Assessment of Electromagnetic Background Levels from Base Stations of Mobile Networks from the Point of View of Technosphere Safety

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Abstract. The growth of communication networks gradually leads to the fact that they become an integral part of the infrastructure of the city. Depending on the features of the building and the location of settlements, the distribution of communication objects may be formed non-uniformly, which leads to a possible deterioration of the electromagnetic environment. This process is difficult to evaluate and predict. The safe coexistence of transmitting radio engineering facilities and residential and administrative buildings is regulated by sanitary norms and rules. The fulfillment of these requirements must be confirmed by appropriate calculations and direct measurements of electromagnetic fields. According to the results of computer modeling and control measurements, the article analyzes the parameters of electromagnetic fields created by cellular communication transmitters near residential buildings. It is concluded that it is necessary to introduce construction restriction zones into the draft urban development plan and continuous monitoring of radiation levels in residential buildings.

1. Introduction
The effect of electromagnetic radiation (EMP) on living organisms has long been studied by biologists and physicians. However, with the increase in the number of transmitting radio engineering objects (RTOs) operating at very high and ultra-high frequencies located within the city, the question arose of assessing the harmful effects on the environment and human health from the point of view of technosphere safety. In the Russian Federation, the standardization of EMR parameters depending on the operating frequency ranges of equipment was established in 2003 in the sanitary-epidemiological rules and standards - SanPiN 2.1.8/2.2.4.1383-03 "Hygienic requirements for the placement and operation of transmitting radio-technical objects" and SanPiN 2.1.8/2.2.4.1190-03 "Hygienic requirements for the placement and operation of land mobile radio communications." Also in these documents the types of radiating objects, the places of possible placement of the PRTO, as well as the maximum permissible level standards (PDU) of the EMP are determined.

In this regard, a project is being developed for any transmitting object, in which the maximum possible boundaries of the construction restriction zones (ZOZ) are modeled taking into account the
technical characteristics of the equipment, as well as the existing buildings and terrain features. Accredited inspection bodies carry out sanitary examination of projects, on the basis of which measurements and the issuance of permits upon commissioning are then carried out.

In accordance with paragraph 3.16 of the Sanitary Rules and Regulations 2.1.8 / 2.2.4.1383-03, the concept of "building restriction zone" (ZOZ) is introduced. This zone is a region of space, at the outer borders of which are more than 2 m above the surface of the earth, EMF levels do not exceed the maximum permissible level. This definition applies solely to the location of the HWP, in contrast to the definition of a sanitary protection zone (SPZ), which in ecology is applied to various areas of anthropogenic pollution. SPZ is a special territory with a special regime of use, which is established around facilities and industries that are sources of impact on the environment and human health [12, 13, 14].

2. Features of the formation of building restriction zones
The main source of electromagnetic radiation in cities is the base stations (BS) of mobile networks. The deterioration of the electromagnetic background in cities became most significant during the transition to the standards of the third generation of communication (3G), because design features did not lead to a replacement, but to an increase in the number of radiating equipment, as a result of which the construction restriction zones increased and continue to grow along with the development of 4th generation networks.

A feature of the distribution of the electromagnetic field from the PRTO is the non-fixed power of the BS. The software packages for the analysis of the electromagnetic environment do not take into account all the factors that negatively affect the propagation of radio waves: parameters of the subscriber unit, features of the terrain and building areas, variability of weather conditions. Therefore, forecasting the level of pollution is not accurate, especially for cities with difficult terrain, such as Vladivostok.

The location of the ATP BS largely depends on the development of the city. Even 10 years ago, the calculation of BRZ and SPZ for the designed base station in the city was not particularly difficult, since only the GSM-900 standard networks were being formed, and the imposition of SPZ from different BSs did not occur.

In addition, the number of radiation sources, the place and method of their placement enhances the electromagnetic background. Significant factors of these reasons are the heterogeneity of the relief, as well as complex development. It is difficult to provide sleeping areas consisting of ten-story multi-access houses descending in cascades along hills with high-quality communication, without being able to establish a full-fledged antenna support. Things are even worse in areas represented by Pentagontype buildings. Therefore, one can meet BS in the yards of residential buildings installed in the territories of car parks or office buildings. The disadvantage of this arrangement is the small height of the antenna suspension, and, as a consequence, the increase in the amount of space where the maximum permissible level is exceeded. Practice also shows that different telecom operators choose the same placement. This leads to a significant increase in electromagnetic radiation in the area. And if, due to the distribution of the frequency resource, the service areas of different operators do not interfere with each other, then the electromagnetic radiation from the antennas of various networks is summed up. In this case, the total value of the energy flux density should not exceed 10 μW/cm² in accordance with SanPiN 2.1.8/2.2.4.1383-03, SanPiN 2.1.8/2.2.4.1190-03.

3. Analysis of the electromagnetic environment of a given area
However, after analyzing the electromagnetic environment in the city of Vladivostok, we were faced with the fact that the results of modeling the electromagnetic environment in some areas of the city are carried out with a significant reduction in the input capacities so that the protection zone can fit into the existing building in compliance with the SanPiN requirements. Earlier in [1], an option was considered to deploy a PRTO of three BSs on the facade of a one-story administrative building surrounded by residential buildings.
Figure 1. Situational plan with the boundaries of the BRZ.

