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Formulation of the Problem of Mathematical Modeling of Accommodation of Basic Stations of Cellular Communication in Residential Territories for Students of it-Directions of Preparation

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Abstract: The relevance of considering the issues of mathematical modeling in the preparation of students of IT-directions is due, primarily, to the trends in the development of the sector of artificial intelligence, modeling in general. Today it is clear that the use of mathematical models for the study and prediction of various processes and conditions, can significantly reduce the cost of introducing new technologies and products, as well as significantly reduce the time for implementation and testing. This led us to the conclusion that close attention should be paid in teaching students of the IT areas of training both in modeling methods and in setting modeling problems, analyzing source data and building interconnections in designing models. The article discusses the general concept of the formulation of the problem of mathematical modeling on the example of modeling the location of cellular base stations in residential areas. The basic principles of estimation are considered, each of which can be detailed depending on the tasks set to the required depth. Based on the selected criteria and characteristics, KPIs and a system of indicators can be compiled, which can be used to solve various problems of electromagnetic hazard analysis. Currently, we can only talk about intermediate results of the study. The study is ongoing at the time of this article. However, the results can be successfully used in teaching students of IT-areas of training in mathematical modeling.

Index Terms: mathematical modeling, teaching at university, teaching students, information technology, mathematical model, base stations, cellular communication, placement model, geometric model.

I. INTRODUCTION

For more than three decades, scientists around the world have been concerned about and occupied by the effects of electromagnetic fields and radiation on the human body and other living organisms. This problem acquired particular urgency at the beginning of the twenty-first century, when the cellular communications sector began to grow at a tremendous pace, cell phones became accessible to a wide range of consumers, and as a result. The number of cell phone towers - base stations (BS) - has rapidly increased in residential areas, that is, territories intended for land intended for the construction of residential and public buildings, roads, streets, squares within cities and urban-type settlements.

On the one hand, mobile operators are concerned about optimizing their placement within the cellular network and other applications [1][2]. The solution to this problem depends on many different, often unrelated factors. The quality and stability of the signal will depend primarily on how the BS will be networked. However, as it may seem at first glance, this does not reduce the task of mathematical modeling of BS placement to a simple geometric placement problem. Among other factors that need to be taken into account when placing the BS, one of the most important is the degree of electromagnetic radiation. Therefore, the layout of placements is reduced to minimizing the number of BSs, covering the required coverage area as much as possible and maximally ensuring subscriber access to the network, as well as minimizing the impact on residential areas. This leads us to the thesis of the need and practical relevance of preliminary mathematical modeling of the level of exposure to electromagnetic radiation on the population and workers in residential areas. In the context of training students of IT-areas of training, it is interesting to set the task of mathematical modeling of the location of cellular base stations in residential areas, since it is multifactorial and allows you to look at it with different initial data, which allowed us to choose it as an actual topic for scientific practical research. In the training of students of IT-areas of training, the construction of mathematical models is a fundamental educational practice, since it lays the basis of the algorithmic thinking necessary for them in their professional work. Much attention is paid to mathematical modeling in the preparation of bachelors and masters of IT-areas of training.

II. METHODOLOGY

A mathematical model can be described using a mathematical equation or a series of mathematical equations that represent the relationship between quantitative variables [3][5].

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The purpose of building a mathematical model is to develop a model that would provide an accurate but relatively simple representation of reality — the behavior of students as part of the educational process. Mathematical models are widely used in science to explain the nature of phenomena and prediction. Behavioral researchers develop mathematical models to represent descriptive theories using mathematical concepts. One of the key advantages of the development of mathematical models explaining theories is the verification of theoretical statements and an assessment of the extent to which the models correspond to the empirical data collected to study a specific field of study. The layout of the BS in the general case can be described using two conditions [6]. The first is the condition of minimizing the number of BS and, as a result, their total cost:

$$\min \sum_i C_i \cdot K_i$$

where Ci is the cost of the i-th station; Ki is the number of stations of the i-th type.

The second condition is the condition of maximum coverage of a given territory [1]:

$$\min_{(a,b)} \frac{1}{\pi \cdot R^2} \int_{(x-a)^2+(y-b)^2 \le R^2} P(x,y)\,dx\,dy \ge P_0, \quad R = 5$$

where P (x, y) is the signal power at (x, y); (a, b) - coordinates of the deviation from the point (x, y).

