ABSTRACT

for dissertation for the PhD degree specialty 6D071900 - "Radio engineering, electronics and telecommunications" of

MANBETOVA ZHANAT DUSENBAYEVNA

Research of methods of protection against electromagnetic fields of cellular communication

Relevance of the dissertation research. Today, cellular networks are the undisputed leaders in terms of the number of subscribers and the volume of traffic generated. The operation of base stations and cell phones contributes to the negative impact on the electromagnetic environment. The regulatory documents of the Republic of Kazakhstan regulate the requirements for radio frequency electromagnetic radiation. Electromagnetic radiation is a factor that adversely affects health. The installation and operation of a cellular networks base station, as well as the level of permissible electromagnetic radiation as a result of their operation, are strictly regulated by the legislation of the Republic of Kazakhstan and controlled by authorized state bodies. The placement of the stations is planned in such a way as to minimize the impact on the population of electromagnetic fields during their operation.

Electromagnetic pollution of the environment has become a serious problem due to the increase in the number of electronic means. Every year, the number of cellular base stations installed in cities and metropolitan areas are also growing, and the development of cellular network systems and services is accompanied by an intensive increase in the spatial density of cell phones. Near the location of the base station, there is often other equipment that creates electromagnetic radiation, radio interference. Therefore, at the moment, the electromagnetic ecology of the environment is deteriorating and the electromagnetic safety of the population is declining due to the intensive penetration of cellular networks into the sphere of human activity with a significant expansion of radio channel bands (up to 20-160 MHz), an increase in data transfer rates up to 5-10 Gbit / s in base station radio channels and territorial density of cellular traffic up to 10 Mbit/s/m^2.

Cellular networks cover the frequency ranges of standards from the 2nd to the 5th generation of technologies, so the electromagnetic environment it creates will be a complex superposition of fields that differ in frequency properties, spatio-temporal structure, and energy characteristics. This circumstance forms the multi-frequency spectral composition of radio emissions in the environment, and the combination of radiation from different standards and cellular radio technologies with different variants of signal modulation frequencies is essential from the point of view of the biological effect of electromagnetic radiation. The biological activity of individual sections of the spectrum can differ dramatically - for 4G and 5G networks, the spectrum width is 10% or more of the central frequency. The electromagnetic

radiation of newly introduced cellular network systems is superimposed on the electromagnetic radiation of existing radio-electronic means for various purposes.

Cellular networks are used in IT communications in a variety of variations and use cases, and in the future, they will be used more and more often due to ubiquitous connectivity and mobility. Any radio transmitting and / or radio receiving devices have a biologically hazardous zone, which is located around the directional beam. At the boundary of this zone, the energy flux density is maximum and equal to the maximum allowable value. Therefore, depending on the power of the electromagnetic radiation device, it becomes necessary to assess the hazardous area and for the safe operation of the personnel serving them.

Electromagnetic safety as a social problem requires the conflict-free development of cellular communication technologies in the interests of the population. Therefore, the urgency of the problem of studying methods of protection against electromagnetic radiation of cellular communications increases sharply. Fulfillment of all requirements to ensure the protection of the population from electromagnetic radiation is becoming an increasingly difficult task: a large number of transceivers for various purposes, operating in different frequency ranges and located within the biologically hazardous zone. There are also many surfaces that reflect electromagnetic radiation. This circumstance determines the need to develop effective methods for predicting the radius of a biologically hazardous zone and the zone of influence of electromagnetic radiation of the main and side radiation of a cellular base station in case of electromagnetic pollution of the environment by cellular communication systems. This will make it possible to solve one of the important tasks of cellular communication - to determine the conditions for reducing radiation exposure by users of cellular communication services.

It is extremely difficult to take into account all the nuances when assessing the level of electromagnetic radiation generated by cellular networks, and it is not always possible to analyze by analytical methods. In many practical cases, data is easy to collect, but dependencies and relationships are difficult to ascertain. Further development of modern cellular communication technologies is in the direction of expanding the use of the spectrum in frequency bands, the biological effect of which has not been studied. All this complicates the processes of monitoring the electromagnetic radiation of cellular networks, increases their complexity and disorients. It is quite difficult to predict the real picture of the electromagnetic radiation of a cellular base station for a specific area. Therefore, to facilitate the solution of the problem and accurately assess the level of electromagnetic radiation of a cellular base station, a fuzzy logic mechanism is used, which also allows solving the difficult task of determining dependencies and relationships in the collected data to predict the electromagnetic situation. Therefore, to solve the problem of predicting the radius of the biologically hazardous zone of sources of electromagnetic radiation in cellular network, a mathematical model is needed that takes into account the nonlinearity in forecasting.

The development of a method for determining the radius of a biologically hazardous zone of a cellular base station based on fuzzy logic serves as a scientific and technical solution for a way out of this situation. Fuzzy models allow taking into

account the uncertainty of input data about the properties of surrounding objects, while being able to ensure decision making in a minimum amount of time. The use of fuzzy logic is advisable in cases of enormous complexity of the object under study, its non-linearity, complexity of formalization, and in situations in which information sources are interpreted qualitatively, inaccurately or indefinitely.

