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APPLICATION OF ARTIFICIAL INTELLIGENCE METHODS IN FORECASTING AND SELECTING OPTIMAL OPERATING FREQUENCIES FOR THE SHORTWAVE RADIO RANGE

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Abstract. This article analyzes the scientific and practical advantages of using artificial intelligence technologies in the process of forecasting and selecting optimal operating frequencies in the shortwave radio range. The quality of signal propagation in shortwave communication systems depends on many factors, such as the state of the ionosphere, solar activity, day and night, seasonal changes, and geographical conditions. Therefore, determining the operating frequency based on traditional methods may not provide sufficient accuracy in some cases. Artificial intelligence, in particular, using machine learning and neural networks, makes it possible to perform a comprehensive analysis of historical radio communication data and ionosphere parameters, predict frequency changes, and automatically select the optimal operating frequency. The study highlights the importance of using artificial intelligence in increasing forecast accuracy, ensuring communication stability, reducing operator workload, and effectively using frequency resources. This approach serves to increase the reliability of emergency communication, aviation, military, and long-range radio communication systems.

Keywords: shortwave radio communication, operating frequency, artificial intelligence, machine learning, neural networks, ionosphere, frequency forecast.

Today, the correct choice of the operating frequency is one of the important scientific and practical issues in ensuring the stability and reliability of radio communication systems. In particular, in communication systems using the short-wave radio range, the signal propagation characteristics directly depend on factors such as the physical state of the ionosphere, solar activity, daily and seasonal changes, atmospheric conditions, and communication distance. The constant change of these factors complicates the process of determining the optimal frequency in advance.

Traditional forecasting methods often use limited parameters and previous observation results. As a result, the ability to quickly adjust the frequency in real time may not be sufficient. From this point of view, the use of artificial intelligence technologies that can process large amounts of data and identify complex relationships is becoming increasingly important.

Machine learning algorithms based on artificial intelligence allow for a comprehensive analysis of ionospheric indicators, meteorological data, solar activity, and previous radio communication results to predict the optimal operating frequency. This approach creates new opportunities to improve communication quality, reduce interruptions, and effectively use frequency resources.

Short-wave (SW) radio communication systems are characterized by the ability to transmit information over long distances. The propagation of a radio signal in this range depends mainly on the reflection and refraction properties of the ionosphere. Therefore, the frequency selected for a particular region and time may not provide the same efficiency in another time interval or in another geographical direction.

The optimal operating frequency is the frequency value that provides sufficient signal strength, minimal noise, and stable transmission in the communication channel. If the frequency is selected incorrectly, the signal may not be sufficiently reflected from the ionosphere, be absorbed, or be distorted by noise.

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For example, if the operator has established stable communication at a frequency of 8 MHz, the signal quality at this frequency may decrease as a result of changes in solar activity or the state of the ionosphere. An artificial intelligence system can predict such a change in advance based on previous observations and recommend, for example, a frequency in the range of 9–10 MHz. As a result, the stability of the communication channel is maintained[1].

Determining the optimal frequency in the QT range is a multi-parameter issue. It requires taking into account several factors together. In particular, solar activity, electron density in the ionosphere, day and night conditions, season, geographical coordinates, radio communication distance, antenna characteristics and electromagnetic noise level are important factors.

When solar activity increases, significant changes occur in the degree of ionization of the ionosphere. This affects the propagation conditions of radio waves. The propagation mechanism of a radio signal can also be different during the day and at night.

For example, a frequency of 6 MHz may provide stable communication in a certain direction during the day, but at night another frequency, for example, 10 or 12 MHz, may be more effective. In this case, instead of choosing a frequency based solely on the operator's experience, an artificial intelligence model analyzes the available data in near real-time mode and generates suitable frequency options.

The main advantage of artificial intelligence is the ability to identify complex relationships between large amounts of data. Signal strength, noise level, frequency, distance, ionospheric indicators and other parameters received at different times in QT radio communication form a large data set.

