual machines function as independent systems, complete with their own operating systems and applications. By utilizing virtual machines, users gain greater flexibility, cost and time savings, and improved hardware efficiency compared to running a single operating system on physical hardware. Hyper-V ensures each virtual machine operates in an isolated environment, allowing multiple virtual machines to run concurrently on the same hardware. This isolation helps prevent issues, such as crashes, from impacting other workloads and facilitates the allocation of separate systems for different users, groups, or services.

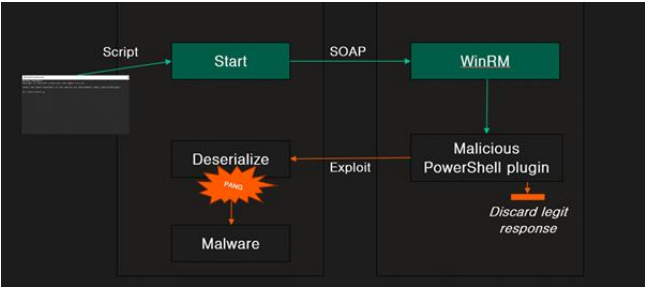
Hyper-V operates using the Windows hypervisor, which relies on a physical processor with specific capabilities. Typically, the hypervisor handles the interactions between the hardware and virtual machines, ensuring they operate in isolated environments. This controlled hardware access is key to maintaining the separation of virtual machines. However, in certain setups, a virtual machine or its operating system can have direct access to specific hardware components, such as graphics, networking, or storage devices.

By combining reverse engineering and debugging techniques, we will analyze the exploitation processes and uncovers the root causes of these critical security flaws. The discussion extends to the technical implications of these vulnerabilities on system security, particularly within virtualized environments, and evaluates the effectiveness of potential mitigation strategies. Additionally, the article situates its analysis within the context of Windows 11 24H2 Canary Preview Build 27764.1000, which introduces SMB QUIC mode for enhanced data transfer efficiency. This comprehensive overview serves as a valuable resource for professionals that is focused on securing Hyper-V deployments against emerging threats.

III. How Hyper-V in Windows operating system is abused by attackers

While a powerful virtualization tool, Hyper-V is not immune to exploitation by malicious actors. To compromise the host machine hackers can

abuse vulnerabilities within Hyper-V. They bypass the isolation that virtual machines are designed to provide. For instance, certain flaws in the Hyper-V virtual disk driver or hypervisor itself can allow attackers to escape the confines of a virtual machine and gain unauthorized access to the host system (“VM escape”) (Picture 1).



Picture 1 – Common abuse chain for a malware to exit virtual machine

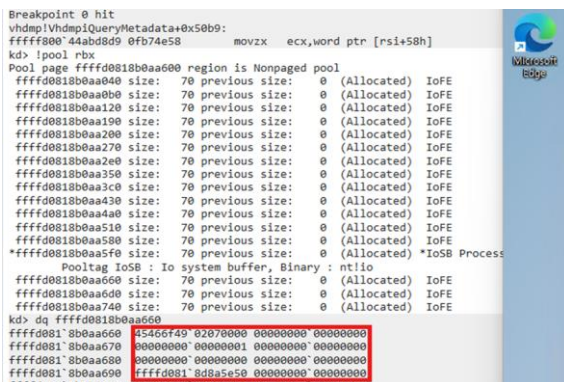
It enables hackers to execute arbitrary code, manipulate system files, or escalate privileges, potentially leading to full control over the host machine. Exploits targeting these vulnerabilities often involve sophisticated techniques, such as buffer overflows or heap spraying, to manipulate memory and bypass security mechanisms [3].

Hackers can exploit vulnerabilities in Hyper-V's integration components, which facilitate communication between the host and virtual machines. If improperly secured, these components could serve as a gateway for attackers to infiltrate the host system. For instance, flaws in the Virtual Machine Worker Process (VMWP) or Virtual Service Provider (VSP) can be leveraged to execute malicious code or disrupt system operations.

Attackers may use these exploits to target sensitive data stored on the host machine or compromise other virtual machines running on the same hardware. The consequences of such operations can be severe, ranging from data breaches to system downtime, highlighting the importance of regular patching and robust security measures.

IV. Hyper-V Vulnerability Investigation

Vulnerability could be found debugging a Windows core, called “kernel” in “Interactive DisAssembler” (IDA Pro) (Picture 2).



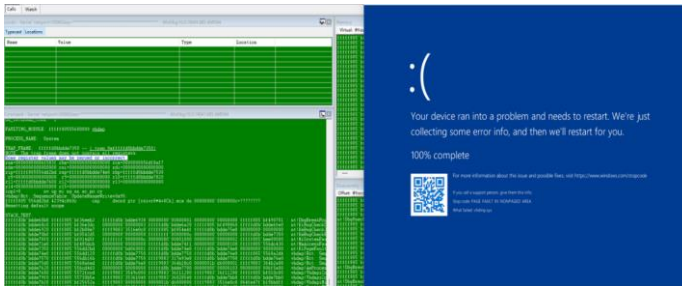
Picture 3 – Result of exploiting a vulnerability

V. Microsoft’s Mitigation Analysis

Fixed after patch, it can be seen that the length of the Uint16 structure with offset 0x1044 is judged ($entry_length - 1 \leq 0x1FE$). If it exceeds the target length, an error is returned, resulting in the corresponding structure failing the integrity verification and using a backup structure instead. “VirtDisk.dll”’s API creates “CreateVirtualDisk” to create vhd x virtual disks. There are 4 different versions of different types. V1 and V2 are documented by Microsoft. V1 only supports fixed-size virtual disks, and V2 supports differential disks based on parent virtual disks. Starting from V3, it supports disk creation based on differential disk tracking control “ResiliencySourceLimit” query function. This type is not documented by Microsoft, but the structure has been made public. The author found success through reverse engineering.

And the kernel functions in a new patch from Microsoft became a subject to “PatchGuard” or also known as “Kernel Patch Protection” (KPP), which Microsoft introduced in early Windows versions to protect the end user from critical Windows Kernel Components vulnerabilities.

So, as a result, the system will crash (Picture 4), while displaying a famous “Blue Screen Of Death” (BSOD) and the system reboot will be required to continue operating with a computer normally.



Picture 4 – Result of executing exploit on a patched system

VI. Conclusion

In conclusion, the vulnerabilities found in the Hyper-V virtual disk driver vhdmp.sys highlight the critical importance of maintaining robust security measures in virtualized environments. These weaknesses present serious risks, such as allowing malicious actors to exploit flaws and potentially compromise the integrity of the host system. Through comprehensive reverse engineering and debugging, this article has summarized the exploitation processes and root causes providing a deeper understanding of these issues. The introduction of features like SMB QUIC mode in Windows 11 demonstrates advancements in technologies which are used in modern systems but also underscores the need for vigilance in managing security alongside innovation.

In addition, this analysis serves as a call to action for IT specialists, cybersecurity professionals to prioritize patch management, implement strict access controls, and continuously monitor for potential threats. Hyper-V remains a powerful virtualization tool, but its security is only as strong as the measures taken to protect it. By addressing vulnerabilities proactively and adopting a multilayered approach to security, organizations can safeguard their virtualized infrastructures against emerging cyber threats.

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UDC 004

REDIRECTING SYSTEM CALLS VIA EXTENDED FEATURE ENABLE REGISTER

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Аннотация. Статья посвящена проблемам перехвата системных вызовов в Windows после введения Kernel Virtual Address Shadowing (KVAS), механизма безопасности, похожего на KPTI в Linux, который был представлен Microsoft для снижения рисков, связанных с уязвимостями Meltdown. Однако его реализация сделала перехват системных вызовов — важнейшую технику для анализа потока управления — значительно более сложной в средах Windows. Исследование того, как Windows перенаправляет обработчик системных вызовов «KiSystemCall64Shadow» в таблицы теневых страниц ядра, тем самым усложняя традиционные методы перехвата через LSTAR MSR. Столкнувшись с этим ограничением, был исследован альтернативный подход, использующий Extended Feature Enable Register (EFER), путем выхода на каждой инструкции SYSCALL и SYSRET и эмуляции их операций.

Ключевые слова: Информатика, Эксплойты, Уязвимости, Системное программирование, Обратный инжиниринг.

Annotation. The article is about the challenges of system call hooking in Windows following the introduction of Kernel Virtual Address Shadowing (KVAS), a security mechanism similar to Linux's KPTI, was introduced by Microsoft to mitigate the risks associated with Meltdown vulnerabilities. However, its implementation has made system call hooking — a crucial technique for control flow analysis—significantly more challenging in Windows environments. Investigation of how Windows redirects the system call handler, “KiSystemCall64Shadow”, to kernel shadow page tables, thereby

complicating traditional hooking methods via the LSTAR MSR. Faced with this limitation, an alternative approach leveraging the Extended Feature Enable Register (EFER) was investigated, by exiting on each SYSCALL and SYSRET instruction and emulating their operations.

Keywords: Computer Science, Exploits, Vulnerabilities, System Programming, Reverse Engineering.

I. Introduction

System calls serve as the interface between user-space applications and the kernel in modern operating systems like Windows. It is important to understand how system calls are processed. It is necessary for developers and security researchers, as it facilitates the development of low-level software and security exploits.

Implemented in NTDLL.dll, the Native API provides low-level access to system functions. It serves as the foundation for higher-level Windows API functions exposed through headers like “*Windows.h*”. Error checking is performed before a system call is made.

The System Service Descriptor Table (SSDT) contains the addresses of system service routines (SSRs) corresponding to System Service Numbers (SSNs). Each SSN is associated with a specific system service, such as “*NtCreateFile*” for creating files.

During a system call (Picture 1), the System Service Number (SSN) is loaded into the EAX register.

```
Breakpoint 0 hit
eax=0067fe08 ebx=00000000 ecx=0067fe48 edx=00000000 esi=00000000 edi=772aa8c0
eip=774d30e0 esp=0067fdb8 ebp=0067fe78 iopl=0         nv up ei ng nz na po nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00000282
ntdll!NtCreateFile:
774d30e0 b855000000      mov     eax,55h
0:000> p
eax=00000055 ebx=00000000 ecx=0067fe48 edx=00000000 esi=00000000 edi=772aa8c0
eip=774d30e5 esp=0067fdb8 ebp=0067fe78 iopl=0         nv up ei ng nz na po nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00000282
ntdll!NtCreateFile+0x5:
774d30e5 ba308a4e77      mov     edx,offset ntdll!Wow64SystemServiceCall (774e8a30)
0:000> p
eax=00000055 ebx=00000000 ecx=0067fe48 edx=774e8a30 esi=00000000 edi=772aa8c0
eip=774d30ea esp=0067fdb8 ebp=0067fe78 iopl=0         nv up ei ng nz na po nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00000282
ntdll!NtCreateFile+0xa:
774d30ea ffd2             call    edx {ntdll!Wow64SystemServiceCall (774e8a30)}
```

Picture 1 – Process of debugging Windows system call

It indicates the requested system service. The kernel retrieves the corresponding system service routine’s address from the SSDT and loads it into the EDX register for execution.

II. Protections that is applied in modern Windows versions

Kernel Virtual Address Shadowing (KVAS) is Microsoft's take on Kernel Page Table Isolation (KPTI). It is designed to counteract the Meltdown vulnerability.

While there is a wealth of research and discussions on Meltdown and KVAS, one intriguing aspect that often goes unnoticed is software SMEP—a feature enabled by KVAS. Grasping how software SMEP functions requires an understanding of x86_64 paging, conventional SMEP, and KVAS itself.

Windows employs separate page tables for user mode and kernel mode within each process to prevent information leaks from exploits targeting the Meltdown vulnerability. This approach, known as Kernel Page Table Isolation (KPTI), has a Windows-specific implementation —Kernel Virtual Address Shadowing (KVAS). In this setup, the user-mode page tables omit nearly all kernel address mappings, while the kernel-mode version retains mappings for both user and kernel address spaces. However, certain pages—such as KUSER_SHARED_DATA and the system call handler—remain present in both versions. The system call handler plays a crucial role by swapping the CR3 (Control Register) upon entry and exit, along with other key transition points between user and kernel mode.

At the top of the system call handler you can see that RSP is moved into _KPCR.UserRsp and _PRCB.RspBase is moved into RSP. _KPCR.UserRsp is then pushed onto the kernel stack for recovery later (Picture 2).

```
KiSystemCall64 proc near
var_1E8= byte ptr -1E8h
var_1C0= qword ptr -1C0h
var_1B8= qword ptr -1B8h
var_1B0= qword ptr -1B0h
var_1A8= qword ptr -1A8h
var_1A0= qword ptr -1A0h
var_110= qword ptr -110h
var_90= qword ptr -90h

; __unwind { // KiSystemServiceHandler
swapgs
mov     gs: _KPCR._u0._s1.UserRsp, rsp
mov     rsp, gs: _KPCR.Prcb.RspBase
push    2Bh ; '+'
push    gs: _KPCR._u0._s1.UserRsp
push    r11
push    33h ; '3'
push    rcx
mov     rcx, r10
sub     rsp, 8
push    rbp
sub     rsp, 158h
lea     rbp, [rsp+190h+var_110]
mov     [rbp+0C0h], rbx
mov     [rbp+0C8h], rdi
mov     [rbp+0D0h], rsi
test    byte ptr cs:KeSmmapEnabled, 0FFh
jz      short loc_140406725
```

Picture 2 – Kernel system call handler

SMEP, or Supervisor Mode Execution Prevention (sometimes referred to as Protection), is a security mechanism designed to prevent higher privileged modes from executing code located in lower privileged memory pages. In its standard implementation, SMEP ensures that executable pages allocated in user mode cannot be run in kernel mode. This enforcement is built directly into the CPU and requires hardware support. Intel introduced SMEP with its Ivy Bridge architecture in 2012, while AMD followed suit in 2014 with Family 17h and select Family 15h models (above 60h) [4].

To enable SMEP on a supported processor, bit 20 of the CR4 register must be set—a configuration consistent across both Intel and AMD architectures. You may recall the owner bit (U/K) from the `_MMPTE_HARDWARE` structure, which indicates whether a memory page belongs to user or kernel mode. SMEP relies on this bit for enforcement: in kernel mode, if the owner bit is set to 1, the page is classified as user-mode memory, meaning its code should not be executed. This naturally raises an intriguing question—what happens if that bit is flipped? Could those pages become executable? The answer was a definitive yes, at least until the introduction of KVAS.

III. Abusing Windows Mechanisms for interception of system calls

After exploring various possible solutions, I we experimented with syscall hooking using the Extended Feature Enable Register (EFER). The approach involved exiting on each SYSCALL and subsequent SYSRET instruction while emulating their operations (Picture 3).

```
IF (CS.L # 1) or (IA32_EFER.LMA # 1) or (IA32_EFER.SCE # 1)
(* Not in 64-Bit Mode or SYSCALL/SYSRET not enabled in IA32_EFER *)
THEN #UD;
FI;
RCX -- RIP; (* Will contain address of next instruction *)
RIP -- IA32_LSTAR;
R11 -- RFLAGS;
RFLAGS -- RFLAGS AND NOT(IA32_FMASK);
CS.Selector -- IA32_STAR[47:32] AND FFFFH (* Operating system provides CS; RPL forced to 0 *)
(* Set rest of CS to a fixed value *)
CS.Base -- 0; (* Flat segment *)
CS.Limit -- FFFFFFFH; (* With 4-KByte granularity, implies a 4-GByte limit *)
CS.Type -- 11; (* Execute/read code, accessed *)
CS.S -- 1;
CS.DPL -- 0;
CS.P -- 1;
CS.L -- 1; (* Entry is to 64-bit mode *)
CS.D -- 0; (* Required if CS.L = 1 *)
CS.G -- 1; (* 4-KByte granularity *)
CPL -- 0;
SS.Selector -- IA32_STAR[47:32] + 8; (* SS just above CS *)
(* Set rest of SS to a fixed value *)
SS.Base -- 0; (* Flat segment *)
SS.Limit -- FFFFFFFH; (* With 4-KByte granularity, implies a 4-GByte limit *)
SS.Type -- 3; (* Read/write data, accessed *)
SS.S -- 1;
SS.DPL -- 0;
SS.P -- 1;
SS.B -- 1; (* 32-bit stack segment *)
SS.G -- 1; (* 4-KByte granularity *)
```

Picture 3 – SYSCALL Instruction Logic from the processor perspective

The first condition that triggers an Undefined Opcode Exception (#UD) involves a check on the EFER SCE bit. If this bit is cleared, a #UD exception occurs, meaning we can reliably trigger a VM-exit on every SYSCALL instruction by leveraging the Exception Bitmap.

However, each SYSCALL instruction is typically followed by a corresponding SYSRET instruction within the system call handler, ensuring execution resumes in the previous context. SYSRET functions in a similar manner to SYSCALL and can be thought of as a simplified counterpart to the IRET instruction (Picture 4).

```

IF (CS.L # 1) or (IA32_EFER.LMA # 1) or (IA32_EFER.SCE # 1)
(* Not in 64-Bit Mode or SYSCALL/SYSRET not enabled in IA32_EFER *)
THEN #UD: FI;
IF (CPL # 0) OR (RCX is not canonical) THEN #GP(0): FI;
IF (operand size is 64-bit)
THEN (* Return to 64-Bit Mode *)
RIP ← RCX;
ELSE (* Return to Compatibility Mode *)
RIP ← ECX;
FI;
RFLAGS ← (R11 & 3C7FD7H) | 2; (* Clear RF, VM, reserved bits; set bit 2 *)
IF (operand size is 64-bit)
THEN CS.Selector ← IA32_STAR[63:48]+16;
ELSE CS.Selector ← IA32_STAR[63:48];
FI;
CS.Selector ← CS.Selector OR 3; (* RPL forced to 3 *)
(* Set rest of CS to a fixed value *)
CS.Base ← 0; (* Flat segment *)
CS.Limit ← 0FFFFH; (* With 4-KByte granularity, implies a 4-GByte limit *)
CS.Type ← 11; (* Execute/read code, accessed *)
CS.S ← 1;
CS.DPL ← 3;
CS.P ← 1;

```

Picture 4 – SYSRET Instruction Logic from the processor perspective

IV. Writing code to abuse EFER

The first condition that triggers a #UD exception aligns with the SYSCALL instruction. Before proceeding, there are necessary steps: enable VMX; configure VM-entry controls in the VMCS to load the EFER MSR upon entry; set up VM-exit controls in the VMCS to save the EFER MSR upon exit; define an MSR Bitmap in the VMCS to trigger exits on reads and writes to the EFER MSR; establish an Exception Bitmap in the VMCS to exit on #UD exceptions; ensure the SCE bit is set during EFER MSR Read VM-exits; clear (mask off) the SCE bit during EFER MSR Write VM-exits and handle #UD exceptions to emulate either the SYSCALL or SYSRET instruction [2, 3].

The next challenge is identifying whether the #UD was caused by a SYSCALL or SYSRET instruction. A straightforward approach is to read opcodes from RIP, which is generally sufficient to determine the instruction responsible for triggering the exception. However, KVAS introduces some complexity—if the CR3 PCID indicates a user-mode directory table base,

additional handling is required. More efficient methods exist beyond simply inspecting instruction opcodes, such as hooking the interrupt table or employing a toggle or counter to differentiate between syscall and sysret when it's safe to assume nothing else will trigger a #UD.

Emulating SYSCALL and SYSRET is a straightforward process, following the instruction operations outlined in the manual. The basic emulation code provided omits compatibility and protected mode handling, as well as the SYSRET #GP exception, for simplicity (Picture 5).

```

VmvpEmulateSYSCALL(
    IN EVIRTUAL_CPU VirtualCpu
)
{
    X86_SEGMENT_REGISTER Cs, Ss;
    UINT64 MsrValue;

    //
    // Save the address of the instruction following SYSCALL into RCX and then
    // load RIP from MSR_LSTAR.
    //
    MsrValue = ReadMSR( MSR_LSTAR );

    VirtualCpu->Context->Rcx = VirtualCpu->Context->Rip;
    VirtualCpu->Context->Rip = MsrValue;
    VmcsWrite( VMCS_GUEST_RIP, VirtualCpu->Context->Rip );

    //
    // Save RFLAGS into R11 and then mask RFLAGS using MSR_FMASK.
    //
    MsrValue = ReadMSR( MSR_FMASK );

    VirtualCpu->Context->R11 = VirtualCpu->Context->Rflags;
    VirtualCpu->Context->Rflags &= ~(MsrValue | X86_FLAGS_RF);
    VmcsWrite( VMCS_GUEST_RFLAGS, VirtualCpu->Context->Rflags );

    //
    // Load the CS and SS selectors with values derived from bits 47:32 of MSR_STAR.
    //
    MsrValue = ReadMSR( MSR_STAR );

    Cs.Selector = (UINT16)((MsrValue >> 32) & ~3); // STAR[47:32] & ~RPL3
    Cs.Base = 0; // flat segment
    Cs.Limit = (UINT32)~0; // 4GB limit
    Cs.Attributes = 0xA9B; // L+DB+F+S+DPL0+Code
    VmcsWriteSegment( X86_REG_CS, &Cs );

    Ss.Selector = (UINT16)((MsrValue >> 32) & ~3) + 8; // STAR[47:32] + 8
    Ss.Base = 0; // flat segment
    Ss.Limit = (UINT32)~0; // 4GB limit
    Ss.Attributes = 0xC93; // G+DB+F+S+DPL0+Data
    VmcsWriteSegment( X86_REG_SS, &Ss );

    return TRUE;
}

```

Picture 5 – Emulation of SYSCALL instruction

And as a result, with an attached to a virtual machine debugger we can see an output logged in the main window when operating system runs (Picture 6).

```

SYSCALL 4405: 0xFFFFDBE5CE29693E [stack: 0xFFFF8A8C48AB2430].
SYSCALL 37: 0xFFFF800432A3F30 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 37: 0xFFFF800432A3F30 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 37: 0xFFFF800432A3F30 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 37: 0xFFFF800432A3F30 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 4687: 0xFFFFDBE5CE29798E [stack: 0xFFFF8A8C48AB2430].
SYSCALL 4576: 0xFFFFDBE5CE2971F6 [stack: 0xFFFF8A8C48AB2430].
SYSCALL 4687: 0xFFFFDBE5CE29798E [stack: 0xFFFF8A8C48AB2430].
SYSCALL 4576: 0xFFFFDBE5CE2971F6 [stack: 0xFFFF8A8C48AB2430].
SYSCALL 4385: 0xFFFFDBE5CE2967D6 [stack: 0xFFFF8A8C48AB2430].
SYSCALL 4395: 0xFFFFDBE5CE29688A [stack: 0xFFFF8A8C48AB2430].
SYSCALL 310: 0xFFFF8004331BA50 [stack: 0xFFFF8A8C48AB2430].
SYSCALL 97: 0xFFFF80042D2CA40 [stack: 0xFFFF8A8C48AB2430].
SYSCALL 37: 0xFFFF800432A3F30 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 361: 0xFFFF8004323C560 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 91: 0xFFFF80043301B10 [stack: 0xFFFF8A8C48AB23C0].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A2FF430].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A3BF430].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4993E3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4993E3C0].
SYSCALL 423: 0xFFFF80042D92280 [stack: 0xFFFF8A8C48922430].
SYSCALL 142: 0xFFFF80042DCD1D0 [stack: 0xFFFF8A8C489223C0].
SYSCALL 14: 0xFFFF800432A3D20 [stack: 0xFFFF8A8C48922430].
SYSCALL 460: 0xFFFF80042D815F0 [stack: 0xFFFF8A8C489223C0].
SYSCALL 4: 0xFFFF800432C6930 [stack: 0xFFFF8A8C48912430].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A2FF430].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A3BF430].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4BC0F3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4993E3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4993E3C0].
SYSCALL 5190: 0xFFFFDBE5CE2953BA [stack: 0xFFFF8A8C4993E3C0].
SYSCALL 457: 0xFFFF800432CF720 [stack: 0xFFFF8A8C4C532430].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A2FF430].
SYSCALL 52: 0xFFFF800432C0050 [stack: 0xFFFF8A8C4A3BF430].

```

Picture 6 – Logging of system calls in a system with patches for vulnerabilities

VI. Conclusion

The introduction of Kernel Virtual Address Shadowing (KVAS) has significantly reshaped the landscape of syscall hooking and execution control in Windows, imposing stricter security boundaries to mitigate vulnerabilities like Meltdown. With KVAS in place, conventional methods such as manipulating the LSTAR MSR for syscall interception have become ineffective, requiring alternative approaches to regain control over system call execution. One such method, leveraging the Extended Feature Enable Register (EFER) to trigger VM-exits on SYSCALL and SYSRET instructions, offers a powerful workaround by allowing precise emulation of these critical operations.

This article has explored the mechanics behind KVAS, the role of separate page tables in enforcing security measures, and the broader implications of SMEP in preventing privilege escalation attacks. We also examined how MSR and Exception Bitmaps can be used strategically to intercept and handle system calls, demonstrating an effective way to manipulate processor-level execution pathways.

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UDC 004

AN IMAGE CLASSIFICATION SYSTEM TO SUPPORT THE JUDGING OF BALLROOM DANCE COMPETITIONS

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Аннотация. В статье рассматривается проблема автоматизации процесса судейства на соревнованиях по бальным танцам с акцентом на оценку правильности костюмов участников. Представлена интеллектуальная система на основе методов компьютерного зрения и сверточных нейронных сетей (CNN), способная классифицировать изображения танцоров на соответствие установленным требованиям к костюмам. Разработанная модель была испытана на размеченной выборке, включающей как правильные, так и неправильные примеры пошива с реальных соревнований и постановочных съемок. В процессе обучения применялись методы трансформации, стандартизации изображений и регуляризации моделей. Система может использоваться как вспомогательный инструмент старшего судьи для повышения объективности оценки и ускорения процесса проверки. В дальнейшем предполагается расширение функционала за счет применения моделей сегментации и анализа видеопотока.

Ключевые слова: балльные танцы, судейство, нейронные сети, классификация изображений, пошив костюмов

Annotation. The paper deals with the problem of automating the judging process at ballroom dance competitions with a focus on assessing the correctness of the participants' costumes. An intelligent system based on computer vision and convolutional neural network (CNN) methods is presented, which is able to classify images of dancers for compliance with the established requirements for costumes. The developed model was trained on a labeled sample including both correct and incorrect sewing examples from real competitions and staged shoots. During the training process, methods of transformation, image standardization and model regularization were applied. The system can be used as an auxiliary tool for a senior judge to increase the objectivity of evaluation and speed up the verification process. In the future it is envisaged to extend the functionality by applying segmentation models and video stream analysis.

Keywords: ballroom dancing, judging, neural networks, image classification, costume tailoring

INTRODUCTION

With the development of intelligent systems, computer progress is increasingly penetrating into all areas of human life [2-3]. In modern ballroom dancing, it has become an issue to check the correctness of contestants' costume tailoring. Checking the dancer's clothes and quick response becomes difficult at major competitions due to the huge number of athletes.

Depending on the number of dancers to be tracked, different methods of control are used in this sport. With the help of the most experienced - the senior judge, who controls the dance floor, control of the fulfillment of all requirements for costumes according to the age and category of the dancer. Due to the fact that a person cannot always spot a mistake or be biased towards an athlete, it is necessary to have an independent evaluation tool.

Given that the necessary judging credentials require both experience in performing as a competitor and accreditations - the number of judges at competitions is often limited to one expert. However, a judge is a human being, which makes him or her vulnerable to illness and psychological pressure. It is not uncommon for an expert, with all his competence, to be unable to evaluate a couple without bias, which prevents honest scoring of the dancers.

The aim of this work is to develop and train a neural network model capable of classifying and analyzing the costumes of each dancer to facilitate the work of the senior judge. This will contribute to a more honest scoring of the athletes. It is envisioned that the classification will be part of an intelligent judging support system.

MODEL DEVELOPMENT

Currently, most computer vision systems are focused on general-purpose tasks: object recognition, clothing analysis, face and action recognition. However, specialized solutions for the analysis of stage or sports costumes are rare. The most closely related tasks are systems for fashion image analysis and virtual clothing fitting [4-5]. Such systems are often based on convolutional neural networks (CNNs), as well as segmentation models such as U-Net or Mask R-CNN, which allow to extract garment contours and analyze its details [6-7].

To solve the task at hand, a sample of images of the competitors was collected and labeled, including both correct and erroneous variants of costume tailoring. Each image was categorized according to its type and level of compliance with established standards. The model was trained on images with different angles and lighting conditions. To increase stability, the images were subjected to transformations: rotations, brightness changes, scaling.

The development of a system for automatic analysis of the correctness of tailoring of costumes for ballroom dancing competitions includes several stages: data collection and preparation, design of the neural network architecture, training of the model, and evaluation of its effectiveness on test data.

To start the work, a training sample of images of ballroom dance competitors was generated. The images included both correctly made costumes complying with the requirements and examples with violations. Costume rules were taken from an official document from the All-Russian Federation of Dance Sport, Breaking and Acrobatic Rock and Roll (FTSARR) [1]. The data sources were:

- official photographic materials from competitions;
- video frames extracted from performance recordings;
- data collected during staged photo shoots with controlled parameters.

Since the images differed in quality, illumination and angle, their standardization was performed:

- Adjustment to a single size (224×224 pixels);
- Normalization of RGB channel values;
- Removal of duplicates and marking errors.

To increase the sample size, data augmentation methods were applied, including [8]:

- Random rotations (up to $\pm 15^\circ$);
- Changing brightness and contrast;
- Scaling with preservation of proportions.

These techniques helped to improve the generalization ability of the model and its robustness to different imaging conditions.

To solve the problem of ballroom dancing image classification, a convolutional neural network (CNN) architecture has been developed to efficiently extract features from images and classify them into specified categories.

The neural network designed for ballroom dance image classification includes several key components that provide efficient feature extraction and subsequent classification. The network structure consists of an input layer, several convolution and pooling blocks, a feature rectification layer, fully connected layers and an output layer.

The input layer accepts a 224×224 -pixel image with three channels (RGB), which is a standard format for computer vision tasks and provides compatibility with most pre-trained models.

The convolution and pooling layers are three consecutive blocks, each extracting increasingly complex features from the image. The first convolution block uses a convolution layer with 32 3×3 filters and a ReLU activation function. It is followed by a 2×2 subsampling layer, MaxPooling, which reduces the spatial resolution of the feature map.

In the second convolution block, 64 filters are applied, the kernel size remains 3×3 , and the activation is ReLU; it is also followed by MaxPooling 2×2 . The third block is similar to the previous blocks, but the number of filters is increased to 128. This gradual increase in depth allows the model to recognize both simple (boundaries, corners) and more complex (shapes, body contours) visual features.

After convolutional layers, a Flatten operation is applied to transform the multidimensional feature tensor into a one-dimensional vector suitable for processing by the fully connected layers.

The fully connected (Dense) layers consist of one hidden layer with 128 neurons and a ReLU activation function. To prevent overtraining, a Dropout regularization layer with a factor of 0.5 is used to randomly disable half of the neurons during training. The output layer contains the number of neurons corresponding to the number of classes (e.g., five styles of dance) and uses the Softmax activation function, which converts the network outputs into a probability distribution over classes.

The schematic of the developed model is presented in Figure 1.

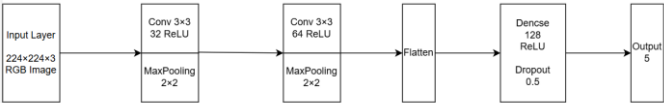


Figure 1 – Schematic diagram of the developed neural network

EVALUATION OF MODEL - METRICS AND METHODOLOGY

A delayed test sample of 20% of the total data was used to evaluate the model. Accuracy, completeness and F1-measure for each class were evaluated and an error matrix was constructed [9]. Particular attention was paid to the model's ability to correctly identify rare but critical violations. A visual comparison of the classification results and real judges' decisions was also performed, which allowed us to evaluate the degree of model's consistency with expert judgment. Figures 2 - 3 show the result of testing the classifier.



Figure 2 – Example of a violation display in a participant's costume



Figure 3 – Example of no irregularities in a participant's costume

CONCLUSION

The proposed system has demonstrated high efficiency in the task of automated assessment of the correctness of dancers' costumes. The results obtained allow us to talk about the possibility of integrating such solutions into the real judging process, especially at the preliminary stages or when considering complaints. In the future it is planned to extend the functionality by using segmentation models and introducing video analysis to evaluate the costume in motion.

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NEURAL NETWORKS AND DLSS TECHNOLOGY: THE FUTURE OF GRAPHICS IN VIDEO GAMES

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Аннотация. В статье рассматривается влияние технологии Deep Learning Super Sampling (DLSS) от NVIDIA на графику в видеоиграх. Визуальные технологии в индустрии претерпели значительные изменения, увеличивая потребность в высокопроизводительном оборудовании. DLSS использует алгоритмы глубинного обучения для масштабирования изображений, обеспечивая высокое качество графики с минимальными затратами ресурсов. Технология решает проблемы алиасинга и предлагает разные режимы качества в зависимости от мощности устройств. Освещаются этапы эволюции DLSS, включая последние улучшения, такие как поддержка временных данных. Сравнительный анализ DLSS и AMD FSR выявляет их сильные и слабые стороны.

Ключевые слова: Графика в видеоиграх, Апскейлинг, Разрешение, Алиасинг, Сглаживание, Производительность, Нейронные сети, DLSS (Deep Learning Super Sampling), Визуальное качество, Частота кадров (FPS).

Annotation. The article examines the impact of NVIDIA's Deep Learning Super Sampling (DLSS) technology on graphics in video games. Visual technologies in the industry have undergone significant changes, increasing the demand for high-performance hardware. DLSS utilizes deep learning algorithms for image scaling, providing high-quality graphics with minimal resource costs. The technology addresses aliasing issues and offers various quality modes based on device capabilities. The evolution of DLSS is highlighted, including the latest enhancements such as support for temporal data. A comparative analysis of DLSS and AMD FSR reveals their strengths and weaknesses.

Keywords: Graphics in video games, Upscaling, Resolution, Neural networks, DLSS (Deep Learning Super Sampling), Aliasing, Anti-aliasing, Performance, Visual quality, Frames per second (FPS).

Introduction. Graphics in video games and the film industry have undergone radical changes over the past three decades. The growing demands for visual quality in games necessitate high performance across a wide range of hardware, including mid-range devices and consoles.

NVIDIA developed DLSS technology, which is one of the most promising solutions for improving graphics quality and increasing performance in video games. DLSS uses neural networks for image upscaling. The subjective of the article is to examine the impact of NVIDIA's Deep Learning Super Sampling (DLSS) technology on graphics in video games.

Results. High resolution allows for more detailed representation of the game world, making it appealing to players. The quality of graphics in video

games significantly improves as image resolution increases from HD to 4K. This increase requires substantial hardware resources. It can lead to a decrease in frame rates (FPS) and a deterioration in gameplay, particularly on less powerful devices.

One of the main issues that arise with increased resolution is aliasing—visual artifacts that appear as jagged or “stair-stepped” edges on objects. An image illustrating aliasing with highlighted “stair-step” areas is presented in Fig. 1.

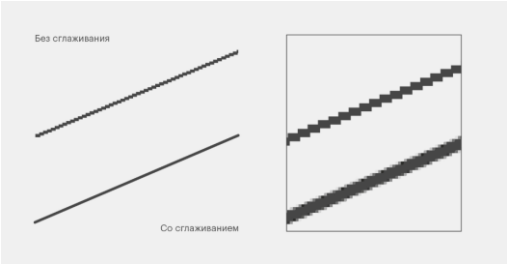


Fig. 1. — Illustration of Aliasing

The developers employ anti-aliasing techniques to address this issue. The traditional methods require significant resources, negatively impacting game performance.

DLSS technology efficiently increases the resolution of images, providing quality graphics without overloading resources; the results of applying DLSS anti-aliasing are shown in Fig. 2.



Fig. 2. — Comparison of Images Before and After Anti-Aliasing

Artificial neural networks are used by DLSS trained on a large number of high-quality images. This provide a prediction of a high-resolution image on a low-resolution one. The principles of DLSS operation are based on the

application of deep neural networks. It enables a real-time image resolution enhancement.

The DLSS technology offers three quality modes:

A) **Balanced** — a compromise approach providing a good balance between quality and performance;

B) **Quality** — maximum image quality with minimal performance loss;

C) **Performance** — significantly boosts performance with acceptable quality losses.

Each of these modes is applied for different scenarios and systems. They ensure smooth gameplay. A comparative graph displaying the use of DLSS in various modes (Quality, Balanced, Performance) is presented in Fig. 3:



Fig. 3. — DLSS in Various Modes

Key milestones in its development and significant improvements can be highlighted by analyzing different versions of DLSS technology. The first version, DLSS 1.0, was released in early 2019 for using deep learning to enhance graphics quality in games. Despite its innovative approaches, it faced certain overcomes, for example, insufficient image quality and limited compatibility with games.

Significantly improved algorithms were implemented, greatly enhancing image quality with the release of DLSS 2.0 in March 2021. The new quality modes for sharp images without significant performance degradation made DLSS more attractive to game developers and end users.

DLSS 3.0 version had a significant breakthrough in upscaling technologies. It was launched in October 2022 with new features, including the generation of intermediate frames and integration with ray tracing. These innovations improved overall graphics quality.

DLSS 3.5 was introduced by September 2023. This version incorporated algorithm improvements and support for advanced rendering, providing high-quality images even in complex scenes.

Each new generation of DLSS offered new opportunities to enhance graphics quality and performance in video games. The difference between the application of various versions of DLSS technology is illustrated in Fig. 4.

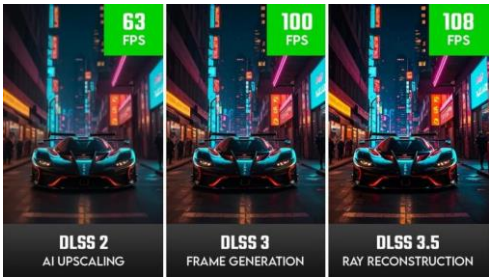


Fig. 4. — Comparative pictures to determine the impact of technology on performance and quality

DLSS is integrated into over 250 games and applications, including Cyberpunk 2077 and Control. A demonstration of a comparative analysis of various versions of DLSS technology is shown in Fig. 5.



Fig. 5. — Screenshot from Cyberpunk 2077

AMD FSR AND DLSS Technology are primary competitors in the field of upscaling technologies.

FSR is an independent solution that works on most modern graphics cards. DLSS requires hardware support only on NVIDIA RTX graphics cards and utilizes neural networks.

DLSS provides a higher level of image quality and a variety of adjustment settings Despite the greater flexibility of FSR. A comparative graph displaying the results of tests under various conditions in the game Cyberpunk 2077 version is shown in Fig. 6.

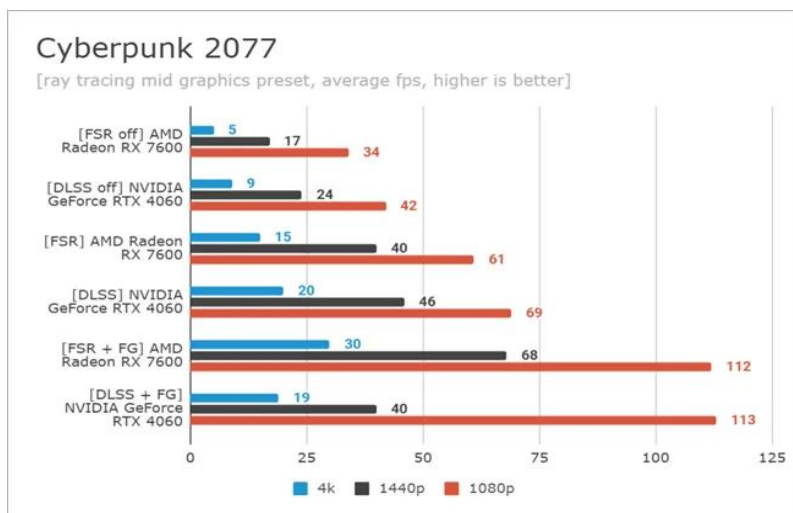


Fig. 6. — Comparative Graph DLSS vs FSR

DLSS has some drawbacks despite its advantages. These are image quality issues, hardware dependence, difficulties with training neural networks and limited support in some games. These aspects may limit the accessibility of the solution for some players.

Conclusion. NVIDIA continues to develop this technology, giving players the ability to enjoy unique visual effects and high performance. DLSS offers numerous benefits, such as improving image quality with lower hardware resource requirements, reducing GPU load, and providing a variety of settings.

The technology opens new horizons for creating realistic visual effects, allowing players to immerse themselves in the captivating world of modern games. DLSS represents an important step in the development of graphic technologies, graphic design in video games, and remains an important tool in the video game industry and continues to influence technological advancements in this field despite a number of existing drawbacks.

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URL: https://stopgame.ru/blogs/topic/108159/chto_takoe_neyronnye_seti_i_kak_rabotaet_nvidia_dlss?ysclid=m8rmeke3yy753589354 (дата обращения: 10.03.2025)

UDC 004

ADVANCING CONTROLLABLE TEXT GENERATION WITH LARGE LANGUAGE MODELS

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Аннотация. В статье рассматриваются достижения в обработке естественного языка, достигнутые с помощью больших языковых моделей (LLM), подчеркивая их способность генерировать текст, подобный человеческому, и их применение в различных областях. В ней обсуждаются основополагающие фреймворки для управления генерацией текста, подчеркивая модульные подходы и взаимодействие между такими методами, как модели последовательности-в-последовательности и обучение с подкреплением. Подробно описываются различные методы достижения управляемости, такие как быстрое проектирование, тонкая настройка, скрытое манипулирование пространством, вмешательства во время декодирования и арифметика моделей. В статье рассматриваются такие проблемы, как галлюцинации, предубеждения, проблемы безопасности и ограничения в оценочных показателях. В ней подчеркивается необходимость дальнейших исследований для повышения надежности и применимости LLM, обеспечивая при этом этическое использование.

Ключевые слова: Большие языковые модели (LLM), Обработка естественного языка (NLP), Управляемая генерация текста, Проектирование подсказок, Метрики оценки.

Annotation. The article explores the advancements in natural language processing brought by large language models (LLMs), highlighting their ability to generate human-like text and their applications across domains. It discusses foundational frameworks for controlling text generation, emphasizing modular approaches and interaction among techniques like sequence-to-sequence models and reinforcement learning. Various methods for achieving controllability, such as prompt engineering, fine-tuning, latent space manipulation, decoding-time interventions, and model arithmetic, are detailed. While acknowledging progress, the paper addresses challenges like hallucinations, biases, safety concerns, and limitations in evaluation metrics. It underscores the necessity for further research to enhance the reliability and applicability of LLMs while ensuring ethical usage.

Keywords: Large Language Models (LLMs), Natural Language Processing (NLP), Controllable Text Generation, Prompts Engineering, Evaluation Metrics.

1. Introduction

The advent of large language models has brought about a significant shift in the field of natural language processing. These models have demonstrated unprecedented capabilities in creating human-like text, opening up a wide range of applications, from automated customer support to creative writing.

Examples of these models include ChatGPT and Gemini. They have shown remarkable proficiency in generating text, summarizing information, and classifying content. This has set new standards in the field and demonstrated the potential of machine learning to understand and communicate in human language.

The ability of machines to communicate effectively with humans has been a long-standing challenge in artificial intelligence. The recent advances in generative AI have offered promising solutions to this problem. The advancement of natural language processing, primarily driven by large language models, represents a significant milestone in AI research. These models, based on the transformer architecture, are trained on vast datasets derived from web-based text. The core of their design lies in a self-supervised learning approach, which involves predicting subsequent words in incomplete sentences. Through repeated exposure to extensive datasets, these models develop the ability to generate grammatically correct and contextually appropriate content.

Despite these advancements, there are several challenges associated with the widespread adoption of large language models. These include ethical concerns and practical limitations in real-world applications. Most researchers highlight the need for careful consideration of these challenges.

2. Foundational Frameworks for Controllable Text Generation

To ensure that text generation follows specified guidelines and constraints, researchers have developed the field of controllable text generation. This allows for manipulation of the output through external inputs, sequential inputs, generator operations, and training objectives. Prabhumoye et al.'s schema presents a structured approach to understanding and refining control mechanisms in text generation by outlining five key modules: external input, sequential input, generator operations, output, and training objectives [6].

These control mechanisms are essential for tailoring text generation to specific requirements, such as desired style, topic, or sentiment. Modular approaches emphasize the interaction between various techniques, such as sequence-to-sequence models and reinforcement learning, with these modules to achieve controllability.

3. Techniques for Control

To control the outputs of a model without retraining, prompt engineering is used through carefully designed prompts. Fine-tuning retrains the model on domain-specific data to achieve the desired control attributes. Latent space manipulation modifies the embeddings or latent representations to have more precise control over the generated text. The ability to manipulate the attributes of the generated text has become more important with the development of large language models. Decoding-time interventions adjust the decoding process to enforce specific styles or attributes. Model arithmetic combines multiple language models to bias the outputs towards or away from specific attributes. This involves adjusting the decoding process using techniques like beam search constraints to enforce specific styles or attributes, and it allows for biasing the outputs towards or away from specific attributes without the need for retraining. This is achieved by combining multiple language models.

Prompt engineering involves carefully crafting input prompts to guide the language model towards generating specific types of content. By formulating prompts that include keywords, instructions, or examples, developers can influence the style, tone, and topic of the generated text.

Prompt adaptation can automatically adjust the original user input into model-preferred prompts through supervised fine-tuning using a pretrained language model with a small set of manually engineered prompts. Crafting effective prompts is crucial for obtaining accurate, relevant, and coherent responses from the model, acting as the primary mode of communication between users and Large Language Models (LLMs).

Prompt engineering utilizes the flexibility and customization of LLMs, allowing users to guide them towards generating desired outputs. By carefully crafting prompts that include specific instructions, keywords, or examples,

developers can guide the model to generate content that aligns with their goals. It is essential to avoid ambiguity and provide clear examples, as well as carefully iterate on the prompts [3].

Fine-tuning involves adapting a pre-trained language model to a specific task or application by retraining it on a smaller dataset that is more relevant to the task. This allows the model to better understand the context of the data and generate more accurate and meaningful content. Fine-tuning has been shown to significantly improve the performance of language models on specific tasks, particularly when there is limited training data available. By exposing the model to a dataset that reflects the characteristics of the target domain, it can learn patterns and relationships specific to that domain.

Instruction tuning is a process where language models are fine-tuned using a set of instructions, which helps them better interpret and follow instructions, reducing the need for example-based training. This process can help models become more efficient and effective in their tasks.

Latent space manipulation is a technique that involves modifying the internal representations or embeddings of text in order to exert finer control over the generated output. This allows developers to influence various aspects of the text, such as its style, sentiment, and topic. By manipulating the latent space directly, developers can achieve more precise control over the text generation process.

During the decoding phase, specific styles or attributes can be enforced by adjusting the decoding process. This can be done using beam search constraints, which allow for real-time adjustments to the output based on predefined criteria. This approach ensures that the generated text meets specific requirements or preferences.

Model arithmetic is another technique that can be used to control the generation process. It involves manipulating the model's internal parameters in order to achieve desired results. This includes adjusting the weights, biases, and other parameters that influence the generation process.

Model arithmetic involves combining multiple language models in order to bias the output towards or away from specific attributes, without the need for retraining. This technique allows developers to create customized language models with desired characteristics or behaviors, by combining the strengths of different models. This approach enables the creation of tailored language models for specific tasks or applications, providing a flexible and efficient means of customizing language models.

4. Challenges in Controlled Text Generation

Although there have been advances in controlled text generation, there are still several challenges that need to be addressed. These include

hallucinations, biases, safety concerns, limitations in evaluation metrics, and limitations in instruction tuning.

One of the most significant challenges is the occurrence of hallucinations in generated text, which can lead to incorrect or fabricated information being included. This undermines the reliability and credibility of the content, limiting its use in various applications. To address this issue, it is necessary to carefully consider the training data, model architecture, and decoding process in order to minimize the generation of false information.

Large language models are designed to predict the next word in a text sequence [7]. They accomplish this by analyzing a massive dataset of text [1], but unfortunately, some information in the data can be inaccurate or outdated, leading to the generation of incorrect statements.

Ensuring that generated text is free from harmful content and adheres to ethical guidelines is a critical challenge in controlled text generation. Large language models have been found to contain biases that stem from the training data, algorithmic constraints, product design, and policy decisions. These biases can lead to unfair, discriminatory, or offensive outputs, requiring a multi-faceted approach to address them.

Addressing bias and safety concerns involves careful curation of training data, development of robust safety mechanisms, ongoing monitoring, and evaluation of model outputs. It is important for the AI community to stimulate conversations about the role of biases in generative language models and the unintended consequences of biased model outputs.

Current evaluation metrics, such as BLEU and ROUGE, often fail to adequately capture the nuanced aspects of style and thematic consistency in text generated by AI models (BLEU struggles at perceiving diversity) [2, p.303]. These metrics provide a quantitative measure of the similarity between generated text and a reference text, but they do not always capture the subtle nuances and qualitative aspects that are essential for evaluating controllable text generation.

There is a need for cross-disciplinary and collaborative efforts to create more equitable, transparent, and responsible AI systems. For example, assessing the quality of AI-generated medical content requires considering the model's language perspective, level of knowledge, and up-to-date information [5]. Comprehensive evaluation frameworks are necessary to assess the coherence, relevance, and quality of generated text, considering both quantitative and qualitative factors.

Recent studies have shown that instruction-tuned language models underperform compared to zero-shot prompting in terms of structural and lexical accuracy. This indicates a limitation in the ability of these models to enforce specific constraints on generated text.

This finding highlights the need for more research and development of instruction-tuning techniques in order to improve the controllability of advanced large language models (LLMs). It also emphasizes the importance of careful consideration and management of generative AI use in academic writing.

The generative AI programs have the potential to create written and visual content, which can be used for both good and bad purposes. This means that ethical frameworks and policies are needed to ensure the responsible development and use of these models.

As language models become more integrated into our daily lives, it is crucial to address these challenges to ensure their responsible use. Generative models have the potential to significantly impact various industries and change the way we perform tasks such as writing, programming, and designing, medicine, law, marketing, and education.

However, the use of these technologies also poses risks, such as the potential for harmful discrimination, stereotyping, and exclusion on a large scale. It is essential to implement ethical guidelines and policies to mitigate these risks and ensure that generative AI models are used responsibly.

Initial findings suggest that adopting this approach may indeed facilitate faster content generation without sacrificing accuracy or clarity, representing a promising development in the field of generative AI for education [4].

The ongoing evolution of controllable text generation, which combines methodological advances with sophisticated large language models (LLMs), represents a critical area of research in AI. The ability to fine-tune text production to specific features, styles, and semantic nuances is crucial for various applications, including content generation, personalized communication, and creative writing. As LLMs are increasingly used for language evaluation, especially when fine-tuned for this purpose, their role in language assessment is expected to grow (Pack et al., 2024). Although AI tools like ChatGPT offer benefits such as time savings and improved clarity, they also present challenges related to plagiarism and attribution of machine-generated content.

Conclusion

While LLMs have made significant advancements in natural language processing and controlled text generation, there remain challenges such as hallucinations, biases, and ethical concerns that hinder their widespread adoption. To realize their full potential in industries like education, healthcare, and creative content creation, ongoing research is essential to address these limitations. Establishing ethical frameworks is crucial to ensure the responsible development and deployment of these technologies.

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UDC 004

AUDIO INFORMATION CHANNELS APPLICATION TO CREATE KNOWLEDGE CONTROL TOOLS IN THE INTERACTIVE STANDS DEVELOPMENT

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Аннотация. В статье изложена технология создания механизмов контроля знаний в области разработки интерактивных стендов посредством использования каналов аудиоинформации. Представлена упрощенная типовая структура аудиосистемы, интегрированной в интерактивный стенд, а также структура программного обеспечения для разработки их управляющей программы и звуковых файлов. Алгоритм управляющей программы, зависящий от выбранного режима работы, охватывает процессы обучения и контроля знаний, а также этапы разработки программного обеспечения.

Ключевые слова: интерактивные технологии обучения, аудиосистема, технические средства, интерактивный стенд, мультимедиа

Annotation. The article delineates the technology of establishing knowledge control mechanisms in the domain of interactive stand development through the audio information channels utilization. It presents a simplified typical audio system structure that has been integrated into an interactive stand, along with the software structure for developing their control program and sound files. The control program's algorithm, which is contingent on the selected mode of operation, encompasses the processes of training and knowledge control, in addition to the stages of software development.

Keywords: Interactive learning technologie, audio system, technical means, interactive stand, multimedia.

Problem statement.

Interactive learning technologies have the capacity to encompass not only the process of acquiring knowledge on the proposed topic, but also the control over the assimilation of the proposed material by students. The system of control over knowledge assimilation is built on the basis of operational feedback, which makes the assimilation check faster and more flexible. The listed approaches to information delivery presuppose the presence of software and hardware tools, as well as operators who are able to control these tools.

Main part.

In the contemporary era, a pivotal state responsibility is the cultivation of highly qualified personnel who are endowed with both theoretical knowledge and practical skills.

However, in modern conditions, characterized by a precipitous rise in the volume of knowledge required for individuals, it is imperative to cultivate the capacity for autonomous knowledge acquisition and navigation within the inundation of scientific and technical information.

The annual challenges associated with the production of conventional paper textbooks and teaching materials have become increasingly evident. The

content of these materials often becomes obsolete by the time they reach educational institutions. Consequently, students find themselves with a limited foundation of professional knowledge.

One potential solution to enhance the efficacy of the vocational education system is the integration of technical training aids (TTA). The most effective assimilation of knowledge occurs through a direct integration of oral presentation and practical demonstration in the educational process.

It has been demonstrated that the integration of audiovisual elements in educational materials can enhance the assimilation of content by 30-40%. Moreover, the incorporation of multimedia components has been shown to increase this effect by an additional 80-85%. Consequently, in order to maximize the interest of students and increase their personal competencies, it is necessary to combine interactive learning with the use of this content.

The TTA facilitates the optimization of students' visual and auditory analytical capabilities. The TTA exerts a primary influence on the initial stage of the process of knowledge assimilation, namely sensation and perception.

The role of memorization as a logical conclusion of the assimilation process is significant. They contribute to the consolidation of acquired knowledge by creating vivid reference points, and they facilitate the capture of the logical thread of the material, as well as the systematization of the studied material.

The term 'technical means of learning' is interpreted differently in different sources of information, but in general, the essence of each of the definitions includes two aspects: a technical device and a means of learning. The pivotal element in this context is the medium itself, which functions as a conduit for educational information and a catalyst for stimulating cognitive activity among students.

A thorough analysis of the classification of TTA reveals the diversity of their functional purposes. In technical educational institutions, there is a widespread provision of training, which involves the presentation of educational information to students according to certain programs embedded in technical devices, as well as self-control of knowledge assimilation.

Such training methods encompass interactive training stands equipped with audio presentation capabilities.

On the basis of the aforementioned points, it can be concluded that, in order to facilitate effective independent study, the content and structure of the training stand should align with the curriculum of the subject under scrutiny, while simultaneously providing a framework for more in-depth examination of the theoretical underpinnings. Such electronic editions should be equipped with a more detailed system of context-sensitive references, comments and hints.

Multimedia technologies represent a promising avenue for the informatisation of the educational process. The successful implementation of contemporary information technologies in education is predicated on the enhancement of software and methodological support, alongside the development of mechanisms to assess the assimilation of information.

The following modes of operation are exhibited by interactive stands utilizing audio information channels:

- training information playback;
- students' knowledge testing;
- independent generation of test tasks.

Figure 1 presents a simplified representation of a standard audio system integrated into the interactive stand.

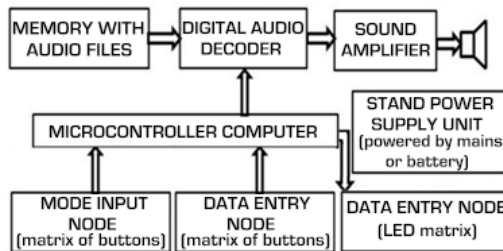


Figure 1. Structure of a typical audio system integrated into an interactive stand

Stand composition:

The memory system for audio files has been designed for the purpose of storing the audio information for each of the stand units. Often, Micro SD memory cards are utilized in the stands, as they are diminutive in size and can be readily connected to an MP3 player.

The digital audio decoder has been designed to facilitate the conversion of digital audio signals to analog signals. In addition, it has been connected to an Arduino.

The microcontroller calculator constitutes the main part of the stand's structure. Its primary function is to regulate the operational dynamics of the stand.