Consider a more complex version of the location of several objects and the formation of the zone. In the area of Nadibaidze st. on one/two-story administrative building placed antenna devices of four BS (Fig. 1). The antennas of two of them are located on the antenna mounts installed on the roof of the two-story part of the building, the third - along the perimeter of the facade of the building, and the fourth - at a distance of 6 m to the south on the antenna mount on the roof of the one-story administrative building. The heights of the antenna mounts are 12 and 15 meters, taking into account the height of the two-story part of the building, the antenna suspension heights vary from 12 to 25 meters. The close location of the BS leads to the formation of a common PRTO with an aggregate BRZ.

As can be seen from Figure 1, a ten-story residential development with a height of 30 meters is located from north to east. The minimum distance to it is 27 meters. Consequently, the length of the SCZ in the north-east direction should be limited by this value, otherwise the excess of the remote control will be in the building. Moreover, taking into account the distribution of the antenna installation heights and the amount of equipment, the excess can be on floors four through eight.

In Figure 1, arrows of various colors indicate the antennas of various BSs, and five of them are oriented to the northeast and east in the direction of residential development. In order for such a calculation to satisfy the SanPiN conditions and be able to pass an examination, the BS parameters are adjusted, in particular, the input power is reduced. In this direction, the supplied antenna power per standard is about 4 W; each BS operates simultaneously in three or five bands. In this case, radiation from neighboring antennas also contributes, therefore their parameters also need to be adjusted. The gain factor (gain) of the antennas and the angle of inclination also influence the formation of the SCR. KU is a technical parameter laid down by the manufacturer, which depends on the design features of
the antennas and varies slightly depending on the electric angle of the antenna. The angle of inclination is a parameter that consists of mechanical and electrical angles and affects both the lower boundary of the SPL and its length.

![Figure 2. Checkpoint Situation Plan.](image)

Given the uneven topography, the lower boundary is set in the north-western direction and is 4.9 meters. This means that the organization of a sanitary protection zone near the location of the PRTO is not required. However, due to the insignificant height of the suspension on the antenna mounts (2 meters), the roof of the building, on which three BSs are installed, gets into the emergency protection zone. The entrance to the roof must be closed, access to people who are not professionally associated with the operation of the equipment is prohibited.

Also, the project makes a point calculation of the level of energy flux density (PES) in places where it is possible to exceed the remote control (Fig. 2). The points are selected both on the street at a height of 2 meters from the surface of the earth, and in rooms on various floors, and on the roofs of buildings. As can be seen from the figure, points 5 and 7 are taken in residential buildings and counted on each floor, since the boundaries of the estimated health protection zone are quite close to the buildings. Points were also taken in three-story residential buildings located in the west. According to the results of the calculation, the DAA passes over the houses and does not fall into them. The results of calculating the total values of the PES does not exceed the remote control. The calculation method does not take into account the reflective and absorbing properties of building materials. Thus, if telecom operators fulfill the conditions recommended in the calculation, then the measured values may be less than the calculated ones.

The next step in the study is to take measurements. There are several types of instruments for instrumental control. The most effective instrument is the Narda SRM-3006 selective electromagnetic field meter. When the field environment is known, as in the so-called “joint nodes”, where several ATP operators use the same antenna ground, the device shows the total field strength and the role of each individual source, both in absolute values and as a percentage of the permissible level.

The measurements at the given control points revealed an excess at the control points No. 3 and 7 (on the 7th floor). As can be seen from fig. 3, the main electromagnetic background is formed at a
frequency of 1800 MHz, on the remaining ranges the PES level is more than unity, however, the total value exceeds the remote control. A similar situation is developing at point 7 on the seventh floor of a residential building.

Figure 3. Spectrum of PES measurements at point No. 3.

The graph shows that at a given point in time, the device gives several options for indications: minimum, maximum, current, etc. The assessment is carried out at the maximum value, since this is an indicator that at that time the load of base stations was maximum for a given period of time. Measurements were taken during the daytime. It can be assumed that the excess may be more significant in the evening hours. Comparison of calculated and measured values shows that both methods have their drawbacks. During measurements, the device captures the signals at a point, taking into account all reflective and absorbing surfaces, which cannot be taken into account in the calculations. In this case, the excess may be due to the large number of reflected signals in the LTE standard, as well as due to the operators not observing the power limits.

4. Conclusion
In each sleeping area of Vladivostok, there is a similar location for PRTO, which, even at the stage of design forecasting, “rests” on residential development. In the course of electromagnetic monitoring of cities with complex buildings and heterogeneous terrain, there is a problem of the lack of free spaces in which the formation of the health protection zone would occur without harm to human health and the environment. The need to enter the calculated design factors into the existing master plan and adjust their boundaries due to point building leads to an increase in the level of electromagnetic background. To protect the population from the effects of electromagnetic radiation, it is necessary to include in the city plan a health protection plan and introduce a ban on the construction of buildings within their borders. And also to monitor compliance with the requirements for limiting power based on calculations and to limit the minimum height of the suspension of antenna devices over underlying surfaces.

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