This condition means that the average power in a zone with a radius of 5 m is not lower than the specified power. The author in [6] set the target radius to 5 meters, so we present this formula without changes, but in fact, in the interests of the computational model or any research, this radius can be changed and set based on the specified conditions.

III. RESULTS

In this article, we consider the formulation of the problem of mathematical modeling of the deployment of cellular base stations in residential areas for students of IT training areas. This formulation is due to the fact that an important aspect of the location of the BS is that the majority of any computer equipment, in turn, has its own, often significant, electromagnetic radiation. For example, in modern treatment of various diseases, physiotherapeutic methods are widely used [7]. The therapeutic effect of many devices on the patient's body is achieved precisely by the electromagnetic field of a certain frequency and intensity. That is why in medical institutions there are strict requirements for facilities, equipment operation, and the procedures for conducting the procedures themselves.

The staff of physiotherapy departments (PEF) must undergo mandatory medical examinations when they come to work, as well as periodic medical examinations once a year and once every 2 years, depending on the frequency range of the device in accordance with the order of the Ministry of Health and Social Development of 12.05.2013 № 302n [8]. It is indicative that, in order to comply with the safety measures, patients and employees of FTO should be divided into cabins shielded from each other and from the corridor with special shielding material. According to the same order, “There are also requirements for the size of the booths in all three dimensions: height - not less than 2.0 m; length - not less than 2, 2 m; width - not less than 1.8 - 2.0 * m (for inductothermy, MKV-therapy, UHF-generators with a power of more than 200 W, the width of the cabin must be at least 2.0 m). The number of devices and patients in one cabin should be no more than one. ”

“Any medical equipment used in the FTO must be certified by means of a certificate of conformity, passport, have registration certificates and be regularly monitored for proper operation (electrical connection, grounding, equipment serviceability) with mandatory documentary confirmation of the test results (inspection report or mark maintenance log) ”[7]. All this speaks of the seriousness of the task. In such conditions, the cross-electromagnetic radiation from nearby BS can create and multiply adverse effects on the personnel of medical institutions and even on patients who are there occasionally. With continuous exposure, it can lead to the emergence of dangerous diseases of varying severity. According to available research, even a short-term exposure to electromagnetic fields with excess of the maximum permissible level can lead to headaches, nausea, turbidity of consciousness [8], [9], [11].

According to the standards in force in Russia, base stations (BS) are “radio receiving and transmitting objects emitting electromagnetic energy in the UHF range (500-1800 MHz)" ... .. "against the background of a higher frequency of complaints of irritability, drowsiness or insomnia, headaches pain, etc., among persons residing or working in residential areas in the immediate vicinity of the BS, changes in the state of the nervous, cardiovascular, neuroendocrine systems were observed beyond the limits of the norm ”[12]. Therefore, when defining the boundaries of the so-called sanitary zone, the BS installation requires measurements at many points, usually they are performed along certain measurement paths (routes), and other permanent sources of electromagnetic radiation are taken into account, as is the case with medical institutions. In order to simulate the impact, the area where the BS is installed is divided into sectors, in each of which a measurement trajectory that is radial with respect to the object is selected. A register of measurement points is compiled. The compilation of a register of measurement points is determined by the need to exclude exposure of the population at the places where it is located, both within and outside the sanitary zone, and also to exclude duplicate radiation, cross-electromagnetic radiation.

Consider the task of locating the minimum number of BSs, taking into account the topography and population density in the area where the health care facility is located. We will write in more detail the condition for minimizing the number of BS:

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$$\ddot{I} = \frac{1}{|G|} \cdot \iint_{x,v \in G} N(x,y)^{-1} \cdot P(x,y)\,dx\,dy \geq P_0$$

$$N(x,y) = \left[\frac{n(x,y)+1}{L}\right], L = 8; N(x,y)$$

where G is the area of coverage; $N(x,y) = \left[\frac{n(x,y)+1}{L}\right], L = 8; N(x,y)$ – call density. This takes into account the fact that the base cell has 8 channels [1].