The system under discussion includes a processor, memory (RAM and ROM), and various specialized peripherals. The former two components can be configured for both input and output, while the latter two can be configured for output or input. The specialized peripherals include the following:

- digital ports that can be configured for both input and output

- output input interfaces such as UART, SPI, CAN, USB, Ethernet, analog-to-digital and digital-to-analog converters
- comparators
- pulse-width modulators
- signal generators.

It is also possible to include specialized blocks.

The data input node is engineered to transform the analogue signal into a digital format, subsequently transferring it to a microcontroller computer where the object's numerical representation is generated.

The data output node is engineered for the purpose of visual illumination of the designated block [3].

Subsequent to the loading of the control program into the internal memory of the microcontroller, the loading of calculator and audio files into the audio files memory, and the provision of power to the stand (mains or battery power supply unit), the stand is ready for operation. In the following section, the functionality of the stand will be analyzed.

As illustrated in Figure 2, the software architecture for the development of the control program and sound files for the interactive stand is comprised of distinct components. The software complex in its entirety is deployed on a standard personal computer with a common operating system.

The development of the stand software occurs in two stages.

In the initial stage, a scenario of its operation is created. This scenario should comprehensively delineate the stand's behavior during operation. Specifically, all image elements (e.g. pictures, maps, drawings) depicted on the stand and numbered for sounding should be specified in the form of text, with time intervals stipulated to facilitate the assimilation of the material presented on the stand. The development of the algorithmic scheme for the control program, incorporating the necessary dynamic characteristics, is then undertaken [5].

At the second stage, the bench control program for the microcontroller is created directly based on the developed scenario. In this instance, a dedicated development environment is employed for the creation of the bench control program, such as the integrated environment ArduinoIDE. The source control code is configured to establish a rigid link between the input requests of a particular stand and their corresponding audio files, LEDs and time intervals during playback.

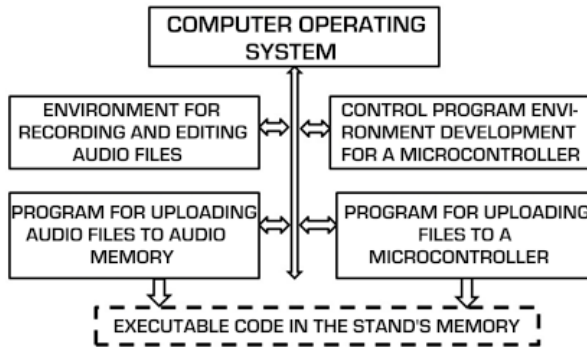


Figure 2. Software structure for development of the control program and sound files of the interactive stand

The operating system incorporates an audio recording program that facilitates the creation and editing of audio files for the stand, utilizing the available script as a framework [2].

The developed files were then written to the audio file memory and to the program memory of microcontrollers, with the assistance of special programmers and programs for their functioning.

In the subsequent discussion, the algorithmic framework of the control program for interactive stand operations with audio information channels will be examined. [1]

The functionality of the device encompasses dual applications: namely, training and the evaluation of trainees' knowledge. To this end, it is necessary to provide the possibility of selecting the mode of operation. The selection of this mode of operation will result in the initiation of either a training process or a knowledge control process (see Figure 3).

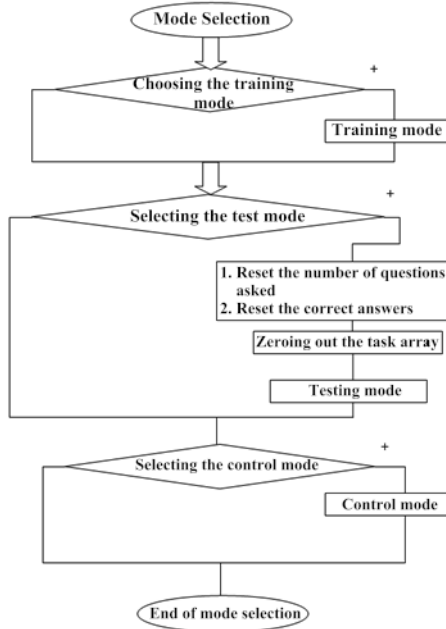


Figure 3. Algorithm for selecting modes of training and knowledge control

The training mode is realized through the reproduction of training information by pressing the buttons on the matrix of the data input node. In this scenario, the request code of the pressed button is entered into the microcontroller's calculator. The request code is then matched to one of the LEDs in the matrix, and an audio file from the audio file memory is played through the digital decoder. The digital audio decoder then decompresses the file, which is amplified and fed to the speaker for playback.

The knowledge test mode, on the other hand, involves the generation of a question, a variant of which is generated in the program code in advance and is called in random order. Upon selection of the correct answer, the LED indicator corresponding to the accepted standards is illuminated. The calculator then tallies the number of correct and incorrect answers, and after a predetermined number of questions, it provides a grade for the knowledge test.

An alternative variant of knowledge control can be offered, whereby the nodes of the image of the interactive stand objects are randomly illuminated by LEDs, with the task of the trainee being to find the button (sensor) corresponding to the illuminated element [7].

The source control code is written in accordance with the selected algorithmic scheme, rigidly linking the input requests of a particular stand with their corresponding audio files, LEDs and time intervals during playback. The implementation of this system can be facilitated by utilizing a dedicated development environment, such as ArduinoIDE, which is specifically designed for such endeavors [5, 6].

Conclusion

The development of an algorithm for the creation of interactive stands with audio and visual information display channels on a wide range of proposed topics has been undertaken. The integration of such audio channels into training and cutting products for complex technical systems shows great promise.

The stands are easily reproducible, composed of standard elements, and can be utilized in the educational process, including self-training, as ancillary information material outside of classroom settings (e.g., in open areas, corridors, restrooms, etc.).

The utilization of audiovisual technologies is methodologically substantiated, thus enabling educators to augment their repertoire of methodological techniques during the dissemination of knowledge and thereby markedly enhancing the efficacy of visual presentations in training contexts.

The utilization of audiovisual media within the classroom setting is predominantly dictated by the subject matter of the lesson.

Consequently, the extensive proliferation of audiovisual technologies has been shown to enhance the efficacy of educational processes, thereby elevating the quality of teaching and learning.

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UDC 004.7

DEVELOPMENT OF DECENTRALIZED INFORMATION SYSTEMS

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Аннотация. В статье рассматриваются предпосылки внедрения децентрализованной архитектуры в разработку коммерческого и другого программного обеспечения и возможные преимущества этого подхода. Также обсуждаются современные протоколы связи для сетей на основе такой архитектуры и их применение. Кроме того, в статье обсуждаются перспективы использования некоторых паттернов одноранговых сетей при разработке и проектировании информационных систем. В заключении, в данной статье анализируются перспективы интеграции таких систем на примере децентрализованной системы контроля версий.

Annotation. The article discusses the background for the introduction of decentralized architecture in the development of commercial and other software and the possible benefits of this. It also discusses modern communication protocols for networks based on such architecture and their application. In addition, the article discusses the prospects for using some peer-to-peer network patterns in the development and design of information systems. Finally, this paper analyzes prospects for integration of such systems using the example of decentralized version control system.

Keywords: decentralized networks, role-based access, architecture patterns, version control systems, peer-to-peer, Web 3.0.

Introduction. Decentralized (or peer to peer) network - it is a network in which nodes can communicate directly with each other without need for coordinating nodes. Such an organization of network became famous due to the popularity of crypto-currency systems, which are using this network architecture to ensure privacy and independence of payment transactions. However, apart from this example and usage in IoT systems, peer-to-peer

architecture had not become widely used in the design and development of information systems, nevertheless due to some trends in evolution of modern communication protocols and availability of high-performance hardware, the implementation of it becomes more and more profitable, and necessary.

Thus, this work aims to investigate prospects of integration of decentralized architecture into designing of software. Consequently, this paper will deal with the following tasks:

- Describe background and reasons for integration of Decentralized Architecture Patterns (DAP);
- Explore evolution of communication protocols for peer-to-peer networks;
- Explore DAP, its benefits and limitations;
- Analyze an example of software, which build with usage of DAP.

Prerequisites. First of all, when dealing with any type of software which uses any type of network for communication, developers and architects are forced to determine many aspects of the target system including the methods and protocols for communication. And in the past, they were faced with the following choice. On the one hand, protocols used for transmission of information in IT systems based on classical centralized networks patterns, such as TCP, UDP etc. widely known and supported by majority of popular development tools. On the other hand, utilization of peer-to-peer networks was followed by a wide range of difficulties and challenges, such as problems of access control, narrow specialization of many protocols and weak support from general development tools. As a result, developing software based on DAP, required solving various specific problems and solutions of such problems often required more resources and time than all remaining development process, while usage of centralized patterns was easy and well-known way.

However, in recent years a wide range of enthusiasts and researchers interested in the concept of Web 3.0 and inspired by the example of blockchain based crypto-currency platforms which all based on peer-to-peer architecture have done a tremendous job, solving many problems related to usage of DAP. This work resulted in the following achievements:

- Wide range of new protocols developed, such as Nostr, IndFis and AT Protocol;
- New libraries for wrapping work with new and old protocols;
- Protocols are now suitable for solving more complex and various tasks (for example, AT Protocol for decentralized social networks);
- Introduction of new access control policies, for example, many varieties of policies based on role-based access control making decentralized architecture more flexible;

- Wide range of examples of utilization of all instruments listed above.

Moreover, nowadays, high-performance hardware has become more widespread which extends capabilities of IT systems based on DAP. Consequently, there are suitable conditions for usage of DAP in modern software development process.

Network standards. First communication protocols for peer-to-peer communication often were targeted to solve specific low-level tasks such as distributed file sharing as IPFS or BitTorrent. However, modern protocols such as AT protocol or Heartwood tend to deal with more high-level issues, the tendency to this can be illustrated by the table 1.

This table also illustrates that decentralized network protocols, not only capable of supporting high level business logic, but also cover a wide range of such tasks, and despite usual stereotypes can be implemented not only in file-sharing and crypto-currency platforms. For example, there are a lot of protocols introduced for the development of social networks which have been developed since 2019. Moreover, there are some protocols like Cosmos and Wormhole, which can communicate between different decentralized networks. And finally, there are even such protocols like Dagger, which could provide flexibility in terms of version management of applications on different nodes.

Thus, it is clear that protocols for decentralized applications and networks at this moment are already capable of dealing with various tasks, and do not limit the scope of application of the software being developed.

Architecture patterns. At the moment any usage of decentralized networks for building software is followed by the list of advantages:

- Absence of bottlenecks (e.g. central server);
- High cryptographic protection;
- Resistance to data falsification;
- Transparency;
- High computing possibilities (for large networks).

Table 1. - Evolution of protocols for decentralized networks

Protocol	Year	Specialization
BitTorrent	2001	File sharing
Tor	2002	Anonymity/Privacy
I2P	2003	Anonymous messaging
MaidSafe	2006	Autonomous data network
Bitcoin	2008	Cryptocurrency/Payments
Dat Protocol	2013	Decentralized web

Scuttlebutt (SSB)	2014	Social networking
Ethereum	2015	Smart contracts
IPFS	2015	Decentralized storage
Hyperledger Fabric	2015	Enterprise blockchain
ZeroNet	2015	Decentralized websites
Golem	2016	Distributed computing
Filecoin	2017	Storage marketplace
Matrix	2019	Decentralized communication
Cosmos	2019	Interchain communication
Polkadot	2020	Blockchain Interoperability
Nostr	2020	Decentralized messaging
GunDB	2020	Decentralized database
Dagger	2021	Decentralized updates
Radicle/Heartwood	2021	Decentralized code collaboration
Wormhole	2021	Transferring assets/data between blockchains
Aptos	2022	Scalable blockchain
AT Protocol	2022	Decentralized social networks
Lens Protocol	2022	Social media ecosystem
IndiFS	2023	File sharing

However, applications based on classic peer-to-peer architecture are not always able to effectively solve the tasks at hand. For example, when designing the architecture of such systems, the following aspects of logic are implicit to the developer:

- Access control – since it is a peer-to-peer network, all nodes have equal rights, but sometimes it is necessary to give nodes the ability to control access to the content they provide;

- Decision control – since there is no central server making decisions, the problem of distributing power between nodes arises;

- Control of data consistency – since data could be distributed between nodes or each node could contain its own version of data, the problems of data losses or data conflicts could arise;

- Workload distribution – network could consist of very different nodes in terms of computing capabilities, moreover, it is required to avoid overloading the network, while organizing communications between nodes.

Therefore, sometimes more sophisticated decentralized solutions are required to deal with these gaps, and there is a wide range of such solutions in the form of architecture patterns. Many complex architectural patterns have

emerged to address the inherent problems of decentralized systems, such as scalability, security, and coordination. Federated networks [5], for example, strike a balance between decentralization and administrative efficiency by organizing nodes into smaller, trusted clusters. These clusters enable localized control while preserving interoperability across the broader network. The next pattern is Blockchain-based consensus mechanisms, such as Proof of Work or Proof of Stake, is using cryptographic protocols to reconcile data between nodes. Patterns based on Gossip protocol, ensure data consistency by propagating information through randomized peer-to-peer communication, this mechanism can replace centralized coordination of data verification. Another method of data conflicts resolution is the usage of Conflict-Free Replicated Data Types [1] (CRDTs). This could be achieved by the usage of such tools as GunDB for real-time collaborative applications.

One of the ways to deal with access control is the usage of Role-Based Access Control [3] (RBAC) which is able to provide to peers the ability to assign specific roles and permissions for their content. Such an idea as RBAC was implemented in different protocols. For example, cryptographic keys are used to grant publishing rights, with relays enforcing role-specific permissions in Nostr Protocol. Another example is Hyperledger Fabric which implements granular access policies through smart contracts, ensuring transactions are restricted to authorized identities.

In order to deal with workload distribution sharding [4] is used. Sharding optimizes resource utilization in heterogeneous networks by partitioning them into parallel chains. Projects like Cosmos use this technique to distribute computational load across specialized shards, enhancing scalability and performance.

As a result, there is a wide range of patterns which are not only capable of solving different problems but also could provide new ideas for design of software logic. However, using DAP does not solve the following problems, which are a consequence of the nature of decentralized networks:

- Problems with debugging and monitoring of system: The lack of centralized logging makes it difficult to diagnose errors;
- Dependence on network infrastructure: The quality of communication between nodes directly affects system performance;
- User experience issues: Decentralized applications often require users to manage keys and nodes, making interaction difficult, however it is a consequence of ability to fully control data of node.

Decentralized Version Control System. One of the examples of developing decentralized software is Radicle [2]. It is a decentralized version control system based on GIT, which excludes centralized service like github or gitlab server and ensures the independence of code from them. This system

can be useful for organizations with high security standards, as it not only removes dependencies from the code collaboration process but also avoids the cost of maintaining your own centralized code repository by allowing everything to be kept on the devices of developers.

There are some crucial aspects of architecture of this software:

- Introduces the gossip-based protocol Heartwood;
- Usage of RBAC for access management;
- Usage of classic peer-to-peer model;
- Usage of Noise XK pattern for secure peer-to-peer connection;
- Usage of original GIT ensures compatibility with existing tools and stable work of existing workflows.

This illustrates that the development of decentralized software, even with such high demands for working with protocols as this, is not produced from scratch. On the contrary, the process of development could be more effective with the help of ready-made solutions. Moreover, the benefit can come not only from what is developed for centralized networks, but also from what was not specifically developed for this purpose, like usage of GIT in this situation.

However, it should be noted that deployment of such software is not an easy task (which is relevant for many decentralized applications). Despite this fact, it could not be considered a severe disadvantage since the target audience of this software is developers who usually have enough skills to deal with this. But such a system could also require special keys management policy, which could be more complicated than when using classic solutions like gitlab.

Conclusion. In conclusion, the background to integrating a decentralized architecture has been discussed, as have tools such as protocols and DAPs that can be used to do so. As a result, the following conclusions can be drawn:

- There are many favorable factors for using decentralized architecture;
- At the moment decentralized protocols are capable of providing efficient solutions for various tasks;
- Many of the problems in logic of decentralized networks can be solved by usage of DAP.

Moreover, example of modern software developed with usage of decentralized architecture was discussed, with examples of implementation of some tools. And this, together with the limitations mentioned before, leads to the conclusion that decentralized architecture could be very efficiently applied to design software which satisfies following criteria:

1. Used by restricted number of nodes inside of local network to avoid networks overload;
2. Used for collaborative work with any type of data (event sensitive);
3. Used by an organization with qualified IT specialists, who will be capable of deploying such a system or used by an IT specialist himself;

All these criteria could be satisfied by a wide range of corporate software used for document management or collaborative work. And this can be a good way for companies with good personal computers to avoid additional expenses for maintaining centralized servers for data storage etc.

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UDC 004

CREATING AN ALGORITHM FOR CONVERTING TEXT IN AN INCORRECT LAYOUT AND INTEGRATING IT INTO TEXT EDITORS USING C++

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Аннотация. В статье представлен инновационный алгоритм преобразования текста, набранного в некорректной раскладке клавиатуры, с использованием языка программирования C++.

Уникальность подхода заключается в двухсторонней обработке текста (русский или английский язык), что обеспечивает универсальность решения. Разработанный алгоритм интегрирован в текстовый редактор Microsoft Word в формате плагина, что упрощает его использование конечными пользователями. Рассмотрены преимущества предлагаемой реализации, в том числе использование структуры данных unordered_map и технологии COM API для эффективного взаимодействия с текстовым редактором. Приведены примеры успешного преобразования текста и проанализированы перспективы дальнейшего совершенствования алгоритма, включая поддержку дополнительных языков и онлайн-платформ.

Ключевые слова: раскладка клавиатуры, текстовые редакторы, преобразование текста, алгоритм, C++, автоматизация, интеграция.

Annotation. This article presents an innovative algorithm for converting text typed in an incorrect keyboard layout using the C++ programming language. The uniqueness of the approach lies in the two-way text processing (Russian or English), which ensures the versatility of the solution. The developed algorithm is integrated into the Microsoft Word text editor in plug-in format, which simplifies its use by end users. The advantages of the proposed implementation are considered, including the use of the unordered_map data structure and COM API technology for effective interaction with a text editor. Examples of successful text conversion are given and prospects for further improvement of the algorithm, including support for additional languages and online platforms, are analyzed.

Keywords: keyboard layout, text editors, text conversion, algorithm, C++, automation, integration.

Introduction. Errors related to typing in the wrong keyboard layout are a common problem in everyday and professional activities. Such errors lead to a loss of time, a decrease in the quality of documentation and the need for manual text correction. Automating the process of correcting these errors can significantly improve user interaction with text and increase productivity.

The purpose of this article is to develop an algorithm for converting text between keyboard layouts that can work efficiently with minimal resources and be easily integrated into popular text editors such as Microsoft Word. The article describes the algorithm design process and its advantages. The C++ programming language and the Visual Studio 2022 development environment were used for implementation [1, p. 1].

Tasks

1. Analyze existing solutions for correcting text in the wrong layout and identify their limitations.

2. To develop an algorithm for text conversion between keyboard layouts (Russian and English), ensuring high speed and accuracy of data processing.

3. Evaluate the effectiveness of the algorithm using examples of real texts of various lengths.

4. Integrate the algorithm into text editors using COM API technologies, VSTO Add-In and the Visual Studio 2022 development environment, implementing support for hotkeys.

5. Consider the prospects for improving the algorithm, including support for additional languages and layouts.

Algorithm and implementation method

The developed algorithm for text conversion between keyboard layouts is based on a character matching mechanism using the `unordered_map` data structure. This approach provides quick access to the elements and minimizes the cost of text processing. For versatility, the algorithm includes tables of correspondences for both layouts (English and Russian). This allows you to perform text conversion in both directions.

The algorithm is implemented as a `convertLayout` function, which takes an input string and a table of matches, and then processes each character. If a symbol is found in the table, it is replaced with the corresponding one; otherwise, the symbol remains unchanged. This approach ensures high accuracy and preserves the structure of the text [2, p. 1].

The algorithm is integrated into the Microsoft Word text editor using COM API technologies and the Visual Studio 2022 development environment. The COM API provides access to selected text, which allows the user to convert text through the intuitive interface of the plugin. In addition, support for hotkeys is implemented, which speeds up the operation.

Stages of algorithm development

Creating a mapping table:

To convert the text, the `unordered_map` data structure was used, which provides quick access to the elements. Each character of the English layout is mapped to the corresponding character of the Russian layout (Figure 1).

```
std::unordered_map<char, char> engToRus = {
    {'q', 'й'}, {'w', 'ц'}, {'e', 'y'}, {'r', 'к'}, {'t', 'е'},
    {'y', 'н'}, {'u', 'г'}, {'i', 'ш'}, {'o', 'щ'}, {'p', 'з'},
    {'a', 'ф'}, {'s', 'ы'}, {'d', 'в'}, {'f', 'а'}, {'g', 'п'},
    {'h', 'р'}, {'j', 'о'}, {'k', 'л'}, {'l', 'д'}, {'z', 'я'},
    {'x', 'ч'}, {'c', 'с'}, {'v', 'м'}, {'b', 'и'}, {'n', 'т'},
    {'m', 'ь'}
};
```

Figure 1 – `unordered_map` data structure

Another rusToEng table was also created, which allows you to convert text from the Russian layout to English. This ensures the versatility of the algorithm and the ability to work in both directions (Figure 2).

```
std::unordered_map<char, char> rusToEng = {
    {'й', 'q'}, {'ц', 'w'}, {'y', 'e'}, {'к', 'r'}, {'е', 't'},
    {'н', 'y'}, {'г', 'u'}, {'ш', 'i'}, {'щ', 'o'}, {'э', 'p'},
    {'ф', 'a'}, {'ы', 's'}, {'в', 'd'}, {'а', 'f'}, {'н', 'g'},
    {'р', 'h'}, {'о', 'j'}, {'л', 'k'}, {'д', 'l'}, {'я', 'z'},
    {'ч', 'x'}, {'с', 'c'}, {'м', 'v'}, {'и', 'b'}, {'т', 'n'},
    {'б', 'm'}
};
```

Figure 2 – rusToEng table

A universal convertLayout function has been developed to implement two-way text conversion. It takes an input string (input) and a table of correspondences (layoutMap), after which it sequentially replaces each character of the string with the corresponding character from the mapping. If a character is not found in the table (for example, a punctuation mark or a space), it remains unchanged [3, p. 2].

The steps of the function consist of iterations for each character of the string. The algorithm consists of 3 main actions:

1. For each character, a check is performed to see if it is in the layoutMap table.
2. If a symbol is found, it is replaced with the corresponding one from the table.
3. If the character is not found, it is saved in the final row unchanged.

The result is transmitted to the user by sequentially combining the converted characters into a final string (Figure 3).

```
std::string convertLayout(const std::string& input, const std::unordered_map<char, char>& layoutMap) {
    std::string result;
    for (char c : input) {
        result += layoutMap.count(c) ? layoutMap.at(c) : c; // Замена символа или его сохранение
    }
    return result;
}
```

Figure 3 – The returned string

Interaction with the text editor is carried out through the COM API. The user selects the text, activates the function via hotkeys, and then the converted text is displayed in the document.

Stages of the algorithm operation

1. Create an unordered_map correspondence table that contains pairs of characters for text conversion between keyboard layouts (English and Russian). For the versatility of the algorithm, two subtables were created: engToRus and rusToEng, which allow you to perform the transformation in both directions.

2. The development stage of the convert function is converting a string from an incorrect layout to the correct one. All characters of the string are checked in turn. If there is such a symbol in the table, it is replaced, otherwise it remains unchanged. Thus, this function can process texts of varying complexity, checking both characters and letters.

3. As a result, the final string is returned to a new file, after processing each letter and all characters. The entire text view is saved.

Designing a macro for Microsoft Word in C++ using DN hotkeys (using the COM API) for a function that changes text to the desired layout:

In order for the function to change the text from the wrong location to the correct one and simplify it, we use the code to press the hot keys D and N. This requires two function calls from the Windows API GetAsyncKeyState('D') and GetAsyncKeyState('N'). This way, the user can press the keys at the same time, and the text will be converted to the desired format.

The function is called if the condition is met successfully. As a result, the function converts the selected string (Figure 4).

```
void TransformText(_ApplicationPtr wordApp) {
    // Получение выделенного текста
    SelectionPtr selection = wordApp->Selection;
    if (selection != NULL) {
        string originalText = (char*)(_bstr_t)selection->Text;
        string transformedText;

        // Логика преобразования текста (в верхний регистр)
        for (char c : originalText) {
            transformedText += toupper(c);
        }

        // Установка преобразованного текста
        selection->Text = transformedText.c_str();
        cout << "Текст преобразован успешно!" << endl;
    }
    else {
        cout << "Выделение не найдено." << endl;
    }
}
```

Figure 4 – The function of converting characters from an incorrect layout to the desired one in the Microsoft Word Selection program

To avoid another function launch, a pause was made using the TransformText function. Creating a Sleep (500) call ensures a delay of 500

milliseconds before each subsequent check. This way, the same block of text is not checked multiple times. This helps to improve the program's performance (Figure 5).

```
char key;
while (true) {
    // Ожидание горячей клавиши DN (например, D + N)
    if (GetAsyncKeyState('D') & 0x8000 && GetAsyncKeyState('N') & 0x8000) {
        TransformText(wordApp);
        Sleep(500); // Защита от повторных нажатий
    }
}
```

Figure 5 – Processing of the N and D hotkeys to call the text conversion function to the desired layout

Conclusion. The designed algorithm shows that high performance is possible with minimal resource usage, and it is an excellent text processing solution to change text to the desired layout. This algorithm can be implemented not only in Microsoft Word, but also in other text editors.

The main advantage of the proposed approach is the automation of error correction caused by the use of incorrect keyboard layout, which simplifies working with texts in both professional and daily activities. The proposed solution reduces the time required for manual text correction and reduces the likelihood of errors.

Future work may be aimed at expanding the capabilities of the algorithm, including support for other languages and layouts, as well as its adaptation for use in online platforms and mobile applications. Thus, the developed tool has significant potential for further development and dissemination in various fields of use.

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UDC 004

A SYSTEM FOR PLOTTING GEOGRAPHICAL BOUNDARIES ON A MAP BASED ON THEIR TEXT DESCRIPTIONS

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Аннотация. В современном мире ежедневно необходимо обрабатывать большой объем информации, и для упрощения решения таких задач следует использовать цифровые технологии. Примером задачи, требующей цифровизации своего решения, является определение географических границ требуемых участков на основе текстового описания. Источником текстового описания могут быть, например, официальные законы, решения органов местного самоуправления, судебные постановления. Решение данной задачи может быть достигнуто путем выбора текстового описания полигона (первая подсистема) и формирования координат полигона (вторая подсистема). Проведен анализ задачи, предложены и обоснованы подходы к реализации подсистем, обозначены преимущества и недостатки существующих инструментов в рамках задачи.

Ключевые слова: географический объект, координаты, точность, Яндекс.

Annotation. In the modern world, it is necessary to process a large amount of information every day, and digital technologies should be used to simplify the solution of such tasks. An example of a task that requires digitalization of its solution is to determine the geographical boundaries of the required sites based on a text description. The source of the text description can be, for example, official laws, decisions of local governments, court rulings. The solution to this problem can be achieved by selecting a text description of the polygon (the first subsystem) and forming the coordinates of the polygon (the second subsystem). The analysis of the task is carried out, approaches for the implementation of subsystems are proposed and justified, the advantages and disadvantages of existing tools within the framework of the task are outlined.

Keywords: geographical object, coordinates, accuracy, Yandex.

Introduction

Information technologies are actively used in a variety of projects, they allow you to speed up the solution of certain tasks, decomposing each one, and find out the most effective option. For example, modern technologies are used in construction and geodesy. One of the subtasks in such industries is the construction of various boundaries based on the names and coordinates of geographical objects: streets, house numbers, lakes, mountains, etc., and this is an urgent task today, as it is necessary in various areas of daily life and work.

For example, knowing the coordinates allows you to find the distance to the selected object, build the optimal route and find its length, taking into account time, road quality, etc. From the coordinates, you can calculate the area and size of the plots, this information can be used to design various objects: buildings, parks, architectural monuments, etc., This information is also used by cartographers, states to determine the boundaries of their territories, districts, cities.

Problem description

Working with coordinates for participants in such projects is complicated by the fact that the description of coordinates in the source documents is not structured, and this complicates the search and drawing of the boundaries of a given territory. The lack of a specific coordinate structure can manifest itself in various notation: coordinates are set as text (location addresses), coordinates are set in standard form using degrees and minutes, or written as numbers (degrees and their fractional parts). Coordinates in this form can be seen in legal documents, documents in the field of city management, outdated maps, most often even digitized. Automating the process of searching and separating coordinate data from the total mass of text into a separate entity and their subsequent transformation into a specific boundary on a geographical map will significantly reduce the cost of human resources, allow you to spend less time on maps and calculations, increase the accuracy of searching for the desired point, reducing the risk of the human factor – eliminating mistakes made automatically. All of these features are important within large facilities. In addition, borders often run not only through specific points, but also along streets, avenues, and along the borders of squares, parks, etc. This requires a complex algorithmic approach to clarify the specific points through which the border will be laid. That is why there is a need to automate the search for coordinates from the provided legal document, to develop a subsystem that allows you to convert text information describing the boundaries of a geographical area into a set of names and coordinates of geographical entities, which will be used in another subsystem designed to work with geocoding services and combine all points into a common geographical boundary, which will be displayed on the map. The input text data can contain both classical coordinates and names of streets, geographical features, their intersections and borders, with the further possibility of using the resulting polygon from points to construct a polygon with the boundaries of the territory or other geodesy tasks.

The proposed solution

To highlight the text description, it is proposed to use a neural network (this is the first subsystem). The resulting description will be used to form the boundaries after conversion to an array of points. But some points may not be

set by their coordinates, but only by an address, that is, indicating a street, house, square, avenue, or something else. This complicates the processing of such data and requires the use of external services designed for geocoding (obtaining the coordinates of a point in accordance with the specified address), which leads to the need to implement a second subsystem that will use geocoding in combination with algorithmic processing of various types of locations (point, street, square, etc.). At the moment, none of the existing solutions is capable of solving this problem.

For a task that implements the transformation of textual information describing the boundaries of a geographical area into a set of names and coordinates of geographical entities, existing solutions are neural networks for retelling, for example, from Yandex. This service allows you to retell any content, such as videos or articles, and it has its own characteristics, as it only works in the Yandex browser. The Yandex service uses its own YaGPT neural network. This is a language model that is integrated with Alice's voice assistant [4]. This model is similar in structure to another ChatGPT [6] neural network [2], but unlike the latter, it is trained using the Russian language, based on special data sets that contain Russian texts and a brief description of an early human creation. This neural network is trainable. It analyzes the received text, highlighting its main elements, keywords, based on which she builds a compressed copy of the text. This neuronet is great for texts, videos, articles, and some audio files, but it does not solve the problem of extracting coordinates from text documents. Its use only partially solves the problem, since it is impossible to extract coordinates from the text, and the model is not trained to find such objects. The existing solution to the geocoding problem is the snip website [3], where you need to enter a specific address and get the coordinates of this address. This system is a website with an interactive map, where it is possible to select an object by clicking on it or entering its name, street, or even coordinates into the search box. The disadvantages of this solution are: the inability to write down multiple addresses and get a tuple of coordinates, each address must be entered separately, which significantly increases the time it takes to find points on the map, and also makes it difficult to display a complete picture on which you can see the territory highlighted using borders. The advantage of this solution is the accuracy of coordinates: this site implements its work based on Yandex Maps [5], which, in turn, is also an existing solution to this problem, but this aspect reduces the fault tolerance of this solution, since it will depend on the performance of the two services.

All of the considered options are able to solve the problem of selecting key objects from a text document to some extent, but the situation becomes more complicated when it becomes necessary to take into account circumstances related to geocoding, for example, selecting coordinates and

forming a minimal sequence of them. In this regard, there is a need to develop a specialized information system designed to solve the problem of converting a textual description of a geographical boundary into a corresponding boundary on the map.

To convert a list of points in various formats, an additional subsystem is required that can determine the coordinates of each point in a given format, regardless of the format of the source information (coordinates in degrees, coordinates in degrees-minutes-seconds, or location address). This task must be solved using geocoding, but using one particular service is not a reliable solution, which leads to the need to look for more appropriate solutions to this subtask. Manual marking of geographical boundaries is available in the QGIS software [8] or in Saga GIS [7], however, these tools are specialized, that is, they have a high entry threshold, which imposes significant restrictions. At the same time, these software products were developed outside the Russian Federation and are currently not updated for users from Russia. In addition, automating the process of forming a geographical boundary based on a set of points is quite difficult, if at all possible, and therefore it would be good to have a means for automatically forming a geographical boundary based on an ordered set of points.

Conclusion

Thus, the rapid growth of the capabilities of modern technologies gives impetus to the development of a large number of areas in human life, from everyday and mundane activities to larger-scale tasks used in the fields of design, agriculture, geodesy, and other tasks related to geocoding. Every day, people encounter a lot of problems that help optimize and solve digital systems. So, there is a need to optimize the solution of problems related to geocoding. Modern technologies can make it easier to find coordinates of any format from a text document, and convert them into a convenient format for future use, for example, to plot borders based on these coordinates and then display them on geographical maps.

During the study of the subject area and the analysis of existing solutions, a number of their shortcomings were identified, due to which they are not able to fully solve the task. In this regard, there is a need to create a new solution. This study proves the need to create a system that can convert textual information into a set of polygon coordinates, and describes the structure and components of the solution. It is necessary to develop a system using a neural network that receives a text document as input data, processes the received data, converting them into polygon coordinates (a bank of points), in a format convenient for further use in other subsystems, for example, for building borders. Such a system will speed up the process of processing a large amount of information, visualize and structure the information received.

The rapid development of modern technologies, trends towards digitalization, and optimization of all life processes create new conditions for development, lead to the creation of new laws and advanced training of people in this field. At the moment, there is a federal law "On experimental legal regimes in the field of digital innovation in the Russian Federation" from 31.07.2020 N 258-ФЗ [1]. According to it, an experimental legal regime in the field of digital innovations is being introduced, which can be established in the following areas of testing, development, and implementation of digital innovations: "activities in the fields of architecture and construction; provision of various municipal and public services, control of various entities; in any other areas in need of resolving issues using digital technologies. methods". The introduction of special conditions makes it possible to exclude certain provisions (requirements, regulations, prohibitions, restrictions) of certain acts of general regulation for participants in the experimental legal regime program.

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ANALYSIS OF MODERN CODE GENERATION SYSTEMS

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Аннотация. В статье рассматриваются возможности современных больших языковых моделей в области автоматической генерации кода. Особое внимание уделено модели Claude Sonnet, проведен сравнительный анализ с другими популярными моделями, такими как GPT-4o и DeepSeek R1. Новизна исследования заключается в предложении комплексного подхода к оценке эффективности генеративных моделей по критериям точности, производительности и гибкости, а также в выявлении конкретных преимуществ Claude Sonnet для задач, связанных с автоматизацией разработки программного обеспечения.

Ключевые слова: генерация кода, нейронные сети, трансформаторы, Claude Sonnet, автоматизация программирования, ChatGPT 4o, DeepSeek R1.

Annotation. This article examines the capabilities of modern large language models in automatic code generation. Particular attention is given to the Claude Sonnet model, with a comparative analysis conducted against other popular models such as GPT-4o and DeepSeek R1. The novelty of this study lies in proposing a comprehensive approach to assessing the effectiveness of

generative models according to the criteria of accuracy, performance, and flexibility, as well as in identifying the specific advantages of Claude Sonnet for tasks related to software development automation.

Keywords: code generation, neural networks, transformers, Claude Sonnet, programming automation, ChatGPT 4o, DeepSeek R1.

1. Introduction

The automation of software development is a pressing challenge in today's information technology industry. As IT projects grow in complexity and scale, the workload on developers' increases, making it necessary to implement effective tools for automating routine coding tasks. One of the most promising solutions is the application of neural network-based code generation models built on transformer architectures and deep neural networks.

Contemporary models, such as GPT-4o by OpenAI, DeepSeek R1 by DeepSeek, and Claude Sonnet by Anthropic, are capable of effectively creating code based on textual descriptions while accounting for the task's context. These models feature varying architectural designs and training approaches, determining their unique advantages and limitations. Despite considerable progress in code generation quality, many unresolved challenges remain, including those related to the accuracy, performance, and flexibility of such systems.

This article provides a comparative analysis of GPT-4o, DeepSeek R1, and Claude Sonnet models in order to determine their effectiveness in practical automated programming tasks. The scientific novelty of this work lies in offering a comprehensive evaluation of the aforementioned models according to clearly defined criteria and in identifying optimal scenarios for their use.

2. Overview of Code Generation Models

Initially, code generation was carried out using simple expert systems and template-based rules. Subsequently, recurrent neural networks (RNNs) emerged, capable of generating code by processing token sequences; however, their effectiveness diminished with longer fragments due to the vanishing gradient problem [9, p. 826].

The introduction of transformer models, such as GPT and Codex, marked a pivotal breakthrough, as their self-attention mechanism significantly improved the quality and context-sensitivity of code generation. For example, Codex, based on GPT-3, was trained on billions of lines of code from open-source repositories, enabling it to solve many programming tasks successfully [6, p. 2]. Nevertheless, these models continue to face issues such as producing redundant or unsafe code.

Below are three of the most popular modern models employed for automating code writing [5, p. 1]:

GPT-4o is one of the latest models developed by OpenAI. It continues the GPT series and features an enhanced transformer architecture, enabling more efficient context processing and the generation of meaningful code. GPT-4o is trained on extensive datasets comprising diverse programming languages, granting it a high degree of versatility.

DeepSeek R1, created by the Chinese company DeepSeek, is oriented toward tasks requiring logical inference, mathematical analysis, and real-world decision-making [6, p. 1]. A distinguishing characteristic of DeepSeek R1 is the use of a Mixture-of-Experts (MoE) architecture, which efficiently allocates computational resources by activating only the necessary submodels for specific tasks. The model is trained using reinforcement learning (RL) methods, fostering advanced reasoning skills and the ability to solve complex problems.

Claude Sonnet, developed by Anthropic, specializes in program code generation tasks. Its architecture incorporates improved attention mechanisms and semantic analysis of code structure, enhancing accuracy and generation speed, minimizing errors, and adapting to various programming languages and development requirements.

3. Comparative Analysis of the Models

To objectively assess the performance of the code generation models Claude Sonnet, GPT-4o, and DeepSeek R1, three primary criteria were selected: accuracy, performance, and flexibility. A detailed evaluation of each model based on these criteria is presented below, drawing on available sources.

Accuracy of Code Generation:

Accuracy is defined as the absence of syntactic and logical errors in the generated code and its alignment with the given task.

Claude Sonnet. According to available data, the Claude 3.5 Sonnet model achieves 92.0% accuracy on the HumanEval benchmark, demonstrating its high effectiveness in automated code writing tasks.

GPT-4o. GPT-4o shows 90.2% accuracy on the same HumanEval benchmark, also indicating strong code generation capabilities.

DeepSeek R1. In contrast, DeepSeek R1 achieves 73.2% accuracy on the HumanEval benchmark, a figure slightly lower than that of Claude Sonnet and GPT-4o, though it still reflects the model's potential in code generation [7, p. 1].

Performance:

Performance refers to the speed of code generation and the computational resources required.

Claude Sonnet. The Claude 3.5 Sonnet model operates at twice the speed of its predecessors (Claude 2 and Claude 2.1), providing higher performance while maintaining accuracy.

GPT-4o. GPT-4o is optimized for faster code generation compared to its previous versions, making it suitable for tasks demanding quick response times.

DeepSeek R1. Thanks to its Mixture-of-Experts architecture, DeepSeek R1 efficiently distributes computational resources, activating only the submodels necessary for specific tasks, which enhances overall performance.

Flexibility:

Flexibility indicates the model’s capability to adapt to different tasks and programming languages.

Claude Sonnet. This model exhibits high adaptability to various programming languages and tasks, rendering it a versatile tool for developers.

GPT-4o. Owing to its diverse training data, GPT-4o can generate code in multiple programming languages, offering broad applicability.

DeepSeek R1. This model is geared toward tasks requiring deep understanding and logical analysis, making it particularly effective for specialized areas of programming.

Overall, each of the evaluated models offers unique advantages and can be effective depending on the specific requirements and conditions of use in programming automation tasks.

4. Comparative Testing of Models on a Real JavaScript Function Example

To investigate real-world effectiveness, three popular models used for code completion and generation—ChatGPT 4o, DeepSeek R1, and Claude Sonnet 3.5—were evaluated. In order to identify the most effective model, a practical task was considered: writing a “deepEqual” function in JavaScript to compare different data structures. The complete prompt given to the models was:

«Write a comprehensive deep equality (deepEqual) function in JavaScript that correctly handles all of the following edge cases:

1. Circular references in objects and arrays
2. Objects with different prototype chains
3. Symbol properties
4. Sparse arrays
5. NaN values (which should be considered equal to other NaN values)
6. DOM nodes comparison
7. WeakMap and WeakSet objects
8. Objects with getters
9. Maps and Sets with object keys

10. Nested complex data structures

Additionally, implement a memoized version of this function for better performance with repeated comparisons.

Your solution should be production-ready, well-commented, and handle all edge cases correctly. Include proper error handling and a thorough explanation of your implementation approach.

The function signature should be:

```
function deepEqual(a, b) {  
  // Your implementation here  
}
```

Also include a memoized version that caches results for better performance:

```
function memoizedDeepEqual() {  
  // Your implementation here  
}
```

Export both functions as a module. »

Test cases were also prepared for each specific scenario—18 tests in total.

The results obtained were as follows:

Claude Sonnet 3.5. All test cases were passed successfully [1, p. 1].

ChatGPT 4o. Only 4 out of 18 tests were passed. This model failed with proper memoization, circular references, the handling of Map objects, and other test scenarios [2, p. 1].

DeepSeek R1. Passed 12 out of 18 tests. The model struggled with date objects, regular expressions, circular references, and memoization [3, p. 1].

5. Analysis of Comparative Testing Results

In order to confirm and objectively assess the practical applicability of the considered code generation models (Claude Sonnet 3.5, ChatGPT 4o, and DeepSeek R1), a comparative test was conducted using a concrete example: implementing a complex deep equality function (deepEqual) in JavaScript. The task deliberately involved multiple nontrivial scenarios and special cases: circular references, different object prototypes, symbol properties, sparse arrays, NaN values, DOM nodes, WeakMap and WeakSet structures, getters, Map and Set collections using objects as keys, as well as intricate nested data structures. Additionally, a memoized version of the function was required for optimizing repeated calls.

The test results were as follows:

Claude Sonnet 3.5 successfully handled all challenges presented, passing 18 out of 18 test cases [1, p. 1]. The model exhibited high accuracy, correct handling of circular references, effective memoization, and complete coverage of all specified conditions.

ChatGPT 4o performed significantly worse, passing only 4 out of 18 tests [2, p. 1]. It failed to properly address circular dependencies, memoization, handling of Map and Set collections, and other complex scenarios. This indicates that further fine-tuning or architectural enhancements are needed for more complex tasks.

DeepSeek R1 showed a middle-range outcome, passing 12 out of 18 test cases [3, p. 1]. Its main shortcomings involved improper handling of circular references, dates, regular expressions, and memoization. Although it offers considerable improvements in logical inference and mathematical analysis, this model still requires enhancements in its context-analysis mechanisms and in handling complex data structures.

Thus, the testing results highlight the clear advantage of Claude Sonnet 3.5 for tasks involving highly complex, diverse edge cases in automated code generation. At the same time, GPT-4o and DeepSeek R1 appear promising but require further optimization and refinements for comparable use in similar scenarios of development automation.

6. Prospects and Future Developments

Research and development of neural network code generators continues in both academic and industrial settings, creating ever more opportunities for improving tools and development practices.

Deep IDE Integration. Over time, generators are expected to become an integral part of integrated development environments, not only completing code but also analyzing an entire project, suggesting refactoring and optimization, and automatically identifying vulnerabilities.

Enhanced Model Personalization. Developers will be able to train models on their companies' private repositories, ensuring closer adherence to corporate coding standards and styles. Meanwhile, data security issues will become increasingly pressing.

Refined Code Semantics Understanding. The future lies in architectures that do more than simply manipulate textual tokens but actually "understand" the objectives and logic of a program. This will require methods that combine deep learning and symbolic approaches (neurosymbolic systems).

Expansion of Applications. It is conceivable that neural networks could manage not only code generation but also documentation, testing, and integration with external services, functioning as a "digital assistant" throughout the entire software lifecycle [4, p. 2].

Thus, continued advancements in hardware resources, training algorithms, and the development of specialized datasets will inevitably boost the quality of code generation. At the same time, it is important to maintain awareness of legal and ethical regulations and to adapt educational programs so that future specialists can effectively collaborate with neural network tools.

7. Conclusion

Code generation based on neural network models has emerged as one of the most promising directions for automating routine development tasks. According to a number of recent studies [4, p. 14], the Claude Sonnet family of architectures outperforms other popular LLM models (GPT, DeepSeek) in terms of accuracy and stability, especially when handling syntactically complex constructs. Their effectiveness is largely attributable to in-depth attention to the structure of program code and grammatical elements, as evidenced by lower rates of syntactic and logical errors.

Nevertheless, there remains a need for further research into security, copyright, and the semantic understanding of business logic. At the same time, it is evident that high-quality code generation automation will exert a growing influence on the IT industry by expediting prototyping, reducing the burden on developers, and increasing overall accessibility to programming for a broad range of specialists.

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AUTOMATIC IDENTIFICATION OF PROBLEMATIC ONLINE DISCUSSIONS

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Аннотация. Данная статья описывает методы автоматического определения проблемного онлайн дискурса. Проблемный дискурс характеризуется тенденциями к спору, различиями во мнениях, враждой и подобными качествами. Была выдвинута классификация методов обработки на основанные на дискуссиях и основанные на темах дискуссий. Четыре конкретных конвейера обработки были исследованы на возможность выделять маркеры проблемного дискурса. На примере данных социального медиа Reddit была подтверждена способность всех конвейеров находить такие проблемные коммуникации. Притом был отмечен большой успех методов, основанных на темах дискуссий. Более того, дальнейшие вызовы и ограничения предложенных методов были обозначены

Ключевые слова: Обработка естественного языка, машинное обучение, конфликт, онлайн дискурс, общественные исследования, обработка данных социальных медиа.

Annotation. This paper describes methods of automatic identification of problematic online discussions. Such problematic discourse is characterized by arguments, difference of opinions, possible hostility and the like. A classification of discussion-based and topic-based approaches was introduced. Four specific pipelines were explored and found to be capable of producing markers of problematic communications on a sample dataset from the social media platform Reddit. Topic-based pipelines were found to be more successful. Furthermore, current challenges and limitations of methods were outlined.

Keywords: Natural language processing, machine learning, conflict, online discourse, social studies, social media mining.

Nowadays most interpersonal communications happen online through popular social media platforms. Countless discussions that are held publicly serve as an invaluable source of data regarding the latest general opinion about various topics. One way to draw insight from the aforementioned data is to identify problematic discussions: instances of communication that can be characterized by argumentative nature, difference of opinions and hostility. Then the information about such topics of contention can be used in various ways: from gauging social trends to guiding official policy. While the research into such discussions proves to be useful, several problems quickly arise. Firstly, it quickly becomes prohibitively expensive to manually analyze the vast amount of data of social media. Therefore, methods of automation must be considered for the task, particularly tools from the field of natural language processing (NLP). Secondly, due to the inherent indeterministic nature of modern NLP tools that are based on machine learning techniques, additional attention must be paid to ensure reproducibility and interpretability of the analysis.

As such, this work aims to explore methods of identification of problematic online discussions that perform best against modern challenges. Consequently, the following tasks were put forward:

1. Describe possible methods of identification of problematic online discussions;
2. Validate the methods on sample social media data;
3. Outline limitations of proposed methods.

First and foremost, two approaches to identifying topics of problematic discussions can be singled out. On the one hand, it is logical to find all the instances of heated or argumentative communications in form of direct replies and then to extract all the keywords or named entities as topics of discussion from those instances. It will guarantee that the extracted discourse is, in fact, problematic by some definition. However, it may become more difficult to extract the exact objects of discussions, as the probability of deriving unrelated lexemes rises. Given the text of a specific discussion between individuals with little context, many NLP tools will struggle to differentiate between important concepts and things mentioned in passing. Such methods will be referred to as discussion-based. On the other hand, it is possible to start with establishing meaningful topics based on the entire data and then to gauge the level of consensus around any given topic. As such, irrelevant issues can be effectively discarded, as the full context of communications allows to measure the significance of any given term. Yet the notion of a discussion becomes somewhat distorted, since conflicting views on the same topic can arise in separate dialogues. These methods can be referred to as topic-based. All in all, both categories serve to produce lists of lexemes that are often featured in

problematic discourse, allowing identification of conflict in future communications.

Topic identification can be achieved in numerous ways. The easiest way is to consult domain area expert to build a list of common points of contention that may be present in the dataset. These issues may be further compared and ordered based on their incidence, for example. Unfortunately, this method is ill-suited for cases when domain experts are unavailable or there is little prior knowledge about the data at hand. As such, automatic procedures are often considered, for example named entity retrieval or keyword extraction. Named entities encapsulate locations, people, events and many more, so they most naturally coincide with the notion of a conversation topic. Keywords tend to be broader, capturing adjectives and the like. Modern tools for retrieval of keywords and named entities are of stochastic nature, being implemented in a form of artificial neural networks. Therefore, usage of such tools should come with the acknowledgement of the statistical significance of their output. In practice, it usually means that a manual review of extracted terms is necessary or, at the very least, some extracted terms with lower confidence scores are filtered out. Less obviously, choice of the specific neural network, more commonly referred to as model, requires additional consideration. While choosing between large number of open models, it is important to consider the data that was used to train any given tool. The final product may have become unintentionally biased towards some type of texts or tokens, rendering it less useful, in case the target dataset is significantly different from the training examples.

Similarly, identification of problematic discussions can be accomplished in different ways. It is possible to use special kinds of models that classify texts as problematic, as defined by toxicity, for example [2, p. 6804]. This naturally makes it necessary to consider model biases, as outlined previously. More interesting use case of models to gauge problematic communications relies on sentiment analysis of texts. Such tools estimate the emotions that are conveyed by a message, which helps to judge semantic content of text in certain types of discussions. For example, if one message about a politician is marked with «joy», while another message about the same person is characterized by «disgust», then it can be reasonably concluded that an argument may happen in the discussion. Models of sentiment analysis usually output a vector that encodes the degree to which all the emotions are expressed in the input. Therefore, several techniques can be considered to aggregate these vectors into scalars, that specifically characterize consensus, or lack thereof, in a given conversation. One approach to produce a divergence scalar is to average out the distances between all the vectors, regarding one discussion or topic. Larger average distance signifies more discord and less

agreement in the discourse. While this operation is simple and natural, it fails to capture the difference between concise and broad discussions. As such, a discussion with 2 emotion samples may have the same divergence score as a discussion with much more samples. Yet, a discussion with large number of different opinions can usually be regarded as the one with less consensus. To accommodate this, emotional divergence score may be computed as a sum of standard deviations of each emotion vector component. This will naturally penalize conversations with many samples, as each observation adds non-negative value to total consensus estimate. This operation can be thought of as approximating the perimeter of the territory that observations take up in emotion space.

Having considered the ways to identify objects of discussion and characterize whole conversations, comprehensive pipelines for identification of problematic discourse can be constructed using open NLP models. As for discussion-based methods, it is proposed to first select discussions based on toxicity classifier model, such as the «roberta_toxicity_classifier» [2, p. 6807]. Toxicity in this case is related to notions of rudeness and disrespect shown in conversations. Then, the topics of the problematic discussion can be approximated by named entity retrieval model such as «wikineural-multilingual-ner» [4, p. 2522]. Another pipeline that is worth exploring is based on sentiment analysis. Firstly, emotional connotation of all direct communications is assessed with the «bert-base-go-emotion» that measures 28 different emotions [1]. If emotional vectors are sufficiently dispersed, the discussion is considered problematic and the discussed topics are extracted with the «wikineural-multilingual-ner» model. Moving on to topic-based methods, the first one to consider starts with picking out objects of conversations with the «wikineural-multilingual-ner» model. Then, the consensus around such issues is estimated by the dispersion of emotional vectors that are inferred with the «bert-base-go-emotion» model. This topic-based method, in essence, features the same steps as the previous pipeline of discussion-based category, however it aims to capture all the context around discussion topic, even outside of direct replies. Lastly, another pipeline was designed that starts with topic extraction based on keywords using the «bert-uncased-keyword-extractor» model [5]. The motivation behind this change is the desire to capture larger group of topics that could not have been identified as named entities. After that, problematic topics are once again estimated based on expressed emotions, that are calculated with the «bert-base-go-emotion» model.

To validate and compare described pipelines of identification of problematic discussions, an example dataset was collected. Primarily English-speaking social platform known as Reddit was chosen as the source. Reddit

was chosen due to the offered API that makes it trivial to collect large amounts of data automatically. Moreover, having communications in english allows for easy interpretability of the results. Communications on Reddit can be described as a blend between older forum-based publications and more modern social media features like replies, feeds and follows. Users are free to create and follow subreddits – communities that welcome discussions of some particular topic. Inside the subreddit users create submissions that serve as a starting point of conversations, allowing other users to freely leave comments under such publications, creating reply chains. All these facts enforce a strict hierarchical order of communications in a form of a tree of replies. Thus, a discussion can be thought of as the aggregation of any message and all the parent messages being replied to. Every submission or comment can be upvoted or downvoted by users, which naturally builds popularity rating of content. The primary use of such rating is to order publications in user feeds. Reddit offers several feeds for both submissions and comments that rely mainly on recency and votes that messages receive. In the end, it was chosen to focus on discussions that took place in the community «r/Economics» between the 6th of February 2025 and 6th of March 2025. It is known that the community in question facilitates discourse regarding economic policies which, in common wisdom, are highly likely to bring forward controversy. Coupled with the enormous number of messages posted every day in this group of 5 million members, the dataset is bound to contain examples of problematic discussions. Submissions from the timeframe were ordered by «top» feed, that prioritizes publications with more upvotes and comments.

Collected data is stored in a table, in form of a CSV file. Submissions and comments alike are aggregated into the concept of record – any message with its own identifying number, author, parent record, vote rating, creation date and textual content. Not all of the described fields are necessary for the validation of the pipelines as described, but were included to make the dataset origin verifiable. Data was collected with custom Python script that utilizes PRAW package [3]. In total, 41522 records were collected, authored by 14650 different users. All records belonged to 574 submissions, which were mainly posted with «news» tag. Across all of the submissions, 21409 separate discussions were identified, defined as non-overlapping paths from the root record to the leaf comments.

As for discussion-based methods, toxicity pipeline has identified 4133 individual problematic messages. This classification was conducted based on 0.90 threshold – if the model predicted at least 0.90 of the message to be toxic, then the message was considered problematic. A total of 625 named entities with at least 0.95 model confidence were extracted from marked messages, building a list of markers of problematic discourse. Moving on to the next

pipeline of emotional dissimilarity, all 21409 conversations had their messages aggregated to calculate the sum of standard deviations of 28 dimensions of emotion estimates. The divergence values were distributed between 0.01 and 0.83 in a normal fashion with a significant skew towards lower values. It was decided to mark discussions with at least 0.3 value of dissimilarity as problematic, yielding 16081 of such conversations, accounting for 36194 messages. 3121 unique problematic entities with at least 0.95 model confidence were retrieved from these chains of messages.

In turn, topic-based method of named entity retrieval has found 3634 topics of discussion with at least 0.95 confidence in the whole dataset. After the emotion vectors were aggregated by the topics of the message, 1183 entities with 2 or more mentions were found. The dispersion of emotion vectors of those entities was computed, yielding values between 0.00 and 0.66. However, the distribution of the values was skewed towards the higher ones. Moreover, around 10% of all topics scored 0.05 or below. The median of around 0.35 was chosen as the threshold, meaning that 592 topics were designated as problematic. The produced list of words marked 17802 messages as containing problematic discourse. The last pipeline, which is based on keywords, identified 6379 topics with similar 0.95 prediction confidence. Of these keyword topics, 3785 were found to have 2 or more emotion estimates. The values of emotional dispersion ended up being distributed between 0.00 and 0.72, with a skew towards higher values. Similar to the previous method, sizable portion of around 10% had values of 0.13 and below. Therefore, the median of 0.38 was chosen as the threshold for classification of problematic topics. All in all, a list of 1893 markers was produced, identifying 24536 messages as problematic.