The research purpose: to predict the radius of a biologically hazardous zone of a cellular base station.

The research objectives. To achieve this goal and in accordance with the subject of research, the following tasks are solved within the framework of the dissertation work:

- to analyze and obtain the results of an experimental assessment of real electromagnetic radiation generated by cell phones and Wi-Fi routers that offload traffic of cellular communication networks;
- search and study of alternative types of domestic shielding materials that minimize the negative impact of electromagnetic radiation from cellular communications;
- to determine the technical parameters of the base station of cellular networks, necessary for predicting the radius of the biologically hazardous zone;
- to develop a mathematical model of a fuzzy system for predicting the radius of a biologically hazardous zone of a cellular base station;
- calculate the radius of the biologically hazardous zone of a cellular base station using a fuzzy MISO system.

The object of research is networks and systems of cellular network.

The subject of the research is methods of protection against electromagnetic radiation of cellular network.

The research methods. The methods of the electromagnetic field theory, as well as methods for transforming input data using fuzzy logic and the method of fuzzy set theory were used as research methods. The Fuzzy Logic Toolbox software package (fuzzy logic package in the Matlab environment) was used as simulation tools, and programming in Matlab was used to process the simulation results.

Scientific novelty:

1. Experimental studies of domestic radio-absorbing materials, in particular, koksu shungite rock, were carried out for the purpose of absorption/attenuation of electromagnetic radiation. In the course of research, the results of the interaction of electromagnetic radiation with samples of absorber materials and the dependence of the transmission coefficients on the angle of incidence of electromagnetic waves in the frequency range of 5-6 GHz were obtained.

The creation and application of domestic wide-range absorbers of electromagnetic radiation with controlled characteristics with predetermined values of transmission and reflection coefficients is proposed.

2. A mathematical model has been developed for determining the radius of a biologically hazardous zone during the operation of cellular communication systems and networks, based on a system of equations with fuzzy cause-and-effect relationships and allowing to analyze methods for protecting biological objects from the effects of electromagnetic fields of cellular communication, showing the ability to

predict the maximum direction of radio emission from electromagnetic source in real time.

3. The resulting 3D model of the surface of the biologically hazardous zone of the cellular network base station has been obtained. The accuracy of the resulting fuzzy model using triangular membership functions to determine the radius of a biologically hazardous zone is higher by 1% compared to the fuzzy model with sigmoid membership functions, and by 4% compared to the regression model.

The theoretical value of the research results is that they can be used to:

- development of algorithms for determining the radius of a biologically hazardous zone for cellular communication systems 4G and TV, broadcasting ;
- science-based planning to ensure the radius of the biologically hazardous zone for cellular network services, including for prompt intervention in the event that the level of electromagnetic radiation exceeds the standard values provided for in the SaniP and relevant documents of the Republic of Kazakhstan on electromagnetic safety;
- an objective assessment of the probability of exceeding the level of electromagnetic radiation in the radio coverage area of a cellular base station and making a decision on planning measures to neutralize possible dangerous levels of electromagnetic radiation.

The practical significance of the research.

1. One of the effective way in the complex problem of protecting the population and objects from the electromagnetic radiation of cellular network is the use of a shielding composite material. The experimentally obtained actual numerical values of the parameters, indicating the radio-absorbing properties of Koksu shungite materials (allowing to reduce the level of external electromagnetic radiation), represent the factual basis for the development of a composite element / screen (or absorbing coating) from domestic shungite rock.

2. The results of experimental studies in the determination of the radius of the BHZ of a cellular base station can contribute to:

- organization of effective protection and the ability to control the electromagnetic environment created by modern cellular network systems;
- improving the electromagnetic ecology of the environment and the electromagnetic safety of the population/service personnel during the full-scale implementation of 4G/5G cellular network systems;
- an objective assessment of the level of electromagnetic safety of the population / service personnel in real time near and / or within the radius of the biologically hazardous zone.

The main provisions for defense:

- Was established a method for effective protection of the service personnel of the population from exposure to electromagnetic radiation using a composite material based on shungite Koksu deposit of the Republic of Kazakhstan;
- Was used in the educational process of the mathematical model of the MISO system, which works on the basis of the mamdani algorithm for the radius of a biologically hazardous zone in the MatLab computer system;

- The quality of the design was evaluated using two static coefficients: the average absolute error in percentage value MARE (mean absolute percentage error) and accuracy.

Personal contribution of the author.

The main experimental and theoretical results obtained during the dissertation research were obtained by the author independently.

Approbation of dissertation results. The main results of the dissertation research were reported and discussed at: International scientific conference: "International Conference on Information Science and Communications Technologies ICISCT 2019", Tashkent; V International scientific and practical conference "SCIENCE AND EDUCATION IN THE MODERN WORLD: CHALLENGES OF THE XXI century" (Kazakhstan, 2019); V International scientific and practical conference "Europe and the Turkic world: science, technology and technology", in Ankara (Turkey, 2020); XV International Scientific Conference "Gylym jáne bilim - 2020" (Kazakhstan); XI International scientific and technical conference "Energy, infocommunication technologies and higher education" (Almaty, 2020)

The practical significance of the work. The results of the study of the dissertation work were carried out at the Almaty University of Energy and Communications named after G. Daukeev, laboratory of the University of Information Technologies. Mohammed Al-Khorezmi, the center "Almaty branch" LLP "KazCEP" (Kazakhstan Center for Environmental Design).