Given this fact, you can write down in the same

$$\ddot{I} = \min_{(a,b)} \frac{1}{\pi \cdot R^2}$$

way:

$$\int_{(x-a)^2+(y-b)^2 \leq R^2} N(x,y)^{-1} P(x,y)\,dx\,dy \geq P_0$$

what actually determines the average signal power over a circular zone of radius R centered at (a, b). This allows, by measuring, to determine the total cross-electromagnetic radiation in the residential area where the health care facility is located. The task in this formulation has a clear practical orientation, which has a positive effect on the formulation of relevant competencies among students of IT training areas. Previously, many scholars and practitioners studied this issue, which made it possible to propose also a formula for a pessimistic estimate of the average total intensity of electromagnetic radiation generated at the observation point at the earth's surface by the entire set of N BS cellular communications randomly located in relation to observation points in its vicinity as a zone of free propagation of radio waves between the BS and a specific point of observation, and the area of interference propagation of radio waves between them

$$Z_{\Sigma BS} \approx \frac{L_{TBS}}{2} \ln\left(\frac{6{,}6 \cdot H_{OP}}{\lambda}\right), L_{TBS} =$$

$$= \rho_{BS} P_{eBS}, Z_{\Sigma BS} = \sum_{i=1}^{N} \left|\ddot{I}_{BSi}\right|, E_{\Sigma BS} =$$

$$= \sqrt{120\pi Z_{\Sigma BS}}$$

[8]:

где $Z_{\Sigma BS}$ –

where $Z_{\Sigma BS}$ is the total EMF intensity [W / m2] generated by the BS at the observation point, defined as the scalar sum of the values of the power flux density Π_{BSi} of the electromagnetic fields of all N BS at the observation point; HOP - height of the observation point above the surface; λ - BS radiation wavelength; LTBS is the electromagnetic load on the territory, [W / m2], created by the BS in the vicinity of the observation point; ρ_{BS} is the mean territorial density of BS, [BS / m2], in the vicinity of the observation point; PeBS is the equivalent isotropically radiated power of BS electromagnetic radiation; E□BS is the total intensity of electromagnetic radiation in units of intensity of electromagnetic fields [V / m] (rms value). After receiving the data using the above formula, they are summarized by observation points with the obtained measurement values, and the result is already evaluated from the point of view of safety or threat to the health of people in residential areas. Taking into account the availability of publications [11], [14], [16] with the results of measurements of the intensity of electromagnetic radiation from cellular systems in various cities and countries, an assessment of the adequacy (verification) of the proposed methodology for predicting the intensity of electromagnetic radiation using the formula can be performed using published measurements, and based on estimates of the electromagnetic load on the territory created by the cellular communication BS in the places of these measurements [6], [9], [14][19]. It is advisable to carry out several (at least three) independent measurements and, as a result, take the maximum of the measured values [20][21]. The process of measuring the parameters of the electromagnetic field is a key point in the environmental monitoring of telecommunications companies and requires increased attention and careful preparation [6], [9], [22],[26].

IV. CONCLUSION

The task of optimal placement of the minimum number of BS is reduced to the solution of both problems considered. The resulting relationships can be used to solve problems by the method of simulation. The state system for monitoring the electromagnetic environment is currently absent in Russia. Systematic observations are carried out only on individual objects, less often in relatively large separate residential areas. However, the application of the formulas given in the article and the observance of the measurement procedure will allow simulating the radiation level even before installing the BS near residential areas subject to risks of exceeding the permissible level of electromagnetic radiation. The organization of current control in accordance with the requirements of the sanitary rules, with subsequent analysis of the data obtained in the format of mathematical models, will ensure the prevention of harmful and dangerous diseases of the population and individuals working in residential areas. A preliminary study of the background electromagnetic radiation in residential areas where BS installation is planned would be desirable. Unfortunately, as long as it is not regulated at all at the legislative level, the majority of mobile operators proceed only from the geometric parameters of coverage to ensure the quality of customer service. It is not uncommon for residents or staff of organizations located in residential areas to conduct, at their own expense, an expert assessment of the level of electromagnetic radiation, which indicates that standards are exceeded. As a result, the BSs are dismantled after long litigation, which causes serious damage to mobile operators. The use of a cellular base station location model in the vicinity of various sites will, in the first place, prevent damage to public health, but.

In addition, minimize the costs due to violations during installation of the BS. As for the pedagogical aspect of the problem of mathematical modeling of the location of cellular base stations in residential areas for students of IT-training areas, the practice-oriented nature of this task, its research value is important. If we turn to professional standards in the field of information technologies, as well as to the corresponding GEF, then we will see that mathematical modeling, the ability to summarize and describe data, to parameterize are among the key competencies required from modern specialists in this field.

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