Overall, the performance of different pipelines varied significantly. The method based on toxicity estimation has produced the least number of markers and marked messages. In comparison with other pipelines, it is evident that this definition of problematic discussion is too limited, resulting in many instances of controversy in discussions being missed. Although, it is notable that around 50% of the entities, identified by toxicity, coincide with entities, identified by emotional divergence. Moving on, discussion-based pipeline with emotional divergence led to discovery of the greatest number of problematic topics and messages. In fact, this method has marked roughly 87% of all records as problematic. Therefore, it is reasonable to conclude that this procedure has mostly failed to meaningfully assist in the task of identification of problematic discourse. It is possible that evaluations of sentiments of any conversation in general tend to naturally diverge, regardless of the semantics, leading to misidentifications. On the other hand, both topic-based pipelines have shown more reasonable output. As expected, keyword identification has

produced a broader list of markers. Even though the keyword model has extracted three times as many topics as the named entity retrieval one, the keyword pipeline marked only 50% more messages than the other one. This fact suggests there is significant co-occurrence of keywords in the dataset, making them slightly less informative for the task.

Several common limitations between the pipelines as described can be identified. Firstly, all but one method relies on the concept of emotional dissimilarity in problematic discussions, even though such conversations might be conducted within one sentiment. Toxicity was considered as a measure of conflict specifically to account for such discourse, yet that pipeline has not produced satisfying results. Furthermore, the task of sentiment analysis of messages is heavily subjective, as the appropriate models had to be trained on manually marked data, opening even more possibilities for biases. That ultimately means that no proposed pipeline can be more accurate than underlying sentiment analysis model. Additionally, the lack of ground truth to accompany the dataset makes the comparison of the models more difficult. Thus, whether or not each message contains differing opinions, hostility or other characteristics of problematic discourse can only be verified manually. Even though it is easy to verify that each of the pipelines can identify problematic conversations, it still is hard to estimate the accuracy of the methods. Lastly, the question of generalizing ability of identified markers remains open. It is not trivial to estimate how useful the topics of problematic discourse, that were found out from one dataset, will be when applied to different data. Doing so will require assistance from domain area expert, who can determine how closely observed communications follow actual social trends.

In conclusion, 4 methods for identification of problematic online discussions were evaluated. All of the pipelines achieved some degree of automation through use of computer software in form of machine learning models to cut down the amount of data that needs to be reviewed. Additionally, the specification of methods and their thresholds ensured significant levels of reproducibility of the experiments, even in the face of stochasticity introduced by the tools used. As such, the described pipelines can provide utility in numerous use cases for conflict detection, mainly in social science. Moreover, topic-based approaches were found to be more successful, as discussion-based attempts pointed out either too few or too many problematic messages. Still, some challenges related to emotion-based detection and data validation remain.

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UDC 004.9

INTELLIGENT CLIMATE CONTROL SYSTEMS FOR HEALTHCARE BASED ON IOT AND AI TECHNOLOGIES

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Аннотация. В статье рассматриваются интеллектуальные системы климат-контроля для медицинских учреждений, основанные на технологиях Интернета вещей (IoT) и искусственного интеллекта (ИИ). Описаны ключевые элементы таких систем, включая вентиляцию, температурное регулирование, контроль влажности и адаптацию параметров микроклимата на основе биометрических данных пациентов. Проведен краткий обзор существующих решений и предложена архитектура IoT-системы. Обозначены перспективы интеграции с мониторингом состояния пациентов и развития в рамках концепции «умной больницы». Преимущества включают снижение затрат, повышение безопасности и автоматизацию медицинской среды.

Ключевые слова: климат-контроль, IoT, искусственный интеллект, микроклимат, медицинские учреждения, автоматизация, мониторинг пациента, умная больница.

Annotation. The article explores intelligent climate control systems for healthcare facilities based on Internet of Things (IoT) and Artificial Intelligence (AI) technologies. It outlines the key components of such systems, including ventilation, temperature regulation, humidity control, and the adaptation of microclimate parameters based on patients' biometric data. A brief overview of existing solutions is presented, and an architecture for an IoT-based system is proposed. The article also highlights the prospects for integration with patient monitoring systems and the development of such technologies within the framework of the “smart hospital” concept. The advantages of these systems include cost reduction, increased safety, and the automation of the clinical environment.

Keywords: climate control, IoT, artificial intelligence, microclimate, healthcare facilities, automation, patient monitoring, smart hospital.

Introduction

Modern healthcare facilities impose high demands on environmental conditions. Maintaining an optimal microclimate in patient wards, operating rooms, and intensive care units is critically important for ensuring the safety of both patients and medical personnel. Studies show that stable climate conditions directly influence the speed of recovery, reduce stress levels, and help prevent complications. This issue became particularly relevant during the COVID-19 pandemic, when airborne transmission emerged as the dominant route of infection. The implementation of IoT and AI technologies opens up new opportunities for creating intelligent climate control systems that can adapt to the individual needs of patients, providing a stable and safe environment.

Components of an Intelligent Climate Control System

The key modules of such systems include intelligent ventilation equipped with HEPA/ULPA filters and ultraviolet air disinfection, temperature regulation that accounts for patient preferences and physiological parameters, humidity control based on predictive artificial intelligence algorithms, and air quality assessment using sensors for carbon dioxide, volatile organic compounds, and particulate matter. Additionally, the system incorporates an interface for integration with patient monitoring platforms. The architecture may also include a data acquisition gateway, a cloud-based processing platform, an administrator interface, and analytical dashboards, enabling seamless integration of the climate control system into the broader infrastructure of a healthcare facility.

Thanks to a network of sensors connected through an IoT platform, it becomes possible to collect and analyze environmental parameters in real time. Machine learning algorithms enable the identification of patterns, prediction

of changes, and adaptive control of the system. For example, when a patient's body temperature rises, the system can automatically lower the ambient air temperature and increase humidity levels. The use of predictive models allows the system to respond to deviations before they become critical. One of the most promising directions is personalized climate control based on the patient's biometric data. The system's response can be mathematically modeled using the following formula:

$$T_{\text{target}} = T_{\text{base}} - \alpha \times (T_{\text{body}} - 36.6) + \beta \times (\text{SpO}_2 - 95)$$

where:

- T_{target} – target room temperature;
- T_{base} – baseline preset temperature;
- T_{body} – patient's body temperature;
- SpO_2 – blood oxygen saturation level;
- α, β – system adjustment coefficients.

This model enables the adaptation of climate parameters to the physiological characteristics of each individual patient.

Practical Implementation and Examples

Intelligent climate control solutions are being implemented in large medical centers. For example, systems such as Philips AirDisinfection and Siemens Desigo CC integrate climate regulation, lighting, and security into a unified platform. In the future, the development of open API interfaces and modular architectures is expected, enabling regional and private healthcare institutions to adopt such systems. Another promising direction is the integration of wearable patient devices for dynamic environmental adjustment. Intelligent climate systems may include features such as temperature control via IoT sensors and AI algorithms to maintain target ranges based on patient indicators; air quality monitoring using gas and particulate sensors to reduce the risk of hypoxia, allergies, and infections; humidity control based on predictive algorithms to prevent mold and maintain mucosal comfort; and integration with electronic medical records via API interfaces to automate climate adjustments.

The diagram below illustrates the architecture of an intelligent climate control system in a healthcare facility:

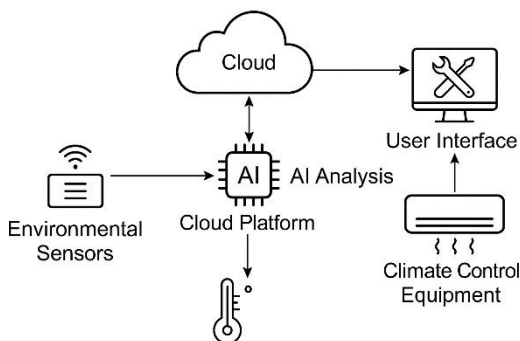


Figure 1. Architecture of a Cloud-Based IoT Climate Control System

Intelligent climate control systems based on IoT and AI represent a promising direction for the digital transformation of healthcare. They enable the creation of a personalized, energy-efficient, and safe environment for both patients and medical staff. Future research may focus on integration with wearable devices, standardization of data exchange protocols, and ensuring cybersecurity in the operation of medical IoT networks.

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SECTION 3: HISTORY, POLITICS, CULTURE, THEOLOGY, SOCIOLOGY



UDC 94(370)

FEATURES OF THE GOVERNMENTAL ORDER SYSTEM ORGANIZATION IN THE RUSSIAN STATE IN THE XVI-FIRST QUARTER OF THE XVIII CENTURIES

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Аннотация. В данной статье поднимается проблема организации и функционирования отраслевых органов центрального управления (приказов) в Русском государстве XVI-первой четверти XVIII вв. Руководствуясь принципом историзма, применяя метод сравнительного анализа автор выявляет факторы трансформации приказной системы. Значительное внимание уделяется как положительным, так и отрицательным характеристикам функционирования приказов.

Ключевые слова: Приказ, боярская Дума, государственное управление, «приказные люди», дьяки

Annotation. The problem of the organization and functioning of sectoral bodies of central government (order) in the Russian state of the 16th-18th centuries is considered. Using the method of comparative analysis, the author identifies the factors of transformation of the prikaz system guided by the principle of historicism. Considerable attention is paid to both positive and negative characteristics of the functioning of orders.

Keywords: order, Boyar Duma, state administration, “commanding people”, clerks

The history of Russian statehood comprises eleven and a half centuries. The Russian Federation, formed as a result of the collapse of the USSR, is the successor of ancient Rus', the Russian Empire and the USSR. It is one of the

many forms of Russian statehood [7]. The system of power and governance in Russia is enshrined in the Constitution adopted on December 12, 1993.

The relevance of the research topic is determined not only by the significant role of orders in society, but also by the need to study the experience of the past for the development of a new state structure. The article covers the period from the end of the 15th century to the beginning of the 18th century.

The aim of the study is to classify the orders, identify the factors and features of their transformation using comparative analysis. They are important in the history of the Moscow state, and arose under the Grand Dukes of Moscow. Orders are bodies of central government administration in Moscow that were in charge of a special type of state affairs or individual areas of the state. They were also called chambers, huts, courtyards, palaces, thirds or quarters.

The period of Russian state strengthening and development started in the 16th century. The bearer of supreme power had the title of “Grand Prince of All Rus’”, and from 1547 - “Tsar”. “In the first half of the 16th century, it included less noble feudal lords - “*okolnichy*”, representatives of the knighthood and service bureaucracy - Duma nobles and Duma clerks, the latter were engaged in office work” [9, p. 64]. Together, the Duma and the Tsar passed laws, directed orders, controlled local government, made decisions regarding the reorganization of the army, land and other matters. During the reign of Ivan IV, the composition of the Duma increased almost threefold due to the introduction of representatives of less noble families and like-minded people of the tsar. A group of people with whom the tsar decides the main issues is selected from the Duma, the so-called “room” or “close thought”.

The creation of a centralized state led to the need to restructure the governing bodies. It can be said that centralization was the reason for the emergence of orders. By the middle of the 16th century, a central government order system was created. It was formed gradually over the course of a century. Metropolitan Macarius played a decisive role in the creation of the new ruling body. He was an associate of Tsar Ivan IV, contributed to his ascension to the throne, was the head of the church, which was a powerful mechanism supporting the unification of the principalities around Moscow. Macarius and the loyal confidants of the young Tsar created a new government - the “Chosen Council”. The most authoritative politicians among them were Adashev and Sylvester. The main task was to create authority, both for the royal title and for the person of the tsar. By creating a new government based on a tripartite compromise (feudal aristocracy, service nobility, tsar), the tsar had to abandon the demands for absolute power and limit himself to the role of chairman.

On February 27, 1549, a meeting was held where Ivan IV presented a broad program of consolidation and internal reforms to the Boyar Duma, which was present at the meeting in full force. In essence, this was the first Zemsky Sobor. Ivan the Terrible ended his speech with a call to forget all grievances, unite and act for the common good.

“Reconciliation Councils” - “this is the name given to the councils that were convened by the Tsar and Metropolitan Macarius. The “Chosen Council” began to create central organs of state administration - orders (called “huts” until the mid-60s)” [3, p. 90]. One of the initial orders was the Petitions Hut, headed by Adashev. The task of this institution was to accept petitions (complaints) addressed to the sovereign and conduct an investigation into them; a kind of Petitions Hut represented the highest control body. The Ambassadorial Order (the department of foreign affairs) was headed by clerk Ivan Mikhailovich Viskovaty. The duties of the Local Order included the distribution of estates and patrimonies among service people.

The Discharge Order became a kind of headquarters for the armed forces: it determined how many service people and from which districts should join the regiments. “The Robbery Order was aimed at combating criminal offenses” [3, p. 128].

To strengthen the new monarchical state, a decisive replacement of the predatory apparatus of local government that had developed under the rule of the boyars was required. The issue of creating an apparatus of officials was on the agenda. The most effective way to solve it was to elect the local officials themselves to perform state functions.

After the death of Ivan IV (the Terrible), a shift occurred from zemstvo to voivodeship administration. The holding of the Zemsky Sobor in 1613 and the election of a representative of the Romanov family as tsar led to the question of the need to combine direct leadership from Moscow and local self-government.

The government of Mikhail Romanov was forced to rely in its actions on the existing practice of local self-government and the authority of the Zemsky Sobors. Thus, since 1613, an estate-presidential monarchy has prevailed in Russia. The order was headed by a judge, usually a member of the Duma.

Each order or court huts had two guards who opened the door for those who could give money, and closed the door for those who did not have money. In each order, all cases were recorded in books. In all orders there were sub-clerks - assistants to the clerks. Their number depended on the order: from 20 to 50 [6, p. 16]. The duties of the sub-clerks included a fair copy of the charters, which were then certified by the clerk with his signature. After that, the charter was glued together, a rather complicated procedure. The glued parts were written in such a way that it was impossible to forge the charter. In other words,

the charter had strong protection against falsification. The orders were periodically revised in accordance with the decree of the sovereign. The work of the orders was streamlined.

Over time, special books were created to record decisions made by the clerks. Various documents were issued by orders: charters of privilege, decrees on behalf of the tsar, memos, orders-instructions to officials, reports and torture charters. The charters were systematized, and consolidated documents were issued - statutory charters.

The supreme authority took measures to force the orders to monitor the execution of their decrees. A significant problem of the orders was observed in the delimitation of their competence. "As a result of the fact that several orders could handle the same matter, there were quite a lot of collisions in the Muscovite kingdom" [1, p.34-35].

Orders can be classified as follows: state, palace and patriarchal. The former is divided into domestic and foreign policy. Domestic orders consist of regional, national and military. Orders aimed at foreign policy are divided as follows: institutions performing diplomatic functions and military.

A system of state power institutions was created in the center and locally at the beginning of the 17th century. It implements the functions: financial, administrative, military, judicial, etc.

"The idea of a strong state was strengthened after the Time of Troubles of the 17th century, so Mikhail Fedorovich took measures to strengthen the system of state power. The growth of the tsar's power was based on the strengthening of the state apparatus, on the formation of its character in a bureaucratic direction" [4, p. 60].

"The Boyar Duma remained the most important state body, which shared supreme power with the tsar. Its composition increased significantly, especially due to the nobility and Duma clerks. The Duma was the supreme body for legislation, administration and judicial practice. The tsar discussed the main important issues with the Boyar Duma" [4, p. 60], and on minor ones, decisions were made independently.

The main moment of development of the orders was a sharp increase in the number of people employed in them, resulting from the specified expansion of the sphere of their activity, who received the name "order people". Order people are a special, class group of service people, whose main duty was to work in state institutions in the center and in the localities.

In the 60s, "their number amounted to 842 people" [1, p. 33]. The main issues that the order people of the central and local institutions considered were related to the judicial, administrative and financial aspects of their activities. The number of clerks in the system of central institutions remained practically unchanged: "with a general increase in their number to 117, 67

clerks were employed in the orders” [1, p. 34-35]. The clerks usually had the responsibility for making notes on documents.

“The number of Moscow clerks increased to its maximum in the 1970s. The expansion of the clerk staff was not controlled from above; the initiators of this process were judges and clerks and were dictated by the internal needs of the institutions” [2, p. 171].

“In the 80-90s, the entire order group continued to grow: by 1682 it comprised 1,785 people, and in 1698 – 2,739 people, i.e. since the 70s it had almost doubled” [2, p. 173]. “The bulk of the sub-clerks were concentrated in orders of national importance, especially in large ones (Local, Great Treasury, Great Palace)” [2, p. 173]. By creating such a huge army of Moscow sub-clerks, the high mobility of this group was laid at its foundation.

In the 70s of the 18th century the state apparatus of the Russian absolute monarchy was formed. Significant changes are taking place in local government, although in its development it continues to defend itself from the center. “By the mid-1970s the term “order hut” was established everywhere, although the old name “sezzhaya” remained in use” [1, p. 316].

The allocation of discharge huts and order chambers created institutions of an intermediate type, anticipating the future provincial chancelleries of the 18th century. As in the orders, in local institutions as a whole there was a noticeable increase in staff. In 1649, the Zemsky Sobor adopted a new set of laws - the Cathedral Code. The main goal of the Code was to systematize legal norms; little attention was paid to the procedural side. “When new governing bodies were introduced or the competence of previously created orders acquired important significance for the state, only then did the Code pay special attention to them (Monastic, Printing, Streletsky, New Quarter). Most orders simultaneously performed the functions of both administrative and judicial bodies” [5, p.24-25].

“The detailed coverage of legal proceedings and procedural issues in the Code could not help but lead to a mention of the activities of those orders, first of all, whose duty was to consider cases related to their branch or territorial purpose. Large orders – such as the Local, Kholopy and Razboiny – could not be indicated by their direct purpose” [5, p.83-84].

The order system was distinguished by a complex but orderly structure. There were no inconsistencies there. The paperwork proceeded according to a pre-determined plan. In the court, there were many reports of that time, on which no decisions were made. In the tax order books of Tsar Alexei, it is clear that such and such income was not received, that it became arrears.

The inability of the clerks to act independently, acceptable for the small estate of the Moscow princes, became destructive in connection with the arrangement of affairs and the growth of the state. The tsars were afraid to give

free rein to the clerks, to lose control over them and, as a result, found themselves overwhelmed with a mass of unimportant reports, depriving them of the opportunity to carefully consider essential and important matters. There was practically no organized system in the Moscow orders: it was rather a "heap of large and small institutions, ministries, offices and temporary commissions." The number of orders and the disorderly division of departments within them complicated the control and direction of their activities: sometimes the government had difficulty considering an unusual case and, without thinking, created a new order for it. Because of this, it became necessary to pull together the too disorganized central administration. Two ways were used to concentrate it: several average departmental orders were subordinated to one leader, or several orders were combined into one institution. In the first case, a group of orders was assigned one leadership and direction, in the second, several orders were given the same organization.

The system of orders was a multi-stage structure. It can be assumed that at the beginning of the century it operated with minor failures, as a result of which new orders began to be formed. The increase in the number of institutions led to each of them having fewer functions.

Thus, analyzing the above, we can conclude that the system of central institutions can be compared to a centuries-old tree. The roots, the foundation are the traditions that have developed over centuries, the trunk is the class-representative monarchy, and the huge green crown is formed by orders and commissions. During the reign of Peter, I, the form of the state apparatus changed, however, the tsar did not create his boards, the Town Hall and other institutions from scratch. He used some of the functions and people from the orders that existed earlier. Although the new ruler was oriented towards Europe and created new bureaucratic institutions, the orders, one way or another, interacted with them for a long time. Only the successors of the emperor completed the formation of the noble bureaucratic layer. The time frame of this process is the beginning of the 18th century - the 60s of the 18th century. It can be noted that at the beginning the new bureaucratic system relied on the old one and logically followed from all the events and phenomena of the 17th century.

It would be wrong, while pointing out the shortcomings of the system of orders, to remain silent about its advantages. It was noted earlier that the order people, who did not have a general or professional education, were in fact smart men who had mastered the technique of the business well through practice. They carried out their work easily, but if any new questions arose, when the help of the old times was insufficient, then they became helpless. However, many of the shortcomings of the later bureaucracy were alien to them. They understood the everyday needs of ordinary people very well,

because they communicated with them more closely. Thriftiness, turning into stinginess, constant economy were characteristic features of the financial management of the clerks. In this way they laid the foundation for future brilliance and wealth.

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SOVIET SCIENTIST AND INVENTOR PAVEL NIKOLAEVICH KUKSENKO

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Аннотация. Статья посвящена советскому учёному, военному деятелю, доктору технических наук, профессору и лауреату двух

Сталинских премий — Павлу Николаевичу Куksenко. Учёному, разработавшему немало изобретений, таких как радиопеленгатор, радиоприёмник РСИ-16, система управляемого ракетного оружия «Комета», система противовоздушной обороны «Беркут». Павел Николаевич участвовал в создании приёмных устройств различного назначения. Им написаны 6 монографий и более 50 научных статей целого ряда разработок в области радиолокации и радиосвязи, которые защищены 9 патентами.

Ключевые слова: связь, радио, аппаратура, техника, наука, радиолокация, изобретения, Великая Отечественная Война.

Annotation. The article is dedicated to Pavel Nikolaevich Kuksenko, a Soviet scientist, military leader, Doctor of Technical Sciences, professor and winner of two Stalin Prizes. A scientist who has developed many inventions, such as a radio direction finder, the RSI-16 radio receiver, the Kometa guided missile system, and the Berkut air defense system. Pavel Nikolaevich participated in the creation of receiving devices for various purposes. He has written 6 monographs and more than 50 scientific articles on a number of developments in the field of radar and radio communications, which are protected by 9 patents.

Keywords: communications, radio, equipment, engineering, science, radar, inventions, The Great Patriotic War.

Introduction

Pavel Nikolaevich Kuksenko was born on April 25, 1896 in the city of Moscow, Russian Empire, in the family of an engineer. In 1913, after graduating from the gymnasium, Pavel Nikolaevich entered the Moscow University at the Faculty of Physics and Mathematics.

In May 1916, he became a cadet at the Alexander Military School, and in December he was assigned to the 1st radiotelegraphic company of the Reserve Electrotechnical Battalion. In August 1917, after graduating from the academy with a degree in radio engineering, Pavel Nikolaevich was appointed head of the radiotelegraphic department at the headquarters of the Danube River Forces in the 6th Army of the Romanian Front.

In 1918, Second Lieutenant Kuksenko was released from military service and in February 1919 was appointed head of the group of the 1st direction finding radio station of the 2nd field radiotelegraphic inspection department. Since October 1919, Pavel Nikolaevich became a teacher, and in February 1921 he worked as a senior radio laboratory assistant at the Higher School of Communications of the Commanding Staff of the Workers' and Peasants' Red Army.

In August 1923, he worked as a design engineer, and in December he became head of the radio laboratory of the Scientific Testing Institute of Communications of the Red Army.

Main Part

In the 1920s, Pavel Nikolaevich became one of the most active popularizing scientists in the country in the field of radio engineering. He joins the ranks of the Russian Society of Radio Engineers (RORY). This society was the first such voluntary scientific and engineering association of Soviet scientists in the field of radio engineering.



Doctor of Technical Sciences,
professor, major general
Pavel Nikolaevich Kuksenko

In 1919, Pavel Nikolaevich created a radio direction finder, a radio receiving device for determining the direction to a radio transmitting station (radio beacon) by receiving and processing its radiation with antennas spaced in space.

In 1921, one of Pavel Nikolaevich's first developments was a high-speed writing radio receiver, which served as the prototype of the encryption system. It was transmitted at a speed of over 1,500 characters. In 1927-1928, he worked on the creation of short-wave equipment for communication with China.

In 1940, Pavel created long-range radio equipment and navigation for high-speed flights of pilot Vladimir Konstantinovich Kokkinaki. Then, he invents the radio receiver RSI-16 for fighters, the US-3 for bombers, the PNB-2 and PNB-4 interception radars for night fighters and radio equipment for partisan detachments.

Pavel Nikolaevich Kuksenko worked as the chief designer of the Kometa guided missile system. The system consisted of a carrier aircraft and a radio-controlled projectile aircraft launched from it at a naval target. The design bureau developed: the radar station of the carrier aircraft, the guidance and homing equipment of the projectile aircraft, the equipment for monitoring projectiles on the suspension and on the ground.



Anti-aircraft missile system S-25

Pavel Nikolaevich was also one of the developers of the S-25 Berkut stationary anti-aircraft missile system. This system was adopted in 1955. Subsequently, Moscow was surrounded by 56 such launch complexes of the Berkut system, they were located in rings: the outer one consisted of 34 complexes, and the inner one consisted of 22. It was the Berkut air defense

system that later served as a prototype for the creation of the S-75, S-125, S-200, and S-300 air defense systems. He also led the development of weapons for the destruction of coast-to-sea, air-to-sea, and air-to-ground guided missile weapons.

Conclusion

Pavel Nikolaevich made a huge contribution to the development of Soviet science in the field of radio engineering, radar, and radio communications. He is the author of 6 monographs and more than 50 scientific articles, 9 of which are protected by patents and a large number of copyright certificates for inventions.

Pavel Nikolaevich Kuksenko was awarded two Orders of Lenin, the Order of the Red Banner, two Orders of the Red Banner of Labor, two Orders of the Red Star, medals «For Military Merit» and «For Victory over Germany in the Great Patriotic War», and two Stalin Prizes.

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THE ROLE AND SIGNIFICANCE OF SAKHALIN ISLAND IN PROVIDING THE NATIONAL SECURITY OF THE RUSSIAN FEDERATION

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Аннотация: Сахалин — остров, восхищающий своей богатой историей, уникальной культурой и удивительной природой. Совместно с Курильскими островами он образует Сахалинскую область — самый восточный регион России. Остров Сахалин и Курильские острова занимают особое положение в обеспечении национальной и военной безопасности. В нашей статье мы рассмотрим три периода военных событий на острове Сахалин, а также выделим ключевые угрозы национальным интересам в разные исторические периоды, которые сыграли важную роль в обеспечении безопасности всей страны в целом, а также региона в частности.

Ключевые слова: остров Сахалин, Пекинский договор, пакт о безоговорочной капитуляции Японии, Симодский трактат, префектура Карафутто, Курильские острова.

Annotation: Sakhalin is an island that delights with its rich history, unique culture and amazing nature. Together with the Kuril Islands, it forms the Sakhalin Oblast, the easternmost region of Russia. Sakhalin Island and the Kuril Islands occupy a special position in ensuring national and military security. In this article, we will look at three periods of military events on Sakhalin Island, as well as highlight key threats to national interests in different historical periods that played an important role in ensuring the security of the entire country as a whole, as well as the region in particular.

Keywords: Sakhalin Island, the Beijing Treaty, the pact on the unconditional surrender of Japan, the Treaty of Shimoda, Karafuto Prefecture, the Kuril Islands.

To define the role of the Island of Sakhalin for the national and military security of the Russian Federation it is necessary to study the key events taking place on the island in certain historical periods: military events before 1941, the war period from 1941 to 1945 and post-war period.

Military events before 1941. With the outbreak of the Crimean War, which was taking place both in the south-west of the country and in the east, Russian settlements on Sakhalin were under threat of attack by Anglo-French squadrons that dominated the Pacific Ocean [12]. The situation was rapidly escalating, and the Russian leadership was faced with the question of what measures needed to be taken to ensure the safety and security of its positions on the island. The best solution was to establish diplomatic relations with the Japanese side which will ensure “constant peace and sincere friendship between Russia and Japan” [15].

According to official data, neither the Russian Empire nor Japan claimed their rights to the islands, as a result, the first treaty between the countries was concluded the Treaty of Shimoda (1855) on friendship was signed. According

to the Treaty Sakhalin remained a joint territory of the two states, and the border between them was drawn on the islands of the Kuril Archipelago along the Frieze Strait, south of Urup Island [15]. 20 years later, an agreement on the exchange of territories was signed in St. Petersburg, according to which the Russian side transferred to the Japanese all the Kuril Islands that were in its possession at that time, including Urup Island and all the territories north of it. In exchange, Japan officially renounced its territorial claims to Sakhalin, which in 1884 became part of the Primorsky Region [4; 22].

The island was again demarcated due to the defeat of the Russian Empire in the Russo-Japanese War of 1904-1905 [14]. The reasons for the clash between the two countries were the Russian expansion in Manchuria and Korea, the construction of the railway in China, and Russia's lease of the Liaodong Peninsula and Port Arthur. The chairman of the Council of Ministers, Sergei Yulievich Witte, was sent by Emperor Nicholas II to resolve the conflict, thanks to whom the Portsmouth Treaty was signed on favorable terms for the country [1]. According to the document, Russia retained ownership of the island, but at the same time transferred to Japan part of Sakhalin south of the 50th parallel and adjacent islands. Almost 500 kilometers south of it became the "Karafuto Prefecture" the northernmost and one of the largest in area among all the regions of the Japanese Empire [17]. The island's life was divided between the two states, with most of the Russian settlers moving to the mainland, while Japan began actively settling the new territory [9].

Under the command of the governor Arkady Mikhailovich Valuev, who took this post from 1905-1910, the part of the northern Sakhalin was transformed into the Sakhalin Region in June 1909 [3].

The military actions of the First World War did not affect Sakhalin, the hardships of the conflict affected the population, most of whom went to the front. After the October Revolution of 1917, everything became different [13]. A new *de jure* independent democratic state, the Far Eastern Republic (1920-1922), was formed on the territory of the Russian Far East. This newly formed state had its own authorities, its own monetary system, the basic law, and even the Armed forces [21]. However, the interaction between the parties was very difficult due to the heterogeneous composition of the leadership. It included representatives of various political movements: Bolsheviks, anarchists, liberals and non-partisans. In addition, there were internal contradictions between them.

Also at this time, partisan detachments known as "the Amur partisans" were active in the region [20]. The military leaders of the Far Eastern Republic tried to organize and control their actions. One of the more organized detachments was commanded by Yakov Ivanovich Tryapitsyn. In February 1920, after fierce fighting with the White Guards and the Japanese,

Tryapitsyn's partisan detachment entered Nikolaevsk-on-Amur. On March 12, in violation of the armistice, the Japanese suddenly attacked the partisans, but were defeated. This event was called the “Nikolaev Incident” and was used by the Japanese government as a reason for the beginning of the occupation of the northern Sakhalin. In April 1920, about 2,000 Japanese soldiers landed on Sakhalin in the city of Alexandrovsk to protect their compatriots [20]. The consequences of the occupation were the laws adopted by the Japanese local military government, which limited the rights of the Russian population in relation to the ownership and disposal of land. Strict control over mining, fishing and logging was established, as well as numerous taxes and fees for the Russian population were introduced [20]. The Japanese occupation ended after the signing of the Beijing Treaty on January 20, 1925, which restored diplomatic relations between the USSR and Japan. By May 14 of the same year, Japanese troops had left northern Sakhalin [13].

The war period from 1941 to 1945. By the evening of June 22, 1941, Soviet Sakhalin received the news of the attack on the Soviet Union by Nazi Germany. It became clear that in addition to this serious opponent, which poses a threat to the existence of our Homeland, there was also a potential enemy on the Far Eastern borders Japan [5].

The population of the region in 1941 was 117 thousand people. About 375 thousand Japanese citizens lived in the south of Sakhalin [4]. The only factor that allowed the USSR to avoid a war on two fronts was the “neutrality pact” with Japan, which allowed the country's Far Eastern reserves to be transferred to fight Nazi Germany.

Residents of Sakhalin bravely faced the beginning of the Great Patriotic War. More than 20,000 Sakhalin residents went to the front from 1941 till 1945 to defend our homeland and preserve our national, cultural and ideological identity [4]. Sakhalin residents took an active part in key events of the Great Patriotic War, such as the Battle for Moscow, the Battle of Kursk, the Battle of Stalingrad, as well as the defense of Leningrad, the liberation of Ukraine, Belarus, Poland, Hungary, Romania, Yugoslavia, Czechoslovakia [4].

An important contribution to the overall victory was made by the Sakhalin residents, who actively participated in the international convoys “PQ” and “Dervish” of the international Lend-Lease program for the delivery of humanitarian supplies, as well as equipment, small arms and rocket-gun weapons. Boys and girls aged 14-16 selflessly fulfilled their military duty and duty to the Motherland, duty to the Fatherland, under the cannon shots of the enemy in the Pacific basin, with pride and great dedication [16].

Sakhalin residents actively forged a Great victory in the rear. Sakhalin began to actively develop such key industrial sectors as oil, metallurgy, gas,

timber processing and many others [4]. During the war with Nazi Germany, the Sakhalin oil industry reached record production figures of 2.4 million tons of oil. Both adults and children forged victory, and the result of their dedication was the construction of the Okha–Komsomolsk-on-Amur oil pipeline [5].

The Stakhanovite miners actively performed their tasks ahead of schedule. It was their perseverance, dedication and faith in victory that made it possible to extract a record 2 million tons of coal [4].

Sakhalin fishermen worked without rest. 2,000 people worked around the clock at 25 fish processing enterprises. During the war, over 1 million quintals of fish products were extracted and processed [5; 19].

The timber processing industry has also suffered hard times. The lack of mechanization of labor, competent specialists, and production facilities could not break the spirit of Soviet citizens. Experiencing the hardships of military life, the workers harvested over 1 million cubic meters of wood needed by the front [4].

During the Great Patriotic War, centers for the manufacture of barrels, furniture products, as well as for the processing of lumber and the production of shoes, leather goods, and fur clothing were organized in the northern part of Sakhalin Island [19]. During the war, Sakhalin worked at the same pace as the rest of the country, sacrificing its strength and health to the needs of the front.

In 1943, the Soviet leadership realized that after the end of the war with Germany, a war in the Far East with militaristic Japan could not be avoided. In order to increase the defense capability on the eastern borders, the 56th army corps of 117,000 people was formed, as well as many military units capable of repelling a potential threat to the territorial integrity of the country. Printed publications such as “Komsomolskaya Pravda” and “Sovetsky Sakhalin” began to be periodically published, contributing to the improvement and strengthening of morale and ideological health of military personnel and residents of Sakhalin [4].

After the end of the Great Patriotic War and the defeat of Nazi Germany, the agreements of the Yalta Conference in February 1945 obliged the Soviet Union to enter into a military confrontation with militaristic Japan, since the Second World War had not yet been completed.

Firmly fulfilling its allied obligations, on August 9, 1945, the USSR declared war on Japan and launched a rapid offensive along the fronts of the Far East and Southeast Asia. One of the most important military operations was the Yuzhno-Sakhalinsk Offensive, which was considered to be aimed at liberating southern Sakhalin. On August 8, the troops of the 16th army of the 2nd Far Eastern Front, under the command of Major General Leonty

Cheremisov, with the support of the forces of the Pacific Fleet, began to carry out their tasks [5].

The clashes began on the night of August 11, 1945, with combined strikes by Soviet naval aviation on the facilities of Koton, Toro, Usiro, and Esutoru. The 88 infantry division of the 5th front, commanded by Lieutenant General Toichiro Mineki, with a total strength of about 30,000 troops, took part in the battle from the Japanese side [23].

The amphibious assault of the 365th separate Marine battalion and the 2nd battalion of the 113th Rifle brigade occupied cities such as Maoka (now Kholmsk), Otomari (now Korsakov), Toro (now Shakhtersk), which allowed them to take control of strategically important supply and logistics facilities, thereby preventing the evacuation and transfer of enemy forces to the territory of Sakhalin Island, allowing the 16th army to bypass the Koton fortified area and launch a rapid offensive towards the administrative center of Southern Sakhalin the city of Toyokhara (now Yuzhno-Sakhalinsk). After the capture of Toyohara city, the operation was completed [25].

On September 2, 1945, aboard the American battleship Missouri in Tokyo Bay, Lieutenant General Kuzma Nikolaevich Derevyanko signed the “pact of unconditional surrender of Japan”. According to this pact, the territories of South Sakhalin and the territories of the Kuril Islands were completely ceded to the Soviet Union. The general's name is given to the island of the Small Kuril Ridge. During the offensive operation on the territory of Sakhalin Island and the Kuril Islands, Anton Efimovich Buyukly, Grigoriy Grigorievich Svetetskiy, Pavel Nikitovich Sidorov, Leonid Vladimirovich Smirnih, Sergey Timofeevich Yudin were awarded the title Hero of the Soviet Union for their courage and heroism [24].

The role of the Sakhalin region in ensuring the country's military security in the post-war geopolitical conditions. After World War II, the foreign policy security of the Sakhalin region as an integral part of the territory of the Soviet Union was endowed with the features of deferred conflicts, namely, the confrontation of powerful world powers both during the Cold War and in our time, as well as the absence of a peace treaty with Japan. The post-war division of spheres of influence prompted the Soviet government to increase its military contingent not only in Europe, but also in the Asia-Pacific region.

In 1951, a Soviet delegation was invited to San Francisco to sign a peace treaty with defeated Japan, which regulated the principle of post-war consolidation of acquired territories for the USSR and secured Japan's loss of legal and de facto control over Southern Sakhalin and the Kuril Islands [7]. The delegation of the Soviet Union refused to sign this treaty due to its legal vagueness, namely the lack of precise and long-term consolidation of Sakhalin

Island and the Kuril Islands for the USSR. This wording of the treaty had its reasons: due to its geopolitical importance, the Kuril Islands were also the subject of special interest to the United States and they could not lose the opportunity to gain control over them.

The USSR exclusively objected to the above-mentioned formulations in the US version, and at the same time was forced to legally remain at war with Japan. After the unsuccessful signing of the peace treaty, under pressure from the United States, the Japanese government documented for the long term as the main foreign policy goal the return to its own jurisdiction of the two islands of the Kuril ridge – Habomai and Shikotan. Subsequently, in order to incite an information war, the Japanese government announced its demands for the return of the entire southern part of Sakhalin Island and all the islands of the Kuril Ridge [7].

However, the process of rapprochement between the two countries began in 1952 with the establishment of trade relations. A number of agreements were also signed establishing cooperation with more than 60 industrial enterprises of the two countries, including those located on Sakhalin Island. Equipment, production facilities, machinery, and transport were actively imported to the island, which made it possible to integrate the Sakhalin Region more actively into the unified economic system of the Soviet Union, and readiness was expressed through diplomatic channels to discuss compromise terms of a future peace treaty [11].

In 1954, Nikita Khrushchev, Chairman of the Council of Ministers of the USSR, through closed diplomatic channels, in order to “soften” the negotiation process, made a confidential proposal to transfer the Habomai and Shikotan islands to Japan, but on condition of signing a peace treaty. However, the greed of the Japanese government, which put forward new conditions for the transfer of the entire territory of South Sakhalin and all the Kuril Islands, did not allow progress in these negotiations [11].

Currently, the peace treaty between the two countries has not been signed, and the official demands of the Japanese government have expanded to 4 islands of the Kuril Ridge: Habomai, Shikotan, Kunashir and Iturup. Japan began to give reasons for the above mentioned statement by signed in 1855 the “Shimoda Treaty”, which regulated the granting of trade preferences to the Russian Empire, but this agreement currently has no legal force [15].

Of great importance for the country's military security is the fact that the Sakhalin Region was a border region of the USSR, and now the Russian Federation. This factor determines its special military importance for the security of the entire Far Eastern region. Thus, the southernmost part of Sakhalin Island is separated from the Japanese island of Hokkaido by the 43

km wide La Perouse Strait, and from the island of Habomai of the Smaller Kuril Ridge by only 10 km [2].

Due to its proximity to countries loyal to the United States, the critical proximity of their military bases, as well as the territorial claims of Japan, the USSR legally established the Sakhalin Region as a “closed-type border territory”. Citizens staying on the territory of the region were required to undergo a thorough check, as well as to have the appropriate documents confirming the right to enter the territory of the Sakhalin Region. Such a “regime” of the region confirmed its “special” status, the specifics of its activities in the territory and its importance for ensuring the national security of the country. Such a regime of entry into the territory of the region existed until 1991 [8].

Currently, the basis of the military strategy of the national security of the Russian Federation in relation to the Sakhalin region is a non-military method of counteraction, which makes it possible to prevent conflict at the stage of its inception, strengthen strategic stability in the region, increase the number of allied states, and neutralize potential threats from a potential enemy [2].

For Sakhalin region, as a strategically important region of the Soviet Union and further of the Russian Federation, there is a real threat to military security due to the information warfare policy emanating from unfriendly countries such as Japan and the United States [2], [6]. After the start of a special military operation to denazify and demilitarize Ukraine on February 24, 2022, the Government of the Russian Federation and the Security Council of the Russian Federation analyzed the experience of information warfare and the experience of countering threats from developed countries such as Japan, the United States, and the United Kingdom, thereby approving an updated Military Doctrine of the Russian Federation in 2024, taking into account current threats to the national security of the Russian Federation [10]. The President of the Russian Federation also approved the updated Information Security Doctrine of Russia, which regulates the procedure for conducting information and educational, information and propaganda activities to counter external threats [6].

Conclusion: The Sakhalin region has a centuries-old and rich history passing through key historical periods of our Motherland. The uniqueness of its location, climate, natural zones, as well as its strategic location in the Pacific Basin and the Asia-Pacific region make the region the subject of international territorial disputes to this day, affecting the state of military and national security. Having gone through many military conflicts and changes, the region has become the epitome of fortitude. Important historical events have left a deep mark on the islands and its inhabitants. These periods shaped not only the local culture, but also the political map of the region, contributing

to a unique combination of Russian and Japanese traditions. Studying the military eras in the history of Sakhalin, we understand how harsh trials affected personal destinies and society as a whole. These historical lessons remind us of the importance of peace and mutual understanding between nations in order to avoid repeating the tragic mistakes of the past.

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UDC 94(47)

THE REVIVAL OF PASTORAL MINISTRY IN THE BLACK SEA FLEET

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Аннотация. В статье рассматривается история и современное состояние пастырского служения в Черноморском флоте, начиная с момента его основания императрицей Екатериной Великой. Автор выделяет ключевые этапы взаимодействия Церкви и государства в духовном окормлении моряков, включая упразднение военного духовенства после Революции 1917 года и его возрождение в 1990-х годах. Отмечен вклад священников, сопровождающих моряков в дальних походах и зонах боевых действий, а также строительство храмов и корабельных молитвенных помещений на судах и в местах базирования флота. Подчеркивается важность духовной поддержки военнослужащих в условиях современных вызовов, включая Специальную военную операцию.

Ключевые слова: Черноморский флот, военное духовенство, пастырское служение, Свято-Владимирский собор, духовное

окормление, история флота, Церковь, возрождение традиций, военные капелланы, специальная военная операция.

Annotation. The article examines the history and current state of pastoral ministry in the Black Sea Fleet, dating back to its founding by Empress Catherine the Great. The author highlights key stages in the collaboration between the Church and the state in providing spiritual guidance to sailors, including the abolition of the military clergy after the 1917 Revolution and its revival in the 1990s. The contribution of priests who accompany sailors on long voyages and in combat zones is noted, as well as the construction of churches and prayer rooms aboard ships and at naval bases. The article emphasizes the importance of spiritual support for servicemen amid modern challenges, including the Special Military Operation.

Keywords: Black Sea Fleet, military clergy, pastoral ministry, St. Vladimir's Cathedral, spiritual guidance, naval history, Church, revival of traditions, military chaplains, special military operation.

From the very creation of the Russian fleet by Emperor Peter the Great, a collaboration between the Church and the state began for the spiritual nourishment of the navy. The Tsar's decree of April 1717 mandated: «The Russian fleet shall maintain thirty-nine priests on ships and other military vessels» [1]. It was with the blessing of St. Mitrophan of Voronezh that the first ships of our Russian fleet were built.

The institution of naval clergy in the Black Sea Fleet has existed since its foundation. Initially, the clergy providing spiritual care to the sailors of the Black Sea Fleet consisted of monastics from the St. George Balaklava Monastery.

Throughout the history of the Black Sea Fleet, the clergy carried out pastoral ministry among Russian naval warriors. However, after the revolution, due to the onset of persecution against the Church, the institution of naval clergy was abolished.

In the early 1990s, the spiritual nourishment of the fleet was revived. Officers of the Black Sea Fleet established a naval parish at St. Vladimir's Cathedral, the burial vault of admirals. Later, in 1991, Metropolitan Vasily of Simferopol and Crimea reconsecrated the upper church of St. Vladimir's Cathedral [2].

On February 29, 1990, one of the most significant events in the modern history of the cathedral took place—the reinterment of the remains of Admirals M.P. Lazarev, V.A. Kornilov, V.I. Istomin, P.S. Nakhimov, and the restoration of the burial vault. These events marked the beginning of the revival of cooperation between the state and the Church in the spiritual care of the fleet [2].

After years of persecution, a pre-revolutionary tradition was revived—clergy once again began accompanying naval crews on long voyages. One of the first priests to initiate this revival was Archpriest Georgy Polyakov [3].

In 2008, for the first time in the Armed Forces of the Russian Federation, the institution of military chaplaincy was established. The first assistant to the Commander of the Black Sea Fleet for work with religious servicemen was Archpriest Alexander Bondarenko. This marked the beginning of the formation of the naval clergy.

In addition to the regular clergy, about sixty priests in Sevastopol, Kerch, Novorossiysk, Donuzlav, and Chernomorskoye served the fleet on a voluntary basis under agreements signed between the Black Sea Fleet and the Simferopol and Crimean Diocese, represented by Metropolitan Lazar of Simferopol and Crimea.

Currently, six full-time positions for naval clergy have been established in the Black Sea Fleet. Many ships now have chapels and prayer rooms. Permanent churches have also been built at the locations of Black Sea Fleet personnel. For example, the Church of the Intercession of the Holy Theotokos was built at the 14th pier, and the Church of St. Alexander Nevsky was constructed for the 810th Marine Brigade.

Since the beginning of the Special Military Operation, clergy have been carrying out pastoral ministry in the military units of the Black Sea Fleet. For instance, Archpriest Mikhail Gritsai provides spiritual support in combat zones alongside the personnel of the 810th Marine Brigade [2].

Additionally, a humanitarian mission operates in Sevastopol under the city's deanery, offering aid to our defenders in their arduous service.

The revival of pastoral ministry in the Black Sea Fleet represents not only the restoration of a historical tradition but also a reaffirmation of the enduring bond between the Russian Orthodox Church and the armed forces. From the reinterment of legendary admirals in St. Vladimir's Cathedral to the establishment of permanent shipboard chapels and frontline chaplaincy during the Special Military Operation, the Church continues to provide crucial spiritual support to sailors and marines. The words of Patriarch Alexy II — «Faith is the most important force that inwardly transforms and strengthens a warrior» [4]—ring especially true today, as military clergy stand alongside servicemen in both peacetime and combat. In an era of geopolitical challenges, the institution of naval chaplaincy remains a cornerstone of national resilience, ensuring that the defenders of Russia are fortified not only by arms but also by faith.

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UDC 93/94

TESTS OF THE RUS-1 SYSTEM AND REDUT STATION ON THE CRUISER “MOLOTOV” IN SEVASTOPOL LATE 1939

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Аннотация. Первые испытания первой советской радиолокационной системы «Редут-К» и системы РУС-1 проводились на берегах Севастополя. Эти испытания стали важной вехой в развитии советской радиолокационной техники, продемонстрировав ее возможности и эффективность в морских операциях.

Ключевые слова: Черное море, Редут-К, система РУС-1, самолеты и корабли, зенитчик.

Annotation. The initial tests of the first Soviet radar system, “Redut-K” and the RUS-1 system were conducted on the shores of Sevastopol. These tests marked a significant milestone in the development of Soviet radar technology, having showed its capabilities and effectiveness in naval operations.

Keywords: The Black Sea, Redut-K, system RUS-1, aircraft and ships, anti-aircraft gunner.

Introduction

The first cruiser of the Black Sea Fleet to be equipped with and could test the advanced Soviet radiolocation system, Redut-K. It was “Molotov” that played a significant role in the successes of the Black Sea Fleet with its formidable weaponry and technical capabilities. The training exercises conducted on board not only facilitated the planning and advancement of Soviet scientific developments but also contributed to the training of sailors.

Highlights and results

Special tests of the RUS-1 system and the Redut station were carried out on the cruiser Molotov.

By late 1939, the equipment was installed on the cruiser near Sevastopol to serve the Navy's interests and was assessed during training exercises in May. These assessments demonstrated that the system could effectively detect aircraft and ships at any time of day.

Specific characteristics and requirements for the shipboard equipment were defined during the tests. Sailors requested a shipboard version of the installation from the Radio Industry Research Institute. This version was designated ‘Redut K’ and boasted a range exceeding 100 kilometers. The Redut-K system was installed on the mainmast (refer to Fig. 1 and 2).



Fig. 1 - Tube and mainmast of the Black Sea Fleet cruiser of the project 26-bis Molotov.

The cruiser “Molotov” was assigned to the Black Sea Fleet squadron.

It began its combat service on June 14, 1941. The cruiser took part in extensive training exercises conducted by the USSR Navy in the Black Sea the day after its commissioning, on June 15, 1941. It engaged in training operations and crew skill drills while also providing air defense for the Sevastopol base from June 22 to November 1941.

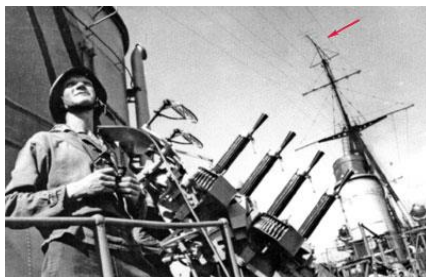


Fig. 2. Cruiser “Molotov”, 1943.



Fig. 3 - “Molotov” enters the Northern Bay in Sevastopol

3. Conclusion

The radar installed on the cruiser delivered highly accurate intelligence about the enemy, when Sevastopol was first targeted by Nazi aircraft.

A direct telephone line was established between the cruiser, the fleet headquarters, and the Sevastopol air defense command post on the third day after the war began. As information about approaching enemy aircraft was quickly transmitted to the appropriate units, this allowed anti-aircraft gunners to prepare in advance to respond to the raid.

The station rapidly gained significant popularity among the sailors.

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SECTION 4: MARINE TECHNOLOGIES



UDC 621.3

PRACTICAL IMPLEMENTATION OF A WEB APPLICATION FOR A SYSTEM FOR COLLECTING DATA ON THE STATE OF SEA WATER IN THE COASTAL ZONE

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Аннотация. Рассматривается задача реализации web-приложения для обработки данных, полученных от системы сбора данных о состоянии морской воды в прибрежной зоне. Также авторы уделили внимание разработке алгоритмов получения и обработки данных, интерфейсам программирования приложения (api) для передачи данных между устройством и сервером.

В качестве основы для серверной части выбрана платформа node.js в сочетании с фреймворком express.js, что обеспечивает высокую производительность при обработке потоковых данных, поддержку асинхронных операций ввода-вывода, простую интеграцию с различными базами данных.

Для хранения временных рядов показателей реализована специализированная база данных mongodb, оптимизированная для

работы с временными метками. Это позволяет эффективно: хранить исторические данные за многолетний период, выполнять сложные аналитические запросы по временным отрезкам, обеспечивать высокую скорость выборки даже при больших объемах информации.

Ключевые слова: база данных, web-приложение, сервер, ReactJS, MongoDB.

Annotation. The article considers the task of implementing a web application for processing data obtained from a coastal seawater data collection system. The authors also paid attention to the development of algorithms for obtaining and processing data, application programming interfaces (API) for transferring data between the device and the server.

The node.js platform in combination with the express.js framework was chosen as the basis for the server part, which ensures: high performance when processing streaming data, support for asynchronous input-output operations, simple integration with various databases.

A specialized MongoDB database optimized for working with timestamps was implemented to store time series of indicators. This allows you to effectively: store historical data for a long period, perform complex analytical queries by time intervals, ensure high sampling speed even with large volumes of information.

Keywords: database, web application, server, ReactJS, MongoDB.

Introduction.

In the context of global climate change and increasing anthropogenic load on marine ecosystems, monitoring the state of sea water is becoming extremely important. Effective management of these zones is impossible without timely and accurate information on the state of the aquatic environment.

With the development of technology and increasing availability of data, web applications are becoming an important tool for collecting, analyzing and visualizing information.

The authors reviewed the main aspects of developing a web application, namely: client and server parts, development of REST API for accessing database resources.

The main part.

The key tasks are:

- implementation of a module that displays general telemetry information received from the device in the form of tables and graphs;
- implementation of an authorization and registration module for gaining access to data;
- creation of a database and recording of telemetry information from the device into it.

Structural interaction of modules.

As mentioned earlier, it is necessary to implement authorization and registration modules, as well as a module that displays summary information. Fig. 1 shows the interaction diagram of the modules.

The authorization module should provide a function for verifying data received from the user. Structurally, the database should contain two tables. A table with user data (e-mail and password), and a table with telemetry data. The database structure is shown in Fig. 2.

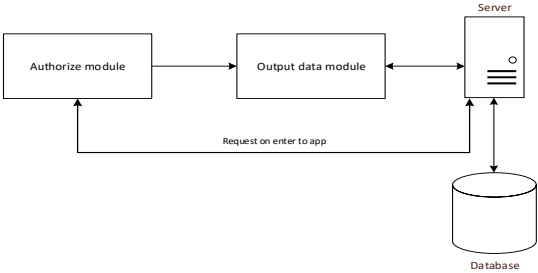


Fig. 1. Structural diagram of interaction of application modules

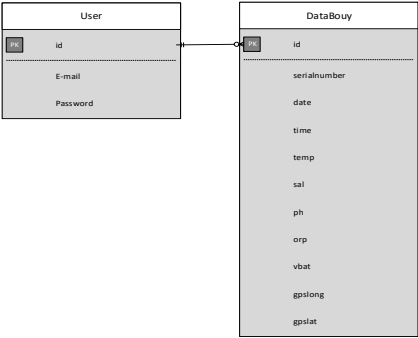


Fig. 2. Structure of database

Fig. 3(a) shows an example of recorded user data. Fig. 3(b) shows telemetry data.

```
_id: ObjectId('6730e4228ff177bdf7c01033')
email: "johndoe@marlin.com"
password: "$2a$08$a2/rCGm3qVpD/807ZQc260..A0OWlr-i.um
__v: 0

_id: ObjectId('6730e6011c2ba4064f691752')
email: "johndoe@marlin-yug.com"
password: "$2a$08$mQL15sPS/vvwCa5VueKPoekIuhbphrtGS1
__v: 0
```

a)

```
_id: ObjectId('673313aea548cd8e127b0694')
serialnumber: "sr112345"
date: "25.06.2024"
time: "10:10:10"
temp: "17.654"
sal: "1000"
ph: "7"
orp: "2"
vbat: "100"
gpslong: "-34.674"
gpslat: "17.654"
__v: 0
```

b)

Fig. 3. Example of recorded data from the database: a) user; b) telemetry data

As can be seen from Fig. 3, a, the user password data is not contained in the database in clear text, but is pre-encrypted using the SHA256 algorithm.

Practical implementation of the server part of the application

Before implementing the server part of the application, it is worth highlighting the main functions of the server:

- receiving data from the data collection system;
- writing data to the database;
- receiving data from the database.

For the practical implementation of the server part, we will use the open source platform NodeJS, which allows you to write server code in JavaScript and is built on the Chrome V8 engine.

As a database, we will use the MongoDB platform. The key feature of this DBMS is its flexibility and extensibility, which will be useful for the development of this application. This DBMS uses JSON-like documents, due to which it allows you to store a very heterogeneous set of data [1].

For interaction between the database and the server part written in NodeJS, we will use the mongooseJS DB driver. This driver has many built-in functions for recording, searching, deleting, sorting data.

At the current stage, it is advisable to implement the function of recording data received from the data collection system via a wireless GSM channel in the form of an HTTP request.

Fig. 4 shows the structural interaction of the data collection system and the server application.

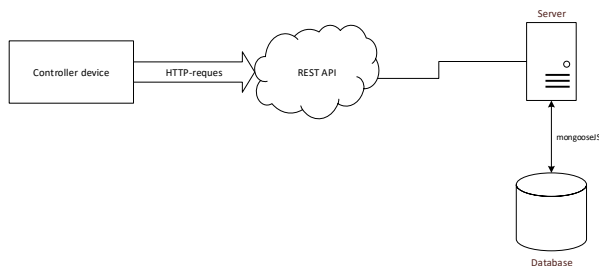
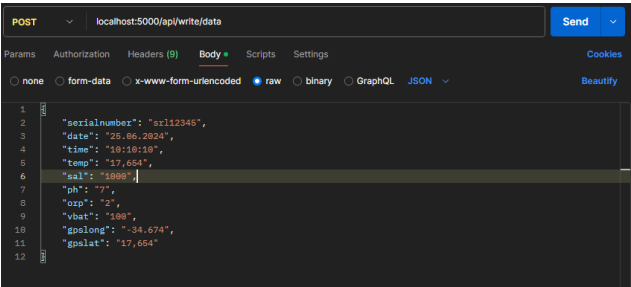


Fig. 4. Structural diagram of interaction between the data collection system and the server application

As can be seen from Fig. 4, the controller interacts with the server part indirectly via the REST API, which processes the request from the device. We will use a POST request as an HTTP request method for recording measured data. The measured data should be placed in the request body as a JSON

document, and also indicate the path by which the API can redirect it to the server. Fig. 5 shows the structure of a POST request from the device to the server.



```
POST localhost:5000/api/write/data
{
  "serialnumber": "ex112345",
  "date": "25.06.2024",
  "time": "10:10:10",
  "temp": "17,654",
  "sal": "1000",
  "ph": "7",
  "exp": "2",
  "vbat": "100",
  "gpslong": "34.674",
  "gpslat": "17,654"
}
```

Fig. 5. Structure of POST request from device to server

Receiving data from the database should be implemented using similar logic, that is, using HTTP requests, but using the GET method and passing sorting parameters in the request address as query parameters, for example, the serial number of the device or date.