The practical significance of the dissertation work lies in the use in the educational process and the results of implementation in production.

The mathematical model proposed in the dissertation was used in the calculations of construction and installation design work, which made it possible not only to describe the boundaries of the biologically hazardous zone, but also to increase the reliability of the results obtained and introduced into production. It was introduced into the educational process when conducting lectures, practical, laboratory classes for master's students, bachelors in the specialty "Wireless networks", "Wireless communication", "Mobile communication system" of the University of Information Technologies named after Muhammad Al- Al-Khorezmi (Appendix A), KazCEP LLP" Almaty branch" (Tashkent, Republic of Uzbekistan).

Publications. The main results of the dissertation research were reflected in 14 scientific papers, including 5 publications in journals The Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan (KOKSON MES RK) in 3 papers reflected in foreign (indexed in the Scopus database), 6 publications in the proceedings of international conferences.

The volume and structure of the dissertation.

The dissertation consists of an introduction, definitions, designations and abbreviations, 4 sections, conclusion, applications. The work is presented on 104 pages, contains 22 figures, 20 tables and 112 bibliographic sources.

The introduction reveals the relevance of scientific work, describes the problem under study. The main idea, scientific novelty, personal contribution of the author, as well as the results of research and approbation of the publication are given.

The first section presents an analysis of the current factors influencing approaches to protection against electromagnetic radiation of cellular communications. When developing the theory and practice of electromagnetic security, the features of radio frequency bands for the deployment of 5G networks from modern trends were studied.

A practical solution is proposed to reduce the intensity of the acting electromagnetic field by using a scheme for connecting a standard handset for an electronic stationary telephone to a smartphone, which makes it possible to remove the radiation source from the user's head.

The second section an experimental study of the radiation power from some modern mobile radiotelephones and a comparison of these indicators with the standard level, as well as electromagnetic radiation from Wi-Fi routers, was carried out. This experimental work is based on a technique that allows you to determine the average radiation power from a mobile radiotelephone.

In the Republic of Kazakhstan, permissible excesses of the normalized values of factors at workplaces and the maximum permissible level for electromagnetic radiation have been established. Based on the research results, practical recommendations have been developed on how to protect against the influence of electromagnetic radiation while talking on a mobile phone.

The third section discusses the properties of electromagnetic radiation absorbers formed on the basis of the domestic natural material of shungite rock from the Koksu deposit. The results of the interaction of electromagnetic radiation with samples of absorber materials and the dependence of transmission coefficients on the angle of incidence of electromagnetic waves in the frequency range of 5.6 GHz are obtained. Research in these frequency ranges is very important and relevant with the development and transition in the future of mobile cellular communication systems and networks of promising generations to higher radio frequency ranges. It has been established that shungite-based composites are able to endure the attenuation of electromagnetic radiation in the range of microwave electromagnetic radiation. Taking into account the characteristics of shungite rock taurite in the microwave range and the ability of these materials, separately or as part of composites, to attenuate microwave electromagnetic radiation, it is possible to create domestic wide-range absorbers of electromagnetic radiation with controlled characteristics (for example, by selecting the type and concentration of the filler, binder, the order of alternation of layers with different electrical conductivities, etc.), with predetermined values of transmission and reflection coefficients.

The use of a promising class of metamaterials as screens and other additional metal structures will significantly expand the methods for ensuring the electromagnetic compatibility of cellular networks.

The fourth section, it is proposed to use a mathematical model that takes into account nonlinearity when predicting the radius of a biologically hazardous zone. Fuzzy logic was used to simulate the calculation of the radius of a biologically

hazardous zone in the study. The Mamdani algorithm was used as a fuzzy inference model. The following approach was presented for solving the problem of constructing a forecast for the radius of a biologically hazardous zone using fuzzy inference: input variables are fed to the input of the fuzzy inference system (in our case, two input variables are the antenna gain and the antenna rotation angle). These variables are treated as real variables of the control process. At the output of the control system, the control variables of fuzzy logical inference are formed (in our situation, one control variable is the radius of the biologically dangerous zone of cellular communication). Using the apparatus of fuzzy sets in predicting the radius of a biologically hazardous zone allows you to systematize disparate information and relationships between objects in the system. By specifying binary relations between cellular network objects in various ways, it is possible to reveal hidden patterns and connections, which will make it possible to more accurately assess the degree (level) of electromagnetic security of the entire cellular communication system.

The results can be used to assess the probability of exceeding the level of electromagnetic radiation in the radio coverage area of base stations, making a decision on planning measures to neutralize possible dangerous levels, including for prompt intervention in case the level of electromagnetic radiation exceeds the standard values provided for by the SaniP. Also, the results of these dissertation research may be useful in choosing the "last mile" technology, as well as for determining / evaluating the survivability of wireless subscriber access networks.

The conclusion reflects the main results and conclusions of the dissertation work.