The machine learning algorithm uses this data to learn which frequency provides the highest efficiency under certain conditions. The input data to the model can be time, geographical coordinates, solar activity, ionospheric parameters, selected frequency and signal quality. The output will be the recommended optimal frequency.

For example, let the system be fed with data on the signal quality received at frequencies of 5, 7, 9, 11 and 13 MHz over the past few months. As a result of the model analysis, it can determine that the 9 MHz frequency showed the highest stability at a certain time and direction. In the next similar conditions, the system will recommend the 9 MHz frequency to the operator as a priority option[5].

Neural networks are one of the promising tools for optimal frequency forecasting. They are able to identify nonlinear relationships between a large number of parameters. Especially in situations where ionospheric conditions change frequently, models based on neural networks can provide useful results.

Such a system can be conditionally divided into three stages. In the first stage, data on radio communications and the ionosphere are collected. In the second stage, the data is cleaned, normalized and prepared for training the model. In the third stage, the neural network predicts future communication conditions based on the available parameters and determines the optimal frequency.

For example, a neural network can determine the following relationship from previous observations: when solar activity exceeds a certain level, the distance is about 1500 km, and the time falls on the evening hours, the signal quality at 10 MHz is higher than at 7 MHz. If similar parameters appear in subsequent observations, the system can recommend a frequency of 10 MHz.

With the help of artificial intelligence, an algorithm can be developed in the optimal frequency selection system, which includes several stages. First, current data is obtained from the radio communication system. Then they are transmitted to the artificial intelligence model. The model analyzes the available parameters and evaluates the efficiency of possible frequencies.

Conditionally, the efficiency of frequency selection can be assessed based on the following indicators:

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$S = w_1Q + w_2R – w_3N – w_4A$

where S is the overall efficiency indicator; Q is the signal quality; R is the communication stability; N is the noise level; A is the signal attenuation level; w_1, w_2, w_3, w_4 are the weighting coefficients of the corresponding indicators.

The model can calculate the value of S for different frequencies and select the frequency with the highest result as the optimal option.

For example, let the following conditional results be obtained for three frequencies: S=0.72 for 7 MHz; S=0.86 for 9 MHz; S=0.78 for 11 MHz. In this case, the system selects the frequency of 9 MHz. This will be a decision based not on the subjective decision of the operator, but on a comprehensive analysis of the available data[2].

The use of artificial intelligence in the QT radio range provides a number of important advantages. First, the speed of the forecasting process increases. Second, it becomes possible to analyze large amounts of data at once. Third, the operator's manual calculations are reduced.

Another important aspect is the flexibility of the system. When ionospheric conditions change, the model can update its recommendations based on new data. This is especially important in systems that require long-range and continuous radio communication.

In addition, frequency selection based on artificial intelligence helps to rationally use the electromagnetic spectrum. In conditions where there are several communication channels, the system increases the efficiency of using radio resources by selecting a frequency with less noise and higher signal quality.

The technology of forecasting optimal operating frequencies in the QT range based on artificial intelligence can be used in long-distance communication, aviation, maritime transport, emergency communication, scientific observation and other special radio communication systems.

For example, in an emergency situation, when the existing communication infrastructure is limited, the QT radio communication system can be used to transmit important information over long distances. In such a situation, fast and correct frequency selection directly affects the efficiency of communication. The artificial intelligence system can analyze real-time data and recommend the most optimal option from among the available frequencies.

Thus, the integration of artificial intelligence technologies into QT radio communication systems allows you to automate the frequency selection process, increase forecast accuracy and quickly adapt to changing radiophysical conditions. In the future, combining such systems with real-time monitoring, automatic frequency control and adaptive radio communication technologies will serve to create more efficient radio communication systems[6].

In conclusion, the use of artificial intelligence technologies in the forecasting and selection of optimal operating frequencies in the shortwave radio range creates significant opportunities for increasing the efficiency and stability of radio communication systems. Since the propagation of shortwave signals depends on many factors, such as the state of the ionosphere, solar activity, diurnal and seasonal changes, and geographical conditions, accurate frequency selection is a complex process.

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