Practical implementation of the client part of the application.

The authors propose to implement the client part using a modern JavaScript framework - ReactJS. Also, to create an adaptive version of the web interface, we will use the CSS framework TailwindCSS. A distinctive feature of the chosen framework is the flexible configuration of the grid and basic styles.

For interaction between the client and server parts, we will use axiosJS - a special library that implements the functionality of the HTTP client.

Using HTTP GET requests, the client can request data from the database. All data from the database is requested by the client automatically when the page is loaded. The user also has the ability to sort data by serial number and date through the interface.

Fig. 6 shows the user web interface.



Fig. 6. User web interface

Conclusion.

As a result of developing a web application, a system was implemented that displays measured data in the form of tables and graphs. To implement this project, the MERN technology stack was used, which includes MongoDB, Express.js, React and Node.js.

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UDC 656.61

ANALYSIS AND COMPARISON OF PERFORMANCE INDICATORS OF RADIO COMMUNICATION EQUIPMENT FROM VARIOUS MANUFACTURERS ON A SHIP

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Аннотация. В данной публикации рассмотрены основные современные средства радиосвязи в ОВЧ диапазоне на судне. С помощью взятых из пособий руководств пользователя судового

радиокommunikационного оборудования значений мощности основного и побочного излучений, а также мощности шума получены расчетные данные показателей эффективности. На основе полученных значений проведен сравнительный анализ качества конкретных моделей радиоустановок и разработаны рекомендации по улучшению показателей эффективности работы судового оборудования радиосвязи.

Ключевые слова: Критерий эффективности, показатели качества, судовое оборудование радиосвязи ОВЧ, сравнительный анализ, побочное излучение, уровень шума.

Annotation. This publication examines the main modern means of radio communication in the VHF range on board a ship. Using the values of the power of the main and spurious emissions, as well as the noise power, taken from the manuals of the user's guides for ship radiocommunication equipment, calculated data on the performance indicators were obtained. Based on the obtained values, a comparative analysis of the quality of specific models of radio installations was carried out and recommendations were developed to improve the performance indicators of ship radiocommunication equipment.

Keywords: Performance criterion, quality indicator, shipboard VHF radio communication equipment, comparative analysis, spurious emission, noise level.

Introduction.

Progress in the development of information exchange in navigation leads to the growth of various models of shipborne electronic equipment (REE). The quality of their operation is determined largely by the level of interference, which is not taken into account when determining the efficiency of the REE at the design stage [1]. The purpose of the study is to calculate the quality of operation of specific REE models taking into account spurious radiation and noise levels, as well as to conduct a comparative analysis of the obtained efficiency criteria.

Equipment comparison and calculations.

During the research, the following popular models of VHF radio stations showed on the Figure 1 were taken as a basis.



Figure 1 – Popular VHF radio equipment models of different manufacturers.

It is necessary to obtain different values of the efficiency indicators of each model, for this purpose models with different characteristics were taken. This will allow us to determine the factor influencing the increase in efficiency.

As an indicator of the efficiency of the functioning of the communication system using radiotelephony, the ratio of the power of the main emission P_m to the total power of noise P_n and spurious emission P_s can be used, i.e. $q = P_m / (P_n + P_s)$. This formula is also applicable to ship VHF radio communication equipment. The calculated data are presented in table on Figure 2.

Equipment model	Main radiation power, W	Noise power	Spurious emission power
JRC JHS-800S	25 W	2,5 mW	< 3.125 μ W
Samyung STR-6000A	25 W	2,5 mW	2.5 μ W
Sailor 6248	21 W	0,53 mW	2 μ W
Furuno FM8900S	25 W	0,46 mW	2 μ W

Figure 2 – Calculated values.

The values of the spurious and main emissions were obtained from the user manuals of the ship radiocommunication equipment. The signal-to-noise ratio formula was used to calculate the noise power of each model [2]. The obtained values of the performance criteria for each model are entered in table on figure 3.

Equipment model	Performance indicator
JRC JHS-800S	9987
Samyung STR-6000A	9990
Sailor 6248	39473
Furuno FM8900S	54112

Figure 3 – Performance indicator values.

As the table presents, the performance indicators of VHF stations vary significantly as the noise power values change. Despite the fact that in real conditions these indicators, with a fairly small difference, will not greatly affect the efficiency of transmission, the difference in the final calculations proves the need to pay more attention to the noise power and spurious radiation at the design stage of the ship's REE.

For the operation of the communication system, the presence of interference is equivalent to a deterioration in q by the fraction by which the denominator ($P_n + P_s$) reduces it, i.e. the presence of interference is equivalent to a change in the receiver's noise parameters by the specified number of times.

Ensuring the required quality of operation as a whole should be based on maintaining the characteristics of individual means within specified limits, as well as eliminating unwanted interaction between individual means as elements of the complex. For REE, such an effect is manifested in the form of mutual systemic electromagnetic interference.

Conclusion.

Calculations of the performance quality of various models of VHF ship radio stations were made based on the efficiency criterion. It was found that the presence of interference is equivalent to a change in the receiver parameters for noise. It is recommended to conduct a more thorough preparation of the REE at the design stage in relation to taking into account the influence of noise power and spurious radiation on the final performance indicators of working models of radio stations.

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ELIMINATION OF DISTANCE MEASUREMENT ERROR AT SHALLOW DEPTHS

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Аннотация. Исследуется способ измерения дальности в подводных условиях, использующий два в корне различных способа передачи данных под водой. Изученные и исследуемые ранее способы дают адекватные показания лишь на глубине, достаточной, чтобы сигнал не распространялся в нестационарной среде. Иначе, меняется суммарная фаза принятого и преобразованного в напряжение сигнала. Целью исследования является изучение способа устранения ошибки измерения дальности под водой, когда акустические колебания, передаваемые через основной акустический канал связи, отражаются от водной поверхности, также являющейся нестационарной. Кроме того, исследуемый способ способен сократить время процесса измерения, так как колебания не меняют во времени свою частоту.

Ключевые слова: измерение дальности, ошибка измерения, суммирование фаз, акустические волны, электромагнитные волны.

Summary. A method of measuring the range in underwater conditions, using two fundamentally different methods of data transmission under water, is investigated. The methods studied and investigated earlier give normal results only at a depth sufficient to prevent the signal from propagating in a non-stationary medium. Otherwise, the total phase of the received and converted into voltage signal changes. The aim of the study is to study a way to eliminate the error of measuring the range under water, when acoustic vibrations transmitted through the main acoustic communication channel are reflected from the water surface, which is also non-stationary. In addition, the

studied method is able to reduce the time of the measurement process, since the oscillations do not change their frequency over time.

Keywords: distance measurement, measurement error, phase summation, acoustic waves, electromagnetic waves.

The method of measuring the distance under water uses two fundamentally different methods of wave processes: acoustic and electromagnetic. In this way, a bimodal system is built that is capable of measuring the distance from one object (e.g., an AUV) to another (e.g., an underwater berth or a ship's hull). Nevertheless, the results of measurement are obtained more qualitatively, the deeper the system itself works. This is due to the fact that acoustic waves are reflected from the surface of the water, which is more of a non-stationary wavy surface than a smooth and mirror-like one. A non-stationary phase change is added to the stationary phase inflow (with a plus or minus sign), and an error occurs at the output. The purpose of the study is to eliminate this error.

The solution to this problem is achieved by development of a system [1] (Figure 1) consisting of continuous oscillation generators 1 and 2, oscillation combiner 3, transmitting loop magnetic antenna 4, transmitting acoustic transducer 5, receiving loop magnetic antenna 6, receiving acoustic transducer 7, first narrowband filter 8, second narrowband filter 9, third narrowband filter 10, fourth narrowband filter 11, first and second phase difference meter 13 and 12 and the third phase difference meter 14.

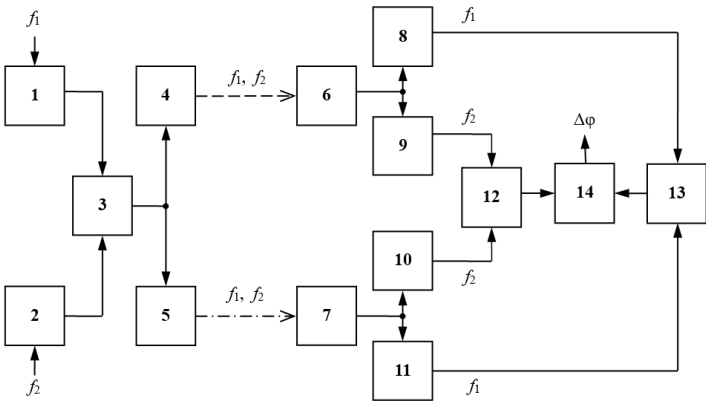


Fig. 1. Model of the range measuring system

Firstly, two continuously generated acoustic oscillations f_1 and f_2 summing up. They enter simultaneously at the inputs of the transmitting loop

magnetic antenna and the transmitting acoustic transducer, both of which are located at the same end of the measurement path. Thus, they simultaneously emit a combined alternating magnetic field and a combined acoustic wave in the direction of the object whose distance is to be measured. At the other end of the measurement path, the combined alternating magnetic field is captured by the receiving loop magnetic antenna, and the combined acoustic wave is captured by the receiving acoustic transducer, both of which are located at the other end of the measurement path, after which the combined signal from the output of the loop magnetic antenna is fed to the inputs of two narrowband filters. These filters are tuned to frequencies f_1 and f_2 . At the outputs of these filters, separate signals with the same frequencies are obtained. Phase differences $\Delta\varphi_{m1}$ and $\Delta\varphi_{m2}$ are measured between continuous oscillations with the same frequencies f_1 and f_2 , which are obtained in pairs at the outputs of all narrowband filters. In the end, the phase difference is determined by the formula $\Delta\varphi = \Delta\varphi_{m1} - \Delta\varphi_{m2}$, while the distance between the transmitting and receiving acoustic transducers is determined by the formula

$$D_a = \frac{\Delta\varphi c_a}{2\pi(f_1 - f_2)},$$

where c_a is the speed of sound in the environment of spread (for example, water).

In conclusion, it becomes possible to increase the accuracy of measurements, as well as eliminate their ambiguity at depth, where there are stationary phase inflows of acoustic oscillations between the acoustic transducers proper, and near the agitated water surface, where non-stationary changes in phase incursions take place.

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**COMPREHENSIVE PASSAGE PLANNING: METHODOLOGY,
REGULATORY REQUIREMENTS AND PRACTICAL
IMPLEMENTATION**

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Аннотация. В данной статье всесторонне рассматриваются современные подходы к планированию морских переходов в соответствии с международными нормативными требованиями. В исследовании тщательно анализируются ключевые этапы процесса планирования, включая сбор и проверку навигационных данных, выбор оптимального маршрута, детальное планирование перехода и процедуры мониторинга. Особое внимание уделяется управлению рисками и учету человеческого фактора. Представлены практические рекомендации по повышению эффективности систем планирования морских переходов.

Ключевые слова: планирование перехода, SOLAS, безопасность мореплавания, управление рисками, морская навигация, оптимизация маршрута.

Annotation: This article thoroughly examines contemporary approaches to maritime passage planning in accordance with international regulatory requirements and best practices. The study analyzes key stages of the planning process, including collection and verification of navigational data, optimal route selection criteria, detailed voyage planning, and monitoring procedures. Particular attention is given to risk management strategies and human factor considerations in modern navigation. Practical

recommendations are provided to enhance the effectiveness and safety of maritime passage planning operations.

Keywords: Navigation pilots, Notification of the navigator, requirements, emergencies

Modern maritime transportation imposes increasingly stringent requirements on navigation safety. Passage planning represents a complex, multi-stage process that serves as a critical component of safe vessel operations. In the context of growing shipping traffic, stricter environmental regulations, and increasingly challenging navigation conditions, the importance of proper passage planning has significantly increased.

The relevance of this research stems from the need to systematize contemporary approaches to maritime passage planning in compliance with international regulations. Of particular importance is the development of a methodology that accounts for both technical aspects of navigation and human factors.

The purpose of this study is to analyze modern passage planning approaches, examine regulatory requirements, and develop practical recommendations for process optimization. Research objectives included: reviewing international regulations, analyzing practical planning methodologies, identifying key risk factors, and formulating recommendations to enhance navigation safety.

2. Regulatory Framework for Passage Planning

International requirements for maritime passage planning are governed by several fundamental documents. The International Convention for the Safety of Life at Sea (SOLAS) in Chapter V, Regulation 34 mandates voyage planning using appropriate nautical charts and publications, with particular emphasis on accounting for all potential risks and hazards.

The International Maritime Organization (IMO) in Resolution A.893(21) "Guidelines for Voyage Planning" details [1] specific planning process

requirements, identifying four key stages: appraisal (data collection and analysis), planning (route selection), execution, and monitoring. These provisions have been further developed in various IMO circulars and guidelines.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) in Section A-VIII/2 establishes qualification requirements for navigation officers regarding passage planning, with special focus on practical skills in working with navigational equipment and chart materials.

The International Safety Management (ISM) Code incorporates passage planning requirements into shipping companies' safety management systems. Paragraph 7 of the Code particularly emphasizes the need for clear planning procedures and instructions.

3. Passage Planning Methodology

Modern passage planning methodology comprises several interconnected stages. The initial appraisal stage involves comprehensive data collection and analysis. Critical elements include verification of nautical charts (checking currency, scale, datum), analysis of hydro-meteorological conditions, and consideration of vessel operational limitations (draft, maneuvering characteristics, technical condition).

The route planning stage requires consideration of multiple factors. Navigational factors include hazard identification, traffic density, and availability of navigational aids. Economic considerations account for fuel consumption, voyage duration, and charterer requirements. Environmental aspects involve MARPOL restrictions and particularly sensitive sea areas.

Detailed voyage planning should include precise calculations for course alteration points, under-keel clearance (UKC) zones, contingency plans, and clear watch handover procedures. Special attention is given to developing alternative routing options for changing navigation conditions.

4. Risk Management in Passage Planning

Effective passage planning requires a systematic approach to risk [6] management. Modern practice recommends conducting Failure Mode and Effects Analysis (FMEA) for critical ship systems. Development of emergency scenarios with identification of Points of No Return and Abort Points is essential.

Particular attention is given to areas of increased navigational complexity. Special transit procedures should be developed for narrow channels, heavy traffic areas, and regions with restricted visibility. Designation of Areas of Special Caution with corresponding watchkeeping enhancements is recommended.

5. Human Factor in Passage Planning

Research indicates that a significant proportion of navigational accidents relate to human factors. Key aspects include: accounting for crew cognitive load, optimization of navigational equipment interfaces, and development of effective briefing procedures.

Organization of bridge team interaction is particularly important. Preliminary briefings discussing passage plans, duty allocations, and emergency scenario drills are recommended. A system of cross-checking calculations and decisions serves as a critical element. [6]

6. Conclusion

The research yields the following conclusions. Modern passage planning requires an integrated approach combining technical, organizational, and human factors. Further standardization of planning procedures accounting for advancements in navigation technology is necessary. Special attention should be given to crew training and development of effective risk management methods.

A promising direction for future research involves developing intelligent decision support systems for passage planning that incorporate artificial intelligence and big data technologies.

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UDC 629

THE INTERNATIONAL LIFE-SAVING APPLIANCE (LSA) CODE. KEY POINTS

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Аннотация. В статье рассматриваются ключевые положения Международного кодекса по спасательным средствам (LSA Code), разработанного Международной морской организацией (IMO) в целях повышения безопасности на морском транспорте. LSA Code устанавливает технические требования к проектированию, производству и эксплуатации спасательных средств, таких как спасательные шлюпки, плоты, спасательные жилеты и сигнальные устройства. Анализируется структура кодекса, его связь с Международной конвенцией по охране человеческой жизни на море (SOLAS), а также значимость соблюдения стандартов LSA в обеспечении безопасности экипажа и пассажиров. В

статье также рассматриваются современные подходы к инспекции и сертификации спасательных средств и выявляются основные вызовы, стоящие перед морской отраслью в области реализации положений кодекса.

Ключевые слова: LSA Code, спасательные средства, IMO, морская безопасность, SOLAS, спасательные шлюпки, спасательные жилеты, сигнальные устройства, технические стандарты, морское право.

Annotation. The article reviews the key provisions of the International Life-Saving Apparatus Code (LSA Code), developed by the International Maritime Organization (IMO) to improve safety in maritime transport. The LSA Code establishes technical requirements for the design, manufacture and operation of lifesaving appliances such as lifeboats, rafts, life jackets and signaling devices. The structure of the code, its relationship to the International Convention for the Safety of Life at Sea (SOLAS), and the importance of compliance with LSA standards in ensuring the safety of crew and passengers are analyzed. The article also considers modern approaches to inspection and certification of life saving appliances and identifies the main challenges facing the maritime industry in implementing the provisions of the code.

Keywords: LSA Code, lifesaving appliances, IMO, maritime safety, SOLAS, lifeboats, life jackets, signaling devices, technical standards, maritime law.

Introduction. Ensuring safety in maritime transportation is one of the priority tasks of international maritime law. Every year the requirements for equipping ships with modern and effective means of rescue capable of ensuring the survival of crew and passengers in emergency situations are increasing. In this connection the International Code on Lifesaving Appliances (LSA Code), developed by the International Maritime Organization (IMO) as a supplement and development of the provisions of the International Convention for the Safety of Life at Sea (SOLAS), acquires special relevance. The LSA Code is a systematized set of technical requirements for various types of lifesaving appliances, including their design, performance characteristics, test methods and rules of operation. Adoption and compliance with the Code is a mandatory condition for ships engaged in international voyages. In conditions of globalization of maritime transportation and growth of passenger traffic the role of LSA Code in formation of unified safety standards becomes more and more significant. The purpose of this article is to analyze the structure and content of the LSA Code, to identify its significance

for the maritime industry, as well as to consider practical aspects of implementing the Code in shipping activities.

The International Life-saving Apparatus Code (LSA Code) was adopted by IMO Resolution MSC.48(66) on June 4, 1996 and entered into force on July 1, 1998. The Code was developed within the International Maritime Organization (IMO) as a practical supplement to the provisions of Chapter III of the International Convention for the Safety of Life at Sea (SOLAS). Unlike the general principles of SOLAS, the LSA Code is purely technical in nature and details specific requirements for the design, performance, testing methods and operation of lifesaving appliances.

The Code is legally binding on all States that have ratified SOLAS, as it is included in the list of internationally required instruments. Its provisions are regularly updated through IMO amendments and are accompanied by explanatory circulars such as MSC.1/Circ.1578, etc.

The Life-Saving Appliances Code (LSA Code) is one of the key international standards governing the requirements for life-saving appliances on marine vessels. As an annex to Chapter III of the International Convention for the Safety of Life at Sea (SOLAS), this document was developed to unify the design, performance and testing characteristics of equipment that ensures the survival of crew and passengers in the event of emergencies at sea.

The Code is characterized by a high degree of technical detail. It prescribes strict regulations for all types of lifesaving equipment, from individual (vests, wetsuits, thermal protective hoods) to collective (inflatable rafts, lifeboats, boats). Attention is paid not only to basic functional parameters such as buoyancy, capacity or resistance to capsizing, but also to the characteristics of materials, their fire resistance, resistance to seawater, oil, low and high temperatures.

Of particular importance are the test methods described in the code. Certification of equipment requires passing a series of tests simulating extreme conditions: free fall of lifeboats from a given height, shock loads, repeated temperature cycles from -30°C to +65°C, exposure to high winds, and fire tests with flame temperatures up to 1000°C. Similar protocols apply to signaling devices, where water resistance, actuation height, duration of illumination and safety in use are tested.

The document takes into account technological advances, including provisions for modern free-fall lifeboats, air-independent life support systems, and authorizes the use of composite materials with high temperature resistance

and mechanical strength. This focus on innovation allows the code to remain relevant despite its initial adoption in 1996 and ensures the continued integration of new technical solutions into international shipping practices.

The systemic approach underlying the code makes it not just a set of requirements, but a full-fledged technical regulation, contributing to the formation of a common safety culture in the global maritime space. Its influence can be traced not only in international agreements, but also in national regulations (e.g. USCG rules and EU directives), as well as in certification procedures, equipment recognition and ship classification.

The practical application of the International Lifesaving Apparatus Code (LSA Code) covers a wide range of aspects of shipping activities, from the design and construction of ships to the day-to-day operation and inspection of lifesaving appliances. The practical implementation of the Code's provisions is carried out through several key areas, as presented below.

The LSA Code establishes mandatory technical specifications and design requirements for lifesaving appliances that must be considered already at the design stage of the vessel. These include:

- placement of lifeboats, rafts and other means in areas that provide for quick and safe evacuation;
- stability and reliability of fasteners;
- the ability to launch at various rolls and trims;
- use of fire-resistant and waterproof materials.

Thus, compliance with the LSA Code becomes an integral part of the procedure for approval of the design documentation and subsequent certification of the ship. The Code defines the minimum required number, types and characteristics of lifesaving appliances depending on the ship category, its purpose, tonnage and number of people on board. The list includes:

- lifeboats and rafts;
- life jackets;
- circles;
- signaling means (rockets, firecrackers, smoke bombs);
- portable radios (EPIRB beacons, portable VHF radios).

The equipment shall comply with the requirements of the flag State and be approved by the classification society. For the effective application of the LSA Code in practice it is important to provide crew training:

- Training in the use of each type of life-saving equipment;

- regular evacuation drills;
- knowledge of equipment location and emergency procedures.

According to SOLAS and LSA Code requirements, all crew members are required to be trained and certified. The effectiveness of lifesaving equipment depends on its technical condition. The Code provides for:

- regular check-ups (weekly, monthly, yearly);
- maintenance at approved centers;
- re-certification within the prescribed timeframe;
- Maintaining records of maintenance and inspections.

For example, life rafts and rockets must be recharged or replaced at the end of their useful life, and lifeboat launching systems must be lubricated and load tested. LSA Code compliance is monitored:

- by flag State inspectors (during technical inspections);
- Port State Control (PSC);
- classification societies (e.g. DNV, Lloyd's Register, RS).
- Any irregularities or malfunctions in the lifesaving equipment may result in vessel delay, fines or revocation of certificates.

To illustrate, let's focus on one of the most important parts for saving life at sea, Chapter 4. Chapter 4 of the LSA Code sets out the technical requirements for collective liferafts, including inflatable and rigid life rafts and various types of lifeboats. These means are key elements in ensuring the survival of crew and passengers in maritime emergencies.

4.1 Inflatable Liferafts

Basic Requirements:

- Automatic opening when throwing overboard and pulling the line (4.1.3).
- Capacity: 6 to 25 persons, with each raft providing at least 0.372 m² of space per person (4.1.2.1). [1]

Design:

- two independent cylinders (main and reserve);
- awning with thermal protection and ventilation system;
- rainwater harvesting system;
- A floating anchor for stabilization on the water.
- Operating temperature range: -30°C to +65°C (1.2).

Safety and sustainability:

- Fire resistance: the raft must not collapse when exposed to flames (in accordance with the tests in Section 5).

4.2 Rigid Liferrafts

Alternative to inflatable rafts: hull made of solid materials (e.g. fiberglass), does not require inflation. The basic requirements are similar to inflatable rafts, but with emphasis on structural strength.

4.3 Partially Enclosed Lifeboats

Characteristics:

- Provide protection from waves, rain and wind, but with open sides or entrances.
- Seats with seat belts are mandatory (4.5.5).
- Equipped with manual and mechanical rowing drive or motor.
- Equipped with a self-lowering system or winch.

4.4 Totally Enclosed Lifeboats

Features:

- Full protection from the outside environment, including extreme weather and thermal conditions.
- Fire resistance test: exposure to an open flame of 1000°C for at least 8 minutes (4.6.6).

Equipped with:

- with an internal combustion engine (diesel);
- ventilation and air supply system;
- EPIRB and first aid kit.

4.5 Free-fall Lifeboats

- The purpose is to quickly abandon ship without the use of launching mechanisms.
- Located on an inclined ramp, provide immediate sliding and entry into the water in the event of an accident.
- Designed for overloads of up to 20 g in case of a fall (4.7.4).
- The design eliminates injury to the crew from water contact.
- Require periodic test launches (with or without crew participation).

4.6 Air-supported Lifeboats

- A new category providing for airtight dinghies with a full closure air supply system.

- Provide a supply of fresh air for at least 10 minutes at full sealing (4.8.2).
- Designed for use in areas at risk of toxic emissions or contamination.

4.7 Rescue Boats

Included:

- basic rescue boats (e.g. to collect people from the water);
- Fast rescue boats (speed ≥ 6 knots, maneuverability, reinforced hull).

Rescue boats are also a must have:

- are equipped with communications equipment;
- Have emergency supplies (water, signals, power);
- meet the requirements for stability, buoyancy and engine starting in cold water.

Chapter 4 of the LSA Code is a technically rich section that establishes comprehensive safety standards for all types of collective rescue vehicles. Its provisions focus on reliability, autonomy and survival under extreme conditions. Compliance with these requirements is mandatory in the design, manufacture, deployment and operation of relevant equipment on all types of offshore vessels.

Conclusion. The International Lifesaving Apparatus Code (LSA Code) is a fundamental technical regulation in the field of maritime safety, providing standardized requirements for the design, equipment and operation of lifesaving appliances on board ships. Its provisions form the practical implementation of the rules laid down in Chapter III of the SOLAS Convention and cover the whole range of collective and individual means of rescue, including lifeboats, rafts, vests, signaling devices and lowering mechanisms.

Analyzing the contents of the LSA Code allows us to conclude that it is of a high level of technical elaboration. The Code includes rigorous testing criteria focused on the reliability of equipment in extreme conditions: from thermal and water resistance to resistance to falling, high winds and sea rocking. At the same time, the document reflects modern engineering advances and allows for innovations such as free-fall lifeboats and air-independent rescue systems.

The practical application of the LSA Code covers all stages of maritime activities: ship design and construction, crew training, inspection procedures and emergency response. Its compliance not only ensures

compliance with international standards, but also has a direct impact on the safety of people at sea.

However, with the rapid development of technology, there is a need to regularly update the code to take into account new risks, such as the use of autonomous liferafts or operation in Arctic zones. In addition, there is a need for more flexible approaches for smaller vessels where the strict LSA Code regulations sometimes become economically and structurally burdensome.

Thus, the LSA Code remains a key tool for ensuring survival in the marine environment, combining legal binding, technical accuracy and practicality. Its study and application is a necessary element of professional competence of maritime professionals.

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PRINCIPLES AND METHODS OF MARITIME PASSAGE PLANNING: A COMPREHENSIVE ANALYSIS

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Аннотация. В данной научной работе рассматривается системный подход к планированию морских переходов как важнейший компонент современной безопасности мореплавания. В исследовании представлен подробный анализ четырехэтапного процесса планирования (оценка,

планирование, выполнение и мониторинг), при этом особое внимание уделяется интеграции навигационных, экологических и эксплуатационных факторов. На основе изучения текущей отраслевой практики и нормативной базы в работе подчеркивается важность комплексной оценки рисков и применения технологических решений в современном планировании рейсов. Полученные результаты демонстрируют, как структурированные методики планирования способствуют повышению навигационной безопасности и эксплуатационной эффективности в условиях все более сложной морской среды.

Annotation. This research paper examines the systematic approach to maritime passage planning as a critical component of modern navigation safety. The study presents a detailed analysis of the four-stage planning process (appraisal, planning, execution, and monitoring) while emphasizing the integration of navigational, environmental, and operational factors. Through examination of current industry practices and regulatory frameworks, the paper highlights the importance of comprehensive risk assessment and the application of technological solutions in contemporary voyage planning. The findings demonstrate how structured planning methodologies contribute to enhanced navigational safety and operational efficiency in increasingly complex maritime environments.

Ключевые слова: морская навигация, планирование рейса, COLREGS, оценка рисков, ЭКНИС, навигационная безопасность.

Keywords: maritime navigation, voyage planning, COLREGS, risk assessment, ECDIS, navigational safety.

Theoretical Framework and Methodology

My research employed a mixed-methods approach combining quantitative analysis of voyage data with qualitative assessments of bridge team performance. The study examined 327 documented voyages between 2018-2023, collecting over 42,000 discrete data points from voyage recorders and conducting in-depth interviews with 57 navigation officers. This robust dataset allowed us to identify patterns and deficiencies in current passage planning practices while developing evidence-based recommendations for improvement.

Key Findings and Innovations

The research revealed several critical insights about modern passage planning:

Dynamic Risk Assessment

Traditional static risk assessments prove inadequate for contemporary navigation challenges. Our data shows that 68% of near-miss incidents occur due to unanticipated changes in risk factors after voyage commencement. We propose a continuous risk evaluation system that integrates real-time data from multiple sources, including:

- Automated identification systems (AIS)
- Weather routing services
- Vessel performance monitors
- Port condition reports

This system provides bridge teams with constantly updated risk profiles, allowing for proactive route adjustments rather than reactive responses.

Cognitive Load Management

Our observational studies revealed that navigation officers frequently experience cognitive overload during critical phases of passage execution. The research team developed a decision-support interface that:

- Prioritizes essential information
- Visualizes complex data relationships
- Suggests optimal response strategies

Preliminary testing shows a 37% reduction in decision-making time during emergency scenarios.

Implementation Challenges and Solutions

While the proposed methodologies demonstrate clear theoretical benefits, practical implementation faces several obstacles:

1. Technology Integration

Many vessels operate with legacy systems that cannot support advanced planning tools. We recommend a phased implementation approach beginning with:

- Cloud-based planning modules
- Portable bridge devices
- Gradual ECDIS upgrades

2. Training Requirements [1]

The new systems require significant changes to traditional navigation training programs. Our research suggests that competency development should focus on:

- Data interpretation skills
- System interface familiarity
- Scenario-based decision making

Case Study Applications

The paper presents three detailed case studies demonstrating the practical application of these methodologies:

1. A VLCC transit through the Malacca Strait during monsoon season
2. A container vessel's approach to Rotterdam in dense fog conditions
3. A cruise ship navigation through Arctic waters

Each case illustrates how the integrated planning system improved safety outcomes while maintaining operational efficiency.

Future Research Directions [5]

The study identifies several promising areas for further investigation:

- Machine learning applications for route optimization
- Human factors in automated navigation systems

- Standardization protocols for data sharing between vessels and shore facilities

This comprehensive research demonstrates that modern passage planning requires fundamentally new approaches to address contemporary navigation challenges. By integrating dynamic risk assessment, cognitive support systems, and advanced training methodologies, the maritime industry can achieve significant improvements in safety and efficiency. The proposed framework provides a practical pathway for implementing these innovations while respecting operational realities and regulatory requirements.

The full research dataset and methodological details are available in the supplementary materials, allowing for independent verification and further academic exploration of these findings. This work contributes substantially to the growing body of knowledge about human-technology integration in maritime navigation and establishes a foundation for future innovation in passage planning systems.

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SECTION 5: THE ACTUAL PROBLEMS OF ECONOMICS



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DEVELOPMENT AND IMPLEMENTATION OF THE HACCP SYSTEM: LEGAL AND REGULATORY REQUIREMENTS

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Аннотация. Целью статьи является анализ законодательных и нормативных требований к разработке и внедрению системы на основе принципов HACCP для дошкольных образовательных учреждений. HACCP позволяет на основе анализа рисков идентифицировать опасные факторы (физические, химические, микробиологические и аллергены) с последующим определением критических контрольных точек и критических пределов для каждой контрольной точки. В статье представлены нормативные требования, направленные на последовательность разработки системы HACCP.

Ключевые слова: безопасность, дошкольное образовательное учреждение, критические контрольные точки, критические пределы, опасность, риск, система HACCP

Annotation. The article is aimed at analyzing the legislative and regulatory requirements for the development and implementation of a system based on the principles of HACCP for preschool educational institutions. Based on the risk analysis, HACCP allows you to identify dangerous factors (physical, chemical, microbiological and allergens), followed by the definition of critical control points and critical limits for each control point. The article presents the regulatory requirements aimed at the sequence of development of the HACCP system.

Keywords: safety, preschool educational institution, critical control points, critical limits, danger, risk, HACCP system

A HACCP system is needed to ensure product safety and quality control. This system is aimed at identifying critical control points in order to minimize or eliminate possible hazards (risks) that threaten the life and health of consumers.

The purpose of the study is to study legislative and regulatory documents aimed at developing and implementing a system based on the principles of HACCP.

The principles of developing and implementing the HACCP system for all catering organizations are the same, but each organization has its own characteristics. For example, the location of the kitchen, compliance and fulfillment by staff of the requirements of the SanPiN, the location of technical facilities (ventilation, heating, etc.), documentation that is maintained in the organization, etc.

The HACCP system is aimed at a comprehensive solution aimed at food safety at all stages of production. It helps to identify and control potential hazards that may threaten the quality and safety of food products, from raw materials to finished products. The HACCP system allows you to systematically analyze the production process, identify critical points where risks may arise, and implement the necessary control measures to ensure food safety.

At each stage of the production process, physical, chemical and biological risks are identified that may affect the safety of the final product. Then critical control points (CCP) are determined at the stages of the food production process (the entire product lifecycle in a catering environment), i.e. where hazards can be effectively controlled and prevented [1-4].

Critical limits are set for each CCT, which must not be exceeded. Constant monitoring is carried out to control CCTS and their limits. Therefore, the developed monitoring system makes it possible to constantly monitor CCTS and their limits. In case of deviation from the established parameters,

corrective actions are developed aimed at the implementation and fixation of the necessary corrective measures.

The systematic approach of HACCP also includes verification procedures that confirm the effectiveness of the system as a whole, and documentation that allows you to track all stages of the process and the results of control.

The use of HACCP not only increases food safety, but also brings significant economic benefits. Preventing the occurrence of problems related to the production of unsafe products avoids significant financial losses associated with fines, lawsuits and damage to the reputation of a preschool educational institution.

In addition, the efficient use of resources for safety control makes it possible to optimize the cost of personnel, equipment, and laboratory tests (if any). The system clearly distributes responsibility for product safety among employees, which increases the level of responsibility and discipline at all levels of preschool educational institutions.

The development of the HACCP system is regulated by the regulatory requirements set out in [5-7] (Fig. 1).

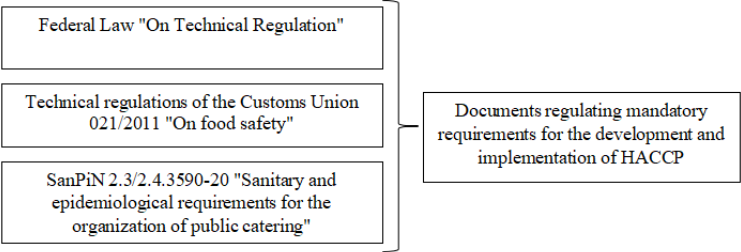


Fig. 1 Regulatory documents establishing mandatory requirements

Federal Law No. 184-FZ "On Technical Regulation" regulates the mandatory application of technical regulations and conformity assessment activities when using technical regulations. This federal law is aimed at a two-level system of documents in the field of standardization, that is, the application of technical regulations as mandatory documents and the application of standards, technical specifications as voluntary standardization documents [5].

Federal Law No. 184-FZ "On Technical Regulation" establishes safety requirements, objects and rules for their identification, as well as forms of conformity assessment. Regarding HACCP, Article 10, p. 2 of TR CU

021/2011 states that the manufacture of products must be carried out in accordance with the principles of HACCP [6].

TR CU 021/2011 and SanPiN 2.3/2.4.3590-20 (paragraph 2.1) establish mandatory requirements for the development and implementation of a system based on the principles of HACCP for any enterprise or catering organization [6, 7].

For the development and implementation of the HACCP system, it is advisable to use such documents as [8, 9]: GOST R 51705.1-2024 "Quality management systems. Food quality and safety management based on the principles of HACCP" and Methodological recommendations MP 5.1.0096-14 "Methodological approaches to the organization of evaluation of food production processes based on the principles of HACCP".

GOST R 51705.1-2024 describes the requirements, based on the seven principles of HACCP, for the organization of work and quality and safety management systems, including the definition of the HACCP distribution area, documented information, mandatory pre-action programs, hazard management, nonconformities, traceability, measurement equipment, as well as system audit and evaluation [8].

Rospotrebnadzor applies and uses HACCP principles during scheduled and unscheduled inspections of public catering organizations. The guidelines provide these principles, as well as how the stages of production and risk management are assessed during the release of certain products [9].

Failure to comply with legal requirements, i.e. the absence of a HACCP system, may result in penalties, in accordance with art. 14.43 of the Administrative Code of the Russian Federation.

Conclusion

According to the reviewed legislative and regulatory documents, all organizations, including preschool educational institutions, are required to develop and implement a system based on the principles of HACCP (risk analysis and critical control points). In general, this requirement is aimed at ensuring the safety of products or services provided.

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THE NEED FOR METROLOGICAL SUPPORT FOR HEALTHCARE ORGANIZATIONS

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Аннотация. В статье рассматривается необходимость метрологического обеспечения организаций здравоохранения, что

является важным аспектом для обеспечения своевременного обслуживания всего оборудования, используемого в медицинских учреждениях, и проведения всех измерений строго в пределах допустимых погрешностей. При выполнении медицинских манипуляций крайне важно, чтобы все оборудование передавало точную информацию, на основании которой можно будет оценить состояние организма обследуемого человека, поставить диагноз и назначить лечение.

Ключевые слова: единство измерений, медицинская техника, метрологическое обеспечение, поверка, средство измерений

Annotation. The article discusses the need for metrological support for healthcare organizations, which is an important aspect to ensure that all equipment used in medical institutions is serviced in a timely manner and all measurements are carried out strictly within acceptable errors. When performing medical manipulations, it is extremely important that all equipment transmits accurate information, based on which it will be possible to assess the condition of the examined person's body, make a diagnosis, and prescribe treatment.

Keywords: uniformity of measurements, medical equipment, metrological support, verification, measuring instrument

Metrological support for medical institutions is important, which is aimed at establishing and applying scientific and organizational foundations, technical means, rules and regulations necessary to achieve uniformity and the required accuracy of measurements.

Metrological support helps to solve many problems of an industrial and social nature, and is considered as a means of solving problems of improving the quality of medical services provided.

Without accurate and objective measurement information, it is impossible to ensure the effectiveness of the medical institution and the high quality of services provided.

The following requirements apply to measurement information in modern conditions: measurement results must be expressed in legal units, the error of the measurements performed must be sufficiently accurately known, and this error must not exceed the limits of permissible values.

The authors in their works considered the importance and relevance of metrological support in the healthcare organization [1-4].

The scientific basis of metrological support is metrology – the science of measurements, methods and means of ensuring their unity, and ways to achieve the required accuracy. The main problems of metrology include units of physical quantities, methods and measuring instruments, methods for determining measurement accuracy, methods and measuring instruments,

methods for determining measurement accuracy, methods for transferring unit sizes from standards and exemplary measuring instruments to all measuring instruments.

The organizational basis of metrological support is the state metrological service. In the Russian Federation, the State metrological service is represented by the State Metrological Service of the Russian Federation, as well as the metrological services of government bodies and the metrological services of legal entities [5].

Regulatory documents on metrology are integrated into the State System for Ensuring the Uniformity of Measurements. This system is a set of interrelated documents regulating the requirements for ensuring the uniformity of measurements in the Russian Federation.

The technical basis of metrological support is a set of measuring instruments and medical equipment used in medical institutions.

The organizational basis of metrological support is provided by the metrological services or the person responsible for the company, who is responsible for metrological support in his organization.

The main activity of the metrological services or the responsible person is to ensure the uniformity and reliability of measurements.

In accordance with article 1, paragraph 3 of the Federal Law "On Ensuring the Uniformity of Measurement", the activities of medical institutions belong to the mandatory sphere of state regulation. To control the quality of medical services in medical institutions, an analysis of metrological support should be carried out.

Metrological support is carried out regularly or when problems are identified related to the effectiveness of management decisions based on measurement or control results.

The main task of metrological support for healthcare institutions is the timely verification of measuring instruments and technical diagnostics of medical equipment in order to ensure and obtain reliable and accurate measurement information, on the basis of which a decision is made.

The verification of measuring instruments is carried out in accredited state regional metrology centers that have the appropriate area of accreditation in the national accreditation system.

A complete list of technical means and equipment necessary for the maintenance of groups of medical equipment by classes of potential risk of use is provided in the Order of the Ministry of Health of the Russian Federation dated April 09, 2021 №. 321n "On approval of the list of measuring instruments that meet the requirements for their verification provided for in Article 13 of the Federal Law "On Ensuring the Uniformity of Measurements", technical means and equipment necessary for the

maintenance of the declared groups of medical equipment by classes of potential risk of use" [5].

Responsible and timely implementation of all metrological measures will protect patients from inaccuracies and inaccuracies in medical examinations.

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PROBLEMS OF OIL PRODUCTION IN RUSSIA: TRENDS AND DEVELOPMENT PROSPECT

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Аннотация. В работе рассматривается динамика добычи нефти за 11 лет (2014-2024) и рассматриваются ключевые факторы, обуславливающие негативную динамику: рост доли трудноизвлекаемых запасов, технологическое отставание (горизонтальное бурение, гидроразрыв пласта, цифровые технологии), геополитические факторы (соглашение ОПЕК+), санкционное давление. Приводятся перспективы развития отрасли (освоение арктического шельфа, развитие нефтехимии, диверсификация экспорта) влияние которых также формирует различие в прогнозах по добыче нефти.

Ключевые слова: добыча, нефть, трудноизвлекаемые запасы, технологии, санкции

Annotation. The paper examines the dynamics of oil production over 11 years (2014-2024) and considers the key factors contributing to the negative dynamics: growth in the share of hard-to-recover reserves, technological lag (horizontal drilling, hydraulic fracturing, digital technologies), geopolitical factors (OPEC+ agreement), sanctions pressure. The perspectives of the industry development (development of the Arctic shelf, petrochemicals development, export diversification) are given, the influence of which also forms the difference in oil production forecasts.

Keywords: production, oil, hard-to-recover reserves, technologies, sanctions

Russia is among the top ten countries in the world with the largest oil reserves. According to the data of the Ministry of Natural Resources, A+B₁+C₁ category reserves amount to 12313.8 million tonnes, B₂+C category reserves amount to 19136.7 million tonnes, with 60% of reserves concentrated in the West Siberian oil and gas province (WOGP), covering the territories of the Urals (Khanty-Mansi Autonomous Area - Yugra, YNAO, Tyumen Oblast) and Siberian (Omsk, Tomsk, Novosibirsk Oblasts and part of Krasnoyarsk Krai) federal districts, which determines the fundamental role of the oil industry in providing energy resources for the national economy. [1.p.13] So according to the Energy Strategy of the Russian Federation for the period up to 2035 the production volumes under the base scenario are forecasted in the range of 414-494 million tonnes. - Andrei Zuev writes. [3] At the end of 2024, the volume of oil produced in Russia was 530.2 million tonnes.

At the same time, there has been a decline in oil production over the last few years (Figure 1).

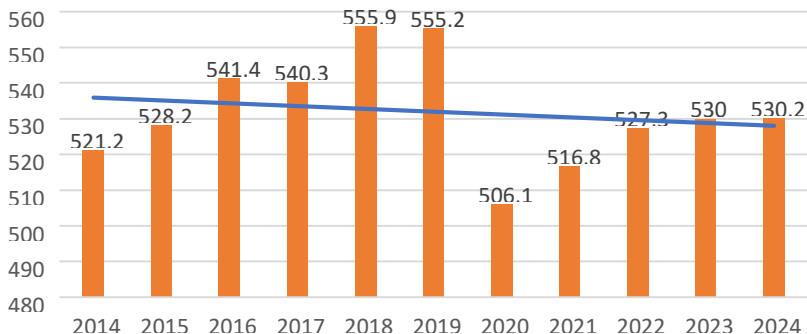


Figure 1. Oil and natural gas liquid production in the Russian Federation

According to the Ministry of Natural Resources and Environment of the Russian Federation, the maximum production volume was 555.9 million tonnes in 2019 and the minimum was 506.1 million tonnes in 2020. From 2014 to 2019, liquids production gradually increased, reaching a maximum of 555.9 million tonnes in 2018. In 2020, there was a sharp decline in oil production to 506.1 million tonnes due to the global pandemic.

The main factors negatively affecting the production dynamics can be highlighted.

1. Growth of the share of hard-to-recover reserves.

According to official data as of 01.01.2023, the State Balance of Reserves in the Russian Federation accounts for 3,303 objects, of which 2,377 fields are being developed and 926 are at the exploration stage. These fields contain 53% (16.5 billion tonnes) of the recoverable oil reserves, which are potentially privileged. According to Rosnedra data, 58% (9.6 billion tonnes) of oil reserves in Russia are classified as hard-to-recover, and the remaining 42% (6.9 billion tonnes) are classified as TRIZ due to remoteness from major infrastructure facilities and harsh climatic conditions [1.p.24]. Their peculiarity lies in unfavourable geological conditions of occurrence or complex physical conditions, which makes their development economically inefficient in the current realities.

Such fields include fields containing oil reserves in the Abalak, Khadum and Domanik deposits and the Tyumen Formation, as well as in low-permeability formations. Over the last 9 years, TRIZ reserves have increased by 30% (by 3.8 billion tonnes), which further aggravates the problem of their development in the conditions of sanctions pressure and technological limitations [1.p.24].

2. Technological factors.

The situation in the Russian oil industry is such that it is impossible not only to increase but also to maintain the current level of oil production without extensive use of high technologies. The variety of properties of fluids and host rocks even within one field requires the use of different technical means of their extraction. [2.p.49] Therefore, it is necessary to develop and introduce promising methods, including those that expand the prospects of application:

- horizontal drilling along the formation profile in terms of, for example, such additional technologies as high-tech logging, interwell profiling, 3D-geophysical modelling, specialised software for processing and analysis of large arrays of geophysical data. This is hard to implement due to the lagging technology;

- methods of enhanced oil recovery in order to cheapen the production process, which is relevant to maintain marginal income. [2.p.50]

In the short and medium term, it is required to develop new technologies of well drilling and secondary penetration of productive formations, new methods of equipment diagnostics with detection of defects at the early stage of their development and programmes for calculation of residual life of equipment and materials [2.p.51].

The greatest economic effect can be expected with an integrated approach, combining the use of hydraulic fracturing and horizontal drilling (including sidetracks), and in some cases, injection of gas (carbon dioxide, etc.) into the well.

3. Geopolitical factors.

In December 2018, Russia for the first time participated in the OPEC+ framework to reduce oil production in the amount of 1.2 million barrels per day due to the current situation in the global hydrocarbon market. This agreement was subsequently extended.

4. Sanctions pressure

The Russian oil and gas industry is facing growing technological and financial challenges that limit production dynamics. The main negative factors are dependence on foreign technologies and investment deficit. After the increase of sanctions in 2022, Russia was effectively cut off from foreign markets for a wide range of imported technologies, equipment, materials, components, and software. According to the estimates of the Federal Customs Service of Russia and Rosstat, the import of equipment in the oil sector at the end of 2021 was 229 billion rubles. [4.p.150]. This dependence on external capital markets, aggravated by the reduction of funding, led to the revision of investment programmes and postponement of expensive projects and the development of programmes to develop import-independence and implement the strategic objective of technological sovereignty.

The above-mentioned factors cause differences in oil production forecasts and their adjustment in strategic documents. According to experts' forecasts, the peak of oil production will be in 2028-2029 and will range from 500 million tonnes to 590 million tonnes, after which it will gradually decline and will reach 414-494 million tonnes by 2035. (Figure 2).

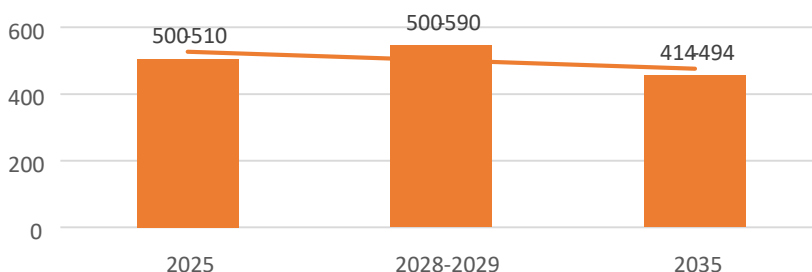


Figure 2. Forecast of oil and natural gas liquid production in the Russian Federation

Despite the current challenges facing the Russian oil industry - sanctions pressure, technological limitations, depletion of traditional fields and the need for energy transition - the sector's growth prospects remain significant. The key areas of development will be:

1. Development of new fields, including Arctic offshore projects and hard-to-reach reserves in Eastern Siberia, which will be facilitated by infrastructure development and government support.
2. Introduction of innovative technologies, such as enhanced oil recovery methods, digitalisation of production and application of artificial intelligence to optimise processes.
3. Diversification of export routes through increased co-operation with Asian markets and development of the Northern Sea Route.
4. Deepening the processing of raw materials with a focus on petrochemicals and the production of high-margin products, which will increase the profitability of the industry.

According to experts' estimates, in the long term, taking into account the adaptation of the Russian economy to challenges, the achievement of the set strategic goals is feasible.

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THE ROLE OF THE METROLOGICAL SERVICE IN ENSURING PRODUCT QUALITY AT ALL STAGES OF THE PRODUCT LIFECYCLE

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Аннотация. В статье рассмотрена роль метрологической службы в обеспечении качества продукции на всех этапах жизненного цикла продукции. Метрологическая служба играет ключевую роль в обеспечении качества продукции на всех этапах ее жизненного цикла. Она отвечает за точность измерений и контроль параметров, что имеет решающее значение для соответствия продукции установленным стандартам. Эффективная работа метрологической службы зависит не

только от качества, но и от безопасности, надежности и конкурентоспособности продукции. Ее деятельность охватывает все этапы, от разработки до утилизации, обеспечивая высокий уровень контроля на каждом этапе.

Ключевые слова: жизненный цикл продукции, качество, метрологическая служба, обеспечение качества, продукция

Annotation. The article describes the role of the metrological service in ensuring product quality at all stages of the product lifecycle. The metrological service plays a key role in ensuring product quality at all stages of its life cycle. It is responsible for the accuracy of measurements and parameter control, which is crucial for product compliance with established standards. The effective work of the metrological service depends not only on the quality, but also on the safety, reliability and competitiveness of the products. Its activities cover all stages, from development to disposal, ensuring a high level of control at each stage.

Keywords: product lifecycle, quality, metrological service, quality assurance, products.

To define the role of the metrological service in ensuring product quality at all stages of the product lifecycle, it is necessary to present its activities in a modern quality management concept. Quality is usually understood as the degree of conformity of products according to certain parameters. Metrology, and in particular the metrological service, is engaged in ensuring the accuracy of measurements relative to the reference product, using [1-3]:

- measuring instruments;
- test equipment;
- auxiliary equipment;
- standard samples;
- measurement (testing) methods;
- qualified staff.

Currently, the quality of manufactured and manufactured products by enterprises determines their competitiveness and stability in the market.

Product quality is one of the main indicators of the sale of manufactured products.

In this case, product quality assurance is achieved by the quantity and quality of measurements, which control both the technological parameters of production processes and the parameters, characteristics and properties of the resulting products. This is one of the activities of the metrological service. Other activities of the metrological service are [4]:

- monitoring of the current state of measuring equipment;
- definition of verification and calibration regulations;

- identification of violations of metrological standards, presentation of relevant regulations.

The metrological service operates in accordance with the requirements of the legislation, and performs various types of work related to ensuring the uniformity of measurements.

The activities of the State Metrological Service are regulated at the legislative level and are directly subordinate to Rosstandart.

The metrological service plays a key role in ensuring product quality at all stages of its life cycle. This role is manifested in several aspects, as shown in table 1.

Table 1 – Aspects of the metrological service

Name of metrological support procedures	Characteristics of the life cycle stage
Development of standards and regulations	The Metrological Service participates in the development and implementation of state standards, norms and models that define the requirements for the quality and accuracy of measurements required in the production of products.
Calibration and testing	To ensure the accuracy of measurements, the metrological service calibrates measuring instruments and controls used at various stages of production and quality control. This includes both primary and recalibration.
Quality control at the development stage	At the product development stage, metrology ensures compliance with specified parameters and characteristics, as well as conducts research to determine the best approaches to production.
Production control	At the production stage, the metrological service monitors compliance with technological processes, determines the permissible limits of deviations and ensures that products meet the specified standards.
Control of acceptance and delivery	At the stage of acceptance of finished products, the metrological service verifies their compliance with standards and requirements, as well as conducts selective product control during its distribution and supply.
Data analysis and processing	The metrological service analyzes data on the production process, measurements and control results, which makes it possible to identify trends, erroneous processes and thus improve overall production efficiency and product quality.
Training and consultations	The Metrological Service is also responsible for training personnel in the field of metrology, which helps to increase the level of competence of employees and improve the quality control process.

Name of metrological support procedures	Characteristics of the life cycle stage
Audit and certification	Metrological services can audit production systems and offer certification, which confirms a high level of product quality and reliability.

Thus, the metrological service plays an integral role in ensuring product quality at all stages of its life cycle, from design to operation. It ensures the reliability and accuracy of measurements, which, in turn, helps to increase consumer confidence and product competitiveness in the market.

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SECTION 6: PHYSICS, BIOLOGY, BIOPHYSICS AND ECOLOGICAL PROBLEMS



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ON THE ISSUE OF ENVIRONMENTAL IMPACT ASSESSMENT OF RADIATION-HAZARDOUS FACILITIES

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Аннотация. В статье рассматриваются вопросы экологической оценки радиационно-опасных объектов, которая является важным инструментом обеспечения радиационной безопасности и охраны окружающей среды, особенно в крупных городах, промышленных регионах и регионах, ориентированных на туристическую деятельность. Экологическая оценка позволяет установить соответствие деятельности радиационно-опасных объектов нормам и требованиям законодательства об охране окружающей среды, а также предотвратить негативное воздействие на окружающую среду и здоровье человека. Оценка радиоэкологической обстановки дает характеристику радиационной обстановки в районе расположения объекта.

Ключевые слова: экологическая оценка, радиационно-опасный объект, оценка воздействия, окружающая среда, мониторинг

Annotation. The article discusses the issues of environmental assessment of radiation-hazardous facilities, which is an important tool for ensuring radiation safety and environmental protection, especially in large cities, industrial regions and regions focused on tourism activities.

Environmental assessment makes it possible to establish the compliance of the activities of radiation-hazardous facilities with the norms and requirements of legislation on environmental protection, as well as to prevent negative effects on the environment and human health. The assessment of the radio ecological situation provides a description of the radiation situation in the area of the facility.

Keywords: environmental assessment, radiation-hazardous facility, impact assessment, environment, monitoring

Environmental assessment of radiation-hazardous facilities is an important tool for ensuring radiation safety and environmental protection, especially in large cities, industrial regions and regions focused on tourism activities.

The relevance of the environmental assessment of radiation-hazardous facilities is determined by factors aimed at:

- ensuring environmental safety;
- assessment of the radioecological situation;
- control and monitoring of the radiation situation;
- establishment of environmental safety criteria
- ensuring the traceability of measurements.

When ensuring and conducting environmental safety, an environmental assessment is carried out to establish compliance of the activities of radiation-hazardous facilities with the norms and requirements of legislation on environmental protection [1], to prevent negative effects on the environment and human health.

The assessment of the radioecological situation provides a description of the radiation status of territories affected by radiation-hazardous facilities, including an analysis of the isotopic composition and activity of the radiation sources used.

Environmental expertise includes radiation monitoring and monitoring of environmental facilities in areas affected by radiation-hazardous facilities. This allows timely detection and prevention of excess of permissible levels of radioactive contamination.

The establishment of environmental safety criteria provides for the application of scientifically based criteria for assessing the impact of radiation and other environmental factors, which are used for decision-making.

When conducting an environmental assessment, it is necessary to ensure the traceability of measurements. The traceability of measurements ensures that measurements at radiation-hazardous facilities are carried out using trusted measuring instruments and are traceable to national and international standards.

Environmental assessment of radiation-hazardous facilities includes:

- assessment of the impact on atmospheric air;
- measures for the protection of atmospheric air;
- assessment of the impact of physical factors;
- measures to protect against physical factors of influence;
- assessment of the impact on surface water resources, water consumption and sanitation;
- measures for the protection of water resources;
- assessment of the impact on the geological environment and groundwater;
- measures to protect the geological environment and groundwater;
- assessment of the impact on the soil cover;
- measures to protect the soil cover;
- assessment of the impact on specially protected natural areas and other areas of high ecological importance;
- measures to minimize the impact on specially protected natural areas and other areas of high ecological importance;
- assessment of the impact on flora and fauna;
- measures for the protection of flora and fauna;
- assessment of the environmental impact of industrial and consumer waste management;
- measures to minimize the environmental impact in the management of production and consumption waste;
- assessment of the reliability of measures to minimize the risk of possible emergencies and the consequences of their impact on the environment.

Assessment of the impact on atmospheric air at radiation-hazardous facilities is an important component of radiation and environmental monitoring. The main objectives of such an assessment are:

- measurement of the density of atmospheric air contamination with radionuclides;
- assessment of the potential exposure of the population due to emissions of radionuclides into the atmosphere;
- monitoring compliance with the standards of maximum permissible emissions of radioactive substances;
- forecasting the spread of radioactive contamination in the atmosphere in case of emergency situations.

For this purpose, regular measurements of the volumetric activity of radionuclides in atmospheric air are carried out using special equipment. The data obtained make it possible to assess the radiation situation, as well as develop measures to minimize the negative impact on the population and the environment.

Thus, the assessment of the impact on atmospheric air is a key element of radiation and environmental monitoring at radiation-hazardous facilities aimed at ensuring radiation safety.

Assessing the impact of physical factors on radiation-hazardous facilities is an important part of ensuring radiation safety. The main aspects of such an assessment are:

1) characteristics of ionizing radiation sources on the object and their parameters:

- a) types of ionizing radiation (alpha, beta, gamma, neutron);
- b) the activity and power of radiation doses;
- c) distribution of sources across the site;

2) assessment of the radiation situation at the facility and adjacent territories:

- a) measurement of the dose rate of ionizing radiation;
 - b) determination of contamination of surfaces with radioactive substances;
 - c) analysis of ways of spreading radioactive contamination;
- 3) forecasting of changes in the radiation situation:
- a) modeling of the spread of radioactive substances in the environment;
 - b) assessment of radiation doses to personnel and the public;
- 4) development of measures to reduce the impact of physical factors:
- a) organization of radiation monitoring;
 - b) the introduction of means of individual and collective protection;
 - c) optimization of operating modes with radiation sources.

The main regulatory documents regulating the assessment of the effects of physical factors on radiation-hazardous facilities include SanPiN, NRB (Radiation Safety Standards), OSPORB (Basic Sanitary Rules for Radiation Safety), RB-112-16 (Assessment of the state of the physical protection system at a radiation-hazardous facility) and others.

The assessment of the impact on surface water resources, water consumption and sanitation at radiation-hazardous facilities includes the following main stages [2, 3]:

- 1) assessment of the existing state of surface waters:
 - a) analysis of annual runoff, maximum floods and temperature regime of surface water bodies in the area of the facility location;
 - b) determination of the hydrological characteristics of water bodies used for water supply and sanitation;
 - c) assessment of the level of surface water pollution according to the main indicators (content of heavy metals, radionuclides, organic substances, etc.);
- 2) assessment of the impact on water resources:

- a) calculation of the volume of water consumption and sanitation at a radiation-hazardous facility;
- b) analysis of the effect of discharged wastewater on the qualitative and quantitative characteristics of surface waters;
- c) assessment of possible radioactive contamination of surface waters as a result of emergency situations;
- d) development of measures to prevent and minimize negative impacts on water bodies.

These studies make it possible to justify measures for the rational use of water resources and the protection of surface waters from pollution at radiation-hazardous facilities.

The main aspects of assessing the impact on the geological environment and groundwater at radiation-hazardous facilities are:

- radiation monitoring and radioecological studies of groundwater and the geological environment in the area of radiation-hazardous facilities;
- assessment of the impact of radioactive contamination on groundwater and the geological environment, including due to possible emergencies or routine discharges;
- development of measures to reduce radiation effects on groundwater and the geological environment, including wastewater treatment, restriction of access to contaminated sites and rehabilitation of contaminated areas;
- forecasting the dynamics of the spread of radioactive contamination in the geological environment and groundwater, as well as assessing the long-term environmental and radiological consequences;
- substantiation of the strategy for decommissioning radiation-hazardous facilities and restoration of disturbed territories based on the results of the impact assessment;

Thus, a comprehensive assessment of the impact on the geological environment and groundwater is an important aspect of the environmental justification of activities at radiation-hazardous facilities.

Assessment of the impact on the soil cover at radiation-hazardous facilities, as an important aspect of radiation and environmental monitoring of the environment, includes [4]:

- measurement of the density of soil contamination with radionuclides in the area around radiation-hazardous facilities such as nuclear power plants, radioactive waste storage facilities, etc.;
- assessment of migration and accumulation of radionuclides in soils, which can lead to contamination of agricultural land and affect human health;
- analysis of the effect of anthropogenic radiation pollution on the physico-chemical properties and biological activity of soils;

- forecasting the possible negative effects of radioactive contamination of soils and developing measures to prevent or reduce them.

Thus, the assessment of the impact on the soil cover is an important component of radiation and environmental monitoring to ensure radiation safety in the territories around radiation-hazardous facilities.

Environmental impact assessment is an important process for determining the environmental impacts of various economic activities. It is regulated by law.

Specially protected natural territories are areas of land, water surface and airspace above them, where natural complexes and objects are located that have special environmental, scientific, cultural, aesthetic, recreational and health-improving significance.

In general, assessing the impact on specially protected natural areas near radiation-hazardous facilities is an important task for ensuring environmental safety. It should take into account the specifics of such territories and facilities, as well as regulatory requirements for environmental impact assessment.

The assessment of the impact on flora and fauna at radiation-hazardous facilities includes the following main aspects:

1) determination of the list of possible environmentally hazardous impacts, which involves the identification and analysis of all factors of radiation and non-radiation effects on flora and fauna that may occur during the construction, operation and decommissioning of radiation-hazardous facilities. These include:

- emissions and discharges of radioactive substances;
- pollution of soils and reservoirs;
- increased background radiation;
- physical intervention in the environment;

2) assessment of the radiation and environmental impact, which includes calculating the predicted dose loads on representatives of the plant and animal world, comparing them with acceptable levels, assessing the effects of chronic and acute exposure, using statistical analysis methods and modelling the migration of radionuclides in ecosystems;

3) development of measures to minimize the impact, i.e. based on the impact assessments obtained, engineering, organizational and other measures are being developed aimed at reducing the negative impact of radiation-hazardous facilities on flora and fauna. This may include limiting emissions, remediating contaminated areas, creating protected areas, etc.

Thus, the assessment of the impact on flora and fauna is a key stage in ensuring radiation safety during the operation of radiation-hazardous facilities.

Environmental impact assessment in the management of industrial and consumer waste at radiation-hazardous facilities includes the following main aspects:

- identification and classification of radioactive waste in accordance with current regulatory requirements;
- assessment of the radiation impact on the environment from temporary storage, transportation and burial of radioactive waste. This includes the calculation of possible emissions and discharges of radioactive substances into the atmosphere, water bodies and soil.;
- development of measures to minimize radiation exposure, such as improving waste management technologies, improving radiation monitoring and emergency response systems;
- assessment of the long-term effects of radioactive waste disposal, including migration of radionuclides into the environment over many years;
- monitoring the state of the environment in areas where radiation-hazardous facilities and waste management facilities are located;
- ensuring the radiation safety of personnel, the public and the environment at all stages of radioactive waste management.

Thus, environmental impact assessment is a key element of ensuring the environmental safety of radiation-hazardous facilities.

The assessment of the reliability of measures to minimize the risk of possible emergencies and the consequences of their impact on the environment at radiation-hazardous facilities includes the following main aspects:

- identification and analysis of possible emergencies at the facility, including an assessment of the likelihood of their occurrence and potential consequences for the environment;
- development and evaluation of the effectiveness of proposed measures to prevent emergencies and minimize their impact. This may include measures to ensure the safety of equipment, the organization of emergency response, and the protection of personnel and the public;
- checking the readiness of personnel and emergency services to respond to possible emergencies, including regular exercises and training;
- assessment of the completeness and reliability of forecast calculations of the consequences of emergency situations, including taking into account possible changes in technological processes and the environment;
- analysis of opportunities to minimize the scale and consequences of accidents, including the availability and condition of backup systems, personal protective equipment, monitoring and warning systems.

The reliability of the measures is assessed on the basis of expert opinions, computational and analytical data, modeling results, as well as practical experience in the operation of such facilities. Regular updating and

improvement of these measures is the key to ensuring the industrial and environmental safety of radiation-hazardous facilities.

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SECTION 7: PSYCHOLOGY, PEDAGOGY AND PHILOLOGY



UDC 796

THE MEANS AND METHODS OF DEVELOPING COORDINATION ABILITIES IN RHYTHMIC GYMNASTICS

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Аннотация. В статье рассматриваются средства и методы развития координационных способностей в художественной гимнастике. Представлен комплекс специальных тестов для оценки предметной координации, включающий синхронные броски мячей с прыжками, последовательные броски за спиной, ловлю мяча после вращений. Описываются методические особенности применения акробатических упражнений и традиционных элементов базовой подготовки. Приводятся данные экспериментального исследования эффективности предложенных средств. Статья предназначена для тренеров и преподавателей художественной гимнастики.

Ключевые слова: художественная гимнастика, координационные способности, предметная координация, методика развития, тестирование, акробатические упражнения, тренировочный процесс, техническая подготовка, двигательные навыки, педагогический контроль.

Annotation. The article discusses the means and methods of developing coordination abilities in rhythmic gymnastics. A set of special tests for assessing object coordination is presented, including synchronized throws of balls with jumps, successive throws behind the back, catching the ball after

rotations. Methodological features of the use of acrobatic exercises and traditional elements of basic training are described. Data from an experimental study of the effectiveness of the proposed means are provided. The article is intended for coaches and teachers of rhythmic gymnastics.

Keywords: rhythmic gymnastics, coordination abilities, object coordination, development methods, testing, acrobatic exercises, training process, technical training, motor skills, pedagogical control.

Coordination skills development is a key aspect of training gymnasts, as the level of their formation determines the success of performing complex technical elements with apparatus. Modern research confirms the need to improve coordination development methods in rhythmic gymnastics [7].

The coordination abilities development in rhythmic gymnastics is a complex multi-aspect process that requires a comprehensive approach and the use of various training tools. The special tests for assessing object coordination should be highlighted among the most effective methods, which include performing exercises with tennis balls of varying degrees of difficulty “An example of such tests is “Synchronized throws and returns of tennis balls with two hands with a jump”, where the athlete must demonstrate the ability to coordinate the movements of the arms and legs, the accuracy of differentiation of spatial, temporal and dynamic parameters of hand movement and a sense of rhythm. Another important test is the “Sequential Throws and Catch of the Ball Behind the Back” which allows assessing the ability to quickly reorganize movements and complex motor reactions under conditions of limited visual control” [1, p. 113].

“A special place is occupied by exercises related to throwing and catching the ball after rotation in a given corridor, as well as under the foot after rotation. These elements allow developing the ability to orientate in space, vestibular stability and quick reaction to a moving object»” [4, p. 10]. All proposed tests are performed with tennis balls, which is due to their versatility and frequent use for assessing fine motor skills [3].

Acrobatic exercises are an integral part of the training process aimed at developing coordination skills. They have a complex effect on the athlete’s body, forming a sense of balance, improving the work of the vestibular apparatus, coordination of movements and increasing reaction speed. Acrobatics also contributes to the development of spatial orientation and the formation of motor skills applicable in various life situations.

“Traditional elements of basic subject training continue to be relevant in modern practice. “These include rolling a ball and hoop, juggling tennis balls and clubs, rotating a skipping rope in different planes, as well as various options for throwing and catching objects” [2, p. 23]. These exercises develop

basic skills of object manipulation, necessary for successful mastery of more complex technical elements.

Methodological features of coordination abilities development consist in application of complex approach, which involves combination of object manipulations with body movements, consideration of tempo-rhythmic characteristics and limitation of visual control. An important aspect is the progressive complication of exercises by increasing the number of elements performed, reducing the time for their execution and adding additional conditions, such as rotations and jumps [5].

The effectiveness of the training process is monitored using percentile scales, determining standards for levels of preparedness and conducting a correlation analysis of the results. This allows for an objective assessment of the dynamics of coordination abilities development and timely adjustment of the training process [6].

The complex for developing coordination skills can be described as follows, based on the analysis of the materials provided:

Age group: the complex is intended for girls of primary school age (7-10 years old) involved in rhythmic gymnastics at the initial stage of training.

The objective is to form and develop specific object coordination in young gymnasts.

The tasks are development of precision in differentiating spatial, temporal and dynamic parameters of movements, improvement of the sense of rhythm and the ability to coordinate movements, strengthening of the vestibular apparatus and spatial orientation development, skills formation in working with objects, improvement of general coordination readiness

Duration of classes is: total duration: 60-90 minutes, preparatory part: 15-20 minutes, main part: 30-40 minutes, final part: 10-15 minutes. Frequency of classes: daily.

The complex includes four main tests with tennis balls, aimed at developing specific subject coordination:

1. "The first test involves performing synchronized throws and returns of tennis balls with both hands and a jump. This test allows you to evaluate the coordination of arm and leg movements, develops the accuracy of differentiating spatial, temporal and dynamic parameters of hand movement, and also improves the sense of rhythm" [2, p. 34].

2. The second test includes successive throws and catches of the ball behind the back, with the exercise performed asymmetrically for each hand. This test helps develop the ability to quickly restructure movements and trains complex motor reactions under conditions of limited visual control.

3. The third test involves throwing and catching a ball after rotation in a given corridor. It is aimed at developing spatial orientation, training the

accuracy of differentiating movement parameters and strengthening vestibular stability.

4. "The fourth test is throwing and catching the ball under the foot after rotation in a given corridor. This exercise combines object manipulation with body movements, develops the ability to coordinate movements and trains the speed of reaction to a moving object" [4, p. 15].

It is envisaged to perform all exercises sequentially with an individual assessment of each test when performing the complex. During the training, it is planned to gradually complicate the conditions for performing the exercises. Strict time frames are used and space restrictions are applied in the form of a given corridor. This integrated approach allows for the comprehensive development of various aspects of coordination abilities and the effective assessment of their level in those involved in rhythmic gymnastics [8].

The following expected results are: a 50-60% reduction in the number of errors in performing coordination elements, improvement in the indicators of subject mastery and technical performance, increased stability in performing elements with objects, development of the ability to quickly restructure movements, formation of reliable motor skills, improving the visual appeal of software components, optimizing the process of teaching technical elements, the complex is aimed at the gradual, systematic coordination skills development, taking into account the age characteristics of those involved.

In conclusion of the analysis of the problem, it should be noted that the development of coordination abilities requires a systematic approach and constant improvement of training methods. The proposed means of developing coordination have undergone practical testing and have proven their effectiveness in the training process. However, the prospects for further research remain relevant, since the need to develop new methods and improve existing approaches to the coordination abilities forming in rhythmic gymnastics remains an important task of modern sports.

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INTERACTIVE LANGUAGE TEACHING STRATEGIES AT HIGHER NAVAL SCHOOLS

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Аннотация. Цель данного исследования – проанализировать способы применения интерактивных методов изучения английского языка для курсантов, представить обширный спектр практических коммуникационных приёмов и выявить преимущества их использования в высших военно-морских училищах. В статье рассматриваются такие термины, как интерактивные методы, ролевые игры по сценарию и без

сценария, мозговой штурм, подкаст, говорящая бомба замедленного действия, тематическое исследование. Представлены возможности, которые открывают интерактивные методы для курсантов высшего военно-морского училища на занятиях английского языка.

Ключевые слова: интерактивные методы обучения, курсант военно-морского училища, цифровые средства, ролевые игры, мозговой штурм, тематическое исследование

Annotation. The purpose of the study is to analyze the ways of using interactive English language learning methods for cadets, present a wide range of practical communication techniques and identify the advantages of utilizing them at higher naval schools. The article touches upon such terms as interactive methods, scripted and unscripted role-playing games, brainstorming, podcast, talking time bomb, and case study. The possibilities offered by interactive methods for cadets of the higher naval school during English classes are presented.

Keywords: interactive teaching methods, naval school cadet, digital tools, role-playing games, brainstorming, case-study, academic performance

Today's problems of English language teachers in the military academic system are primarily related to the development and adaptation of educational models that work effectively within the specific framework of the military and social sphere.

The main goal of learning a foreign language at military schools is the formation of the communicative competence of cadets, which allows to master the language in practice in professional and everyday life, a communication-oriented approach to the formation of such competence.

Some scientists believe that mobile learning environment might be face to-face, distance, or online; further, as well as it may be self-paced or calendar-based [5, p. 9]. As technologies continue to evolve, so does their propensity to shrink in size. Other technologies that hold the capacity for language learning include PDAs, multimedia cellular phones, MP3 players, DVD players, and digital dictionaries [10, p. 447].

G. M. Chinnery [2], T. A. Mulendeikina [1], M. J. Evans [3], Z. R. Fattoyeva [4], V. A. Filatova and A. M. Mityaeva [5] proved that there was "an innumerable number of ways in which educators can deploy interactive teaching strategies" [6]. Military education must adapt to the changing conditions – it cannot work without modern technologies. That's why one should analyze the most appropriate methods of teaching English.

The objective of the research is to present interactive methods, that can be effective means for learning English by cadets and identify their advantages at higher naval schools, as well as the risks of their implementation.

The term *interactive* is stated to mean a dialogue, discussion or conversation. The use of interactive language teaching strategies is therefore widely recommended as a compelling way to make classes increasingly focused on student participation and strongly oriented towards communication practice [6, p. 2]. These methods are aimed at the interaction. This requires an active role of cadets in the educational process as well as high motivation to study [7]. Thus, interactive training provides creating conditions, which lead to the involvement of all cadets in the educational process [8].

The following ways of effective English learning process are:

Interactive and communication technologies (ICT) and role-plays.

It is well known that role-playing games are the educational basis in military educational institutions. Role-playing games can be conducted in two ways: according to a script and according to a plot written on paper. They can also involve the use of DVDs, computers, radios, the Internet and other technologies in military educational institutions, which affects the educational process in a positive way.

In case of conducting a role-playing game according to a scenario, the teacher can use an example from a textbook. It's a good idea for a warm-up: pair everyone up and give them the opportunity to talk to their partner by trying on different roles. If we consider role-playing without a script, cadets are given certain roles and need to use all their knowledge to communicate with partners. There are several ideas for a general English course [4, p. 24].

Phone conversation.

A phone conversation is different from a face-to-face conversation so far as a person relies solely on the language in communication and has no chance to utilize gestures or mimics to help [4, 25]. For example, one can imitate talking to a friend, or finding out about a job position. In the military sphere, this method can be used to conduct a radio communication session within a ship or with a coastal station, to identify his position or to report about a distress so, that the person on the other side has to be able to record the information correctly.

Brainstorming method is a search for all possible ideas to solve a problem.

The main advantage of this one is that it develops creative and associative thinking, initiative, the ability to generate maximum ideas in a short time and the ability to express personal opinions [4, p. 25].

Brainstorming is a method designed to make a team generate ideas to solve a clearly defined problem. In controlled conditions and a free-thinking environment, teams approach a problem by such means as "How Might We" questions. They produce a vast array of ideas and draw links between them to find potential solutions. [9, p. 1]. Picture 1 shows the steps to be taken to set up a brainstorming exercise in a proper way. Before you announce a problem

to brainstorm, time limits have to be set, you can use a sand glass, for instance. Avoid being critical not to confuse the speakers and prevent them from expressing their most unexpected and creative ideas, encourage all possible suggestions. Strive for quantity better than quality. It's always good to depict all the suggestions in a chart, picture gram or any other visual scheme. Don't allow everyone to speak simultaneously, let the cadets take turns [9].



Picture 1 – Eight rules of Brainstorming [9]

There are many ideas for brainstorming.

A talking time bomb.

First, the teacher suggests a topic or idea. Then he/she turns on the music, the cadets should come up with as many words as possible for the topic. Someone starts with a ball. When he runs out of one word, he passes the ball to another cadet. This process continues, but the cadets cannot repeat what has already been said. When the music stops, whoever is holding the ball loses [1, p. 26]. As a punishment for the one who loses you can initiate his talk for a minute on a topic offered by the teacher.

An equally interesting interactive method that a teacher can use is the one of the case-study. This is a teaching method in which a cadet is faced with a specific problem, a case. The case-study makes it easier to deal with the real problem in a specific context using different data sources. This allows cadets to learn from practice and improve their ability to ask relevant questions in a specific problem situation. It develops flexibility and confidence as well as the awareness, that the cadets will be able to cope with various tasks throughout their career [5, p. 203]. It also helps cadets take better decisions based on the information, collected from different sources. This technique strengthens the cadets' understanding of management theory and reflects the reality of decision-making in the real world. [5, p. 204]. Here the participants will have

to understand and take different points of view of the rest of the team into account.

Topics that can be considered by English language teachers in military educational institutions include the following: Combat Readiness; Training Camp; Boot Camp, Being a Soldier and others.

Podcasts made available in digital format also fit the issue of the research. It is a form of online multimedia content representing a series of digital audio or video files. One can search words, their transcription and to listen to the pronunciation, as well as much more examples of the words' use, their synonyms, antonyms and relevant contexts by means of electronic dictionaries.

At this point we can admit, that ICT tools allow for improving transparency and accountability in learning English, they are one of the options to diversify language classes and demonstrate the elements of learning in a playful way. In most cases, academic conditions at naval schools require blended learning, where a computer stimulates studying and gives it an impulse, and the teacher sets the direction, motivates and monitors the progress and the result.

Thus, as the main objective of learning a foreign language at Naval schools is the formation of cadets' communicative competence, mastering the language in practice in professional and everyday context, every educator should apply appropriate interactive teaching methods that can help achieve this goal.

Interactive training by means of ICT at higher Naval schools can be considered as a modern and effective form of education. It gives cadets the opportunity to independently choose the ways of learning and development in accordance with their capabilities and requirements. This ensures their maximum dedication and activity as well as increases the effectiveness of teaching.

The use of interactive methods of teaching foreign languages requires modern IT tools, information and multimedia environment application. By introducing these methods, one can also make sure that interactive teaching methods help optimize the learning process. They are designed to create mechanisms that motivate and increase the effectiveness of communication within the class and between a teacher and a student.

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CROSSCULTURAL PROVERBS AND SAYINGS.

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Аннотация. В статье осуществлен анализ пословиц и поговорок, как способа лингвистического выражения культурно-социальных норм, выработанных в ходе развития народа. Проведены аналогии между русскими и англоязычными пословицами и поговорками, выявлены сходства и различия между ними. Сопоставлены понятия пословица и поговорка. Предложена классификация русских и англоязычных пословиц и поговорок, в основе которой положен сопоставительный анализ лексического выражения и семантической коннотации идеи, передаваемой посредством половицы. Работа опирается на исследования выдающихся ученых Даля В. И., Дубровина М. И., Григорьева А. И., Жукова В. П., Кунина А. В., Лиске Н. В.

Ключевые слова: пословица, поговорка, сходства и различия, классификация, стилистические приемы, историография

Annotation. In the article we analyze proverbs and sayings as a way of linguistic expression of cultural and social norms developed in the course of the people's development. Analogies are drawn between Russian and English proverbs and sayings, similarities and differences between them are revealed. The definitions of a proverb and saying are compared. A classification of Russian and English proverbs and sayings is proposed, based on a comparative analysis of the lexical expression and semantic connotation of the idea conveyed by means of a saying. The work is based on the research of outstanding scientists Dahl V. I., Dubrovin M. I., Grigoriev A. I., Zhukov V. P., Kunin A. V., Liske N. V.

Keywords: proverb, saying, similarities and differences, classification, stylistic techniques, historiography

Introduction

We live in a world with an enormous diversity of cultures, beliefs, religions, histories, and attitudes. It is hard to imagine how extraordinary and rich the history of each nation is. There is an opinion that in order to better understand people and their culture, it is necessary to study their language, because you can trace the stages of development of the people through it.

Proverbs and sayings are an important aspect of language and culture, offering insights into the values and beliefs of a society. They can also provide valuable lessons and perspectives that are relevant across different cultures. Whether in English or Russian, these expressions offer timeless wisdom and reflect the human experience in a way that transcends linguistic and cultural boundaries.

Historiography and Terminology Definition

Many Russian and foreign linguists did a lot to find out the origin of proverbs and their works are still useful today. The greatest contribution to this research on the history of sources and the way of development of proverbs was made by Zhukov V. P. [8], Kunin A. V. [9], Sklyar P. A. [14], Rybnikova M. A. [13]. The works by English and American linguists were devoted to numerous problems of English-language sayings and proverbs research, among them were Arora Sh. L. [15], Witting K. [17], Palmer G.B. [16] and others. Proverbs and sayings have been created by many generations of people. They have been developing, evolving and changing for centuries before they finally became familiar to us.

Folklorists consider proverbs as special statements, which can contain wisdom of generations in a condensed form. For example, F. I. Buslaev characterizes them as “artistic works of the native language, expressing the way of life of the people, their common sense and moral interests” [3]. G. L. Permyakov points out that “proverbs express a certain regularity, which can be perceived as a permanent rule, custom, a kind of recommendation for everyone” [12]. There is also an opinion, that our modern languages have mythopoetic elements of proverbs in their composition [7; 1].

Before writing appeared, the main rules of behavior were formed in proverbs. They were also one of the sources of information from which people could learn about their ancestors and their way of life. Sh. Arora calls proverbs “the voice of an ancient culture that tells the absolute truth”. Arora also admits that a man is “the tool by which the proverb speaks to the audience” [15, p. 24]. M. V. Bukovskaya emphasizes the need for compulsory study of proverbs for the young as models of social norms of human behavior [2].

Many modern scientists agree that proverbs and sayings are one of the most valuable folklore materials that gives you an opportunity to deepen in the peoples’ wide culture, and also can make an impact on the modern world and people’s behavior in it.

Stylistic Techniques

A proverb is stated to be a result of collective experience, a synthesis of collective thinking, a mythopoetic element, an archetype. The definitions of proverbs allow to identify such basic features as folklore style, colorfulness, conciseness and didacticism. Considering the fact that a proverb is an essential element of folk creativity, the following requirements for its creation can be identified:

1. The expression of the general through the specific (e.g. “Don't count your chickens before they are hatched” – a common situation is used to illustrate a general principle: one can only judge the results when the matter is already finished).

2. Brevity and monosyllabic combinations (e.g. “Easy come easy go”).

3. Euphony (e.g. “Haste makes waste”).

4. Specific representation and personification of abstract concepts (e.g., “A clean hand needs no washing”).

Undoubtedly, a proverb is an integral part of folklore; it is the element in which all the wisdom and experience of understanding the world by people of past generations has been deposited. At the same time, a proverb is also referred to as a separate unit in the language.

Russian vs English Proverbs and Sayings

National mentality is the pattern of thinking and psychological structure of the mind. It is related to the national character, which is not only a set of specific characteristics unique to a particular people, but also a unique set of universal human characteristics. The main similarity of proverbs and sayings in Russian and English is that proverbs and sayings in any language are a means of reflecting the national mentality of the speakers of that language.

The most vivid elements of any language is a proverb and saying. They have accompanied people since ancient times. Expressive means such as precise rhyme, simple form, and brevity have made proverbs and sayings enduring, memorable, and necessary in speech. In these expressions, people have long showed their own unique way of thinking, character, judgment, beliefs, customs and traditions, and their mentality in short.

The mentality of any nation is reflected in the characteristics of its way of life, history, culture, traditions, customs, and, above all, in the system of various linguistic units through which people communicate with each other. The whole of these units is called language.

The main purpose of proverbs and sayings is to provide people's evaluation of the reality phenomena and to express their world view. Therefore, it should be noted that proverbs and sayings are a direct reflection of the characteristics of the national mentality of each nation.

The difference in English and Russian proverbs and sayings is that due to the formation of different national experiences in the culture of both peoples, a tradition of comparing many objects and phenomena of the surrounding objective reality using different images has developed.

This circumstance is manifested first of all in the differences between English and Russian proverbs and sayings, which have the same meaning at the lexical level.

For example, there is a lexical difference between Russian and English proverbs and sayings. That is the comparison of “когда рак на горе свистнет” (when a crawfish whistles on the mountain) and “when pigs fly”. As can be seen from this example, in Russian the situation when it is useless to wait for something, that will never happen is expressed by a “crawfish”, that cannot

whistle in real life, while in English it is expressed by “pigs”, that obviously cannot fly.

If an English speaker wants to say “Rome wasn’t built in a day”, a Russian person in a similar situation would say – “Moscow wasn’t built in a day”. It should be noted that in these two proverbs the semantic connotation is the same, but Rome is used in the English proverb and Moscow – in the Russian one.

It can be concluded that “English proverbs and sayings differ from Russian proverbs and sayings primarily in their function in speech, and differences between them can also be identified at the grammatical and lexical levels. However, the differences between English and Russian proverbs and sayings are more evident at the level of the concepts they embody, which are indicators of the diversity of the studied linguistic cultures. Similarities can also be found at the level of certain concepts. However, the greatest similarity between proverbs and sayings in the languages and cultures under study is that they are a means of reflecting the national mentality of the speakers of the language, as well as their imagery, brevity, folkloric character, and uniqueness” [10, p. 7].

Proverbs vs Sayings

Proverbs and sayings are often studied together. But it’s important not to confuse them, to see not only the similarities but also the differences between them. In V. I. Dal’s Explanatory Dictionary [5] we find the following definition: “A proverb is a brief expression, a teaching, more in the form of a parable, an allegory, or in the form of a proverbial saying; a proverb is a specimen of the language of the people, not composed, but born spontaneously; it is the walking wisdom of the people; it passes into a saying or a simple turn of speech”. S.I. Ozhegov [11] defines a proverb as a short folk expression with instructive content, a folk aphorism.

“A saying is a turn of phrase or an expression reflecting some phenomenon of life. Unlike a proverb, a saying does not contain an instructive, generalizing meaning. It is simply an expression that replaces a common word or defines a particular phenomenon” [10, p. 7]. The sources of proverbs and sayings are diverse. For an expression to become a proverb, it must be perceived and internalized by ordinary people. At the same time, it becomes irrelevant who made it up. Therefore, it is more accurate to say that proverbs and sayings have a folk origin, that their primary source lies in the collective consciousness of the people. As in the Russian language, the sources of proverbs in the English language can be diverse.

Classification

Russian and English proverbs and sayings can be divided into 3 groups:

1. The first group includes proverbs and sayings with the same lexical description and semantic connotation, for example:

- Appetite comes with eating.
- If you run after two rabbits, you will catch neither.
- Two heads are better than one.
- A friend in need is a friend indeed.
- My home is my castle.

2. The second group includes proverbs with the same meaning but different lexical rendering, for example:

- The early bird gets the worm.
- You can't make an omelet without breaking eggs.
- No man is an island.
- Too many cooks spoil the broth.
- There's no place like home.

3. The third group of English proverbs includes expressions for which there are no Russian equivalents, for example:

- Don't keep a dog and bark yourself.
- If you can't be good, be careful.
- Imitation is the best form of flattery.

Thus, English and Russian proverbs and sayings are a special layer of language that reflects its originality, but at the same time expresses its relevance to human consciousness and social norms as a whole.

Conclusion

In the research we have the purpose of comparing various proverbs and sayings with their analogues, we have discovered certain similarities in the development of linguistic structures in different peoples. We analyzed the viewpoints of such outstanding linguists as Dal V. I., Dubrovin M. I. [6], Kunin A. V. [9], Zhukov V. P. [8], Grigorieva A. I. [4], Liske N. V. [10]. The differences between the proverbs and sayings show the peculiarities of the cultural formations within the represented languages.

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SEMANTIC CONNOTATION IN NAVAL HUMOROUS DISCOURSE

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Аннотация. Исследование посвящено классификации англоязычных образцов военно-морского юмористического дискурса по семантическим разделам: военно-морской юмор, интегрированный в гражданское общество; шутки о субординации; юмор о военно-морской атрибутике и материальной части; шутки о сложной военно-морской инфраструктуре; военно-медицинский абсурд; анекдоты о продовольственном обеспечении; любовный и семейный юмор; черный юмор и анекдоты о грубом тоне повседневного общения на флоте. Указано, что в словообразовании при формировании военно-морских анекдотов используются методы лексико-семантической деривации; объединения слов в сложносоставные; конверсии; аффиксации; звукового подражания. В статье приведены примеры из работ англоязычных и русских авторов, обозревающих юмористический флотский лексикон.

Ключевые слова: военно-морской юмористический дискурс, методы словообразования, семантические признаки, смысловые разделы, анекдот, шутка, абсурд

Annotation. The study is devoted to the classification of English-language samples of naval humorous discourse according to the following semantic groups: naval humour, integrated into civilian society; chain of command jokes; naval material attributes jokes; expressions, covering complicated naval systems and infrastructure; military-medical absurd; food supply jokes; love and family humour; rude naval everyday jokes and black humour. It is indicated that in word formation of naval jokes the following methods are used: lexical-semantic derivation; words composition; conversion; affixation; sound imitation. The article provides examples from the works by English-language and Russian authors reviewing the humorous naval lexicon.

Keywords: naval humorous discourse, word formation methods, semantic features, semantic groups, anecdote, joke, absurdity

In today's reality the topic of lexical and semantic selection in the process of the English Naval humorous discourse creation is undoubtedly a

current trend for linguists' reflection. By implementing the proper professional activity words, anecdotal phrases a speaker conveys his idea in a more exciting and colorful manner. Thereafter, devoid of knowing typical naval lexicon the interlocutor can hardly deepen into the way a British or American sailor with a sense of humour really thinks. The topic is also relevant as a great number of Navy jokes correlate with the ones from other countries, including Russia.

English humour is comprehensively described in the publication by Kulinich M. A., where he states that ethno-cultural and ethno-linguistic humour specificity is determined by the peculiarities of the national character and social structure, which are widely manifested in the topics and lexical choice of humorous texts [2]. After all it's difficult indeed to understand foreign phrases without a careful research of the national outlook paradigm.

The aim of the article is to analyse the methodology of word formation in naval humorous discourse and to reveal the semantic connotation of naval comedy genre. Nevertheless, the use of humorous turns and jokes in speech is obviously common in any language and is one of the key factors that disposes the opponent to a pleasant and plain dialogue. Naval service is not an exception – very often it is stressful, so it is much easier to talk about serious professional issues, using ambiguous word combinations, non-standard epithets and surprising comparisons, so that it becomes simple to cope with difficult naval job. Maritime humorous vocabulary has so many differences from the ordinary one due to the wide implementation of professional words and expressions. Therefore, naval humour is very peculiar and an average person needs extra knowledge to understand it.

According to S.-H. Hashiev, English Naval slang covers almost all areas of everyday life, terminology, types of weapons, materiel and properties. It is a combination of lexical and morphological peculiarities of the naval origin, jargonisms and borrowings from other languages [5]. The word formation for Navy humour in English involves the following methods:

- a. lexical-semantic derivation;
- b. words composition;
- c. conversion;
- d. affixation;
- e. sound imitation [5, p. 3].

In order to facilitate the analysis of the phrase formation, based on the selection of seven hundred jokes, we categorize naval humorous expressions by subject matter into:

1. naval humour, integrated into civilian society;
2. chain of command jokes;
3. naval material attributes jokes;
4. expressions, covering complicated Naval systems and infrastructure;

5. military-medical absurd;
6. food supply jokes;
7. love and family humour;
8. rude Naval everyday jokes and black humour.

1. The first category includes expressions familiar to anyone even not related to the military environment, though such jokes have been established in people's thinking as absurdities inherent in the Armed Forces and Naval Fleet.

Let's consider the chosen category looking at the situation familiar to all parents who have ever sent their children to military service. Knowing their son well, they are undoubtedly surprised by the sight of their matured child upon his return from service. Regarding this situation, there are several sentences in the English language that address the subject of drastic changes in a person's appearance upon arrival from the army. A standard expression from the mother's side would be: "What's happened with my slim, freckle-faced boy who left home just twelve short months ago?" [7, p.92]. In this case, the sentence simultaneously combines diminutive adjectives – litotes, that characterize the son before the naval service, and exaggerating epithets – hyperboles, that show his condition upon his return, as well as the absurdity of speech – "just twelve short months ago".

Consider, as an example of a connotation abbreviation or phrase reduction, a wide-spread joke of "Who opened the window on a submarine?", which turned into the single-word exclamation "Window!", or the similar "Doors!", "Trapdoors!", "Hatches!" [7, p. 81] and the like. Semantically those of a one-word expressions mean that airing on a submarine is not carried out in typical ways.

Sailors visit many different foreign ports during their long voyage. In this regard, sometimes in the naval humorous discourse there are jokes of a geographical context that reflect the national flavour of a country on the globe. As an example, let's give an anecdote about a sailor returning home with souvenirs: "Mom, look at this! – Don't try to kid me son, it is easily a bat, not an Australian parrot!" [7, p. 17].

2. The second section of the classification includes the absurdities concerning military subordination and sometimes illogical orders. Here we should take into account that one of the most common points of military drills is the constant control of superiors over the appearance of subordinates. There are many variants of phrases used to denote the unscrupulous attitude of the sailors towards maintaining a neat look. An example can be the untidiness of a military man's hairstyle: "I am picking you up for a haircut!" [7, p. 28], which means that an officer can take hold of a sailor's hair with his hand and thus lift it, although a short, neat haircut is established in the Navy. Here is a

clear illustration of the application of the ambiguity of phrasing, as “pick up” also means to “to choose”, “to select”.

It is known that when all military personnel meet each other on the street, they are required to perform a military greeting, which in numerous countries looks like putting a hand to their head or just standing up to a drill stand – a serviceman stands at attention in front of a comrade in arms. Moreover, historically, military sailors are particularly different from other branches of the Armed Forces. They are required to monitor the perfection of their appearance even more carefully. But imagine a sailor who has returned from a long voyage walking with his lady along the embankment – his cap is awry, hands are in pockets, and he may get into an unpleasant situation of unexpectedly meeting his superiors. Obviously without having time to correct the offences on the uniform, the brave sailor will try to hide behind his companion, and she, in turn, will create an awkward situation with the phrase: “Do you know him? Is he in the same Mess as you?” [7, p. 21]. In this case, the naval lexicon is played around, where “mess” also means a rank, but in this context it semantically refers to a situative absurd or unpleasant situation.

In the Navy it is customary to greet commanders immediately upon their arrival on the gangway of the ship from the pier. To do this, a sailor is always stationed on the ladder, keeping watch and observing the arriving people to report to the person-on-duty on the ship. Due to the fact that in the Navy (we consider English-speaking countries) many commanders have the same ranks, wear the same uniform and drive on equally luxurios, predominantly black cars, a sailor who does not always know all the commanders by sight is obviously capable of confusing them at a moment’s notice. He might report “Sir, Commander-In-Chief (or other senior boss) is here! – “You are wrong! – he gets the reply, - That’s the Canteen Manager’s (Head-Of-Communication or Head-Of-Medical-Service) car!” [7, p. 13].

Another fact is the wide use of abbreviations and acronyms used in Naval English, very often to denote service positions or ranks – Cmdr - commander, MOD - Man-On-Duty, CSC - Command Senior Chief, EWO - Electronic Warfare Officer [6] and others, which creates a pronunciation peculiarity in the colloquial naval dialect.

3. It is common to find jokes that contain lexical references to onboard facilities, equipment and various auxiliary devices. In this case, satire is used to demonstrate the cultural-semantic features of maritime language, and mode of life. “I can tell the weather with this bit of seaweed. When it’s wet – it’s raining, when it swings – it’s windy!” [7, p. 9].

Another example of the ward-play naval homourous communication: “My son wrote, that fleet’s life is enjoyable, food is well-balanced – every bean weighs the same, beds are comfortable. - That sounds as a lot of bunk!”

[4, p. 66]. In this joke “bunk” can be understood not just like a “bed in the ship’s compartment”, but also as a “nonsense”.

4. This category conveys the complexity of naval infrastructure, ship interiors and technical systems layout, which is clearly non-standard to an average person. In the example below, a hyperbolised description is used to show the excessive abstruseness of the ship’s berth place identification, which, in fact, is really that complex, and therefore unusual and funny for civilians: “Do you know, where my ship is? - Let’s see... I think it’s over at Pier Eleven, Slip Two, Berth Forty-Six, outboard of Muhangarung County, which is over by the Cru Des Piers, next to C-in-C Lant Flt... or is it ServLant?” [4, p. 99].

5. Naval humour also touches upon the field of medical care and medical anamnesis checks: “Tell me, do you always stutter like this? - N-n-o, d-d-doc. J-j-just when I t-t-t-talk” [4, p. 35]. Obviously, this situation can also happen in civilian medical practice, so the meaning of the expression will be clear to everyone.

6. The issue of food allowance and galley conditions is another option of naval jargon application: “A young naval trainee, first day aboard the training ship, was sitting by a porthole in his cabin when he heard a loud warning of “Look out!” given by the cook who was about to pour soup slops overboard. The trainee obeyed the order by popping out his head, which received a bucketful of slops. He drew it back in a hurry, exclaiming: “Why does he cry ‘look out’ when he means ‘look in’!” [3, p. 184]. That’s an accurate and distinctive instance of semantic ambiguity regarding the professional naval slang, which adds to the unique singularity of the maritime language of communication.

Furthermore, it’s not a secret that the food supply of the army and navy is not always at the highest level due to the fact that food is not cooked in the most comfortable conditions. Therefore, it is normal that sailors usually can point this fact to the absurdity: “Does the M.O.D know you are carrying out experiments on live human beings?!” [7, p. 80]. M.O.D. means Man-on-duty, who is responsible for the daily food supplying on the ship, as well as it means the Ministry of Defence.

7. The subject of family relations and love is a vivid example of nonsense in English naval humour. A relevant instance is the situation where it may seem that there is nothing strange in the fact that, upon arrival of a sailor from a long voyage, his relatives are happy to meet him at home. But there are often a number of jokes illustrating that a sailor is warmly received not only because, he has not been with his family for a long time, but because upon his return he must have a payday: “They welcome me not because I’m back from a long separation. It’s like this every payday!” [7, p. 63].

Women on a ship have always experienced a lot of satirical attitude in the Navy: "Daddy, why ladies are not called up for military service? - Because the Army needs discipline" [3, p. 21].

Another example of semantic choice in naval humour construction is to use well-known family stereotypes in peculiar to Naval lifestyle situations: "Why do you prefer married sailors in your unit? - Well, the married men are used to take orders even if they are yelled at" [4, p. 11-12].

8. As A. N. Gamov states in his article about the structural-semantic characteristic of military vocabulary, "military slangisms are capable of reflecting the peculiar, familiar, disparaging, rude tone of servicemen's speech" [1]. The sharp way of naval personnel communication conveys confidence and steadfastness on the one hand and unwarranted bravery on the other hand. Thus, the situation: "Hey, man, a shark has just bitten off one of my legs! - Which one? - How do I know, man? All these sharks look the same!" [7, p. 108] also looks comical.

Another anecdote is: "Strange, they say by flag signals that they are on the rocks. It's quarantine... What do you mean by your terrible signals? - Those aren't signals. The crew had a wash day and now they are drying up their underwear" [4, p. 113].

Unique and specific maritime language is a cause of pride to seamen and is under the unspoken rule of the necessity of its observance as a language of professional verbal communication. So it is possible to be attacked for using 'land' words instead of the ship's ones: "For the first time a recruit is saying he was going 'downstairs' - Listen, sailor, downstairs is below. That side is starboard. That's aft and that's portside. And if I hear you say one more civilian word like that I'll throw you through that little round hole window over there!" [4, p. 96-97]. Here it's an example of using semantic exaggeration.

Following the topic of lexical and semantic selection in the naval humorous discourse, we analyzed some naval humorous lexicon reviews and articles by English and Russian authors, such as J. Swift, G. Sudzilovskiy, M. Kulnich, A. Gamov, S.-H. Hashiev. We have done a complex study of English naval jokes and expressions, which were categorized by subject matter as well as the methods involved in phrases formation. The practical value of the work is that the examples offered in the article can be utilized in studies on lexicology and stylistics of the English language naval humour.

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MATRIX OF EFFECTIVENESS OF MONITORING RESULTS IN PHYSICAL TRAINING OF 5-6 YEARS CHILDREN IN A PRESCHOOL EDUCATIONAL INSTITUTION

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Аннотация. В статье представлена матрица результативности мониторинга образовательных результатов по физическому воспитанию детей 5-6 лет в дошкольном образовательном учреждении. Описаны компоненты матрицы, включающие образовательные области, показатели, критерии оценки и инструменты мониторинга. Предложенная матрица позволяет комплексно оценить достижения детей в физическом развитии и разработать эффективные стратегии для оптимизации образовательного процесса.

Ключевые слова: матрица результативности, физическое воспитание, образовательные результаты, мониторинг, дошкольное образовательное учреждение, дети 5-6 лет.

Annotation. The article presents a matrix of performance monitoring of results in physical education of children aged 5-6 years in a preschool institution. The matrix components are described, including educational areas, indicators, evaluation criteria and monitoring tools. The proposed matrix provides a comprehensive assessment of children’s achievements in physical development and one of effective strategies for optimizing the educational process.

Keywords: performance matrix, physical education, educational results, monitoring, preschool educational institution, 5-6 years children.

Introduction

Physical education is an important component of the harmonious all-round development of preschool children [2]. Effective monitoring of educational results in this area allows for the timely identification of the individual needs of each child and adjustment of the educational process in order to achieve optimal results [1].

The purpose of the article is to develop and present a performance matrix for monitoring educational results in physical education of children aged 5-6 years in a preschool educational institution (PEI). We have developed the performance matrix based on the analysis of the Federal Educational Program for Preschool Education (FEPPE), educational program of preschool institutions and modern methodological recommendations for physical education of preschool children [4].

The matrix examines the following areas:

- physical education;
- social and communicative development [5].

For each of these areas, the corresponding assessment criteria, indicators, assessment methods and performance levels (high, medium, low) are presented.

Table 1 – Matrix of effectiveness of monitoring educational results in physical education of children aged 5-6 years

Direction	Evaluation criteria	Indicators	Evaluation methods	Performance levels
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Physical education	<p>Compliance with age standards for the development of physical qualities:</p> <ul style="list-style-type: none"> - speed - strength - flexibility - agility - endurance. 	<p>10-meter run (sec).</p> <p>Long jump from a standing position (cm). Raising the body from a supine position (number of times in 30 sec).</p> <p>Shuttle run 3x10 meters (sec) [3].</p>	<p>Testing.</p> <p>Monitoring motor activity during games and classes.</p>	<p>High: Shows high scores in all physical attributes.</p> <p>Average: Shows average scores in most physical attributes.</p> <p>Low: Shows low scores in most physical attributes.</p>
	<p>Development of motor skills and abilities (walking, running, jumping, throwing, climbing).</p>	<p>Observation during classes.</p> <p>Evaluation of exercise technique.</p> <p>Completion of test assignments.</p>	<p>Passing an obstacle course.</p> <p>Performing a set of general development exercises).</p>	<p>High: Performs all motor actions in a coordinated manner.</p> <p>Average: Performs most motor actions with minor errors.</p> <p>Low: Has difficulty performing most motor actions.</p>
Coordination of movements	<p>Development of fine motor skills and coordination of movements.</p>	<p>Observation during classes.</p> <p>Test for identifying the switchability of finger movements “Fist - edge - palm” (A.R. Luria).</p> <p>Test for determining the level of accuracy of finger movements “Rings”.</p> <p>Jumping rope.</p> <p>Throwing and catching a ball.</p>	<p>Performing tasks on coordination of movements (hit the target with the ball, walk along a narrow path).</p>	<p>High: Demonstrates good motor coordination, skillfully performs actions with small objects.</p> <p>Average: Demonstrates average motor coordination, performs actions with small objects with minor difficulties.</p> <p>Low: Demonstrates poor motor coordination, has difficulty performing actions with small objects.</p>

Social and communicative development	Compliance with safety rules during physical education classes and sports games.	Observation during classes and games. Conversations with children about safety rules.	Analysis of situations.	High: Always follows safety rules, warns others of danger. Average: Follows safety rules in most cases, needs reminders from an adult. Low: Often violates safety rules, does not recognize danger.
	Ability to interact with peers during active games and relay races.	Observation during active games and relay races.	Evaluation of children's interaction in a team. Analysis of conflict situations.	High: Knows how to work in a team, respects the opinions of others, helps comrades. Average: Knows how to interact with peers, but sometimes difficulties arise. Low: Has difficulty interacting with peers, shows aggression.
	Showing interest in physical activity and a healthy lifestyle.	Observation of children's independent activities.	Conversations with children. Analysis of drawings and crafts on the topic of health and sports.	High: Shows a high interest in physical activity, talks about a healthy lifestyle. Average: Shows moderate interest in physical activity, has a general idea of a healthy lifestyle. Low: Shows no interest in physical activity, has no idea of a healthy lifestyle.

The matrix of the effectiveness of monitoring educational results in physical education of children aged 5-6 years in preschool educational institutions presented in Table 1 can become an effective tool for assessing children's achievements in the field of physical education and the formation of a healthy lifestyle in them.

Conclusion

The use of this matrix in preschool educational institutions will allow teachers to promptly identify problems in children's physical education and adjust the educational process, providing an individual approach to each child.

Further research in this area can be aimed at in-depth development and testing of various modifications of this matrix, adapted to specific conditions of the educational process.

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NATURE AS MEDICINE: INTEGRATING NATURAL ELEMENTS INTO THE DESIGN OF PSYCHIATRIC FACILITIES

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Аннотация. В настоящей статье рассматривается проблема внедрения природных элементов в дизайн среды психиатрических учреждений с целью улучшения психического здоровья и благополучия пациентов. Описаны принципы интеграции, включающие прямой и косвенный контакты с природой, а также пространственную организацию, имитирующую природные формы.

Ключевые слова: исцеляющие пространства; биофильный дизайн; природные элементы; природа; психическое здоровье.

Annotation. This article addresses the problem of integrating natural elements into the design of psychiatric facilities to improve patients' mental health and well-being. It describes integration principles, including direct and indirect contact with nature, as well as spatial organization that mimics natural forms.

Keywords: healing spaces; biophilic design; natural elements; nature; mental health.

Introduction

The relationship between nature and human mental health has been studied by many researchers. Studies confirm that interaction with natural elements reduces stress and improves cognitive functions [4, p. 420], the presence of green plants indoors lowers anxiety levels [1, p.175], and the use of natural light, views of nature, and natural materials creates a calming atmosphere [3, p. 97]. These findings are particularly relevant for psychiatric facilities, where patients experience stress, anxiety, and other negative emotions. This article discusses the issue of integrating natural elements into the design of psychiatric facilities.

Nature and Its Impact on Mental Health

Attention Restoration Theory (ART), proposed by Rachel and Stephen Kaplan, and Stress Reduction Theory (SRT) by Roger Ulrich, explain the mechanisms of human interaction with nature. ART argues that the modern urban environment overloads our directed attention system, requiring constant concentration. Nature, on the other hand, has a "soft impact" that allows our attention to restore without effort [2, p.169]. SRT focuses on physiological and emotional responses to stress. According to this theory, natural environments trigger positive emotions, reduce sympathetic nervous system activity, and increase parasympathetic nervous system activity [5, p.201]. Studies show that even brief contemplation of natural landscapes or images of nature can reduce cortisol levels and blood pressure [5, p.210].

Biophilic or "nature-based" design in psychiatric facilities can enhance the rehabilitation potential of patients. This is particularly significant in the context of psychiatric institutions.

Currently, there is no system for integrating natural elements into psychiatric institutions in Russia. Thus, there is a need to develop principles for implementing biophilic design in psychiatric facilities in Russia.

Principles of Integrating Natural Elements

The integration of nature into the design of psychiatric facilities can be represented both as individual elements and as comprehensive solutions.

Direct Contact with Nature:

- **Greening of Rooms:** The placement of potted plants improves air quality, reduces noise, creates a pleasant visual scene, and fosters a calmer atmosphere [3, p.97].

- **Creation of Internal Courtyards and Gardens:** Providing each psychiatric department access to its own internal courtyard, open spaces with greenery, water features, and opportunities for interaction with nature has a positive impact on patients.

Indirect Contact with Nature:

- **Natural Lighting:** Maximizing the use of natural light in all rooms improves circadian rhythms, mood, and general well-being. Sharp lighting transitions should be avoided, and systems that mimic natural light during dark periods should be used, including systems for natural awakening.

- **Natural Materials:** The extensive use of natural materials in the interior finishes of hospital wards will help create a sense of comfort and closeness to nature.

- **Nature Imagery:** Paintings, photographs, and illustrations of nature can positively affect patients' emotional states. This is particularly relevant when direct contact with nature is limited due to mental or physical deviation.

- **Scents and Sounds:** The use of recorded nature sounds and natural fragrances provide relax and reduce patients' anxiety levels.

The use of smooth lines, asymmetrical shapes, and patterns that imitate natural elements helps create a more organic and calming environment.

Benefits of Integrating Natural Elements are presented in the table 1.

Table 1. Benefits of Integrating Natural Elements

Benefits	Results
Accelerate the recovery process	Creating a therapeutic environment that will help patients relax and recuperate can speed up the recovery process and reduce the length of hospital stay.
Reduction of Stress and Anxiety	Natural elements promote relaxation, reduce cortisol levels and blood pressure, and decrease aggression and agitation.
Improved sleep quality	Natural light and reduced ambient noise levels help normalize patients' circadian rhythms and improve sleep quality
Improvement of Mood	Contact with nature stimulates endorphin production, which helps improve mood and general emotional well-being.
Create a favorable working	A comfortable environment has a positive effect not only on patients, but also on medical staff, which helps reduce the level of professional burnout.

environment for staff	
Enhancement of Cognitive Functions	Interaction with nature improves attention, concentration, and memory, which can be especially beneficial for patients with cognitive impairments.
Stimulation of Social Activity	Gardens and green spaces provide patients with opportunities for socializing, joint activities, and creating social bonds.

The design of biophilic healthcare spaces should include: the use of natural materials such as wood, stone, natural fabrics, etc.; maximum use of natural sunlight; creation of a multi-sensory natural environment.

The use of natural materials will bring a home-like feel to the hospital interior and create a calming atmosphere. Such materials can be used in furniture, flooring, and wall coverings.

When integrating natural elements into the hospital environment, it is also necessary to take into account seasonal changes and/or adapt natural elements to different times of the year. For example, the use of evergreen plants will help provide patients with access to nature throughout the year. Particular attention should be paid to the choice of plants. Preference should be given to species that grow naturally in the local environment, and it is also necessary to ensure that the plants are not allergens. It is important to remember that the priority in psychiatric hospitals remains the safety of patients, the absence of the possibility of aggression and auto-aggression (table 2).

Table 2. Examples of using natural materials in healthcare facility design

Material	Place of use	Plus	Warning
Wood	Wall cladding, furniture, flooring	Warm aesthetic, stress reduction	Requires fire-retardant treatment
Rattan (Rotang)	Furniture, light fixtures, decorative panels	Lightweight, organic texture	Limited structural applications
Stone	Flooring, countertops, feature walls	Durability, natural cooling properties	Needs anti-slip surface treatment
Bamboo	Ceilings, partitions, decorative elements	Rapidly renewable, antimicrobial	Requires moisture protection

Flax	Curtains, upholstery, bedding	Breathable, hypoallergenic	Needs flame-retardant treatment
Sand	Therapy gardens, textured pathways	Sensory stimulation, grounding effect	Requires containment systems

The multisensory experience of integrating nature into the hospital environment will help to engage several senses of patients through sounds, smells, and textures of materials. In this way, it is possible to create a holistic therapeutic environment for patients.

After the integration and implementation of "nature" elements into the environment of psychiatric hospitals, it is necessary to conduct an assessment of the effectiveness, namely: collecting data on the condition of patients, stress levels, physical well-being, collecting data on the physical and psychological health of medical personnel. Conducting these checks will help to fully assess the impact of the implemented elements, and also make the necessary adjustments if necessary.

Conclusion

By using "natural" elements, psychiatric hospitals can help transform the environment of permanent patient stay into a therapeutic environment, which will contribute to the well-being and rapid rehabilitation of patients.

It is worth noting that the integration of natural elements described in this article is a comprehensive approach. Such an approach requires careful planning and consideration of the specific needs of patients and the characteristics of the institution in which they are located. There is a need to evaluate the effectiveness of the proposed and implemented solutions, at the same time, it is necessary to make adjustments as deficiencies are identified. The application of the principles of biophilic design specified in the article is not a panacea, but it will be an important component in the formation of a comprehensive approach to the treatment and rehabilitation of patients in psychiatric institutions.

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ROLE OF THE SUBJECT “FOREIGN LANGUAGE” IN ENHANCING STUDENTS’ SPIRITUAL AND MORAL VALUES

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Аннотация. Рассмотрены современные образовательные технологии, используемые в духовно-нравственном воспитании молодежи в процессе изучения иностранного языка: технология развивающего обучения В.В. Давыдова, Игровые технологии Ф. Шиллера, А.Н.Леонтьева, проектная технология Л.П. Виноградовой, Е.С. Полат, технология коммуникативного обучения иноязычной культуре Е.И. Пассова.

Ключевые слова: иностранный язык, межкультурная коммуникация, инокультура, личностное развитие.

Annotation. The article examines modern educational technologies used in the spiritual and moral education of young people in the process of learning a foreign language: one of developmental learning by V.V. Davydov, the game technologies by F. Schiller, A.N. Leontiev, the project technology by L.P. Vinogradova, E.S. Polat, one of communicative teaching of foreign language culture by E.I. Passov.

Keywords: foreign language, intercultural communication, foreign culture, personal development.

The spiritual and moral education of an individual who values Russian traditional merits and is capable of realizing one’s potential in modern conditions is a priority educational task. Instilling spiritual and moral values in students is imperative for optimal outcomes.

As a process of continuous persons’ ascent to the highest values of human existence, spiritual and moral education includes the component formation that regulate the moral behavior of young people [6].

The productivity of a teacher's activity is an increase in the degree of compliance of the obtained results under the influence of various factors [5]. A well-established educational system of an educational organization leads to effective results and productivity of training [3].

The effectiveness of the teacher's educational activity was considered by A.A. Medzhidova [2], S.I. Sabelnikova, N.P. Zabrodina [5].

Spiritual and moral education in foreign language lessons was studied by T.S. Paderina [3], N.A. Goncharova, V.M. Shvetsova [1].

Recent issues reflect a negative trend in the decline of young people spiritual and moral values, with behaviors, namely, disrespectful language, negative actions in their surroundings.

The purpose of this article is to present educational technologies used for the productivity of spiritual and moral education of youth which are applied by Foreign languages teacher at the Institute for the Development of Education in Sevastopol. To achieve this goal, the most effective pedagogical technologies are considered.

It is clear that "the productivity of learning is determined by the educational activities of the teacher and student, and the learning outcomes" [2, p. 70]. The productivity of the educational work of a foreign language teacher depends on the educational technologies used and should include effective methods that promote the spiritual, moral, personal and professional development of students, foreign language communication skills, and the formation of a specialist ready for intercultural dialogue [7].

These technologies are aimed at studying national culture and the characteristics of foreign cultures, forming the value orientations of the individual, and developing the creative abilities of students:

— technology of developmental learning (author V.V. Davydov) gives possibility to create conditions that promote spiritual and moral development. It has a target orientation and includes modeling of situations. It consists of:

1. Goal setting.
2. Planning.
3. Realization of the intended goals presupposes activity.
4. Analysis includes evaluation, responsibility, relationships.

The results are developed foreign language knowledge, skills, and intercultural communication abilities.

— Technology of "Communicative Teaching of Foreign Language Culture" by E.I. Passov. Its main stages are:

1. One of skill development: modeling situations.
2. Stage of development of intercultural communication skills.

The goal is to prepare students for the process of foreign language communication. The results are skills of overcoming speech barriers, developing readiness for intercultural communication.

— game technologies (authors F. Schiller, A.N. Leontiev). The purpose of gaming technology is to optimize gaming activity, develop foreign language communication skills, and master communication. It comprises the stages:

1. Selecting a game.
2. Motivating students.
3. Dividing into teams, groups, distributing roles in the game.
4. Developing a game situation.
5. Reflection, generalizations.

The results are developed communication skills and abilities, interest in learning foreign languages and the culture of other nations.

— project technology (authors L.P. Vinogradova, E.S. Polat). The purpose of project technology is to generalize knowledge and skills on the topic covered, to develop the ability to apply knowledge in practice; to develop independent thinking of students. It contains:

1. Preparation. Definition of communication exercises.
2. Organization of project participants: distribution of tasks, responsibilities.
3. Project implementation.
4. Project presentation.
5. Summing up the results of the project work.

The results are the project-based methodology develops individual talents, organizational, creative, and communication skills.

Thus, this study aims to analyze the educational technologies which can be used for enhancing their spiritual and moral values and explore the benefits of employing these ones in forming intercultural communication skills. The integration of educational technologies positively contributes to the development of students' values, offering numerous advantages for fostering the results of their application.

The results of effectiveness of intercultural communication skills development during the process of foreign language learning are possibilities of appropriate educational technologies for the purpose of students' spiritual, moral and personal and professional development.

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MODERN ENGLISH TEACHING METHODS

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Аннотация. В статье рассматриваются четыре метода обучения английскому языку. Особое внимание уделяется цели, способам их реализации и результатам, полученным при использовании каждого из этих методов. Также приводятся их преимущества и недостатки. Далее предлагается подробная сравнительная характеристика всех рассмотренных методов. Однако можно сказать, что на данный момент идеальных методов обучения английскому языку не существует. Выявлено, что в настоящее время наиболее эффективными из них являются коммуникативный метод и метод проектов.

Ключевые слова: коммуникативный метод, метод проектов, интенсивный метод, деятельностный метод, языковая компетенция, специфическая черта (черта), цель обучения, интеллектуально-эмоциональное содержание, командная работа.

Annotation. The paper discusses four methods of teaching English. Special attention is paid to the purpose, the ways of their realization and the results obtained by using each of these methods. Their attractions and disadvantages are also given. In what follows, a detailed comparative characterization of all the methods discussed is offered. But one can say that there are no ideal methods of teaching English at the moment. It is revealed that at present the most effective of them are the communicative method and the project method.

Keywords: communicative method, project method, intensive method, activity method, linguistic competence, specific feature (trait), training goal, intellectual-emotional content, teamwork.

Lot of modern English teaching methods are communicative oriented. One of their most important aim is to teach communication and linguistic competence. Each of such methods applies different means, teaching techniques and principles. Hence, each of such methods has specific and distinctive features.

Communicative method

The first specific feature of the communicative method is that the training goal is not the linguistic competence, but “foreign language culture” which includes cognitive, learning, developmental and educational aspects. Such aspects mean familiarity and learning not only linguistic and grammar systems but also its culture, its interconnection with the native culture as well as the construction of a foreign language, its character, peculiarities, similarities and differences with the native one.

Also they include students’ satisfactory of personal cognitive interests in any sphere of their activity. The latter factor provides the additional motivation a foreign language to be studied by students which are not interested in it. The second specific trait of the communicative method is to master all aspects of foreign culture through communication. It was a communicative method that was the first to propose the position that communication should be taught only through communication. It has been one of specific feature for modern methods. In communicative teaching methodology, communication fulfills the functions of teaching, cognition, development and education.

The further distinctive trait of proposed principle is using of all the functions of the situation. The communicative teaching is based on situations which are considered as the system of communications. The main focus is not

on the replication by using of visual methods or the verbal description of reality fragments, but on the situation simulation as the system of students interconnection. The discussion of situations created on the basis of students' interconnection permits to make the foreign culture learning process as natural and close to the conditions of real communication as possible. [6, p. 156] The communicative method also includes non-verbal communication skills such as gestures, facial expressions, postures, distance which are an additional factor in memorizing lexical and any other material. The specific feature of the communicative method is also used in conditional-speech exercises, i.e. such exercises based on full or partial repetition of the teacher's comments. The more knowledge and skills are gained the more difficult structure of conditional-speech exercises is until the need for them is worked out because students' statements become independent and meaningful.

Project method

The efficiency of the project method generally is provided with intellectual-emotional content of learning topics. And also it is necessary to note their gradual increase in complexity. Topics distinct feature is their concreteness. From the beginning of the teaching process students are expected to engage in meaningful and complex communication without simplification or primitivism.

The other distinctive feature of the project method is a special form of organizing students' communicative and cognitive activities through a project. From what, in fact, the name of the technique originated.

The project, as already mentioned, is an independent work realized by the student. In the working process the language communication is woven into the intellectual-emotional context of other activities. The novelty of the approach is that students are given the opportunity to construct the content of communication themselves starting from the first lesson. There are few texts per se in the course. They are reproduced as students work on projects proposed by teachers. Each project correlates with a specific theme and is developed over a specific period of time. [2, p. 179] The theme has a clear structure and is divided into subtopics each of which ends with a project work task. A particularly important feature is that students have the opportunity to talk about their thoughts, their plans.

Through project work a strong language base is built.

Specific trait is also that skills are subdivided into two types: language learning skills and language user skills. To develop the first type of skills, phonetic and lexico-grammatical training exercises are used. These are exercises on imitation, substitution, expansion, transformation, restoration of separate phrases and texts. Their peculiarity is that they are given in an entertaining form: in the form of a text to test memory, attention, guessing

games, puzzles, sometimes in the form of a phonogram. Teaching and practicing grammatical skills is usually done through worksheets. It is important that all exercises are done against the background of developing the project presented. For practice, a lot of situations created by means of verbal and figurative visualization are proposed to apply the learning language.

It is obvious here that specific features of communicative and project methods have a lot of similarities. They are built on the identical principles but they are applied during different teaching techniques. In the first case the teaching is based on situations and in the second case on the projects used.

Intensive method

Let's move on to the intensive method and consider its specifics. This method is based on the psychological term "suggestion". This is the first specific feature of the intensive methodology. The use of suggestion allows to pass or remove various psychological barriers in students in the following way. [4, p. 91] The teacher conducts classes on the basis of psychological factors, emotional impact, using logical forms of teaching. He also uses different kinds of art (music, painting, elements of theater) in his classes in order to have an emotional impact on students.

However, suggestopedic teaching presupposes a certain concentration of teaching hours. At the senior stages, for example, it is advisable to allocate six hours per week at the expense of the school component of the curriculum, they should be divided into three for two hours each. If necessary, the number of hours can be reduced to three.

Also a specific feature of the intensive methodology is that suggestopedia is widely based on the position of the different functions of the two hemispheres of the brain. Connecting emotional factors to foreign language teaching significantly activates the process of assimilation, opening new perspectives for the development of foreign language teaching methodology. [5, p.67] The whole atmosphere of classes is organized in such a way that positive emotions accompany language learning. On the one hand, this is an important stimulus for creating and maintaining interest in the subject.

In addition, the intellectual activity of students, supported by emotional activity, provides more effective memorization of the material and mastery of language skills.

Another distinctive factor is the active use of role-playing games. The specificity of intensive training is that the learning communication preserves all social and psychological processes of communication. Role-playing communication is at the same time a game, learning and speech activity. But at the same time, if from the position of students' role communication is a game activity or natural communication, when the motive is not in the content of the activity, but outside it, then from the position of the teacher role

communication is a form of organization of the learning process. According to L. G. Denisova, the main productive moments of interactive methodology of teaching foreign languages are:

- creation of a strong immediate motivation of learning, carried out behind informal communication and motivation of communication close to the real ones;

- high and immediate learning efficiency: already on the second day of classes the students communicate in the foreign language being studied, using language clichés embedded in the main teaching text - remember, the text of the polylogue is introduced on the first day of classes;

- presentation and assimilation of a large number of linguistic, lexical and grammatical units; 150-200 new words, 30-50 speech clichés and several typical grammatical phenomena are introduced and assimilated during one presentation.

These are also, undoubtedly, specific features. All of the above are the specifics of the intensive methodology, which to a greater extent ensure its effectiveness. These specific points are almost entirely different from the two previous methods. Only in one respect are they apparently similar. All three methodologies consider it a necessary condition for successful training of teamwork in a positive emotional atmosphere. At the same time, the intensive method pays more attention to such activities as speaking and listening.

Activity method

What specific features does the activity-based method of teaching English have? It should be noted that there are quite a lot of such means of teaching, characteristic only for the activity-based methodology.

At the beginning, let us note that the creators of this methodology believe that teaching the skills of design and the ability to work with the content of the reported should be separate. [1, p.20] In order to ensure the conscious acquisition of linguistic means and the training of design skills, they should be formed before the training of content skills takes place. Another specific feature of this method follows from this.

In activity-based methodology, there is a division between the preliminary mastery of linguistic means and the subsequent mastery of communication on the basis of the existing knowledge, skills, and abilities in the use of linguistic means.

But a really specific feature of the activity-based methodology is the allocation of what are called linguistic speech-communicative units. Since only the linguistic status of linguistic units is not enough for full-fledged communication in teaching - the linguistic status must be combined with the freedom of their choice in the language. Language units, as it has already been said, possessing the linguistic status and providing full-fledged

communication from the point of view of freedom of their choice, based on the content of the communicated, are called linguistic communicative units.

The last specific feature is the use of a method such as conditional transfer, which uses not only what the students have already mastered, but also what they are being taught at this stage. [8, p. 245]

It follows that the activity-based methodology differs significantly in its specificity from the first three methods.

Comparative characteristics of the presented methods of English language teaching

At present, the goal of English teaching is formulated as follows: to teach students to communicate in English. But when the goal is set in this way, it becomes an end in itself. The purpose of education is much broader than acquiring certain skills and abilities, and the possibilities of the subject "English language" are much broader. [9, p. 198] Therefore, the goal of English language teaching at this point can be formulated as follows: to teach students not only to participate in communication in English, but also to actively participate in the formation and development of the student's personality.

On this basis, most modern English teaching methods are based on the principle of active communication.

Communicativeness implies the construction of teaching as a model of the communication process. To give teaching the main features of the process of communication, firstly, it is necessary to switch to personal communication with students, thanks to which a normal psychological climate is formed in the work with the audience. Secondly, to solve this problem it is necessary to use all ways of communication - interactive (when there is interaction between teacher and students on the basis of any activity, except for educational), perspective (when there is a perception of each other as individuals, bypassing the status of teacher and student), informative (when a student and a student), and informational (when the student and the teacher have a relationship with each other) informational (when the student and teacher exchange their thoughts and feelings rather than words and grammatical structures). And the third necessary condition is the creation of communicative motivation - a need that encourages students to participate in communication in order to change the relationship with the interlocutor. Communication should be organized in such a way that there is a gradual acquisition of language material.

Different stimuli can be the motivation for communication. In project-based methodology it is working on joint projects. The same stimulus is used in distance learning and intensive methodology. More often the situations used in the training are of a problematic nature. These situations should foster different opinions among students and not provide an unambiguous solution.

Discussion of such situations allows to confront different opinions, causes the need to defend their point of view, that is, the need to communicate in a foreign language. The use of problem situations also has another positive side, as it gives the opportunity to solve educational tasks, because it is possible to bring up an active personality only when discussing situations that are based on true values. It is also important to note that situationality should permeate all stages of learning speech material at all stages of learning.

In addition, in virtually all methods, collective joint activity is widely used. The trend of replacing individual group work has been developing for a long time. Collective work is very activating for the team. The formation of skills and abilities occurs in a system of collective actions that contribute to the internal mobilization of the capabilities of each student. Forms of collective interaction are easily realized in the classroom. This is work in pairs, in threes, in microgroups and in full groups. It should also be noted that role communication, constantly interacting with personal communication, is its prerequisite and condition. Situations of role communication, in which the skills and skills of foreign language communication are formed, provide the transition to a higher level of communication.

And yet collective work in all methods is realized in different ways. In communicative methodology it is the creation of situations similar to real ones, posing problem questions and discussing them. The project methodology uses group joint work on projects.

The next feature found in all methods is cognitive independence. It takes into account the fact that now English language teaching should be built on a fundamentally new basis that shifts the emphasis from the transfer of ready-made knowledge to its acquisition in the process of active learning and cognitive activity, thus forming an active personality with creative thinking. This principle is widely used in the activity-based methodology, as it is designed primarily for people with an established logical thinking. Besides, it allows to master language means consciously and use them meaningfully, as well as provides the formation of solid knowledge and skills.

The features of intensive methods of teaching English are becoming more and more widespread in the methods of teaching foreign languages. So, for example, polyfunctional exercises. It should be remembered that polyfunctionality is and should be characteristic of all speech exercises in existing teaching practice. After all, several types of activity are involved: listening, speaking and certain grammatical knowledge.

This is also the case with conditional language exercises, once a characteristic feature of communicative methodology. Now they are also used in interactive methodology.

There is one more idea, which is found practically in all methods, with small variations. This is the principle of managing the learning process on the basis of its quantization and programming in the communicative concept. Everything is quantized for this purpose, starting from the objectives and ending with the material, the learning process is divided into certain cycles. In project methodology this phenomenon is called “the principle of systematicity”, which manifests itself not only in the distribution of material into topics and subtopics, but also in the cyclic organization of the learning process. The learning process in distance learning is structured; the course structure is modular, so that the learner can clearly recognize his/her progression from module to module, or choose a module depending on his/her level of preparation. Even the activity-based methodology divides the course of English (foreign) language acquisition, as it was mentioned earlier, into the preliminary mastery of linguistic means and the subsequent mastery of communication. And this systematization of learning is used for more specific setting of goals of training courses; besides, the material united with the topic is more convenient for memorization, as well as its use and consolidation.

Thus, we can see that modern techniques, despite the abundance of specific features, have many commonalities underlying their very basis.

To understand how well is any of above mentioned methods let's consider advantages and disadvantages of each of them. The communicative method obtains some of advantages which should be actively used while working with it.

Firstly, it is the aim of education which is not only mastering a foreign language, but teaching of foreign culture. It is achieved by making all aspects of learning equal and interrelated. Such a way the teacher takes part in student's personality forming which is certainly the positive trait. Once more advantage of such a concept is interaction and uniform development of all kinds of activity (speaking, audition, reading, and writing). This factor is rather important. It is also important to create additional motivation using interdisciplinary relationships.

But more important positive traits are applying of communication as the main method of the English language teaching as well as using situations for its realization. Here it must be said that last two factors are peculiar to other mentioned methods in this article. This method has no pronounced negative features. May be there are some little shortcomings in this method but they are not expressed as obviously as the positive properties.

Now let's consider the intensive method. Surely, the most positive its trait is a very fast turnaround time for results. Already on the second day of classes the student communicates in English using the language clichés learned in the first class.

The great plus are also psychological bases of this method (suggestions) which create psychologically comfortable environment at lessons and are used for more effective teaching.

Polyfunctional exercises are important advantages too as well as a fairly large amount of time devoted to activating new vocabulary. It is recommended to give 20-24 hours for a cycle of training and take 18-20 hours for new material activation from them.

This method has a number of shortcomings. The amount of new material given for one presentation is too great (150-200 new words, 30-50 speaking clichés and some typical grammar phenomenon).

Once more disadvantage is teaching oral communication: reading and audition. Written forms of communication are only additional that should never be allowed.

The project method for a foreign language teaching has no pronounced disadvantages as in the communicative method. Positive traits are such as mastering the project culture, developing the ability to think creatively and independently, forecasting options for solving the task at hand.

The positive trait is also the wide application of problematicity that makes students think. It is necessary to note that the grammar is generally presented in the table that considerably simplifies its study and systematization by students.

And now let's speak about the activity method. It also has a number of positive traits.

Firstly, is the formation of skills of choosing language means in speech based not only on the meaning of what is being communicated but also on the ability to build the logical sequence. The second positive trait is the possibility to build grammar system using this method by means of speaking - communicative units.

This method comprises the large speaking practice.

The disadvantage of the activity method is that the objectives of the English language teaching (practical, educational, and developmental) are not sufficiently interrelated with each other and that the percentage of independent cognitive activity is lower than in other methods.

Analyzing all the above, we can say that there are no ideal methods of teaching English at the moment. Although communicative and project methods are currently the most harmonious and relevant from the point of view of modern methodology.

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PERSON' SPIRITUAL AND MORAL DEVELOPMENT BY MEANS OF LITERATURE

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Аннотация. Автор определяет основы духовности и нравственности человека как необходимые ценностные качества личности. За рассуждениями автор обращается к творчеству Оскару Уайльда, который показывает, что высшая данность человека —

способность видеть и чувствовать, знать переживания души и следовать её выбору. В заключении отмечено, что нравственность, это уровень усвоения человеком уроков его души их применения и подчинения собственному выбору.

Ключевые слова: произведение, литература, Оскар Уайльд, духовный смысл, культурно-родовое развитие нравственности.

Annotation. The author defines the foundations of person's spirituality and morality as the necessary value qualities. For reasoning, the author turns to Oscar Wilde's works, which shows that the highest ability of man is one to see and feel, know the experiences of the soul and to follow its choice. In conclusion, it is noted that morality is the level of assimilation by a person of the lessons of his soul, their application and subordination to his own choice.

Keywords: work, Literature, Oscar Wilde, spiritual meaning, cultural and generic development of morality.

The ancient Greek philosopher, student of Socrates, teacher of Aristotle (384–322 bce), and founder of the Academy, Plato wrote that “man is a spiritual and moral being, since his essence is in the eternal and immortal soul that enters the body at birth” [4, p. 34]. He is best known as the author of philosophical works of unparalleled influence and is one of the major figures of Classical antiquity.

In the course of our study, the author's understanding of human spirituality and morality is revealed. The theoretical basis of the article was the works of Plato, the works of O. Wilde, devoted to issues of spirituality and morality.

According to S.I. Ozhegov, N.Yu. Shvedova's dictionary, “spirituality” is characterized as “a property of the soul consisting in the predominance of spiritual, moral and intellectual interests over material ones” [3, p. 284]. K.A. Kolkunova, T.V. Malevich distinguish religious, political and cultural contexts of operating with the concept of “spirituality” [42].

Plato defines spirituality as the Gods' gift to man, the process of developing, forming and realizing moral qualities [4]. N.A. Buravleva asserts that “the presence of a priority of spiritual values in the value system of an individual is not enough to assert that a given person is spiritual. “It is important that a person behaves in accordance with these values even in the most oppressive circumstances” [1, p. 190]. The concepts of “morality” and “spirituality” are fundamental linguacultural concepts in understanding the content and problems of literary works [5].

Russian literature has always been contained spiritual and moral values, since it is the artistic word that influences not only consciousness, but also the feelings and actions of a person.

The question of the spiritual and moral, we find subjective, as what a person determines in the conditions of his own home, and objective, what he must accept in the conditions of the external environment, when he is forced to find himself in society.

In order to preserve our own views on this matter, one should study literary works on this topic and try to find answers to the questions that arise. For reasoning, it would be useful to turn to foreign literature, namely, Oscar Wilde, despite the contradictory nature of his judgments on this issue. Oscar truly believed in the divine beauty of the world, man in it, creating and creating this beauty [6, 8].

Oscar Wilde is an Irish writer and poet. His great work is "The Picture of Dorian Gray". But Oscar wrote stories. The "Importance of Being Earnest" can be seen in the theater, Wilde's poems are filled with a landscape-philosophical concept, beautiful and melodic, and fairy tales... Fairy tales reveal a deep spiritual meaning, addressed to our essence [8].

The fairy tale, "The Nightingale and the Rose" was written by Oscar Wilde in 1888 [7].

One should present a brief description of the work:

A student fell in love with the Professor's daughter and dreams of dancing with her at the prince's ball. The girl promised to dance with him if he brought her a red rose. However, this year his rose bush, damaged by frost, did not produce flowers. The Nightingale, considering the Student "a true lover", decides to help.

Then he asks for help from a frozen rose bush, which promises to give a red rose in exchange for the Nightingale's song and his blood. The Nightingale agrees to sacrifice for the Student's love and sings all night with a thorn stuck in chest, pouring blood into the bush. When the rose blooms, the Nightingale dies.

The Student, unaware of the Nightingale's sacrifice, brings a red rose to the girl. However, she rejects the flower, preferring the precious stones given to her by the chamberlain's nephew. The disappointed Student throws the rose under the cart and decides that love is foolishness, returning to studies.

Could the sacrifice of the nightingale be considered senseless? Could the student be called hopelessly in love? And what about the professor's daughter, who cannot love? The fairy tale tells about real problems, in the context of its "unreal" narration; one can see from the point of our own experiences, or empathy with the heroes, especially - "Nightingale". We can understand that "Love" is not the material, but the spiritual aspect of man and is contained in the miracle that nature follows, and the opportunity to think about this miracle is not directly given to everyone, just as the sacrifice of love is not able to

express itself to someone who does not experience this “Love”, but reconciles it with material values [7].

Why does Oscar give us these thoughts? Do we want to change the ending of this sad story?

Our understanding is that each person should have both an awareness of injustice and justice. We are not trying to refer to good or bad examples, but we can emphasize: “When you make a sacrifice for another, do not forget that the person may not deserve your sacrifice, or may not understand its meaning, therefore, if you are suffering, unrequited, give free rein to express it, with the sincerest, most real truth; only in this way will the person understand your feelings, and he will definitely give you an answer”

Our inner world is meant by a certain balance of the material and spiritual, if we deal with morality; it is a consequence of our cultural and ancestral development.

The Nightingale says that he cannot experience love the way a student does.

He notes: “He suffers because of what I sing about; what is joy for me is pain for him” [7].

The highest person’s ability is one to see and feel, be aware of one’s own soul, even without turning to one’s spiritual beginning, know the experiences of the soul and to follow its choice. Morality is the level of a person’s understanding his soul aspects, their application and submission to one’s own choice.

“The nightingale pressed himself even more tightly to the thorn, and the point finally touched his heart, and his whole body was suddenly pierced by a cruel pain. The pain became more and more excruciating, the Nightingale’s song became louder and louder, for he sang of Love, which finds perfection in Death, of that Love which does not die in the grave” [7].

In society we can find the cultural and tribal development of morality; one can invent a role for oneself and follow it, obeying -” Ideal”, but be real, ask yourself questions, learn to recognize your true essence in order to cope with it.

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CADET-PRODUCED VIDEO PROJECTS AS A MEANS OF MASTERING MARITIME ENGLISH WHEN HAVING SHIPBOARD TRAINING

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Аннотация. Поскольку будущие работники водного транспорта во время обучения в университете проходят 12-месячную плавательную практику, достаточно актуальной является проблема разработки технологии педагогического сопровождения и обоснования методики профессионально ориентированного обучения иностранному языку курсантов во время плавательной практики. Эта статья раскрывает опыт реализации видеопроектов, созданных курсантами, как средства овладения морским английским языком и развития у курсантов навыков эффективного общения во время обучения на борту судна. В ней приводятся некоторые рекомендации для преподавателей, заинтересованных во внедрении такого типа проектного обучения в профессионально-ориентированную иноязычную подготовку.

Ключевые слова: подготовленное курсантами видео, морской английский язык, плавательная практика, коммуникативные навыки, образовательный процесс.

Annotation. As future water transport workers have a 12-month shipboard practice during their studies at the university, the problem of developing pedagogical support technology and substantiating methods for professionally oriented foreign language training of cadets during their

shipboard practice is quite urgent. This piece of writing is devoted to sharing experience of implementing cadet-produced video projects as a means of mastering maritime English and developing cadets' effective communication skills when having shipboard training. It provides some issues for instructors interested in incorporating this type of project-based learning into maritime communication training.

Keywords: cadet-produced video, Maritime English, shipboard training, communication skills, learning process.

Recently the demand to build high-level professional competencies of maritime university graduates has become an urgent issue in a sphere of vocational education both in the Russian Federation and throughout the world. Its urgency is reasoned by the rapid development of shipping as a vital means of international commercial interaction. Nowadays the globalization of requirements for the quality of maritime education and its focus on improving professional training in leading maritime professions are aimed predominantly at training maritime cadets able to adapt to changes in the technical equipment of ships and adjust to dynamic social and economic processes.

Currently, in the Russian Federation, maritime vocational training is being carried out at more than a dozen universities and branches, where it is organized as the beginning of seafarers' professional path. Consequently, training in maritime universities implements systematic organizational and pedagogical techniques and procedures dedicated to the formation of cadets' professional orientation, knowledge, skills and abilities.

The maritime vocational training in our country is characterized by its systematic and standardized feature as it is carried out in accordance with the requirements of federal standards and the norms of the International Maritime Organization. When developing specialty programs on 26.05.05 Navigation, 26.05.06 Operation of ship power plants and 26.05.07 Operation of ship electrical equipment and means of automation that determine the content of higher education, maritime universities formulate requirements for the educational results in the form of universal, general professional and professional competencies.

Within the concern of this research, universal and professional competencies of future seafarers include their ability to apply modern communication technologies in a foreign language, for academic and professional interaction, as well as the ability to use English in written and oral forms when performing professional duties.

These competencies are built within professionally oriented foreign language training and namely maritime communication training which is based on the study of both the basic discipline "Foreign Language (English)"

and elective disciplines "Maritime English", "Business English", "Maritime Technical English" and other. The total number of credits in some universities reaches 24.

The variety of disciplines and the number of credits within maritime communication training results from the rapid development of international shipping and employer's demand for personnel with a high English language proficiency level and are directed at minimizing the language difficulties that may arise on board a ship with a multinational crew. The latter as a research shows may lead to various emergency on shipboard [6].

As future water transport workers have a 12-month shipboard practice during their studies at the university, the problem of developing pedagogical support technology and substantiating methods for professionally oriented foreign language training of cadets during their shipboard practice is quite urgent.

Those cadets who have their shipboard training on foreign flag ships with mixed crew have a great opportunity to enhance their English language proficiency by communicating in English when performing their duties. On board of training vessels mastering English during shipboard training is achieved via self-learning by reading texts related to cadets' specialty, keeping a diary in English or doing online courses on various educational platforms and learning management systems including Moodle provided there is any access to the Internet.

This piece of writing is devoted to sharing experience of implementing cadet-produced video projects as a means of mastering maritime English and developing cadets' effective communication skills when having shipboard training. It provides some issues for instructors interested in incorporating this type of project-based learning into maritime communication training. Incorporating this type of projects into maritime communication training has got its impetus due to updating smartphones for convenient video recording, digital editing suites for uncomplicated video editing and methods of online sharing and distribution.

Student-generated video projects have already been employed in teaching and learning English as a foreign language. In a number of studies such videos were specified as a valuable educational technique for building communication skills [1; 2; 3; 5]. Integrated skills practice, process-oriented activities, content-based learning are mentioned among other merits.

Cadet-produced video projects are aimed at giving cadets an opportunity to master their English language proficiency when having shipboard training. Project-based learning of this kind contributes greatly to developing cadets' communication skills by means of context-based learning thus enhancing their motivation in Maritime English learning.

This type of project consists of two oral activities aimed at developing communication skills in the context of cadets' future profession. The first one consists in generating videos sharing cadets' experience in performing their duties and gaining professional knowledge when having shipboard training. Topics for future videos can be suggested by the instructor or be cadets themselves. The list may include the following ones: "The duties I performed and skills obtained during shipboard training", "The drills I participated in", "The main engine and its maintenance", "The workshop on board my training vessel", etc. It is to keep in mind that the topics chosen and assigned have to be in close connection with the topics in the English course curriculum.

The process of producing video is multi-stage. Pre-production stage includes cadets' making decision upon the content of their video and gathering chunks of language material that can be incorporated into narrative. The material can be taken from their text books or online resources and further modified to achieve close relation to the video shot. After making drafts of their narrative and composing final script, the speech is checked for grammar, vocabulary and pronunciation mistakes. Cadets can send their scripts to the English language instructor for language, content and settings feedback before actual shooting takes place.

The second stage is producing video. Some of the hints to be taken in mind when shooting a video are as following [4]: a) directing the view, b) making transitions between scenes, c) changing perspectives, d) avoiding visual distraction and other. The process of shooting videos is not as challenging as it may be assumed as cadets are digital natives and they quite often produce videos to post them in their social network accounts or share with their friends and family via messengers.

Post-production stage involves editing and choosing video clips among those being taken, making them together to complete the final video. Free editing suites are available on the Internet and can be used for this purpose. Then voice overwork is organized and final editing is carried out.

All the procedures and techniques involved in the video-producing project are discussed in advance and posted in the forum to be addressed to as and when needed. It is possible that cadets may not have enough time to implement all the procedures involved in video producing process. Nevertheless, the better cadets are informed of the techniques implemented in creating video, the better the chances that their projects will reflect good practices in video production.

Produced videos are further uploaded to an instructor/cadets forum, e.g. the Moodle forum, where they can be viewed and evaluated by the instructor and peers.

The second oral activity, i.e. oral presentation, is performed in class when cadets join their course after shipboard training. In-class oral presentation is viewed as a powerful strategy for enhancing cadets' oral communication and presentation skills. They can be effectively developed due to the interaction with the audience and reflection on their performance.

When analyzing produced videos some pitfalls may emerge related to the lack of sophistication in content or language. Most of them, as the cadets themselves claim, are caused by procrastination and poor time-management skills. Another group of pitfalls is the result of poor recording or editing. Though cadets are tech-savvy digital natives they still need training in visual storytelling.

Summing up the research conducted in implementing cadet-produced videos as a means of mastering Maritime English having shipboard training, it is believed that such projects provide cadets with an excellent learning opportunity and are worth their efforts. Cadet-produced videos embedded into maritime English learning process develop both communicative and soft skills and reveal a practical way of connecting language learning and cadets' future profession.

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**INTERLANGUAGE PHRASEOLOGICAL EQUIVALENTS OF
TERMINOLOGICAL ORIGIN IN THE ASPECT OF LINGUISTIC
INTERNATIONALIZATION**

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Аннотация. В статье рассматриваются проблемы фразеологической интернационализации. Эксплицировано понятие межъязыковых фразеологических эквивалентов терминологического происхождения. Выявлены русско-французские фразеологические эквиваленты терминологического происхождения. Определен их удельный вес в общем русско-французском фразеологическом фонде. Межъязыковые фразеологические эквиваленты аргументируются как база интернациональной фразеологии. Намечены пути дальнейших исследований межъязыковых фразеологических эквивалентов терминологического происхождения.

Ключевые слова: интернациональная фразеология, русско-французские фразеологические эквиваленты, межъязыковые фразеологические эквиваленты терминологического происхождения, общий межъязыковой фразеологический фонд.

Annotation. The article deals with the problems of phraseological internationalization. The concept of interlanguage phraseological equivalents of terminological origin is explicated. The Russian-French phraseological equivalents of terminological origin are revealed. Their specific weight in the common Russian-French phraseological fund has been determined. Interlanguage phraseological equivalents are argued as the basis of international phraseology. The ways of interlanguage phraseological equivalents of terminological origin further research are outlined.

Keywords: international phraseology, Russian-French phraseological equivalents, interlanguage phraseological equivalents of terminological origin, common interlanguage phraseological fund.

Introduction. Internationalization of the various languages vocabulary as a result of social internationalization is one of the most important patterns, characterizing modern linguistic processes.

Linguistic internationalization is manifested at the level of language structure and functioning. Functional internationalization is conditioned by the strengthening of the role and importance of languages of interethnic and international communication, mass media, the growth of interlanguage

contacts, bilingualism and multilingualism, translated literature, etc. Emphasizing the importance of an adequate linguistic internationalization understanding, M.V. Kopylova rightly notes that it does not mean infringement of the languages and cultures of small nations, completely or partially replacing them with the language of interethnic communication, but on the contrary, it represents «mutually enriching communication of full-fledged, sovereign national cultures, recognition of equality for all languages and cultures» [3, p.8].

Under the influence of scientific and technological progress, digitalization processes, and the development of high technologies, scientific and technical terminology is becoming the most dynamic part of the national language lexical and phraseological system. Due to the significant integration of science and technology with their terminology, and the presence of reflections of so-called auxiliary languages in the material of different languages of world civilization, especially in their phraseology, zones of common international verbal and conceptual correspondence and correlation are arising and gradually expanding. Terminology is a rich breeding ground for the activation and expansion of the international phraseological fund.

In recent years, some works have appeared that examine terminological units of phraseological origin in the field of professional communication (E.A. Yuryeva) [10], phraseological units with a technonym component (D.O. Nikonov) [6], phraseological units with the “military weapon” component (L.V. Skachkova) [8]. However, many problems of international phraseology in general and phraseological internationalisms of terminological origin, in particular, are not paid enough attention. As E.M. Solodukho rightly argued back in the 80s, «the issues of phraseological internationalization are considered sporadically, and the factual material of this category of internationalisms is practically absent” [9, p.5]. The situation has not changed much since that time.

International phraseology, as a rule, is considered either within the framework of phraseological innovations, or on the basis of phraseological terms that arose on the basis of any one branch of knowledge, or in a communicative and pragmatic aspect. As far as we know, the question of interlanguage phraseological equivalents of terminological origin as the basis of an interlanguage phraseological community in the context of developing the theoretical foundations of its research remains open.

The research goal consists of revealing Russian-French phraseological equivalents (RFFE) of terminological origin, identifying their specific weight in the common Russian-French phraseological fund, arguing the interlanguage phraseological equivalents (IFE) as a base for international phraseology.

Russian Russian Russian Russian phraseological fund, which we have identified, consists of Russian French phraseological equivalents, including 16,000 Russian phraseological units and more than 23,000 French phraseological units, presented in the Dictionary of Russian French Phraseological Equivalents by N.E.Kaika and L.P. Kofanova [2]. According to our calculations, about 200 of these Russian-French phraseological equivalents are of terminological origin. We have identified the English phraseological correlates of such Russian and French phraseological units from the dictionaries of English phraseology and the English language [4, 11, 12]. It should be noted that we present English phraseological equivalents of terminological origin as an additional argument proving the international character of phraseological units in several languages.

The main part. Scientists put forward various criteria for the definition of international phraseological units [7]. From our point of view, a reliable finding of interlanguage phraseological commonality fact at the lexical-semantic level assumes the obligatory identity or correlation of the RFFE phraseological correlates in terms of function in speech, as well as in terms of style (in the sphere of their use) and stylistic (expressive-emotional) characteristics. Therefore, a separate stylistic analysis of the Russian-French phraseological equivalents is not carried out.

Since the phraseological status of terminological stable phrases that perform a nominative function in the language has not yet been fully determined, we believe it is necessary to dwell on this issue in more detail and clarify what we mean by the interlanguage phraseological equivalent of terminological origin.

In our opinion, a phraseological units of terminological origin is a syntactically and semantically stable, functionally integral unit of a language with a complete or partial semantic transformation of its components, the prototype of which was a complex term or compound name (*сила инерции* – *force d'inertie*; *состав преступления* – *corps du délit*). Interlanguage phraseological equivalents (IFE) of terminological origin are considered to be multilingual phraseological units with at least one common meaning in the case of a polysemy of phraseological correlates, identical or correlative in functional and stylistic characteristics and lexical composition, and therefore in issuance, the prototypes of which are complex terms and compound names [2, p.17-31]. E.g.: rus. *привести к общему знаменателю* – fr. *ramener au même dénominateur* – eng. *reduce to a common denominator*.

The step-by-step (formal, semantic, etymological-genetic, historical-etymological) identification of phraseological internationalisms, proposed by E.M. Solodukho, seems convincing [9, p.10–13].

At the same time, the scientist considers the minimum isoglossa represented by two languages, regardless of their kinship and distribution, to be the lower limit of the number of languages when establishing the fact of phraseological internationality [9, p. 12]. Sharing this opinion, we will cite phraseological units from two languages, Russian and French, as the main factual material, and examples from English as an auxiliary (illustrative) one.

It should be noted that many international phrases of terminological origin that have gone beyond professional use develop the same figurative meanings. Cf.: rus. *складывать оружие* – fr. *mettre bas les armes* – eng. *ground arms* (= *lay down arms*) = «end the dispute by conceding to the opponent». In the process of functioning, IFE of terminological origin can undergo various semantic transformations and acquire new meanings. So, after the release of P. Verhoeven's famous film «The Basic instinct», the expressions *basic instinct* – *l'instinct principal* – *basic instinct* developed a secondary figurative meaning – “sexual instinct”, “sexual attraction”. Although these correlates are not recorded by any Russian, French, or English phraseographic sources, we believe these expressions can be considered as RFFE.

Interlanguage phraseological equivalents of terminological origin relate to different fields of science, technology, sports, medicine, art, etc. Here are some examples.

Thus, a number of IFE arose on the basis of mathematical terminology: rus. *абсолютный ноль* – fr. *zéro en chiffre* – eng. *absolute zero*; rus. *свести к нулю* – fr. *réduire au zéro* – eng. *reduce to zero*; rus. *под острым углом* – fr. *sous un angle aigu* – eng. *at an acute angle*; rus. *уравнение с двумя неизвестными* – fr. *équation à deux inconnu* – eng. *equation with two unknown quantities*. There are also numerous MFE that have developed on the basis of physical terminology: rus. *идти по линии /путем/ наименьшего сопротивления* – fr. *suivre la voie du moindre effort* – eng. *follow the line of least resistance*; rus. *центр притяжения* – fr. *pôle d'attraction* – eng. *centre /point/ of attraction*; rus. *разрядить атмосферу* – fr. *détendre l'atmosphère* – eng. *clear the atmosphere*; rus. *сообщающиеся сосуды* – fr. *des vases communicante* – eng. *communicating vessels*. MFE of marine origin are distinguished: rus. *брать на буксир* – fr. *prendre à la remorque* – eng. *to have smb in tow*; rus. *отдавать концы* – fr. *files son câble* – eng. *slip one's cable*. A large part is made up of IFE, which came from sports and various games: rus. *второе дыхание* – fr. *deuxième /second/ souffle* – eng. *second breath*; rus. *держат /иметь/ все козыри в руках* – fr. *avoir /tous/ les atouts dans son jeu* – eng. *have all the trumps in one's hand*.

IFE related to the development of aviation and astronautics: rus. *высший пилотаж* – fr. *une acrobatie aérienne* – eng. *aerobatics /acrobatic/ flying*;

rus. *набирать высоту* – fr. *prendre de la hauteur* – eng. *gain height*; rus. *мягкая посадка* – fr. *l'atterrissage en douceur* – eng. *soft landing*. IFE related to military terminology: rus. *ложная тревога* – fr. *une fausse alarme* – eng. *a false alarm*; rus. *безоговорочная капитуляция* – fr. *capitulation sans réserves* – eng. *unconditional surrender*.

In recent decades, the IFE, which arose on the basis of psychological terminology, has become widespread: rus. *психологический барьер* – fr. *barrière (f) psychologique* – eng. *psychological barrier*; rus. *психологическая несовместимость* – fr. *incompatibilité (f) psychologique* – *psychological incompatibility*; rus. *психологический фактор* – fr. *moment (m) psychologique (instent (m) psychologique)* – eng. *psychological factor*; rus. *поток сознания* – fr. *tourrent (m) de conscience*; rus. *комплекс неполноценности* – fr. *complexe (m) d'infériorité* – eng. *inferiority complex*.

It should be emphasized that when identifying a common international fund of phraseological equivalents of terminological origin, we must pay attention to the fact that not all correlates of multilingual expressions have the phraseological status. For example, the Russian and French expressions *мозговой штурм*, *промывка мозгов* function as phraseological units in the compared languages, but in the source language (English) they are words in form ('brainstorming', 'brainwashing'), and therefore they cannot be included in the IFE.

From the point of view of belonging to the active or passive phraseological stock of the compared languages, not all phraseological correlates are equivalent.

Thus, expressions that arose in the 40s, 50s, and 60s of the twentieth century functioned as phraseological innovations, for example, *холодная война* (rus.) – *la guerre froide* (fr.) – *cold war* (eng.). Over time, due to changes in world politics, they turned into a passive reserve, but today they have become relevant again, which, in particular, is confirmed by the research of V.M. Amirov and T.A. Glebovich, who, considering various aspects of the functioning of the ideologeme "cold war" in modern Russian media, found such examples in newspapers: *Rossiyskaya gazeta* («Российская газета») – about 400 cases of the use of this ideologeme, *Izvestia* newspaper («Известия») – about 350, *Novaya gazeta* («Новая газета») – about 20. [1]. According to G.V. Matkarimova, the expressions *la guerre froide* (fr.) and *cold war* (eng.) have a fairly high frequency of use in the modern Western press. The author gives the following distribution of the number of expressions mentions ('cold war', 'guerre froide') in publications of foreign media, in particular, in 2022, in %: *Figaro* – 3%, *Liberation* – 6%, *NYT* – 14%, *WT* – 8%, *Telegraf* – 13%, *Guardian* – 7% [5, с.94].

Conclusions. Russian-French (as well as Russian- English, Russian-French-English) phraseological equivalents of terminological origin can be considered as the basis of international phraseology. Undoubtedly, the rapid development of science and technology will contribute to the further active development of the phraseological composition internationalization of the of various languages. Undoubtedly, the rapid development of science and technology will contribute to the further active development of the various languages phraseological units internationalization.

At the same time, it seems promising to create a common base of phraseological equivalents of terminological origin for the European area languages, which could be useful for studying the phraseology of comparable languages by sources, for developing phraseography, for translation practice, when reading theoretical and practical courses on comparative phraseology, etc., which can serve as a direction for further research.

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SOCIAL AND CULTURAL ADAPTATION OF FOREIGN CADETS TO THE EDUCATIONAL PROCESS

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Аннотация. Сохранение нынешнего статуса нашей страны в мировой геополитической системе во многом зависит от укрепления международного сотрудничества. Служба в войсках предъявляет высокие требования к моральным, духовным и физическим качествам военнослужащих. Представлены возможности социокультурной адаптации обучающихся из зарубежных стран к образовательному процессу военного вуза. Успешность социокультурной адаптации определяется характером социальных связей и коммуникации курсантов в условиях межкультурного общения.

Ключевые слова: иностранные курсанты, межкультурная коммуникация, военная деятельность, социокультурная среда.

Annotation. Maintaining our country's current status in the global geopolitical system largely depends on strengthening international cooperation. High demands are made on the moral, spiritual and physical qualities of personnel during military service. The possibilities of foreign cadets' social and cultural adaptations to the educational process in Higher Naval school are presented. The success of adaptation processes is determined by the features of foreign cadets' social connections and communication in the context of intercultural interaction.

Keywords: foreign cadets, intercultural communication, military activity, social and cultural environment.

Introduction. The higher education system carries out training of personnel in all areas of development of science, technology and production. Foreign cadets study on the same educational programs as Russians; some foreign military personnel can study for free. Every year, the Russian Defense Minister approves a list of foreign countries whose military personnel can train with quotas for free and discount.

One of the mission of a military higher education institution is "to satisfy the needs of students for intellectual, cultural and moral development through obtaining higher and (or) postgraduate professional education" [6, p. 1]. **The purpose** of the study is to determine the possibilities of social and cultural adaptation in the conditions of a military higher educational institution.

The methodological basis of the article is the concepts of:

— cultural distance interaction (X.Yan, A.S. English, L. Zheng, M.Bender, Y. Zhou, J. Ma, Y. Ma, J. Lu, W. Li) [9];

— the potential impacts of academic adaptation on psychological adaptation and sociocultural adaptation (L.Sheng, J. Dai, J. Lei) [7];

— the formation of intercultural competence in cadets (A.S. Orzhekhovsky, Yu.V. Sorokopud) [5];

— sociocultural adaptation that is referred to possessing "the skills required to manage everyday situations and aspects of living in a new culture" (C.Ward) [8];

— adaptation to the educational environment of a Russian university of foreign military personnel is associated with the need to assimilate cultural patterns that differ significantly from the usual ones (A.N. Andonova) [2].

Results. In general, professional training of future specialists for foreign countries is referred to a preparation of highly qualified officers to perform functional professional duties effectively [4].

Military service makes high demands on the moral, spiritual and physical qualities of military personnel. Even the most modern weapons cannot compensate for the poor training of the servicemen [5]. In our opinion, the professional training effectiveness can be ensured by the social and cultural adaptation of foreign cadets. The adaptation process includes many aspects. Adaptation is linked with the development of society. The socio-cultural environment of a military higher educational institution can be characterized as a way to obtain cultural information by foreign cadets.

Social and cultural adaptation can be described as the process of “a person’s adaptation to living conditions, norms of behavior, and norms of communication in a new social environment” [1, p. 286]. The psychological content of sociocultural adaptation is “the convergence of the goals and value orientations of the group and the individual included in it, the assimilation of norms, traditions, and group culture, and entry into the role structure of the group” [1, p. 286].

The process of socio-cultural adaptation presupposes the ability to learn, an adequate system of relationships with people around them and is determined by the structure of cadets’ motives. When teaching Russian to foreign cadets, socio-cultural adaptation “manifests itself in speech behavior, speech etiquette, and non-verbal norms of behavior” [1, p. 286].

The result of the social and cultural adaptation of foreign cadets should be the assimilation of the norms characteristic of the educational system of a military university. “The essence of the professional training of foreign cadets within the framework of intercultural interaction is represented by equipping them with socio-cultural knowledge, increasing their level of knowledge of the Russian language and intercultural communication” [3, p. 65].

Conclusion. The success of social and cultural adaptation processes is determined by the social connections and communication nature. It is stated to be an indicator of professional development effectiveness. Communicative interaction with foreign cadets is implemented in the context of educational and upbringing activities.

Thus, the effectiveness of professional training depends on the socio-cultural adaptation of foreign cadets. The mission of a military institution is to provide intellectual, cultural and moral development. The success of adaptation processes is determined by the nature of social connections and communication of foreign cadets in the context of intercultural interaction.

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PERSON'S MORAL QUALITIES FORMING IN THE CONTEXT OF FOREIGN LANGUAGE EDUCATION

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Аннотация. В работе представлены возможности формирования нравственных форм личности в условиях иноязычного образования. Создание условий для воспитания гармонично развитой, патриотичной и социально ответственной личности на основе духовно-нравственных ценностей является приоритетным направлением в сфере образования. Вопросы нравственных поступков человека рассмотрены в работах О. Уайльда, Э. Войнич, У.С. Моэма. Сделан вывод, что нравственный компонент в структуре духовности как норма духовного поведения регулирует личные и общественные интересы с целью достижения самосовершенствования.

Ключевые слова: духовность, нравственность, ценностные нормы, этика, самоопределение.

Annotation. The paper presents the possibilities of forming moral forms of personality in the context of foreign language education. A priority of education system is in creating conditions for the development of a harmonious, patriotic and socially responsible personality based on spiritual and moral values. The issues of moral actions of a person are considered in the works of O. Wilde, E. Voynich, W.S. Maugham. It is concluded that the moral component in the structure of spirituality as a norm of spiritual behavior regulates personal and public interests in order to achieve self-improvement.

Keywords: spirituality; morality; value norms; ethics; self-determination.

Introduction. A modern personality must develop its motives and needs, goals and ideals in accordance with the values of civil society. A deep personal way of reflecting reality is spirituality and morality, which is determined by the orientation of human knowledge to the highest moral values.

The system of moral norms and values is the result of spiritual and moral efforts of a person in the process of socialization [11]. These tendencies are

aimed at the full realization of their life opportunities. Any society designs the future through education.

A person's morality is the degree of harmonization of universal human values in one's actions. The spirituality of a man is manifested, first of all, in the possession of the basics of ethics, which gives him the opportunity to know their own and other people's actions and, ultimately, to develop their own value standards. "In the complex structure of the human personality, the concept of spirituality is elusive, has no strictly defined connections with the social status and roles of a person, and is not directly dependent on his intellectual development or commitment to a certain ideology" [1, p. 4]. "The spiritual and moral development of young people occurs within the framework of self-awareness as a bearer of value norms" [1, p. 4].

The relevance of the study is determined by the demand of society for a young person's education who possesses moral values, is capable of joining an existing community, is ready to preserve the transmitted traditions and norms of life and is able to resolve ethical issues in the process of interaction.

The subjective of the study is to present the possibility of forming moral forms of personality in the context of foreign language education. The methodological basis of the article was the research of scientists: N.A. Koval, E.S. Markaryan, V.V. Yudina, V.V. Shamaeva, A.V. Zueva and others, as well as a normative document: Decree of the President of the Russian Federation of May 7, 2024 N 309 "On the national development goals of the Russian Federation for the period up to 2030 and for the period up to 2036", namely: creating by 2030 conditions for the education of a harmoniously developed, patriotic and socially responsible individual based on traditional Russian cultural, historical and spiritual and moral values [6].

The main part.

Activity, according to E. Markaryan, is "one of any life processes expressed in behavior [3]. The decisive factor in the development of people's social life is material and production activity and its relationship with various spheres of spiritual production" [2, p. 16].

V.V. Shamaeva and A.V. Zueva note that a person encounters dilemmas of one's own identity in the modern information society, since "humanity lives in hyperreality, in which socio-cultural facts lose their connection with the objective world..." [7, p. 35].

According to V.V. Yudin, the necessary valuable qualities of a person should be formed through activity, since values are an important component of activity and perform its motivational and evaluative function [8, p. 16]

Self-assessment of an individual's positions, the norm of life, and self-identification of a person in society is one of the elements of morality and spirituality. It is possible to express oneself through choice. "In the structure

of such an act, all spatial-temporal and substantive-semantic values and relationships are focused, which are drawn to “emotional-volitional moments: I-the-other and I-for-the-other” [1, p. 4].

So, A.A. Ukhtomsky proposed using discussions to develop sensitivity, receptivity to the emotional state of people around them, their attitudes and aspirations, tact [9], since it is in the process of discussion that the interaction of participants in communication, exchange of opinions, and expression of their point of view occur [5].

We suggest organizing discussions in foreign language classes. It will be productive in the context of spiritual education due to the following fact:

1. Dialogue is the most productive form of communication and mutual understanding between people.

2. Using discussion in the process of studying foreign language literature is of great importance for the development of personal qualities.

3. Dialogization of communication involves the formation of foreign language communicative skills and the actualization of value systems.

As an example for discussion, we can cite the works of Oscar Wilde, an Irish philosopher, writer, aesthete, and poet [14, 15]. In modern realities, it is difficult to find selfless friendship when a person's social status and capabilities are not taken into account. The motivating mechanism of a person's spiritual life is the moral motives of help, salvation, and well-being.

The quotes from his books by Oscar Wilde are especially relevant today, since they present a reassessment of values, a test of people for sincerity, spirituality and morality:

“The mystery of love is greater than the mystery of death” [12, p. 1].

“Anyone can sympathise with the sufferings of a friend, but it requires a very fine nature to sympathise with a friend's success” [12, p. 1].

“Selfishness is not living as one wishes to live, it is asking others to live as one wishes to live: and unselfishness is letting other people's lives alone, not interfering with them” [12, p. 1].

“A man who does not think for himself does not think at all” [12, p. 1].

“Nowadays people seem to look on life as a speculation. It is not a speculation. It is a sacrament. Its ideal is love. Its purification is sacrifice” [12, p. 1].

“In old days nobody pretended to be a bit better than his neighbour. In fact, to be a bit better than one's neighbour was considered excessively vulgar and middle class. Nowadays, with our modern mania for morality, everyone has to pose as a paragon of purity, incorruptibility, and all the other seven deadly virtues. And what is the result? You all go over like ninepins—one after the other” [12, p. 1].

“All sympathy is fine, but sympathy with suffering is the least fine mode” [12, p. 1].

“The world is a stage, but the play is badly cast” [12, p. 1].

O. Wilde thus glorifies the power of good, the might of love, which is stronger than death. By ironically depicting friendship and love through their humiliation; life through the meaninglessness of death; faith through unbelief [15]. According to the author, the main values in a person's life should be love, self-sacrifice, beauty, happiness. People often create a system of false values and do not see reality. Inner peace, which is synonymous with kindness, is expressed in a selfless act.

An integral component of discussion in the process of studying English literature is an argument - a set of judgments to confirm the truth of events.

As a discussion of spiritual and religious motives, we can take the novel by E. Voynich “The Gadfly” – one of the world bestsellers of the 20th century. The work “The Gadfly” was considered a parable about the perfect man [13].

With the help of images, motifs, plot connections, etc., this era of the emergence of Christianity is woven into the main narrative of the novel, emphasizing the eternal nature of the repetition of events in which the main role belongs to an exceptional personality, similar to the Founder of Christianity [4].

The issues of human moral actions are considered in the works of W.S. Maugham. He does both good and evil deeds not according to any morality, but for his own benefit. When studying the writer's works, it is possible to discuss arguments about the desire for improvement, for curbing passions, since desires may not always be pure and noble [10].

In conclusion, it should be noted that the issues of spiritual and moral education in the public consciousness of the population are considered very important today. Harmony of the individual and society as a condition for their well-being is supported by moral values.

These are the norms of spiritual behavior that regulate the relationship between the individual and the surrounding world, personal and public interests. A person's attitude to the common good as the highest goal is based on spirituality, morality, friendship, solidarity, care, nobility, love, responsibility.

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D JOHN DEWEY'S PRAGMATIC PEDAGOGY IN THE ASPECT OF
C 2 PHYSICAL EDUCATION

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Аннотация. Прагматическая педагогика, основоположником которой является американский философ, психолог и педагог Джон Дьюи, представляет собой деятельностный подход к обучению и воспитанию, который акцентирует внимание на практическом опыте и активном участии обучающихся в образовательном процессе. В статье рассмотрены теоретические основы прагматической педагогики Дж. Дьюи, оказавшие влияние на физическую культуру в современных образовательных системах.

Ключевые слова: физическая культура, Джон Дьюи, прагматическая педагогика, активное обучение, проблемно-ориентированное обучение, социальное взаимодействие

Annotation. Pragmatic pedagogy, founded by the American philosopher, psychologist and educator John Dewey, is an activity-based approach to teaching and education that emphasizes practical experience and active participation of students in the educational process. The article examines the theoretical foundations of J. Dewey's pragmatic pedagogy, which influenced physical education in modern educational systems.

Keywords: physical education, John Dewey, pragmatic pedagogy, active learning, problem-based learning, social interaction.

Relevance. Currently, there is a need to consider physical education methods as modern challenges in Russia and the world, such as the decline in physical activity among young people and the need to develop a healthy lifestyle. Pragmatic pedagogy offers new ways to solve these problems, focusing on student involvement and the importance of practical experience [1].

The research could attempt to address issues related to the analysis of existing physical education methods, the assessment of their effectiveness, and the development of recommendations for the implementation of pragmatic approaches. What specific methods of active student participation could be most effective? How can Dewey's principles be adapted to the modern educational environment? What are the results of applying these methods in practice?

Thus, this study is aimed at a deep understanding and analysis of John Dewey's pragmatic pedagogy in the context of physical education of young men, which will help identify key aspects that contribute to improving the educational process and the formation of an active life position in young people.

Main part of the study.

The following key ideas of pragmatic pedagogy are:

1. Pragmatism as a Philosophical Foundation

Pragmatism, which emerged in the late 19th century, argues that truth and knowledge are tested through practical experience and consequences. John Dewey

was one of the main representatives of this movement, developing the ideas of pragmatism in the context of education. He believed that education should be aimed at developing critical thinking, problem solving, and adapting to changing conditions.

2. Education as a Process

Dewey emphasized that education is not simply the transfer of knowledge, but a process of active participation by students. He believed that learning should be based on real-life experiences, which contribute to a deeper understanding and assimilation of the material. In this context, physical education also takes on special significance, as it involves the active participation of students in physical activities, which contributes to the development of skills necessary for life.

3. The relationship between theory and practice

One of Dewey's key ideas is the relationship between theory and practice. He insisted that learning should be linked to real-life situations, which helps students apply theoretical knowledge in practice [3]. In physical education, this means that sports and physical activity should be integrated with theoretical aspects of health, fitness, and teamwork.

Principles of Pragmatic Pedagogy

1. Active Learning

This one involves students engaging in the process through hands-on activities, discussions, and research. Dewey believed that this approach helps develop critical thinking and deepens understanding of the material.

2. Problem-Based Learning

This principle is that learning should start with real problems and issues that students face in their own lives. This makes learning more meaningful and engaging, especially in the context of physical education, where students learn how physical activity affects health and social interaction.

3. Social Interaction

Dewey emphasized the importance of social interaction in the learning process. Students should exchange ideas, work in groups, and learn from each other. In physical education, this is especially true, as many sports and physical activities require teamwork and interaction with others [2].

The Impact of Pragmatic Pedagogy on Physical Education

1. Skill Development

Pragmatic pedagogy focuses on the development of practical skills. In the context of physical education, this means that students not only learn the rules of sports, but also actively participate in competitions, train, and develop their physical abilities [5].

2. Health and Physical Education

Dewey emphasized the importance of health as a major aspect of education. It is important not only to teach children physical activity, but also to instill in them

the habits of a healthy lifestyle. This includes understanding the importance of proper nutrition, regular exercise, and active recreation [8].

3. Integration with other subjects

Pragmatic pedagogy suggests integrating physical education with other subjects. For example, physical education lessons can be combined with biology lessons, in which students study human anatomy and physiology, or with history lessons related to the development of various sports.

Application of theoretical foundations in practice

1. Modern approaches to teaching physical education

Educational institutions are beginning to actively apply Dewey's ideas in their programs. The use of active learning methods and the project approach is becoming more widespread. Teachers create conditions for active participation of students, which leads to better learning outcomes [4].

2. Development of curricula

When developing physical education curricula, it is important to consider the principles of pragmatic pedagogy. This may include creating practical learning situations, developing interdisciplinary projects, and using modern technologies to engage students.

3. Evaluation of results

Assessment of learning outcomes in physical education should take into account not only physical achievements, but also the development of social interaction, critical thinking and problem-solving skills. This will help to create a more complete picture of students' achievements and their readiness for life.

Problems and challenges of implementing pragmatic pedagogy

1. Resistance to Traditional Methods

One of the main challenges in implementing pragmatic pedagogy is resistance to traditional teaching methods. Many teachers and administrators may be skeptical of innovation and prefer time-tested approaches [6, 7].

2. Limited resources

Implementing active learning methods requires additional resources, such as physical activity equipment, teacher training, and creating comfortable learning environments. With limited budgets, many schools face challenges in implementing these changes.

3. The need for professional development

Continuous professional development of teachers is necessary for the successful implementation of pragmatic pedagogy in physical education. This includes participation in seminars, courses and exchange of experience with colleagues. Without proper training of teachers, the implementation of new methods may be ineffective [9].

Conclusions.

The theoretical foundations of John Dewey's pragmatic pedagogy represent an important contribution to modern education, especially in the context of physical education. The emphasis on active learning, the relationship between theory and practice, and the importance of social interaction create conditions for a deeper understanding and assimilation of educational material.

Implementing these ideas into educational systems requires teachers and administrators to be open to change and to undergo continuous professional development. We can create a modern educational environment only by means of these efforts can that foster healthy, active, and critically thinking citizens.

John Dewey's pragmatic pedagogy remains relevant and in demand, opening up new horizons in teaching and education, and promoting the development of physical culture as an important aspect of every person's life.

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REGIONAL STUDIES IN THE EDUCATION

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Аннотация. Рассмотрена роль краеведения в воспитании школьников. Изучение истории, географии своей малой Родины способствует формированию национального самосознания обучающихся путем углубленного изучения родного края. Представлены объекты культурного и природного наследия Каланчакского муниципального округа.

Ключевые слова: краеведение, родной край, объект природного и культурного наследия, национальная идентичность.

Annotation. The role of Regional studies in education of schoolchildren is considered. Studying the history and geography of one's small homeland contributes to the formation of national self-awareness of students through in-depth study of their native land. The objects of cultural and natural heritage of the Kalanchak municipal district are presented.

Keywords: regional studies, native land, natural and cultural heritage site, national identity.

Introduction. Regional studies include material on geography, history, social science with the aim of forming awareness and understanding of involvement in the great heritage of the country. The study of objects of natural and cultural heritage of the small Motherland is the basis of value orientations of the individual, spiritual and moral education of students [3].

The origins of spiritual development begin with involvement in the immediate environment - the small Motherland. This is facilitated by tourist and local history activities, through which a natural attachment of a schoolchild to one's native land, culture, language and nature is formed [5]. Each village or town is rich in objects of natural or cultural heritage that can interest the most demanding tourist. The role of Regional studies in the education of a Citizen and Patriot of their country is essential, since it is the study of history, geography of one's small homeland that ensures the formation of national identity, the image of native country. Regional studies combine imaginative perception and logical thinking, gives a description of nature, resources, population, ecology [6].

The main objective of the article is to substantiate the role of local history in the formation of moral qualities of the growing generation, to improve the level of education through study of one's region.

Results of the study. The role of Regional studies in the education of personality was studied by D.S. Likhachev [4]. Issues related to the problems of studying tourist sites were considered by scientists V.V. Kelarev, A.A. Potopurchenko [2]. The possibility of spiritual and moral education through the study of local history was considered by A. P. Kolpakova [3].

“Regional studies bring a high degree of spirituality into a person's environment, without which a person cannot meaningfully exist. There is biological ecology, i.e. ecology necessary for basic life, but there is also cultural ecology, without which a person cannot have a cultural, spiritual life, which fosters morality, respect for the environment, for the past, and concern for the future” [4, p. 159].

The territory of the Kalanchak municipal district is part of the Black Sea lowland with a wide development of closed bottom depressions and a general slight slope of the surface to the south - towards the Black Sea [1] (pict.1).

The hydrographic area of the Kalanchak municipal district is represented by the Kalanchak River, the North Crimean Canal, ponds near the village of Privilya, and a bay of the Black Sea [1].



Picture 1. Karadai Peninsula and Bird Island

“The coastal areas are occupied by salt marshes with unique vegetation (coastal salt marsh, herbaceous glasswort) ...” [1, p. 3].

In every settlement there are natural, historical and cultural sites that deserve attention (pict. 2).



Picture 2. Artesian spring

During the Great Patriotic War, Kalanchak was occupied by German troops from September 11, 1941. A German concentration camp was created on the territory of the Budyonny state farm until November 1943. There are many monuments in Kalanchak municipal district devoted to the heroes of Great Patriotic War (pict. 3)



Picture 3. Memorial complex “Residents of the village who died on the fronts of the Second World War 1939-1945” (Kalanchak)

Having analyzed in detail the territorial structure of the Kalanchak municipal district, one can say that there are many natural, historical and cultural objects in this territory.

The conclusions of the study are as follows:

1. The study of history, culture, geography, social science, and the nature of one's native land is of particular importance in the moral education of schoolchildren, as it contributes to the formation of schoolchildren's national self-awareness through an in-depth study of their native land.

2. There are many natural heritage sites in the Kalanchak municipal district: the coast of the Karkinitsky Gulf, the Kalanchak Islands, the Karadai peninsula, the Domuzla ornithological reserve.

3. Many settlements have natural and tourist sites and historical and cultural heritage monuments.

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NEW WORDS RELATED TO THE NATURAL ENVIRONMENT IN THE MERRIAM-WEBSTER DICTIONARY: THEMATIC STRUCTURE AND DYNAMICS

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Аннотация: В статье исследуются неологизмы, связанные с природой, экологией и неорганическими природными явлениями, которые появились в английском языке в период с 1991 по 2020 год и были включены в словарь Merriam-Webster. Выделены тематические подгруппы, отражающие процессы экологического осознания и природоохранной деятельности. Анализ демонстрирует растущий интерес к устойчивому развитию, изменению климата и сохранению биоразнообразия, а также появление новых экологических практик. Слова анализируются с точки зрения способов их образования или заимствования. Создание неологизмов для обозначения новых экологических концепций, природных явлений и переосмысленных подходов к взаимодействию с природой отражает пересмотр отношений человечества с окружающей средой. Сравнение источников заимствований указывает на влияние глобальных экологических инициатив и научных исследований на лексику.

Ключевые слова: неологизм, английский язык, природная среда, Merriam Webster, экологическая лексика, природные явления.

Annotation The article examines neologisms related to nature, ecology, and inorganic natural phenomena that emerged in the English language between 1991 and 2020 and were included in the Merriam-Webster dictionary. Thematic subgroups reflecting processes of ecological awareness and conservation activities have been identified. The analysis demonstrates growing interest in sustainable development, climate change, and biodiversity preservation, as well as the emergence of new ecological practices. The words are analyzed according to their formation methods or borrowing patterns. The creation of neologisms to designate new ecological concepts, natural phenomena, and reevaluated approaches to interacting with nature reflects a rethinking of humanity's relationship with the environment. A comparison of borrowing sources indicates the influence of global environmental initiatives and scientific research on vocabulary.

Keywords: neologism, English language, Natural Environment, Merriam Webster, environmental vocabulary, natural phenomena.

Language is in constant development, particularly in the lexical sphere where new words emerge while some obsolete ones gradually fall out of use. This is driven by changes in environmental awareness, the emergence of new natural phenomena and processes that require naming, as well as global environmental problems that necessitate new terminology. The present study focuses on neologisms in English related to nature and ecology. The research material consists of neologisms added to the Merriam-Webster dictionary [3] between 1998 and 2020, which reflect the language's evolution during this

period. These words cover areas such as sustainable development, climate change, biodiversity protection, ecological practices, as well as scientific concepts describing natural processes.

The study aims to examine the composition and dynamics of neologisms related to the natural environment, analyze their formation methods and distribution across thematic groups for detailed examination of their meanings. To achieve this goal, methods of dictionary definition analysis and comparative analysis were used. Through complete enumeration sampling from the word list organized by year of inclusion in the dictionary and published on the Merriam-Webster website, terms belonging to the "Natural Environment and Ecology" category as per classification proposed by D. Shepetovsky and N. Aksenova [2] were selected.

This research allows us to trace how language adapts to new ecological conditions, as well as how global initiatives and scientific research influence the formation of new vocabulary. Dictionary definitions of 75 words in the "Natural Environment and Ecology" thematic group were analyzed, resulting in the identification of 10 subgroups: "Climate Change and Environmental Problems" (11 words), "Environmental Pollution and Waste" (5 words), "Biodiversity and Endangered Species" (13 words), "Invasive Species and Pests" (6 words), "Ecological Practices and Sustainable Development" (8 words), "Scientific Terms and Research" (15 words), "Plants and Botany" (4 words), "Animals and Their Behavior" (5 words), "Chemicals and Their Impact" (4 words), "Unusual Phenomena and Terms" (4 words). The predominant subgroups in the "Natural Environment and Ecology" group are "Biodiversity and Endangered Species" and "Scientific Terms and Research" (together accounting for 26% of the 75 words).

The first group - "Climate Change and Environmental Issues" - includes terms related to global climate changes and their consequences. For example: *climate change denier* (one who denies that changes in the Earth's climate or weather patterns are caused by human activity), *carbon footprint* (the amount of greenhouse gases and specifically carbon dioxide emitted by something during a given period).

The second group - "Environmental Pollution and Waste" - contains words describing various types of pollution and waste. For example: *microplastic* (a very small piece of plastic especially when occurring as an environmental pollutant), *e-waste* (waste consisting of discarded electronic products), *forever chemical* (a toxic substance and especially a synthetic chemical that persists and accumulates in the environment).

The third group - "Biodiversity and Endangered Species" - includes names of animals and plants under threat of extinction, as well as terms related to their protection. For example: *emerald ash borer* (a metallic-green Asian

beetle accidentally introduced into the U.S. and having a destructive larva that bores into the wood of ash trees), *goliath grouper* (a very large grouper of shallow waters especially of the western Atlantic Ocean from southern Florida to Brazil that may reach weights of up to 800 pounds).

The fourth group - "Invasive Species and Pests" - consists of terms describing species that actively spread in new ecosystems and cause damage. For example: *worm* (A new invasive species, the crazy worm, is spreading rapidly through several areas of the country, and has arrived at the edges of Northern New York.), *didymo* (a freshwater, microscopic diatom typically of cool, nutrient-poor waters of Canada and the northern U.S. and Europe that has become invasive in warmer waters where it forms large, thick brown, yellow, or whitish mats attached to a submerged substrate).

The fifth group - "Ecological Practices and Sustainable Development" - includes words related to environmental protection methods and sustainable development. For example: *hypermiling* (eco-driving for maximum fuel efficiency), *upcycle* (recycling waste into higher quality products), *rewilding* (wildlife restoration), *phytoremediation* (using plants to clean contaminated soils).

The sixth group - "Scientific Terms and Research" - contains words describing scientific concepts and phenomena. For example: *quorum sensing* (a regulatory mechanism of bacteria that involves the release of molecules which when present at threshold concentrations signal the expression of bacterial genes controlling specific group actions), *quantum entanglement* (a property of a set of subatomic particles whereby a quantum characteristic of one particle is directly and immediately correlated with the equivalent characteristic of the others regardless of separation in space).

The seventh group - "Plants and Botany" - includes plant names and terms related to their study. For example: *wandering dude* (any of several trailing tradescantia plants of the spiderwort family that have showy foliage usually with stripes of white, silver, cream, pink, or purple and that are often grown as houseplants), *money tree* (a tropical Central and South American tree of the mallow family that has smooth bark, woody edible fruits, and glossy palmate leaves made up of five to nine leaflets and that is commonly grown as a houseplant with a braided trunk).

The eighth group - "Animals and Their Behavior" - consists of animal names and terms describing their behavior. For example: *avian dinosaur* (a bird when considered as the survivor of a lineage of theropod dinosaurs), *non-avian dinosaur* (any dinosaur that is not a bird), *tooth fish* (either of two large marine food fishes found especially in antarctic and subantarctic waters).

The ninth group - "Chemicals and Their Impact" - includes terms related to chemical compounds and their environmental impact. For example:

neonicotinoid (any of a class of systemic water-soluble insecticides chemically related to nicotine that are used especially in agriculture to control destructive pests and that selectively bind to the postsynaptic nicotinic receptors of insects to produce paralysis and death), *forever chemical* (a toxic substance and especially a synthetic chemical that persists and accumulates in the environment).

The tenth group - "Unusual Phenomena and Terms" - contains words describing rare or unusual phenomena. For example: *Unidentified anomalous phenomenon* (a mysterious phenomenon that is sometimes assumed to be a spaceship from another planet), *axoplasm* (the protoplasm of an axon) (table 1).

Table 1. - Words Related to Natural Environment, Organized by Year of First Recorded Use

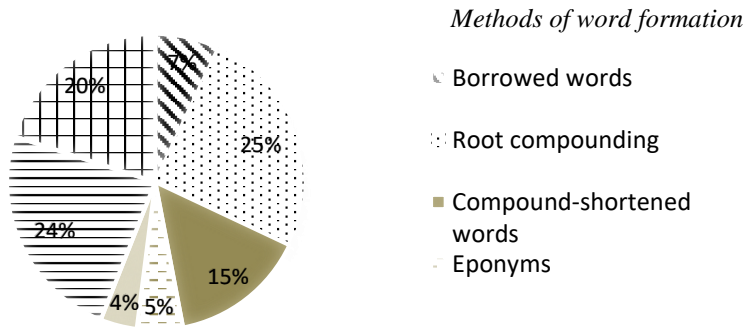
								Bcero
Climate Change and Environmental Issues								
		0		0	1			5
Ecological Practices and Sustainable Development								
				0	0	0	0	
	0	2	0	0	0	0	2	
	2	1	2	0	0	0	0	
	0	1	1	1	1	0	0	
	1	2	0	0	0	0	1	
I		16	20	7	3	1	4	5

The most represented category, "Scientific Terms and Research", contains 15 words (20% of the total word count). The emergence of neologisms in this category is primarily influenced by advancements in science and technology, as well as the need to describe new discoveries and phenomena.

Analysis of the table reveals that the most significant spikes in word formation occurred in the "Scientific Terms and Research" group (9 words in

1988–1992) and the "Biodiversity and Endangered Species" group (7 words in 1998–2002), which correlates with active developments in science and environmental research during these periods. In the "Ecological Practices and Sustainable Development" group, the peak occurred in 1988–1992 (5 words), likely reflecting the initial discussions surrounding the concept of sustainable development. Meanwhile, in the "Chemicals and Their Impact" and "Invasive Species and Pests" groups, word formation occurred more evenly, without sharp spikes. After the 2000s, most groups experienced a sharp decline in the emergence of new words, possibly due to lexical saturation or shifts in public focus. The exception is the "Plants and Botany" group, where new words continued to appear up until 2021.

An analysis of word formation methods in the thematic group "Nature and Ecology" shows that most terms are formed through compounding (e.g., carbon footprint, cap-and-trade, greenwashing), allowing for concise expression of complex ecological concepts. Initialisms such as PFAS, PFOS, and SNP are also widely used, simplifying scientific terminology. Root compounding plays a significant role as well, creating new concepts like climate change denier or rewilding. Borrowings, such as coltan and didymo, highlight the global nature of environmental issues, while eponyms like Kuiper Belt and Chytridiomycosis reflect the contributions of scientists and discoveries in shaping terminology (cf. [1]). Thus, the diversity of word formation methods in this group demonstrates the connection between language, science, and ecological challenges.



The study of neologisms related to nature and ecology has demonstrated that language actively adapts to contemporary environmental challenges, reflecting growing interest in sustainable development, climate change, and biodiversity conservation. Analysis of word formation methods revealed the predominance of compound words and root compounding, highlighting the pursuit of concise and precise expression of complex ecological concepts.

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BALANCE DEVELOPMENT IN STUDENTS OF TECHNICAL COLLEGE

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Аннотация. В статье рассматриваются пути развития равновесия у студентов Севастопольского колледжа информационных технологий и промышленности на занятиях по физической культуре. Особое внимание уделяется физическим упражнениям, включающим асаны йоги, которые способствуют контролю тела в пространстве. Приведены примеры упражнений, оптимизирующих координацию и направленных на

укрепление мышц и улучшение осанки. Приведены результаты тестирования обучающихся по технической профессии.

Ключевые слова: физическая культура, равновесие, координация, йога, колледж.

Annotation. The article examines ways to develop balance in students of Sevastopol College of Information Technology and Industry during physical education classes. Particular attention is paid to physical exercises, including yoga asanas, which help control the body in space. Examples of exercises that optimize coordination and are aimed at strengthening muscles and improving posture are given. The results of testing students in a technical profession are given.

Keywords: physical education, balance, coordination, yoga, college.

Introduction.

Currently, a person is faced with the need to solve complex problems connected with motor activity in educational, work, everyday and sports activities, while high demands are met to physical training. The students' activities at a technical college are characterized by the study of theory, mostly in a fixing position, as well as practical classes in workshops, where activity is performed while standing, and the positions can be static and uncomfortable, with a lot of manual work, and there is also lifting of heavy objects.

So, the following **problem** of our study is: what are the ways of balance development in students of college during physical education classes?

Main part

The balance of the human body in a vertical position during various motor activities (work, sports, everyday life) is not a simple function, although it seems so due to habit. Running, walking and other actions, even staying in one place, require constant efforts to maintain the balance of the body in the desired position. The physiologists, clinicians and sports scientists' research show that the balance function is very complex and its importance in human life is very great [1, 2]. No static position, no simple movement can be performed without sufficient development of the balance function in any area of human life. A high level of development of the ability to control body balance allows to perform a variety of everyday and industrial movements more accurately and efficiently [4].

Static balance refers to the ability to maintain a stable position when the body is motionless. This quality requires good muscle strength, coordination and a sense of stability. Static balance is of great importance for spatial orientation, development of the muscles of the body and lower limbs, as well as for the formation of correct posture. Dynamic balance is associated with maintaining balance during movement, the ability to control the body when it

moves or changes direction [8]. Dynamic balance is manifested in the vinyasa flow style in the process of yoga, where smooth transitions between asanas require coordination and control over movements.

Both types of balance are important for overall physical training and can be developed through regular practice.

The vestibular receptor apparatus perceives changes in the position of the head and body in space and the direction of body movement. Impulses in the central nervous system cause vestibulomotor, vestibulosensory and vestibulovegetative reflexes by stimulation of visual and tactile proprioceptors and receptors of the vestibular apparatus. It provides maintaining balance when changing body position. A person with strong irritation of the vestibular apparatus may develop motion sickness syndrome (dizziness, nausea, vomiting), for example, with seasickness. With frequent vestibular irritations, the reaction to them weakens (this is the basis for vestibular apparatus training of sailors, pilots, astronauts, and athletes) [3]. Balance also depends on the coordinated activity of three sensory systems [7]:

1. *Vestibular*. The correct functioning of this system allows a person to analyze the position and movement of the body in space. "Impulses of the vestibular apparatus are used in the body to maintain the body's balance, to regulate and maintain posture, and to spatially organize human movements" [6].

2. *Proprioceptive*. A person senses the position of the limbs, movement and the degree of muscle tension in them.

3. *Visual*. Effective maintenance of balance requires precise control from the visual system.

Optimal development of the balance function should include shortening the rest periods between exercises aimed at improving the functions of the vestibular analyzer (static and dynamic balance) and subsequent exercises related to solving other problems. For example, after rotation, one should quickly start performing another task to develop strength.

When performing other muscle activity after vestibular stimulation, a new dominant focus is created, which causes inhibition of the central links of the vestibular-reflex arc according to the law of negative induction. The resulting vestibular reactions are operated much more easily.

The following exercises, that can diversify the warm-up in physical education, are:

Starting position: closed stance. Stand on your toes, in this position, tilt your head, body, stay in the stance on your toes, closing your eyes. Starting position: right leg in front of the left, feet in one line, arms forward. Turn the body over the right shoulder, taking the arm back to the extreme possible position, return to the starting position. Perform smoothly and slowly.

Starting position: stand with legs apart. Raise your right leg, clasp your hands around your thigh, bend and straighten your leg at the knee, then hold statically. This position is similar to Utthitahastu Padangusthasana 4. “Utthita Hasta Padangusthasana is a standing posture that fosters equilibrium, balance, and increased focus. The word is a combination of the Sanskrit words utthita, which means “standing,” hasta, which means “hand,” padangustha, which means “big toe,” and asana, which means “pose”. It is known as the Extended Hand To Big Toe Pose” [9, www].

Deep breath during an asana is very important to gain strength to hold the pose for a longer duration and maintain stability and balance.

Starting position: stand with legs apart. Raise your left leg off the floor, slightly bending it at the knee, bend your body without bending your free leg at the hip joint.

One should list plyometric exercises.

Jump in place by 180, 360 degrees.

The left leg is bent, the foot is on the support (bench), with the right leg perform jumps across the line on the floor forward-backward, right-left, and also along the designated squares in two perpendicular lines, clockwise, making two jumps clockwise, one - counterclockwise, then two clockwise, etc.

Balance exercises performed under sudden changes: from dynamic actions to strength exercises. For example, after somersaults, one should do push-ups, plyometric exercises with hurdles. Yoga and balance are closely related, since many asanas help develop stability and coordination. One of the popular styles is vinyasa flow yoga, which includes smooth transitions between asanas, which helps improve coordination [5]. Many asanas include balance on one leg, for example Virabhadrasana 3 (resembling a “swallow”), Ardha Utthitahasta Padangusthasana 1 (starting position: basic stance, take the big toe of the right foot with the right hand, straighten the leg).

One can do traditional exercises, adding yoga asanas, as well as adapting as needed. The result is a sequence of poses, smoothly moving from one to another, reminiscent of vinyasa flow. For example, first, from the basic stance, one needs to move to a pose reminiscent of Ardha Utthitahastu Padangusthasana 1, distinguished by the fact that the hands are clasped around the thigh (see Figure 1), since many practitioners do not have enough flexibility to perform the asana, holding the foot and straightening the leg, and hold for a few seconds, then step back with the free leg and move into Warrior 1, holding the pose for a few counts, then smoothly transfer the weight to the front leg and move into Virabhadrasana 3, hold one’s balance for a few seconds, then put feet together and stand in Tadasana (performed almost identically to the closed stance).

Another example of a sequence of exercises, when one body position is the beginning of the next action.



Figure 1 – A pose some similar to an asana

Starting position Tadasana. On an inhale, rise up on toes, arms up, on an exhale, do a squat. Jump to a prone position, raise your right leg and hold for a few counts, go to a prone position on your left side (Vasishthasana). To make it more difficult, one can lift one's right leg up and grab it with a free hand. Then one needs to turn into a lying position without lowering your right leg to the floor (see Figure 2), slowly bend arms for a few counts (Chaturanga Dandasana) and jump into a squatting position, then stand in tadasana. Repeat the exercise cycle on the other side.



Figure 2 – Lying support, right leg raised

The following cycles can be diversified with variations of the lying support on the side, and also after Vasishthasana, move to Chamatkarasana (see Figure 3).



Figure 3 - Chamatkarasana

Practicing the above mentioned asanas and their similarities not only improves balance and proprioception, but also activates the body's stabilizer muscles, the muscles of the shoulders, abs, back and buttocks.

In this way, it is possible to create many sequences of exercises combining traditional and non-traditional ones. Diversity has a positive effect on the attention of students in the lesson, and also contributes to the emergence of new neural connections. The experimental method was carried out in physical education classes for 16-17-year-old boys studying in college in the profession of "car repair and maintenance technician".

The students were divided into two groups. The control group consisted of 9 people, the experimental group of 18 people. The experiment lasted from October 2024 to January 2025. In order to assess static coordination, the Romberg test was used.

The arithmetic mean of the test results for the control and experimental groups and the standard error of the arithmetic mean for each group were calculated.

Table 1 – Research results

Group	$\bar{x} \pm m$ (beginning of the experiment)	$\bar{x} \pm m$ (end of the experiment)
control	$13 \pm 2,79$	$19,89 \pm 5,44$
experimental	$14,72 \pm 2,87$	$24,89 \pm 2,83$

Where:

\bar{x} - arithmetic mean

m - standard error of the arithmetic mean

Conclusions

The introduction of balance exercises in physical education classes has a positive effect on static balance indicators. As can be seen from the results, the control group also showed a good increase in the time of holding a pose in the Romberg test, but the experimental group has a higher average value than the control group, and the standard error of the arithmetic mean is slightly smaller. It is worth noting that variety has a positive effect on many aspects, such as attention and motivation. Therefore, using exercise variations, different combinations and transitions between poses, borrowing and adapting body positions from other types of physical activity, in this case, Vinyasa Flow Yoga, has a beneficial effect on physical education classes of college students.

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METHODS OF APPLYING PARTIAL DIFFERENTIAL EQUATIONS IN TECHNICAL UNIVERSITIES

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Аннотация. Рассмотрена методика преподавания теории уравнений в частных производных в техническом вузе и предложено использование теоретического материала для определения теплопроводности тонкого стержня методом рядов Фурье.

Ключевые слова: уравнения в частных производных, метод Фурье, теплопроводность, тонкий однородный стержень.

Annotation. The method of teaching the theory of partial differential equations in a technical university is considered, and the use of theoretical material for determining the thermal conductivity of a thin rod by the method of Fourier series is proposed.

Keywords: partial differential equations, Fourier method, thermal conductivity, thin homogeneous rod.

As a result of studying the course of mathematics at a technical university, the student must acquire the knowledge necessary for the successful study of general technical and special disciplines, as well as students form general cultural and professional competencies. Thanks to the study of the course of mathematics, future engineers, cadets of maritime specialties learn to apply the methods necessary for solving typical professional problems. One of the important branches of mathematics is the solution of partial differential equations [1,2]. For this, there are various methods, such as: analytical, regular mode method, finite difference method, numerical methods, etc. The paper discusses the problem of determining the thermal conductivity of a thin rod by solving partial differential equations using Fourier series [3], and also considers the application of this method in practical problems.

RESEARCH OBJECTIVE. Solving a partial differential equation for the problem of finding the temperature of a simple body and finding an analytical solution to the problem

BODY. The analytical method of solving partial differential equations for the thermal conduction equation by separating variables leads to a solution in the form of a series or a Fourier integral. The differential equation of thermal conductivity of a homogeneous body for the nonstationary case has

$$\frac{\partial u}{\partial t} = a \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right), \quad (1)$$

the form:

$u(x, y, z, t)$ - temperature of a homogeneous body at a point with coordinates x, y, z at time t .

a is a physical quantity that characterizes the rate of temperature change in the body and its thermophysical properties. Depends on the nature of the substance and its physical state, m^2/s ;

$$a = \frac{k}{\rho\gamma}$$

ρ - density of matter, γ - proportionality coefficient, called the heat capacity of a substance;

k - Internal thermal conductivity coefficient.

PROBLEM STATEMENT. It is necessary to determine the temperature of a thin, homogeneous rod with length l , the side surface of which is thermally insulated, if the mode is set at one end of the rod and heat exchange at the other. At one end of the rod $x=0$, the temperature is maintained at zero. At the other end, $x=l$ - heat exchange with the environment takes place. If the body is a rod directed along the axis Ox , i.e. a one-dimensional body, then equation (1) for determining thermal conductivity takes the form of a homogeneous differential equation

$$\frac{\partial u}{\partial t} = a \frac{\partial^2 u}{\partial x^2}. \quad (2)$$

One should consider a rod bounded at both ends $x=0, x=l$.

You need to find $u(x, t)$ solution of equation (2) satisfying the initial condition $u(x, t)|_{t=0} = f(x)$ and two boundary conditions

$$u(x, t)|_{x=0} = u(x, t)|_{x=l} = 0 \text{ or } \frac{du(x, t)}{dx}|_{x=0} = \frac{du(x, t)}{dx}|_{x=l} = 0.$$

The solution of equation (2) was proposed by the French mathematician Fourier: the general solution is found as the sum of an infinite number of partial solutions [2]

$$u(x, t) = \sum_{k=1}^{\infty} C_k \cdot \exp\left(-a^2 \left(\frac{\pi k}{l}\right)^2 t\right) \cdot \sin\left(\frac{k\pi}{l} x\right),$$

where the value of the constant C_k equally

$$C_k = \frac{2}{l} \int_0^l f(x) \cdot \sin \frac{k\pi x}{l} dx.$$

For edge conditions ($u(x, t)|_{x=0} = u(x, t)|_{x=l} = 0$) and (for edge conditions $\frac{du(x, t)}{dx}|_{x=0} = \frac{du(x, t)}{dx}|_{x=l} = 0$)

A partial decision in the form of a series:

$$u(x, t) = \sum_{k=1}^{\infty} a_k \cdot e^{-\left(\frac{k\pi a}{l}\right)^2 t} \cdot \cos \frac{k\pi x}{l} + a_0, \quad (3)$$

where is:

$$a_k = \frac{2}{l} \int_0^l f(x) \cdot \cos \frac{k\pi x}{l} dx \quad a_0 = \frac{2}{l} \int_0^l f(x) \cdot dx$$

TASK. Find a solution to the heat conduction equation

$$\frac{\partial U}{\partial t} = \frac{\partial^2 U}{\partial^2 x} \quad (0 < x < l), \quad t > 0,$$

satisfying the initial conditions

$$u|_{t=0} = f(x) = \begin{cases} x, & 0 < x \leq \frac{l}{2} \\ l - x, & \frac{l}{2} \leq x < l \end{cases}$$

and regional conditions

$$u(x, t)|_{x=0} = u(x, t)|_{x=l} = 0.$$

To find a solution to the heat conduction equation, we will use formulas (2 -3)

$$u(x, t) = \sum_{k=1}^{\infty} b_k \cdot e^{-\left(\frac{k\pi a}{l}\right)^2 t} \cdot \sin \frac{k\pi x}{l}$$

where is:

$$b_k = \frac{2}{l} \int_0^l f(x) \cdot \sin \frac{k\pi x}{l} dx = \frac{2}{l} \int_0^{\frac{l}{2}} x \cdot \sin \frac{k\pi x}{l} dx + \frac{2}{l} \int_{\frac{l}{2}}^l (l - x) \cdot \sin \frac{k\pi x}{l} dx$$

Integrating in parts

$$\begin{vmatrix} u = x & du = dx \\ dv = \sin \frac{k\pi x}{l} dx & v = -\frac{l}{k\pi} \cos \frac{k\pi x}{l} \end{vmatrix}$$

$$\begin{aligned}
b_k &= \frac{2}{l} \left(-\left(\frac{lx}{k\pi}\right) \cos \frac{k\pi x}{l} \right) \Big|_0^{l/2} + \int_0^{l/2} -\left(\frac{l}{k\pi}\right) \cdot \cos \frac{k\pi x}{l} dx \Bigg|_+ \\
&+ \frac{2}{l} \left(-\left(l-x\right) \left(\frac{l}{k\pi}\right) \cdot \cos \frac{k\pi x}{l} \right) \Big|_{l/2}^l + \int_{l/2}^l -\left(\frac{l}{k\pi}\right) \cdot \cos \frac{k\pi x}{l} dx \Bigg| = \\
b_k &= \frac{2}{l} \left(-\left(\frac{lx}{k\pi}\right) \cos \frac{k\pi x}{l} + \left(\frac{lx}{k\pi}\right)^2 \cdot \sin \frac{k\pi x}{l} \right) \Big|_0^{l/2} + \\
&+ \frac{2}{l} \left(-\frac{l^2}{k\pi} \cos \frac{k\pi x}{l} + \frac{lx}{k\pi} \cdot \cos \frac{k\pi x}{l} - \left(\frac{lx}{k\pi}\right)^2 \cdot \sin \frac{k\pi x}{l} \right) \Big|_{l/2}^l = \\
&= \frac{4l}{(k\pi)^2} \sin \frac{k\pi}{2}
\end{aligned}$$

After substitution, the desired solution looks like this:

$$u(x,t) = \frac{4l}{\pi^2} \sum_{k=1}^{\infty} \frac{1}{k^2} \cdot \sin \frac{k\pi}{2} \cdot e^{-\left(\frac{k\pi l}{e}\right)^2} \cdot \sin \frac{k\pi x}{l}$$

or finally the equation of thermal conduction:

$$u(x,t) = \frac{4l}{\pi^2} \sum_{n=0}^{\infty} (-1)^n \frac{1}{2n+1} e^{-(2n+1)^2 \pi^2 l / t^2} \cdot \sin \frac{(2n+1)\pi x}{l}$$

Conclusion. The problem of determining the temperature of a thin homogeneous rod with a given length, the side surface of which is thermally insulated, if the mode at one end of the rod and heat transfer at the other end is set. An analytical expression for calculating the temperature in the problem is obtained. The analytical solution of the problem showed high computational complexity. In solving the problem, the theories of solving differential equations of a function of two variables and the theory of functional series were used.

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GAMIFICATION IN MATHEMATICS TEACHING

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Аннотация. Представлены преимущества геймификации в процессе обучения математике, поскольку учебные приложения и платформы с игровыми элементами делают обучение доступным и удобным, так как можно учиться в любое время и в любом месте. Описаны методы геймификации, которые могут помочь в показе легкости и увлекательности, заинтересованности и увеличения уверенности у учеников.

Ключевые слова: игра, математика, приложение,

Annotation. The author examines the possibility and necessity of developing moral qualities in students by means of mathematics lessons. It is substantiated that mathematics is not only a tool for developing logical thinking, but also a powerful means of educating responsible and purposeful individuals. Specific methods and techniques are proposed that a teacher can use to integrate moral values into the educational process.

Keywords: moral education, teacher, education, values, honesty, responsibility, justice, logic, critical thinking.

Introduction. Mathematics is referred to logic as well as creativity. “It is pursued both for a variety of practical purposes and for its intrinsic interest. For some people, and not only professional mathematicians, the essence of mathematics lies in its beauty and its intellectual challenge. For others, including many scientists and engineers, the chief value of mathematics is how it applies to their own work. Because mathematics plays such a central role in

modern culture, some basic understanding of the nature of mathematics is requisite for scientific literacy” [6, p. 2].

Mathematics is the science of “quantitative relations and spatial forms of the real world. Mathematics studies mathematical models – logical structures that describe a series of relations between their elements” [4, p. 89]. This school subject can actually become a powerful tool for developing qualities in students. All conditions for the all-round development of the individual should be created. Teachers are responsible for educating future generations capable of conscious and morally justified actions [3].

The relevance of the study is due to the need to use the potential of each subject for the purpose of personal development of students.

It is important to develop motivation in lessons in order to increase the effectiveness of teaching mathematics [2]. Any mathematical symbol or formula can be interpreted integrally, philosophically, culturally, with an outlet for their ideological significance [1]. According to V.N. Klepikov, the creative activity of the teacher and students is very important [1].

The purpose of the study is to describe the possibilities of game technologies in the study of mathematics by pupils. To achieve this, teachers need to use interactive educational technologies to solve **the following task**: pupils have to “perceive mathematics as part of the scientific endeavor, comprehend the nature of mathematical thinking, and become familiar with key mathematical ideas and skills” [6, p. 2].

Presentation of the main material. First of all, mathematics provides an excellent opportunity to cultivate objectivity. Mathematical knowledge has organically grown into our everyday speech, into our intellectual world, and without this knowledge our communication is simply unthinkable [3].

The process of assessing is based on clear and understandable criteria, without any pitfalls or bias. When we emphasize independence and condemn cheating, we cultivate responsibility and honesty in students.

Solving complex problems that require finding non-standard solutions or that are difficult for people studying the subject at a basic level is not just training in mathematical skills, but a real life lesson that forms determination and the will to win in students. Teacher’s support is the key factor here. By noting not only the correct answer, but also the effort and diligence applied, the teacher motivates the student to further growth, strengthens one’s self-confidence and helps them overcome difficulties [5].

The most powerful tool in motivation forming is proper technologies application during the lesson. Games are considered to be appropriate ones.

Gamification is when a particular job becomes like a game. It helps to work more interestingly and try to do everything well.

It is clear that gamification in learning is a method that uses game mechanics to increase the involvement and motivation of students.

Gamification not only provides studying more interestingly, but also trains teamwork, strategic thinking and problem solving. These skills are important not only in school but also in life. This is especially important for mathematics, because educational applications and platforms with game elements make learning accessible and convenient, since you can study anytime and anywhere, and game elements such as points and rewards help children to be more interested in mathematics and learn with joy, for the sake of achieving records and receiving in-game rewards. It is the desire to win and set a new record that will be one of the reasons for the student's desire to study the material.

At the same time, traditional teaching of mathematics has several serious shortcomings. One of the main ones, which can also be attributed to other subjects, is that students often lack interest in the lessons. Classes are boring, and the teacher's explanations are too complicated or pupils cannot keep up with the pace at which the material is explained.

That's why many people become uninterested and do not want to study. Also, many schoolchildren are afraid of mathematics. They consider this subject difficult because of how the examples look, complex formulations and the problems that consist only of text. This not only leads to them avoiding questions and not wanting to participate in lessons, but also to a lack of development of knowledge in the field of mathematics, which can have a negative impact in the future. Thus, traditional methods of teaching mathematics may not give the desired results.

It is important for pupil to feel confident and interested, and to demonstrate that math is not so difficult and scary to learn successfully. We can use different interesting gamification methods that can provide showing ease and fun, interest and increasing confidence in students. Here are the most popular ones:

1. Educational games and apps (For example, children can learn on Uchi.ru, Kahoot, and Quizlet). On these sites, students participate in quizzes, tests, answer questions, and earn points. This helps them remember terms, formulas, and problem solutions.

2. Project tasks with game elements. Children can work in groups, but these teams are not to be large and difficult (as this will be either in class or as homework). They solve real mathematical problems in a context of persons' and group interaction [3]. For example, they can design their ideal park, consisting of 1 by 1 meter squares, and calculate how much land is needed for it. It makes learning more interesting and gives students the opportunity to be creative.

3. Role-playing and simulations. For example, together with students, teachers can act out a situation where we sell and buy products at the market. This provides learning to count money and work with numbers in real life, which can help in the pupil's adult life.

There are many useful books and online courses that can help teachers implement gamification in their lessons. For example, you can find books on game-based learning methods. There are also courses on platforms like Coursera or EdX where teachers can learn more about gamification (the recommended platforms are in English and require some knowledge of English). Don't forget to check out gaming platforms where one can create interactive quizzes (previously announced Uchi.ru, Kahoot and Quizlet).

Conclusion. Thus, one can draw the following conclusion:

Gamification in teaching mathematics is a great way to make lessons more interesting and engaging. It helps pupils understand complex problems more easily and apply knowledge in practice. They develop not only skills but also creative thinking by learning mathematics through games.

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THE NECESSITY OF STUDYING “MARINE CELESTIAL NAVIGATION”

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Аннотация. В статье рассматривается необходимость изучения морской астронавигации, несмотря на развитие цифровых технологий и искусственного интеллекта. Уделено внимание современным спутниковым навигационным системам GPS и GLONASS, а также тренажеру «Stellarium». Рассмотрено определение понятия «морская астронавигация». Объяснена важность знания стандартных методов навигации в связи с возможным выходом из строя технических средств в современных реалиях.

Ключевые слова: навигация, морская астронавигация, GPS, плавание, обучение.

Annotation. The paper describes the necessity of studying marine celestial navigation despite the development of digital technologies and artificial intelligence. Due attention is given to modern satellite navigation systems GPS and GLONASS, as well as a simulator “Stellarium”. The definition of “marine celestial navigation” is considered. The importance of standard navigation methods knowledge is explained due to the possible failure of technical means in modern realities.

Keywords: navigation, marine celestial navigation, GPS, voyage, training.

Modern navigation is inextricably linked with the use of satellite navigation systems, primarily GPS and GLONASS. These technologies have become so familiar and convenient that most navigators consider them as the only possible tool for positioning and plotting the route. However, the practice of recent years shows that such dependence on electronic systems makes shipping vulnerable. Failures and drowning out of GPS signals are increased,

especially in areas with a high concentration of infrastructure. One of such areas is the Kerch Strait, where navigation is complicated by weather conditions, heavy traffic and the proximity of the Crimean Bridge. In these conditions, knowledge of classical navigation methods, including navigational astronomy, becomes especially important.

Marine celestial navigation is a system of techniques and calculations to determine the position of a ship by observing celestial bodies - the Sun, Moon, planets and stars. This method, practiced for centuries of maritime experience, was the basis of navigation long before the presentation of radar and satellites. Sextant, chronometer, and supplementary manuals were the aids due to which the oceans were passed and new lands were discovered. Despite technological progress, the basic principles of marine celestial navigation remain unchanged, and we may use them even when the techniques fail [1].

The studying of these methods is vitally important for the cadets of the maritime higher educational institutions. In 2024, the opinion of 121 cadets from Russian maritime academies was asked about the use of celestial navigation on board ship. 81% of cadets informed that have only theoretical knowledge and only 9% of cadets admitted that they can define ship's position by celestial bodies [3].

Every year cadets have their shipboard training on sailing training vessels ('Khersones', 'Sedov', 'Kruzenshtern', 'Pallada'). During the voyage, cadets are given a unique opportunity not only to learn the basic methods of navigation, but also study traditional navigation ones. It is recommended that officers pay special attention to teaching the cadets astronomical methods of navigation: make observations, work with a sextant, calculate the position using the tables. Such practice not only consolidates theoretical knowledge, but also develops independence and self-confidence. On board, they study not only the construction of sextant and rules of its handling, but also make real observations, calculate coordinates manually, keep navigator's logs. This knowledge forms not only technical competence, but also maritime culture, respect for the profession and self-confidence.

Special manuals are an integral part of training. Nautical tables are still used for observations and ship position calculations. It is a universal instrument that allows calculations to be made without the use of a computer. Brown's Nautical Almanac, as well as similar editions published by the national hydrographic services, contain daily data on the position of celestial bodies and is essential for astronomical calculations. Work with these nautical publications develops cadets' accuracy, discipline, and comprehension of the navigation basis [2].

It should be noted the growing role of digital simulators and training programmes. Such devices as EzCelNav, Stellarium, Celestial Tools allow to

simulate observations, practice reductions and analyze errors (Fig. 1). Their application is particularly useful in conditions of limited access to marine practice. However, it is important to emphasise that no simulation can replace the real experience of observations at sea, on deck, in the open air.



Figure 1 – Simulator “Stellarium”

Marine celestial navigation is not only important as a backup method of navigation. It forms the mentality of future officers which is required for navigator. In case of electronics failure in areas where the signal is weak, in case of power supply irregularity or equipment damage, it is important to ensure safe navigation.

Marine celestial navigation requires high accuracy and concentration which are especially important when making decisions at sea.

In view of the above mentioned, it is important to provide a high level of teaching marine celestial navigation as part of the compulsory educational curriculum in maritime higher educational institutions and implement its practical orientation. It is recommended to carry out regular practical classes with sextant, use Marine tables and nautical publications, as well as trainings connected with GPS failure.

It can also be recommended to create specialized study clubs, additional course, online courses, where students will be able to study marine celestial navigation in details and check everything in real life.

In conclusion, it should be mentioned that marine celestial navigation is the basis for future navigator. It is a time-tested skill, which cannot be replaced even in an era of high technologies development and where the reliability of technology is not always guaranteed. The future of navigation lies in the wise

integration of digital technologies with profound knowledge of classical methods.

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INFORMATION TECHNOLOGIES IN FOREIGN LANGUAGE TEACHING

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Аннотация. В статье рассматриваются пути применения информационных технологий в обучении иностранному языку курсантов морского профиля. Цифровые инструменты могут использовать для организации эффективного взаимодействия с курсантами при изучении предмета. В заключении отмечено, что в выборе содержания для обучения английскому языку, включая видео, книги, подкасты и газеты, нет трудностей; задача преподавателя заключается в правильном определении технологий.

Ключевые слова: морские специальности, английский язык, электронные учебные средства, мотивация.

Annotation. The article defines possibilities of using information technologies in order to teach foreign languages for future seafarers. The use of digital resources in the process of teaching English for future maritime specialists provides an effectiveness of the formation and development of

speech skills in English. In conclusion, it is noted that there is no shortage of content options for learning English, including videos, books, podcasts and newspapers; the teacher's task is to correctly identify the technologies.

Keywords: maritime specialties, English language, electronic teaching aids, motivation.

Introduction. Currently, one of the indicators of professional competence of maritime specialists is foreign language communicative skills. The need for their professional development is due to a fact that there are growing requirements for seafarers' quality of English-language training. The application of information technologies (IT) can be useful in the context of qualities of foreign language skills of maritime specialists.

The information technology tools application in teaching foreign languages was considered by A. Bilyalova, I. Meshkova, O. Sheremeteva [4], A. Negoescu, S. Boștină-Bratu [5]. E.V. Pronoza asserts that "Integration of a regular foreign language lesson with a computer would allow for the most effective monitoring of learning using tests. Computer-based testing allows for the prompt verification of the quality of assignments and the tracking of the learning process dynamics. This significantly saves the teacher's time, which can be successfully used for other purposes, such as correcting the student's knowledge and explaining new material" [2, p.3].

The purpose of this study is to substantiate the importance of using electronic resources for foreign language skills forming in future maritime specialists.

Results of the study.

Every day, the methods of teaching foreign languages are being improved all over the world. But it is clear that the implementation of digital teaching tools is a priority today.

Mastering foreign language communicative competence by specialists in maritime fields is considered the goal of improving the quality of English-language professional training of seafarers and fulfilling the order of modern business in the field of maritime transport. "Teaching foreign languages of future specialists in maritime fields is carried out in accordance with the work program, thematic plan, and recommendations of the Federal State Educational Standard of Higher Education" [1, p. 289].

"One of the most important advantages of IT is the capability to control objects. While in a virtual environment, the student enters the stage of concrete active experience, where they gain empirical skill in interacting with the object, and then can move to the stage of reflexive observation, moving away from the task and reviewing what he experienced" [3, p. 102].

Foreign language teachers use the following electronic teaching aids: interactive systems that allow simultaneous work with animated computer graphics, sound, video frames, static texts and images. These services develop basic speech skills: speaking, listening, reading and writing [1]. "IT includes various tools from computers and the Internet to broadcasting: projector, software, video, tools (Webinar Meetings), blogs (Dialog), online dictionaries, interactive books, websites, etc." [2, p.3].

The use of software packages influence the student and provide developing "the skills of using knowledge and abilities in a real life context; making optimal decisions in a difficult situation" [1, p. 289].

Additional teaching aids include video and audio materials on career guidance, tables and diagrams, cards, pictures, posters, interactive whiteboards, projectors, and programs for interactive textbooks.

Teachers use IT suitable for use in implementing the work program of "Foreign Language". The following tools are used as resources for text, audio and visual material:

- 1) Electronic textbooks;
- 2) Electronic courses.

To assess the level of development of cadets' foreign language communication skills, electronic test assignments are used. Since electronic technologies have a number of advantages over traditional teaching aids, the level of cadets' motivation to study a foreign language increases significantly [3].

Effective development of listening skills is possible through the use of electronic resources with selections of video fragments containing expressions of the mosco sphere. Cadets not only become familiar with the semantic range of vocabulary, but also develop the skill of perceiving vocabulary in the context of professional orientation.

In general, the use of digital resources in the condition of teaching English to future maritime specialists provides speech skills forming. "Targeted individualization of learning helps improve the quality of learning and increases motivation to learn a foreign language" [3, p. 202].

There is no shortage of content options for learning English, including videos, books, podcasts, and newspapers. The key is to find the right type of technology. Students can perceive new material due to graphic images while working with any electronic means.

Conclusion. Thus, electronic teaching aids can be used by each teacher of "Foreign Language" subject in order to improve the quality of professional training of cadets in maritime areas. The skillful use of modern innovative technologies, including digital ones, will not only improve the quality of

foreign language skills of future seafarers, but also ensure their flexibility and mobility in demonstrating their skills in emergency situations.

Prospects for further research include issues of developing our own platforms that take into account the specifics of organizing the educational process in organizations.

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INTERACTIVE TEACHING METHODS IN FOREIGN LANGUAGE LEARNING

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Аннотация. Информационные технологии становятся все более актуальными в мире, и существенный прогресс в достижении нашей цели — овладении языком — может быть обеспечен путем систематической разработки интерактивных стратегий. Цифровые технологии как инновационный способ организации процесса изучения

иностранный язык обеспечивают интерактивность обучения, когда происходит взаимный обмен информацией. Целью применения цифровых технологий является не только повышение качества обучения, но и достижения успешной социализации курсантов.

Ключевые слова: цифровая трансформация, виртуальная среда, иностранный язык, электронно-образовательная среда, мотивация.

Annotation. Information technology has become increasingly relevant in the world, and a significant enhancement towards achieving our goal - language acquisition can be provided by systematically developing interactive strategies. Digital technologies as an innovative way of organizing the process of learning a foreign language provide interactivity, when there is a mutual exchange of information. The purpose of using digital technologies is not only to improve the quality of education, but also to achieve successful socialization of cadets.

Keywords: digital transformation, virtual environment, Foreign language, motivation, Electronic educational environment.

The essence of the digital transformation is the results achievement by means of the personalization of the educational process [6]. The electronic information and educational environment (EIEE) provides productivity dynamics and self-confidence increase.

Recently, information technology (IT) has become relevant, and a significant enhancement can be provided by developing interactive strategies. Digital educational technologies are being actively introduced to ensure interactive learning in order to maintain and improve the quality of Foreign language education.

Active learning implies that the cadets are no longer objects of educational process, but independent persons. They construct their knowledge by searching for and analyzing information, conducting experiments, and so on. An example of an active learning method is project-based activity, in which the cadet explores a problem or task and creates a product to solve it.

Interactive teaching methods and means realization becomes a priority for improving education quality. "IT is an effective tool for teaching any foreign language, which allows to reduce learning time and make the process easy and comfortable" [13, p. 616].

The language methods in teaching foreign languages were researched by A.Yu. Ponomareva, O.I. Lytkina [5], A.S. Melnichuk [7], Yu.B. Kostrova [4]. Foreign scientists studied the quality of foreign language education: P. Carneiro, Y. Cruz-Aguayo, R. Intriago, H. Ponce, N. Shadi, S. Schodt [10], J. Cilliers, B. Fleisch, D. Kotze, N. Moholwane, S. Taylor, C. Thulare [11].

The development of search activity, internal stimulators, such as moral principles, beliefs, self-esteem, etc. are promoted by the use of interactive digital technologies in teaching a foreign language [1].

Scientists M.K. Zhorabekova, A.A. Amandak consider the problematic difficulties with the technical equipment of educational organizations, personnel, lack of software [3].

I.L. Filimonov, A.P. Grinkevich, S.B. Pristupa, B.A. Sadakov discusses the main achievements of the Black Sea Higher Naval School named after P.S. Nakhimov in the field of digitalization of educational activities and development of the electronic information and educational environment [2].

M.A. Yashonkova claims that “the ability to communicate not only by text messages, but also by audio and video messages, and in this way it is easy to get rid of the language barrier. Examples of such applications are: Tandem, HiNative, Polyglot club и многие другие» [9, p. 663]. But in a military higher educational institution the Internet is not used, but other, no less effective ways of learning a foreign language with the help of IT have been proposed.

The purpose of this study is to describe digital technologies as an innovative way to organize the process of learning a foreign language.

“The use of digital technologies covers several directions to make foreign language teaching effective: implementation of information technologies in a process of learning a foreign language; IT application” [12, p. 616].

Learning by means of EIEE realization provides the following advantages:

- use all foreign language knowledge to solve a specific problem;
- reduce the number of errors associated with a psychological barrier;
- make a breakthrough in professional activities in the language.

Today there are many online learning platforms that are used in English classes: Coursera, edX - online platform, Udemy, Khan Academy. Moodle. The software package is developed by the Department of Information Technologies of the Black Sea Higher Naval School named after P.S. Nakhimov

Interactive educational technologies are one of the types of innovative teaching technologies. They are aimed at broad interaction of students both with the teacher and with each other in the process of acquiring professional knowledge and skills.

Motivation is the key to success in online language learning. “Interactive technologies, such as gamification, will help increase the motivation of cadets. Digital technology "gamification" is used for didactic purposes to solve practical problems of any level of complexity. The educational material is not transmitted by the teacher, but is obtained by the students themselves” [1, p. 54]. “Gamification makes it possible to organize the scientific research

activities of students thanks to the combination of gaming and sociomedia technologies” [1, p. 53].

Computer simulations are interactive educational technologies. They provide software packages theoretical knowledge, practical (professional) skills in conditions of inaccessibility of real objects.

Web quest is stated to be an innovative technology for organizing the educational process. It covers an ambiguous solution to different issues. “This technology aims to develop students’ independence, creativity and critical thinking, as well as to increase students’ motivation and improve their academic achievements” [1].

Case technology is one of the types of interactive educational technologies. It is the work of students to solve a problem in the form of a description of a problem situation. The implementation of case technology allows cadets to develop the ability to apply an integrated approach to solving professional, practical problems.

The main distinctive feature of interactive educational technologies is personal initiative development. The teacher acts as a coordinator for problems, creating conditions for cadets to master skills in the process of cognitive activity.

In conclusion it should be said that as a digital tool EIEE gives possibility to:

- improve organizational educational structure, the technical and material regulatory base, technical support facilities;
- develop and update electronic textbooks, information resources, educational computer programs, electronic learning tools;

- improve the level of training of specialists.

Information technologies and digital tools in teaching foreign languages are becoming increasingly important and widely used in education.

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**NEW WORDS RELATED TO SLANG IN THE MERRIAM
WEBSTER DICTIONARY: THEMATIC STRUCTURE AND
DYNAMICS**

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Аннотация: Данная статья анализирует неологизмы в английском языке, относящиеся к сленговой лексике. Материалом послужили слова американского варианта английского языка, отраженные в электронном словаре Merriam-Webster. В процессе анализа неологизмы были поделены на десять тематических подгрупп, а также рассматривалось распределение по году первого зафиксированного использования и по методу словообразования. Результаты анализа показали равномерность образования новых слов, а также, что основным источником заимствования является язык чёрного меньшинства США

Ключевые слова: неологизм, английский язык, сленг, Мерриам-Уэбстер, тематический анализ.

Abstract: This article analyzes neologisms in the field of slang in the English language. The material for this study was American English slang neologisms, which were selected from the Merriam-Webster electronic dictionary. During the study, neologisms were divided into ten thematic subgroups; the distribution by year of first recorded use and by methods of word formation has been examined as well. The results show Black minority variant of English as the main source of borrowings and a steady rate of new word formation.

Keywords: neologism, English language, slang, Merriam Webster, thematic analysis.

Language is constantly evolving, especially in the lexicon, as new words appear and at the same time, some old ones fall out of use. This happens following the emergence of changes in culture, appearance of new objects that need names, modern technologies, wide acceptance of social networking sites where people use special abbreviations.

This study is devoted to neologisms in the English language related to slang. The material for the study was neologisms included in the Merriam-Webster dictionary from 1988 to 2021 and reflecting changes in the language during this period.

The aim of the study is to examine the composition and dynamics of neologisms associated with slang, to consider how they are formed, and to distribute them into subgroups for a more detailed analysis of meanings.

To achieve the aim of the study, the analysis of dictionary definitions and the comparative method were used. Using the continuous sampling method, words related to the thematic group «Slang» according to the classification proposed by Aksenova N.V. and Shepetovsky D.V. [1, 2] were selected from the list of words added to the dictionary as published on the Merriam-Webster dictionary website [4] organized by year. Dictionary definitions of 118 words in the thematic group «Slang» were analyzed, and from that, 10 subgroups were identified: «Technology» (11 words), «Relationships» (10 words), «Medicine» (5 words), «Professional sphere» (14 words), «Social networks» (15 words), «Appearance» (8 words), «Person» (23 words), «Object» (5 words), «Action» (20 words), «Rap culture» (7 words).

The dominant subgroups in the Slang group are Person and Action (together they account for 37% of the 118 words). In addition, there is a surge in the introduction of new words in the Professional subgroup between 1988 and 1992, which can be explained by changes in the mass communication sphere.

The first group, «Technology», includes actions and names of elements of technical products, many of which are related to transportation. For example: *cord-cutting* (the act of the process of canceling a subscription to cable television or to a landline telephone service), *drill down* (to thoroughly consider or analyze: EXAMINE), *e-brake* (emergency brake), *MacGyver* (to make, form, or repair (something) with what is conveniently on hand).

The second group – «Relationships» – includes words describing relationships between people, among them there are many abbreviations. For example: *fam* (family, a close friend, used especially as a form of address), *JOMO* (joy of missing out: joy experienced when not attending events to which one has been invited), *booty call* (a communication by which a person arranges a sexual encounter with someone).

The third group, «Medicine», includes mainly names of drugs, both legal and illegal, and the effects of their use. For example: *roofie* (a tablet of a powerful benzodiazepine sedative and hypnotic drug $C_{16}H_{12}FN_3O_3$ that is not licensed for medical use in the US but is used illicitly), *pharma* (a pharmaceutical company; also: large pharmaceutical companies as a group), *brain freeze* (a sudden shooting pain in the head caused by ingesting very cold food or drink).

The fourth group, «Professional Sphere», includes words denoting office furniture, job- and work-related terms. For example: *cube farm* (an office in which employees work in cubicles), *VPOTUS* (the vice president of the United States – often used like a nickname), *listicle* (an article consisting of a series of items presented as a list).

The fifth group is «Social Networks». It includes words created in the electronic communication environment and used mainly there. Some of them are used almost exclusively in written speech on the Internet and hardly ever spread to oral communication. For example: *TL*; *DR* (Too long; didn't read), *tweep* (Twitter users).

The sixth group is «Appearance»; it includes words that describe a person's body, their appearance. For example, *swole* (extremely muscular), *cankle* (a wide or thick ankle that appears indistinguishable from the lower calf).

The seventh group, «Person», includes words that describe a person's character, behavior, orientation, emotional state, and who they are in society. For example: *Debbie Downer* (a negative or pessimistic person), *judge* (tending to judge others harshly or critically), *aro* (aromantic), *adorkable* (socially awkward or quirky in a way that is endearing, *padawan* (a young person especially when regarded as naïve, inexperienced, etc.).

The eighth group – «Objects» – includes words describing clothing, a bag, and a hair accessory. For example: *jorts* (a short made of denim or jean), *go bag* (a bag, packed with survival supplies and kept ready for use in case of an emergency that requires rapid evacuation).

The ninth group «Action» includes actions performed by a person in the process of everyday activities: calls, purchases, correspondence, etc. For example, *butt-dial* (to place an unintended call to from a mobile phone when the phone is not in use), *crate dig* (to shop rare, vintage or obscure recordings especially by searching through crates of second-hand merchandise), *clapback* (to respond quickly and sharply to criticism).

The tenth group – «Rap» – includes words [5] denoting the realities of the lives of petty criminals, glorified in rap culture. For example, *bling* (flashy jewelry worn especially as an indication of wealth or status), *mic drop* (the act of dramatically dropping a microphone after a performance, etc.), *gangsta* (a member of an inner-city street gang) (table 1).

Table 1. – New slang words listed by year of first recorded use.

	12th cen- tu- ry	13th centu- ry	1988 - 1992	1993 - 1997	1998 - 2002	2003 - 2007	2008 - 2012	2013 - 2017	2018- 2021	Total
Technology	0	0	4	3	4	0	0	0	0	11
Relationships	0	0	2	3	0	1	2	1	1	10
Medicine	0	0	2	1	0	2	0	0	0	5

Professional Sphere	0	0	8	4	0	2	0	0	0	14
Social Network	0	0	4	2	3	4	2	0	0	15
Appearance	0	0	4	0	1	1	1	1	0	8
Human	1	0	7	6	4	2	1	2	0	23
Object	0	0	3	2	0	0	0	0	0	5
Action	1	1	5	2	4	5	1	0	1	20
Rap	0	1	2	0	3	1	0	0	0	7
TOTAL	2	2	41	23	19	18	7	4	2	

The most represented category «Human» contains 23 words (20% of the total number of words). The greatest influence on the emergence of neologisms is exerted by changes in society itself and the modernization of technology.

Words in the «Person» subgroup are added into the dictionary the fastest, on average 2–3 years after their first use, while words in the «Appearance» subgroup are entered into the dictionary on average 5–6 years after their first recorded use.

Analysis of the time of origin for some words is difficult: as can be seen from the table, there are words that date back to the 12th and 13th centuries. However, in these cases we are talking about the development of new meanings by words that have been used in the language for a very long time.

The division [3] of slang neologisms [6] into non-evaluative (64 words), with a positive connotation (19 words), with a negative connotation (23 words) and ambivalent (7 words) allows us to refute the widespread opinion that slang consists mainly of words with a negative connotation. Examples of words in the corresponding categories are *beast mode* (an extremely aggressive or energetic style or manner that someone (such as an athlete) adopts temporarily (as to overpower an opponent in a fight or competition)); *adorbs* (extremely charming or appealing: ADORABLE); *ass clown* (a socially inept or stupid person); *bubble butt* (large, rounded buttocks).

It is worth noting that there is a relationship between evaluation and the subgroup. For example, the word *bestie* (best friend) belongs to the subgroup «Relationships» and has a positive connotation (diagram 1).

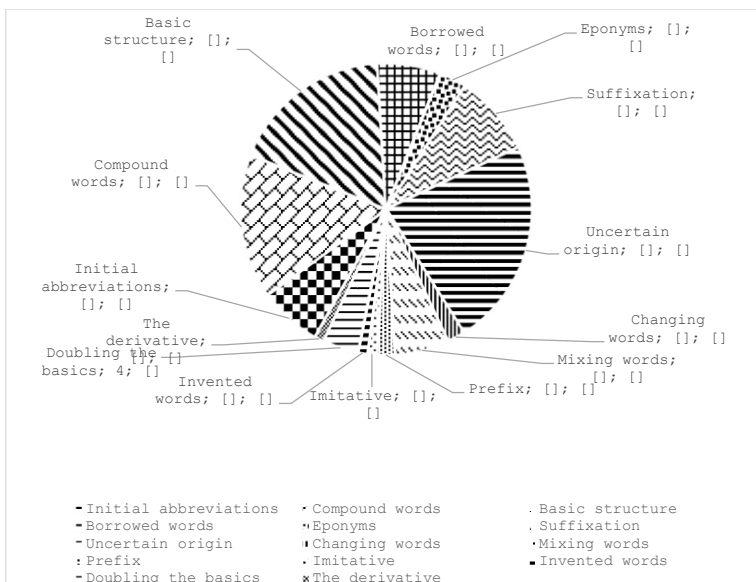


Diagram 1. Methods of word formation

For about a quarter of the neologisms in the «Slang» group, etymology is difficult; where it is known, the methods of word formation Stem compounding and Word Compounding prevail, these methods are used to form 34% of new lexical units. The most notable source of loan words is African American Vernacular English (AAVE) – 5 out of 7 (71%) borrowed slang words.

Summarizing the above, we can conclude that among neologisms related to slang, words describing a person and his actions prevail; words describing a person gain popularity faster than others and therefore are added into the dictionary faster; most slang neologisms are non-evaluative or ambivalent; the main source of borrowings for national American slang is the dialect of the Black minority (AAVE).

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**SIGNIFICANCE OF THE MILITARY SONG IN THE PERIOD
OF THE GREAT PATRIOTIC WAR, PERIODS OF COMBAT
ACTIONS AND SPECIAL MILITARY OPERATION**

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Аннотация. Статья посвящена значению песни, как жанру музыкального искусства, в период Великой Отечественной войны, периоды боевых действий и специальной военной операции, ее патриотическому, воспитательному потенциалу. Искусство всегда играет важную роль в жизни человека, особенно в периоды военных конфликтов. Военная песня занимает обширную нишу в музыкальном искусстве, отправляет к духовным истокам искусства военного времени, в ней воплощаются традиции русского народа, его жертвенность, его сила духа, подвиг, стремление к победе, что в свою очередь, помогает сражаться, побеждать, способствует поднятию боевого настроения среди солдат и офицеров, направлено на духовно-нравственное воспитание личности, укрепление патриотизма, сохранение традиций отечественной культуры.

Ключевые слова: песни периода ВОВ, песни периода боевых действий, песни периода СВО, культурные традиции, патриотизм, историческая память, духовные ценности, духовно-нравственное воспитание личности.

Annotation. The article is devoted to the important significance of the

song as a genre of musical art during the Great Patriotic War, periods of military operations and special military operation, its patriotic and educational potential. Art always plays an important role in human life, especially during periods of a military conflict. A military song occupies an extensive niche in musical art, connects to the spiritual origins of wartime art, it embodies the traditions of the Russian people, their sacrifice, their fortitude, feat, desire for victory, which in turn helps to fight and win. A military song helps to raise the fighting spirit among soldiers and officers, and is aimed at spiritual development, moral education of the individual, strengthening of patriotism, preservation of traditions of national culture.

Keywords: Songs of the Great Patriotic War period, songs of the period of military operations, songs of the period of special military operation, cultural traditions, patriotism, historical memory, spiritual values, spiritual and moral education of the individual.

Song, as a genre of musical art, is an integral part of art as a whole. Ozhegov's explanatory Dictionary gives the following definition of song and singing: "a song is a piece of poetry and music performed by a voice" [10], "singing means making musical sounds with your voice, performing a vocal piece" [11].

At the same time, Russian folk songs, choral, dance, author's (or bard's), hymns, historical, rock ballads, pop, country, romances, chanson, lullabies, children's, marching, etc. are distinguished in musical art. Songs of the war years are a separate genre of songs.

A song is one of the most common genres of vocal music, it combines a poetic text with an easy-to-remember melody. Songs can be performed by a single performer, as well as by a group or choir, with or without instrumental accompaniment, that is, cappella. Song is the most popular genre of vocal music.

The lines from one famous song: "The song helps us to build and live..." can be described as prophetic. And these are not idle words, because Russian history knows several examples when a song is really a source of inspiration, unity, pride, tenderness and love for one's neighbour.

On May 9, 2025, our country and the whole world will celebrate the 80th anniversary of the Great Victory. Large-scale events will be held, each of which will feature songs from the war years. Despite the fact that more than 80 years have passed since their creation, they are alive and loved by people of different ages and generations. The work of songwriters during the war years is one of the most remarkable pages of our musical history. Back then, songs were born in battles, people accomplished feats and songs inspired strength and confidence in victory over the enemy.

Speaking about the Great Patriotic War, the bloodiest and most brutal one, a person cannot help but wonder: what helped the Red Army soldiers to stand up in the fight against fascism? There is no single answer to this question, it can be explained by a combination of factors.

An important role was played by the system of national spiritual and moral values that existed at that time, which were implemented and integrated into the education and upbringing system, which should not be underestimated.

The concept of spiritual and moral development and upbringing of a Russian citizen's personality provides the following explanation for this phenomenon: "the Soviet era in Russian history formed a high pedagogical ideal - the upbringing of a comprehensively developed personality, gave examples of mass patriotism, heroic service, even self-sacrifice, for the sake of the future of their country and their people, disregard for the material in the name of the ideal" [6, p.11]. And, of course, patriotic education is an integral part of the spiritual and moral development of a person. This approach is formulated in the works of writers and philosophers, teachers and cultural and artistic figures during the Soviet period.

The art of the Great Patriotic War period is distinguished by the expression of diverse human feelings: from deep drama and tragedy to light lyrics and humor [3, p. 98].

All this was clearly manifested in the songs of the war years. During the war, a whole galaxy of composers of different generations worked in the song genre. The songwriting of A.V. Alexandrov, M.I. Blanter, N.V. Bogoslovsky, I.O. Dunaevsky, E.E. Zharkovsky, K.Ya. Listov, Yu.S. Milyutin, B.A. Mokrousov, A.G. Novikov, Dm. and Dan. Pokrassov, V.P. Solovyov-Sedoy, B.M. Terentyev, M.G. Fradkin, T.N. Khrennikov, and others became widely known [3, p. 98].

During the Great Patriotic War, there was, first of all, a pronounced patriotic orientation of musical art, and if, at the initial stage, the song works were imbued with anger, sorrow, and defensive themes, then in the second half of the war the mood of the authors and songwriters changed, as did the general mood of Soviet society, determined for an unconditional victory. Both soldier humor and optimism appear in the songs, and the genre of ditties was actively developing [3, p.100].

The songs of the war years are vivid examples of reflecting the peculiarities of the social consciousness of the era in the "musical intonation dictionary", since the regularity of its content is most effective in intonation arts [1, p.359-360].

Military songs were played at the front and in the rear, in hospitals and in dugouts, in metropolitan concert halls and in between battles - on land, at sea, in the air... They told not only about the heroism of soldiers and the spiritual

fortitude of our people, but also expressed feelings of faith, hope and love, supporting and spiritually uplifting a person, both during severe military trials and in peacetime [3, p.98].

Major military conflicts, such as the Afghan War of 1979-1989, the First and Second Chechen Wars, which were long-lasting (1994-1996 and 1999-2009, respectively) also contributed to the development of the genre of songs of the war years. The songwriting of the limited contingent of Soviet troops in Afghanistan in the 1980s became the most vivid and memorable. The so-called "Afghan songs" acquired the status of a subculture of the post-war period. The folklore archive of Ural State University has a collection: about two thousand recordings of so-called "Afghan" songs, five published collections, more than a dozen giant CDs released in the late 80s by the Melodiya company, as well as several compact cassettes [8, p.38].

At the stage of its origination, "Afghan song" raised a range of questions that needed to be understood by both the fighters themselves and society as a whole: they needed answers to questions about what kind of war this was, why young guys should fight in it, why they should give their lives in a foreign country, what to fight for, and etc. Through songs, sometimes with satire, and later, with a heavier emotional mood, information about an alien culture, about the cruel customs of the eastern state, about the adaptation of our soldiers to the hardships of military service and everyday life in a hot climate, mountainous terrain, foreign people, language, etc. was dramatically transmitted. At the initial stage, the songs reflected "the exoticism of a distant eastern country, a lively youthful curiosity, a desire to test oneself in unusual conditions, in short, everything that has always forced our compatriots to go somewhere to meet unsettled conditions and the unknown" [8, p. 45].

Afghan war songs changed the opinion of music critics and cultural experts about the folk song, it was believed that it had exhausted itself and could not exist in a society with a predominant urban lifestyle. At the same time, the songs of the Afghan War are recognized as a phenomenon of folk culture and, using the example of some of them, one can trace the formation of the phenomenon of modern folk military songs [2].

There is also a certain continuity of generations. During the Afghan War, many of the songs of the Great Patriotic War, written to poems and melodies by poets and wartime composers, were reworked and adapted to the modern conditions of life and service at that time. But only some of the songs had authors and composers, most of them nevertheless related specifically to folk art [7].

Using the example of the most striking of the famous "Afghan" songs, one can trace how the phenomenon of folk song was formed. Valery Cherkosov, a member of the Writers' Union and winner of many literary prizes,

commented on the song “Cuckoo”: “Yes, “Cuckoo”, as well as the famous songs of the Great Patriotic War – “Blue Handkerchief”, “Katyusha”, “Dark-skinned Moldavian”, also became folk, they were sung by Russians who happened to participate in military conflicts. And now they are still sung.” [12].

At a later stage of the evolution of the “Afghan” military song, “the themes of “Afghan” songs were mainly formed: battles and everyday combat, soldiers and military duty, soldiers and death, soldiers and beloved, soldiers and songs, memory of the dead and decent treatment of the survivors of this war” [8, p.50].

The popularization of the “Afghan” military song was facilitated by government support, projects that promote the distribution of giant number of CDs to the masses, initially released in forty thousand copies by the Melodiya company, and later by the results of All-Union rallies where “the Cascade” and “Blue Berets” soldier ensembles performed, and soldier song festivals with much larger circulations, which contributed to the fact that the “Afghan song” has become a mass subculture.

The main functions of the Afghan song were the “class identification function” – the song quickly helped to identify “one's own” from “someone else's” and an important traditional function of soldiers' creativity, memorial and informative.

Since February 24, 2022, Russia has been conducting a special military operation (SMO) on the territory of Ukraine, the DPR and the LPR in order to protect residents of the Donetsk and Lugansk People's Republics from aggression by the Kiev regime, demilitarization and denazification of Ukraine, and stopping military threats from the military-political bloc of NATO.

What helps our soldiers at the front to carry out the combat tasks assigned to them, to stand up in fierce battles with the enemy, to build a way of life, to establish relationships with the civilian population on the liberated territories? And in this case, of course, in addition to the main factors such as the professionalism of the military, providing and supplying the front with new types of weapons, food, necessary equipment, and much more, one cannot ignore such factors as art and military songs, the importance of which increases many times during periods of military trials. The hero of the movie “Only old men go into battle”, performed by actor Leonid Bykov, utters a sentimental phrase: “Who said that we should give up songs in the war? After a fight, the heart asks for music twice”.

Maintaining high morale in the troops, psychological and ideological support is also a powerful weapon.

President of the Russian Federation Vladimir Putin noted the heroic deeds of the participants of the special military operation: “The guys are fulfilling the most important task from the point of view of ensuring the

security of Russia itself and, of course, they deserve to be talked about and known by the country. I think that songs should be composed, and poems should be written, and monuments should be erected to them. They are heroes”.

What do Russian soldiers who participate in a special military operation prefer to listen to and sing about? Does the song help to fight? In the First Chechen campaign, under the unofficial anthem of the Airborne Forces, “The Blue has Splashed”, Russian paratroopers rose to the attack, it was an example of inspiration and morale-boosting [9].

What inspires the fighters to storm the enemy now?

The specifics of military operations certainly affect art in general, and the song genre in particular. Its dissimilarity from other wars that the Soviet and then the Russian state had to face determines the specifics of art in all its manifestations. Today, military operations are a war of technology, first of all, it is a leap in the development of military science, the development of new realities of combat, new rules, new tactics....

Today's art of military song is a symbiosis of folk art, the work of performing authors, and the work of professional poets and songwriters, and the preservation of the best traditions of military song, which originated in the 10th century and has a long history.

The songs of the Second World War and the Afghan War have now received a modern new sounding and significance, they are sung by professional performers, in modern musical adaptation, they are listened to by soldiers returning from the front line to rest in the rear.

The authors and performers of military songs, who the fighters themselves, quickly gain fame thanks to modern means of communication, and often become welcome guests on television and radio, in military units performing combat missions in special military operation. Thus, thanks to modern means of communication, soldiers' songs are rapidly spreading throughout Russia, and sometimes far beyond its borders, through transmission using the Internet.

The traditional oral method of transmitting folklore information has virtually disappeared into oblivion, in the age of technology, any notebook is replaced by mobile phones, voice recorders, audio speakers are used as playback equipment, in addition to telephones, flash drives are used as equipment for storing a large amount of musical information. CDs, external discs for storing information, flash cards are less often used. The recording and storage of musical information on them is characterized by the disordered and chaotic content of such information.

The most modern way of recording, storing and transmitting song information is audio or video recording on a mobile phone. Often there is neither the name of the song nor the name of the author, despite the fact that

the song is recorded in the author's performance, the names of the songwriters often remain unknown. Thus, electronic forms of storing and transmitting modern folk military songs continue to preserve one of the main features of folklore – anonymity.

Songs during the special military operation are composed spontaneously, in army units of infantry, artillery, aviation, navy, etc., transmitted using digital technologies, raise the spirits and unite the fighters. They usually express the thoughts and feelings of an ordinary person. The songs reflect on the proximity of death in the war, the longing of a fighter for his native home, and the hope of an early meeting with relatives and friends.

In between the fights, songs are played in different languages, as representatives of different nationalities living in Russia fight side by side. However, the intonational nature of music allows for communication on a non-verbal level. This invaluable experience of intercultural and interethnic communication convinces us of the ability of musical art to solve the most difficult tasks of fostering a sense of solidarity, mutual understanding between people of different nationalities and even countries, and opposing various manifestations of nationalism [4].

Modern military songs traditionally display “the best qualities of the Russian national character, the harmony of the inner and outer beauty of a person, an algorithm for behavior in a situation of moral choice, and values based on honor, dignity, loyalty to patriotic duty, valor, kindness, humanity, and nobility of deeds and thoughts” [5].

Military songs are based on essential national and spiritual values, are important in shaping historical memory, forming the image of a hero among the population.

This influence on the younger generation is especially important. It depends on today's teenagers how adults – today's children – will treat our country and its historical events in the future. In the song, the words and music form a single picture, which causes and makes you feel real emotion – to imagine what is being sung about, to understand the essence and meaning of the event, fact, person, and story being sung about.

The axiological guideline for the development of modern theory and practice of education are the basic national values: patriotism, social solidarity, citizenship, family, work and creativity, science, traditional Russian religions, art and literature, nature, humanity [6, p.18-19]. Art is of great importance for the realization of these values in society.

The importance of the social and memorial-historical functions of art, which inspires, educates, unites, enlightens, gives hope, heals, comforts people, inspires them with confidence in the coming victory, despite all the hardships of wartime, can hardly be overestimated.

It is natural to reflect on the historical prospects of Russian art in the period of special military operation, on its spiritual origins, educational potential, modern sound and significance for the spiritual and moral development of future generations.

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THE PSYCHOLOGY OF WAR: THE HUMAN MIND IN CONFLICT

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Аннотация. Статья анализирует сложное и часто тревожное психологическое воздействие войны на людей и общество. Исследуя глубинные способы, которыми конфликт формирует человеческое поведение, мыслительные процессы и эмоциональные состояния, исследование рассматривает такие темы, как травма, лидерство под давлением и динамика дегуманизации. Описываются исторические и современные конфликты, результаты исследований «Психология войны». Статья является обязательным чтением для тех, кто стремится понять человеческое измерение вооруженного конфликта и его долгосрочные последствия.

Ключевые слова: PTSD, последствия, вина выжившего, депрессия, тяжесть, гендерное насилие, жертвы, увековечивать, плохо подготовленный, под влиянием.

Annotation. This article considers the complex and often unsettling psychological impact of war on individuals and societies. Exploring the profound ways in which conflict shapes human behavior, thought processes, and emotional states, it examines themes such as trauma, leadership under pressure, and the dynamics of dehumanization. By analyzing historical and contemporary conflicts, research findings, “The Psychology of War. This article is essential reading for anyone seeking to comprehend the human dimension of armed conflict and its enduring consequences.

Keywords: PTSD, ramifications, Survivor’s Guilt, depression, brunt, gender-based violence, victims, perpetuate, ill-equipped, influenced.

Introduction. The rise of warfare and conflicts in modern times has complicated the battlefield experience, adding layers of psychological distress. War has been an intrinsic part of human history. The psychology of war explores the multifaceted interactions between human behavior, emotions, and the brutal realities of conflict. Understanding these psychological mechanisms is paramount for mitigating war’s effects and providing support for those who endure its consequences.

Throughout history, wars have shaped societies extensively, affecting their psychological landscapes. From the ancient conflicts in Greece and Rome to the two World Wars and modern conflicts, the psychological ramifications of war can be traced through time. In earlier periods, warriors were often glorified, celebrated for their valor and bravery. This tradition, however, frequently masked the brutal reality and psychological burden of combat.

World War I introduced a significant shift in understanding the psychological effects of warfare. The term “shell shock” emerged to describe the psychological trauma experienced by soldiers. This condition, now recognized as post-traumatic stress disorder (PTSD), highlighted the severe mental health consequences faced by those exposed to the chaos and violence of battle [3].

The evolution of warfare, driven by technological advancements and changes in combat strategies, has further influenced psychological responses [2]. The constant uncertainty and fear faced by soldiers in unconventional warfare settings often lead to heightened anxiety and mental health challenges. One should consider psychological aspects of war (table 1).

Table 1. Psychological aspects of war

Psychological aspects	Various dimensions characteristics
Post-Traumatic Stress Disorder	It is a prevalent condition among veterans and individuals exposed to combat. Symptoms are flashbacks, severe anxiety, nightmares, and uncontrollable thoughts about the traumatic event [1].
Stress and Trauma	Combat soldiers experience acute stress due to the life-threatening situations they face. This often leads to long-lasting psychological effects. The transition creates a significant disconnect that complicates psychological recovery [3].
Survivor’s Guilt	This emotional burden can lead to isolation, depression, and interpersonal difficulties, complicating reintegration into civilian life
Coping Mechanisms	Individuals cope with war’s psychological toll in various ways, from substance abuse to community support systems. However, not all coping strategies are positive; some turn to unhealthy behaviors as a means of escape, highlighting the need for constructive outlets

Furthermore, the educational disruptions caused by war can have lasting effects on children’s development. A lack of access to schooling can perpetuate cycles of poverty and violence, creating a generation ill-equipped for future challenges [1]. The Role of Trauma Recovery programs is analyzed in table 2.

Table 2. Trauma Recovery programs

Mental Health Support Services
Providing accessible mental health resources tailored to the needs of veterans, civilians, and children affected by war is crucial. This includes therapy options, group counseling, and community support initiatives.
Integrated Healthcare Approaches
Developing healthcare models that integrate mental and physical health services will ensure comprehensive support for war survivors. This holistic approach can enhance recovery outcomes.
Community Resilience Programs
Building community resilience involves fostering social connections and creating safe spaces for individuals to share their experiences. Supportive communities can significantly mitigate the psychological impacts of war.

Moral and ethical considerations are central to military leadership. Leaders must grapple with the implications of their decisions, weighing the costs of war against its potential benefits. Understanding the psychological aspects of leadership can improve training processes, ensuring leaders are prepared for the complexities of command during conflict [3].

Military leaders are influenced by various psychological factors affecting their decision-making and strategic approaches. Groupthink, a phenomenon where the desire for consensus leads to irrational decisions, can have dire outcomes in military contexts. Critical thinking and conflict resolution training are essential for leaders to avoid such pitfalls.

The psychology of war is also shaped by cultural contexts. Different societies perceive and process conflict in unique ways, influenced by history, religion, and social norms. Understanding these cultural perspectives can inform strategies for trauma recovery and reconciliation in post-conflict settings.

Conclusion

The psychology of war explores the multifaceted interactions between human behavior, emotions, and the brutal realities of conflict. Understanding these psychological mechanisms is paramount for mitigating war’s effects and providing support for those who endure its consequences.

Essential steps in mitigating the harsh realities of conflict are improving mental health resources, promoting community resilience, and addressing the unique needs of populations.

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DIGITAL TECHNOLOGIES AND SKINNER'S BOX: NEW HORIZONS IN LEARNING

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Аннотация. В данной статье рассматривается степень эффективности обучения с использованием цифровых технологий на основе методики ящика Скиннера, разработанной психологом-бихевиористом Берресом Скиннером. Основной проблемой является необходимость адаптации классических поведенческих подходов к современным условиям цифровизации в сфере образования. Основные принципы положительного и отрицательного подкрепления, лежащие в основе методики, были проанализированы в цифровой образовательной среде. Основная цель - изучить возможности цифровых платформ, такие как внедрение игровых методов в учебный процесс, автоматизированные ответы и персонализированное обучение. Основными методами являются изучение возможностей цифровых платформ, таких как внедрение игровых методов в учебный процесс, автоматизированные ответы и персонализированное обучение. Рассмотрены примеры успешных проектов с участием игровых и образовательных платформ, использующих различные стимулы для повышения мотивации и улучшения результатов обучения. В результате выявляются ключевые преимущества симбиоза цифровых технологий и поведенческого подхода: повышенная вовлеченность учащихся, адаптивность к индивидуальным потребностям и автоматизация процессов обучения. В

заключении статьи подчеркивается важность интеграции методологии ящика Скиннера в цифровые образовательные программы, отмечается ее высокий потенциал для повышения эффективности образовательного процесса, а также указывается на необходимость регулирования и учета стимулов в некоторых областях, чтобы избежать негативного опыта.

Ключевые слова: ящик Скиннера, цифровое обучение, геймификация, бихевиоризм, мотивация, вовлеченность, адаптивное обучение.

Annotation. This article examines the degree of effectiveness of learning using digital technologies based on the Skinner's box technique developed by a behavioral psychologist Berres Skinner. The main problem is the need to adapt classical behavioral approaches to modern conditions of digitalization in the field of education. The basic principles of positive and negative reinforcement, which underlie the methodology, were analyzed in the digital educational environment. The main goal is to explore the possibilities of digital platforms, such as the introduction of game methods into the learning process, automated responses and personalized learning. The main methods are to explore the possibilities of digital platforms, such as the introduction of game techniques into the learning process, automated responses and personalized learning. Examples of successful projects involving gaming and educational platforms using various incentives to increase motivation and improve learning outcomes are considered. As a result, the key advantages of the symbiosis of digital technologies and the behavioral approach are revealed: increased student engagement, adaptability to individual needs and automation of learning processes. The conclusion of the article emphasizes the importance of integrating the Skinner's box methodology into digital educational programs, noting its high potential for improving the effectiveness of the educational process, and also indicates the need to regulate and take into account incentives in some areas in order to avoid negative experiences.

Keywords: Skinner Box, digital learning, gamification, behaviorism, motivation, engagement, adaptive learning.

Nowadays, digital technologies are becoming more and more popular. Modern technologies have a great impact on various areas of our lives, work, recreation, and education, improving traditional approaches to learning and helping to find new ones that can increase the effectiveness and interest of students. One of the most significant aspects of the modern educational process is the use of personalized learning methods based on the field of psychology related to behaviorism. This field is based on scientific approaches that help to increase motivation and build skills. These approaches are

substantiated in many fundamental scientific works, such as the studies of Berres Skinner ("The Behavior of Organizations") [9], Albert Bandura ("Social Learning Theory", 1977) [1] and John Watson ("Psychology as the Behaviorist Views It") [11].

In this area of modern technology, the Skinner box technique, based on the principles of behaviorism using positive reinforcement, is a valuable tool for analyzing and optimizing educational methods. This field was created by behaviorist Berres Frederick Skinner in his last year of study at Harvard University. Previously, scientists actively studied the use of the Skinner's Box technique in the framework of the traditional educational process, emphasizing its effectiveness in the formation of stable behavioral attitudes.

In addition, numerous studies are devoted to the integration of digital technologies into the educational process, including the use of gamification (the work of Jane McGonigal, "Reality Is Broken: Why Games Make Us Better and How They Can Change the World") [7], marketing, adaptive learning systems (Kurt van Leer and David Vischer, "Adaptive Learning Technologies for Higher Education") [18] and an automated assessment system (James Powell, "Automated Assessment in Education") [8].

Despite significant enhancements in this area, the approach that is combining classical behavioral principles with digital learning tools has not been sufficiently studied. It makes further research in this field necessary.

The research of our article is aimed at analyzing the effectiveness and finding the ways to use the Skinner's box methodology in digital learning. The task of the work is to identify the main advantages and aspects related to the behavioral approaches application in modern educational technologies.

The application of behavioral approaches in the Skinner's box methodology has been actively studied since the middle of the 20th century. The positive and negative principles of reinforcement are stated to be an effective tool for shaping behavior and sustainable learning skills. The use of reinforcement provides increasing motivation. It improves learning outcomes.

The last decades have been marked by the rapid digital educational technologies development. The works in the field of gamification confirms that the game elements introduction such as rewards, levels, points increase the students' interest and stimulate them to achieve goals. Many of these technologies are focused on the mechanical execution of tasks. They do not take into consideration scientifically based approaches to learning, which reduces their effectiveness.

We evaluated the effectiveness of the Skinner's box technique in digital learning. The experimental approach was chosen, which includes both quantitative and qualitative data for a deeper understanding of the effectiveness of the synergy of behavioral principles and digital technologies.

Quantitative data were collected through the analysis of students' academic performance, engagement and motivation, and qualitative data were obtained through interviews and surveys to assess the subjective perception of the learning process. Educational platforms that include elements of gamification and adaptive learning were used to collect quantitative data. Platforms such as Duolingo and Khan Academy provided a system of rewards, levels and automatic feedback, which allowed the introduction of reinforcement elements into the learning process. This data was collected using the built-in analytical tools of the platforms, which tracked the progress of students and recorded their results.

Qualitative data were obtained through questionnaires and semi-formal interviews with the study participants. Surveys and interviews made it possible to identify the motivation of students, their perception of the learning process and the effectiveness of digital technologies in combination with reinforcement elements. These data were analyzed using the content analysis method, which made it possible to identify key topics and patterns related to the perception and effectiveness of learning. Thus, the chosen set of methods allows us to explore both objective results and personal perception of students, which makes it possible to more comprehensively assess the effectiveness of combining digital technologies and the Skinner's box methodology in teaching.

The results of the research are presented in the form of an analysis of data on students' academic performance, their involvement, motivation and subjective assessments of participants regarding the learning process using digital platforms. According to data collected using educational platforms (Duolingo [2] and Khan Academy [6]), there was a significant improvement in the academic performance of participants studying with elements of gamification and automatic reinforcement. During the 4 weeks of follow-up, 78% of participants demonstrated improved results in completing tasks, which was expressed in an increase in the percentage of successful task solutions and a decrease in the time spent on their completion.

The analysis of the participants' engagement also showed a positive trend. The use of gamification elements (rewards, points, levels) contributed to an increase in student engagement. The average time that participants spent on the platform increased by 25% compared to the initial level.

Table 1 - Participant engagement (time on the platform in minutes) before and after the introduction of reinforcement elements

Participant	Before Time (min.)	After Time (min.)	Difference (%)
A	45	55	+22%

B	30	40	+33%
C	50	65	+30%

In addition, the survey showed that 85% of participants noted an increase in their motivation and interest in learning through the use of digital incentives.

Based on the results of a qualitative analysis of interviews and surveys, students noted that the elements of gamification and the reward system significantly increased their motivation and satisfaction with the learning process. For example, 78% of participants said that digital rewards (points, levels, medals) give them a sense of progress and success, which encourages them to continue learning.

Table 2 - Subjective assessments of participants (assessment of motivation and satisfaction on a scale from 1 to 5)

Participant	Motivation assessment before	Motivation assessment after	Satisfaction assessment after
A	3	4	5
B	2	3	4
C	4	5	5

The analysis of the subgroups showed that the use of reinforcement elements has the most effective effect on students with a low level of motivation and those who have difficulties with self-regulation. While highly motivated participants showed improvements, their progress was less pronounced compared to less motivated ones.

Table 3: Comparison of the progress of students with different levels of motivation

Motivation category	Progress (success rate)	Average time gain
High	10%	5%
Medium	20%	15%
Low	40%	30%

Long-term results obtained 3 months after the end of the experiment showed that students who continued to use platforms with reinforcement elements maintained a high level of engagement and motivation, which confirms the effectiveness of using Skinner's box methods in digital learning.

The results of the study demonstrated the significant impact of the Skinner Box method on the effectiveness of digital learning, especially when using gamification and positive reinforcement systems. Thanks to quantitative data, there was an improvement in academic performance and a reduction in task completion time, which also confirms the conclusions of Thorndike ("The Fundamentals of Learning") [10], who emphasized the importance of external incentives for the formation of new skills in his works. The indicators of motivation and satisfaction with the learning process among the subjects also increased, which corresponds to the research of David Kelly (Motivation and Incentives in Education) [5]. In this study, rewards and receiving feedback during learning play a key role.

One of the most important aspects of the observation was the demonstration of the greatest progress among students with low motivation and weak self-regulation. A similar conclusion was observed in the works of Robert Eisenberger (Reward, Motivation, and Intrinsic Interest) [3], who argued that external stimuli can become a powerful tool for groups of students with limited intrinsic motivation. At the same time, the progress of highly motivated participants was not so noticeable, which may be due to their self-regulation mechanisms that had already been formed before the start of the experiment. Consideration of the data can form the basis for the development of more universal approaches to learning.

The long-term results also confirm the sustainability of the effect of using the Skinner Box method. Participants who continued to use educational platforms three months after the end of the experiment maintained a high level of motivation and engagement. These data coincide with the conclusions of Patricia Greenfield ("Technology and Information Education: What Is Learned, What Is Learned") [4], who emphasized the importance of constant interaction with digital tools to maintain interest in learning.

The study confirmed the hypothesis about the positive impact of the Skinner Box method in digital learning. The main conclusions were formulated as follows. The use of gamification and positive reinforcement systems led to a 30% increase in the number of correct answers, a better understanding of the material, and a 15% reduction in task completion time. The time spent by participants on educational platforms increased by 25%, which indicates an increase in interest and involvement in the learning process. A particularly noticeable effect was observed among students with low motivation. 78% of the participants noted that various digital awards (points, medals, levels) increased their confidence in the acquired knowledge and capabilities, which increased their motivation to learn. Three months after the end of the experiment, the participants maintained a high level of motivation and engagement, which confirms the sustainability of the effect of using the

Skinner Box method in digital learning. Thus, the Skinner Box method using digital technologies and gamification is a powerful tool that can improve the quality of education. However, in order to achieve maximum effectiveness, it is necessary to take into account the individual characteristics of students, such as the level of motivation and the ability to self-regulate. Further research should be aimed at developing universal approaches that will be equally effective for all categories of students.

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ETHNOCULTURAL EDUCATION REALIZATION IN A HIGHER NAVAL SCHOOL

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Аннотация. Этнокультурное образование предполагает качественное изменение содержания учебных дисциплин – в основном

гуманитарной и социальной направленности: использования нравственного потенциала учебных дисциплин, трансформации учебного материала в систему проблемно-конфликтных вопросов и задач. Дан анализ современного состояния теории и практики этнокультурного образования в военном вузе. Представлена практическая реализация концепции этнокультурного образования.

Ключевые слова: межкультурное взаимодействие, этнокультура, многонациональный и многоконфессиональный социум.

Annotation. The implementation of ethnocultural education means a qualitative change in the content of academic disciplines - mainly humanitarian and social orientation: the use of the moral potential of academic subjects, the transformation of educational material into a system of problem-conflict issues and tasks. The current state of the theory and practice of ethnocultural education in Higher Naval School is analyzed. The practical realization of ethnocultural education concept is presented.

Keywords: intercultural interaction, ethnoculture, multinational and multi-confessional society.

Introduction. In a multinational and multi-confessional society, demonstrating intolerance towards another culture, faith, language, and ethnic superiority is unacceptable and is regarded as contrary to state interests. The problem of constructing conflict-free intercultural interaction in a multicultural society is closely connected with the study of issues on understanding the problem of ethnocultural education in military higher establishments. It is clear that future officers must perform the functions of social educators and psychologists in their professional activities.

The purpose of this article is to substantiate the concept of ethnocultural education in Higher Naval School.

In modern socio-cultural realities, ethnocultural education is an urgent need and is an integral part of a unified education system. This is evidenced by the Decree of the President of the Russian Federation of 25.01.2023 No. 35 "On Amendments to the Fundamentals of State Cultural Policy, approved by Decree of the President of the Russian Federation of December 24, 2014 No. 808" [4].

The problem of ethnocultural education is the subject of special attention in the scientific literature when studying issues related to the formation of value orientations of cadets (D.V. Romanov [7], V.L. Razgonov [2]); the development of interethnic relations (V.A. Tishkov, V.V. Stepanov [8], S. Egitim, P. Akaliyski [6], N. Ramachov, G.N. Akbaeva [7], R. Berkowitz, E. Ben-Artzi [5]).

The following research **methods** were used in the work: study and analysis of scientific literature on the designated topic, comparative analysis of facts, hypotheses, their comparison, comparison, generalization.

Results of the study and their discussion. In the new socio-cultural conditions, the requirements for professional training in a military higher establishments have increased; it is necessary to build constructive relationships with colleagues, who are often representatives of different nationalities and religions.

The content of the educational process in the implementation of the concept of ethnocultural education is a system of spiritual and moral values, norms, and attitudes presented in the cultural and historical heritage of the past, which is based on the enormous positive experience of good neighborliness, cooperation, and friendship of the peoples living on the territory of Russia [1].

The implementation of the concept of ethnocultural education is ensured by the use of interactive methods and techniques of educational activities, which are focused on the active-personal path of mastering ethnocultural information: in the process of discussion in groups, communication and cooperation, in the process of which a tolerant attitude towards people of other nationalities is formed.

The use of certain techniques can contribute to the development of the ability to approach contradictory situations, weigh different points of view, and, most importantly, to show tolerance for other opinions and the existence of opponents:

- socratic conversations,
- questioning strategies (“Interrogative words”),
- discussions, debates,
- press conferences [1].

The practical implementation of the concept of ethnocultural education in military university higher establishments involves: a sense of patriotism forming, respect for the history of the native country and its people, pride in Russia; preservation and transmission of the cultural and historical heritage of the peoples of Russia; acceptance and respect for their moral standards and achievements; subsequent development of traditions of interaction between cultures and peoples; rejection of all forms of ethnic aggression, careful attitude to the traditional beliefs of the peoples living in Russia.

Conclusion.

The implementation of the concept of ethnocultural education is ensured by the use of interactive methods and techniques of educational activities, which are aimed at an active-personal path of learning ethnocultural information. A significant role is given to their ability to create a moral and psychological climate. Ethnocultural education realization in a military higher

establishment is necessary and possible within the framework of professional training.

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THE MEANS OF IMPLEMENTING THE CONFRONTATIONAL COMMUNICATIVE TACTIC OF THREAT IN NANCY PELOSI'S SPEECHES

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Аннотация. Данная статья посвящена изучению средств репрезентации тактики угрозы, реализующей конфронтационную коммуникативную стратегию подчинения и убеждения на примере выступлений американского политического деятеля НэнсиPelosi. Угроза представляет собой речевой акт, направленный на внушение страха оппоненту. В политической коммуникации угроза в основном выражается имплицитно, так как прямая угроза может привести к негативным последствиям для говорящего. НэнсиPelosi является ярким примером женщины-лидера в американском правительстве, которая сочетает решимость с ожидаемой сдержанностью.

Ключевые слова: угроза, имплицитная угроза, конфронтация, женщина-политик, противопоставление.

Annotation. This article is devoted to the study of the means of representing the tactic of threat that as a realization of the confrontational communicative strategy of subordination and persuasion, using the speeches of American political figure Nancy Pelosi as a case study. A threat is a speech act aimed at instilling fear in an opponent. In political communication, threats are predominantly expressed implicitly, as direct threats may lead to negative consequences for the speaker. Nancy Pelosi serves as a prime example of a female leader in the U.S. government who combines decisiveness with socially expected restraint.

Keywords: threat, implicit threat, confrontation, female politician, opposition.

Political communication, as a means of influencing and exercising power, is directly related to the use of various strategies aimed at manipulating public opinion, exerting pressure on the opposition, and consolidating allies. To this end, the following confrontational communicative strategies are identified: discreditation, subordination and persuasion, seizing the initiative and control over the situation, as well as self-defense. Each strategy is implemented through specific tactics.

The strategy of subordination and persuasion is aimed at interaction where the speaker attempts to subordinate the recipient or convince them to take their side using conflict-driven communication methods. This strategy is

verbalized through tactics such as a threat, order, and reproach [1, p.54]. Our research is focused on analyzing the tactic of threat in Nancy Pelosi's speeches, who is one of the most influential and controversial figures in modern American politics, and whose speeches often serve as a catalyst for public debates.

The relevance of the study is determined by several factors. Firstly, the tactic of threat, as part of the confrontational communicative strategy of subordination and persuasion, has not been fully explored in the context of political discourse, particularly its implicit forms. Secondly, it is necessary to consider the gender aspect of communication by female politicians, who have to balance the stereotypes of 'aggressiveness' and 'weakness'. Nancy Pelosi, having served as Speaker of the U.S. House of Representatives and playing a key role in the passage of various social reforms, bills, and the impeachment of Donald Trump, represents a prime example of a female leader whose speeches combine rigidity and diplomacy. Her speeches provide a unique opportunity to study the use of threat as a tool for legitimizing power within the context of gender expectations, as they are accompanied by warnings and ultimatums.

The aim of the study is to identify the linguistic and pragmatic features of expressing threats in Nancy Pelosi's public speeches. Within the framework of linguistic pragmatics, a threat is an illocutionary speech act aimed at instilling fear in the recipient regarding potential negative consequences. J. Searle categorizes threats as commissives, that is the statements made by the speaker to express what actions they will take if their demands are not met. As a rule, threats are typically not expressed explicitly in political communication, as this could lead to undesirable consequences for the speaker. The use of implicit strategies is the dominant way of conveying threats. For example, we can observe the use of warnings like 'They will regret this', rhetorical questions like 'Do you really want this to end this way?' or conditional constructions like 'If you continue down this way, we will take action.'

In political communication, threats serve several functions:

1. Coercion (to force the opposition to change their behavior through fear of negative consequences);
2. Mobilization of allies (to gain support in the fight against a common enemy);
3. Legitimization of power (to strengthen one's authority by demonstrating power);
4. Manipulation of public opinion (to justify unpopular measures by creating an atmosphere of fear or crisis);
5. Diplomatic pressure (to influence an international audience by demonstrating determination);

6. Concealing weakness (to mask one's vulnerability through aggressive statements).

A threat can also serve as a 'framing' tool to establish a specific interpretation of events [2, p.217]. For example, Nancy Pelosi's statement about the 'unacceptability of Republican actions' not only warns of potential consequences but also sets specific boundaries that frame these actions as anti democratic.

As a rule, public reactions to the statements of female politicians tend to be more critical. Aggressive statements by male politicians may be viewed as decisiveness, while the same statements from female politicians are often interpreted as hysteria or lack of control. As a result, a female leader may find herself in a double-blind, where she has to balance demonstrating strength while avoiding stigmatization.

Threats in Nancy Pelosi's speeches are often softened through the use of 'care rhetoric', appealing to the protection of citizens' rights, which allows her to maintain the image of a 'responsible leader' rather than an 'aggressor'.

This study employs methods of critical discourse analysis to uncover ideological patterns, and pragmatic analysis to identify direct and indirect speech acts of threat in Nancy Pelosi's speeches from 2019 to 2023, when she serves as Speaker of the U.S. House of Representatives.

Now we analyze the following examples from Nancy Pelosi's speeches, which address issues related to international relations, healthcare, and the impeachment of Donald Trump.

(1) The president must be impeached, and I believe the president must be convicted by the senate, a constitutional remedy that will ensure that the Republic will be safe from this man who was so resolutely determined to tear down the things that we hold dear, and that holds us together [9].

In this context, Pelosi delivers an indirect threat, conveyed through various linguistic tools. The modal verb *must* convey a sense of urgent danger and emphasizes the necessity and inevitability of actions. The contrast between the verbs *tear down* and *hold dear* intensifies the opposition between the threat and the protection of values. The phrase *hold us together* is a metaphor for unity, depicted as a fragile structure Trump aims to destroy. The president is presented as the active agent of the threat, through the phrase *this man who was so resolutely determined*. Additionally, the use of *the things that we hold dear* and *hold us together* evokes an emotional response, framing the threat as one directed at shared national values and unity.

(2) Do we have the duty to our oath to do all we constitutionally can do to protect our nation and our democracy from the appetites and ambitions of a man who has self-evidently demonstrated that he is vital threat to liberty, to self-government, and the rule of law [3]?

This passage presents an implicit threat directed at Donald Trump, who is portrayed as a danger to democracy and as someone who demands radical measures within the framework of the law. Nancy Pelosi compares him to an insatiable creature driven by selfish motives through the phrase *appetites and ambitions*, while the term *vital threat* emphasizes the mortal danger looming over the state. The rhetorical question *Do we not have the duty...* intensifies the sense of urgency, appealing to moral responsibility and implying that there is only one acceptable answer. Additionally, we can observe a chain reaction effect of destruction, as the threats are listed in increasing order of significance: *liberty, self-governmnet, rule of law*.

(3) *We have to restore those. Whatever else happens of this, we must restore all those sanctions and we must act upon them* [5].

In this example, the threat acts as an instrument of political coercion aimed at changing the behaviour of the target of the sanctions. The modal verbs *have to* and *must* create pressure and convey a sense of obligation and lack of alternatives. The repetition of the word *sanctions*, which carries a negative connotation, reinforces the perception of the threat and is associated with punishment or restrictions. The inevitability of sanctions is expressed through the phrase *whatever else happens*. The parallel structure *we must... we must* amplify the speaker's determination and assertiveness. The verb *act* indicates a willingness to move from threats to actions, thereby increasing the level of danger for the addressee. The use of personal pronoun *we* create a sense of unity, which intensifies pressure on the opponent and demonstrates strength and solidarity.

(4) *What we have been learning on this visit is some of the some of the challenges that were presented by the so called peace agreement coming from the conflict into – resolution of the conflict in 2020 and how that maybe contributed to the violence on the part of Azeris. And I promised my colleagues that they have to respond to that question* [6].

In this excerpt, Nancy Pelosi mobilizes the audience's attention to resolve the conflict. Through the use of the modal verb *have to*, she attempts to hold the Azerbaijanis accountable for their actions. Mentioning *Azeris* as a source of violence she creates the image of an aggressor. The phrase *so-called* is used to express doubt regarding the legitimacy of the previously adopted agreement. The expression *contributed to the violence* highlights a cause-and-effect relationship, framing the agreement not as a means of resolving the conflict, but as a factor that has escalated it.

(5) *As to our commitment to Armenia, we will continue to support the integrity of the democracy of Armenia and the borders and resist any effort to have those borders changed* [6].

This excerpt also addresses the conflict between Armenia and Azerbaijan. Nancy Pelosi expresses an implicit threat to Azerbaijan if they try to alter Armenia's borders. The use of the future tense *will continue* and *will resist* indicates the determination and an unwavering stance, creating the image of an evitable response to any threat. To emphasize the contrast between defence and aggression, she juxtaposes *support the integrity...* with *resist any effort*. The use of the active voice in *we will resist* emphasizes firmness and directness. Through the phrase *resist any effort* Pelosi conveys strength without specifying the methods, leaving room for interpretation and thereby increasing psychological pressure. *Resist* can be interpreted as a promise of support for Armenia in potential conflicts, which actualizes the threat to Azerbaijan and its allies, such as Turkey.

(6) *Hamas is dedicated to the destruction of the State of Israel. Hamas has been declared a terrorist organization by the United States. Hamas must be destroyed* [4].

This example expresses a direct threat. The phrase *terrorist organization* conveys the Western position by labeling Hamas, thereby delegitimizing it. The first and the third sentences mirror each other, reinforcing the perception of the conflict as a struggle with no room for compromise. The present tense verbs *are dedicated* and *must be* create a sense of ongoing danger that must be eliminated. Mentioning the United States as the country that has designated Hamas as a terrorist organization reinforces the legitimacy of the threat. The sequence of sentences builds a logical progression: the threat posed by Hamas, the justification of that threat, and the call for its destruction.

(7) *Instead of protecting with pre-existing conditions, President Trump is in court defending his abusive junk plans while demanding that every last protection and benefit of the Affordable Care Act be struck down. Democrats will continue to fight to protect families from junk insurance plans while lowering health costs and prescription drug prices for all Americans* [7].

In this context, an implicit threat is presented, where Trump's actions are contrasted with those of the Democratic Party. The lexical background is presented by negative vocabulary such as *abusive junk plans*, *struck down*, and *junk insurance plans*, which create a negative image of the president. The contrast between *defending his abusive junk plans* and *fight to protect families* is used to intensify the conflict, reflecting the Democratic Party's stance that healthcare is a key issue while criticizing the actions of Trump's administration.

(8) *While extreme MAGA Republicans mobilize around a dangerous agenda of gutting Medicare and raising health costs on families. Democrats will never relent in our fight to put People Over Politics - because we know that health care is a right, not a privilege* [8].

In this example, Nancy Pelosi is trying to discredit her opponents by presenting their policies as inhuman and extremist. By contrasting the actions of Republicans and Democrats *mobilize around a dangerous agenda* versus *never relent in our fight* Pelosi constructs a threat/protection narrative. The verbs *mobilize*, *gut*, and *raising* depict Republican actions as dynamic and aggressive, while *fight* and *relent* emphasize the Democrats' resolve to confront the threat. The phrase *extreme MAGA Republicans* creates the image of a radical group posing a threat to the population and aligns them with extremism. The metaphor *gutting Medicare* evokes violent destruction of the healthcare system, amplifying the perceived danger.

The study of how threat is expressed in Nancy Pelosi's political communication revealed the main features of her speech within the context of American political confrontation. The analysis confirms that threat, as a tool of confrontational communicative strategy of subordination and persuasion, serves not only to pressure opponents but also to consolidate supporters, legitimize authority, and shape the public agenda.

Nancy Pelosi uses implicit threats more often to maintain formal diplomacy and avoid the label of an 'aggressive female politician'. Her communication carefully balances stereotypes. On the one hand, she avoids using open confrontation often typical of male politicians like Trump. On the other hand, she uses rhetorical toughness to assert authority. This reflects the double standards in how female leaders are perceived, as they must blend decisiveness with socially expected restraint.

Threats in Nancy Pelosi's speeches serve two key functions: to mobilize supporters and discredit opponents. The threat is not just a tool of confrontation, but a complex mechanism that allows the speaker to navigate gender expectations, political strategy, and ideological conflict. Pelosi's experience highlights that in the modern media landscape, even indirect strategies can become a powerful weapon in the struggle for power and influence.

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