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ENGINEERING RISK ASSESSMENT OF ELECTROMAGNETIC SITUATION IN THE AREA OF ROSTOV-ON-DON TELEVISION CENTER

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The electromagnetic field (EMF) poses a serious threat to human life and health. The biological effect of EMF exposure in a long-term exposure accumulates. The result of this may be degenerative diseases of the central nervous system, blood cancer (leukemia), brain tumors, hormonal diseases, and malfunctions of certain organs and the human body as a whole. The purpose of the work is a theoretical assessment of the danger of electromagnetic situation in the area of Rostov-on-Don television center. The task is to determine the dangerous and harmful zone for the population due to the electromagnetic impact of the television center. The authors plan to: find the electric field strength taking into account the television center power transmitters, antenna amplification and the distance to residential facilities; determine radiant exposure at different distances from the television center; compare the results with the MPL of EMF radiant exposure taking into account sanitary and epidemiological requirements; find ways to protect residents from EMF effects. The result of the research is the theoretical assessment of the electromagnetic situation near the station. The dangerous and harmful zone for the population and the compliance with the sanitary norms and rules of placement of radio-television and radar stations №1823-78 are determined. The objects of the Zheleznodorozhny

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ИНЖЕНЕРНАЯ ОЦЕНКА ОПАСНОСТИ ЭЛЕКТРОМАГНИТНОЙ ОБСТАНОВКИ В РАЙОНЕ ТЕЛЕЦЕНТРА ГОРОДА РОСТОВ-НА-ДОНУ

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Электромагнитное поле (ЭМП) представляет серьезную опасность жизни и здоровью человека. Биологический эффект от воздействия ЭМП в условиях длительного многолетнего воздействия накапливается, в результате возможны дегенеративные заболевания центральной нервной системы, рак крови (лейкозы), опухоли мозга, гормональные заболевания, нарушения нормального функционирования как отдельных органов, так и организма человека в целом. Целью настоящей работы является теоретическая оценка опасности электромагнитной обстановки в районе телецентра города Ростов-на-Дону. Задача работы состоит в определении опасной и вредной для проживания населения зоны, возникшей в результате электромагнитного воздействия телецентра. Авторы планируют: найти напряженности электрического поля с учетом мощностей передатчиков телецентра, усилений антенн и расстояния до жилых объектов; определить энергетические экспозиции на различных расстояниях от телецентра; сравнить полученные результаты с предельно допустимым уровнем (ПДУ) энергетических экспозиций ЭМП с учетом санитарно-эпидемиологические требований; определить способы защиты жителей района от воздействий ЭМП. В результате выполненной работы: проведена теоретическая оценка электромагнитной обстановки в районе расположения станции; определена опасная и вредная зона для проживания населения; выяснено соответствие радиотелевизионных и радиолокационных станций №1823-78 санитарным нормам и district of Rostov-on-Don the inhabitants of which are exposed to electromagnetic waves are specified. Ways of protection of inhabitants from EMF are found.

Keywords: electromagnetic field, electromagnetic impact, electromagnetic environment, TV center, electric field strength, magnetic field strength, radiant exposure.

правилам размещения; указаны объекты Железнодорожного района г. Ростов-на-Дону, жители которых подвергаются облучению электромагнитными волнами; определены способы защиты жителей района от ЭМП.

Ключевые слова: электромагнитное поле, электромагнитное воздействие, электромагнитная обстановка, телевизионный передающий центр, напряженность электрического поля, напряженность магнитного поля, энергетическая экспозиция.

Introduction. Electromagnetic field (EMF) has a negative impact on human health. Factors affecting the development of pathological reactions of the organism under the influence of EMF are:

- electric and magnetic field strength;
- duration of the electromagnetic impact;
- person's age and state of health;
- air humidity;
- irradiation area (arms, legs, head, etc.));
- frequency and modulation of electromagnetic radiation.

Exposure to EMF leads to the appearance of ionic currents that flow only through the intercellular fluid, since the cell membranes are dielectrics.

Main part. Thermal and non-thermal effects characterize the biological effect of EMF in the radio frequency range. Thermal effect means an integral increase in body temperature or its individual parts under general or local irradiation. Non-thermal effect is associated with the transition of electromagnetic energy in the human body into a non-thermal form of energy in the form of a molecular resonance process, photochemical reaction, etc. Due to the fact that the biophysical properties of body tissues are heterogeneous, the absorption of heat energy causes uneven heating at the interface of tissues with high and low water content, which determines the respectively high and low absorption coefficient.

EMF most intensively affect organs with a high water content. Overheating is especially harmful for tissues with poorly developed vascular system or with insufficient blood circulation (kidneys, brain), since the circulatory system can be regarded as a water cooling system. Eye irradiation causes clouding of the lens, which manifests itself quickly enough (a few days or weeks after irradiation). Intensive electromagnetic field of industrial frequency causes malfunction of the central nervous and cardiovascular systems. In this case, there is an increased fatigue, reduced precision in movement, changes in blood pressure and pulse, heart pain, accompanied by palpitation and arrhythmia. Special attention should be paid to the assessment of individual consequences of long-term contact of the population with EMF: the development of cancer (including leukemia), diseases associated primarily with the degradation of nerve cells.

The earliest clinical evidence of the effects of electromagnetic radiation on humans is nervous system functional disorders in the form of autonomic dysfunction of neurasthenic and asthenic syndrome. Persons who have been in the area of exposure to EMF for a long time, note weakness, irritability, fatigue, memory impairment, sleep disturbance. Often these symptoms come with vegetative functions disorders. Cardiovascular system disorders are, as a rule, in the form of cardiophyshoneurosis: lability of pulse and blood pressure, tendency to hypotension, heart pains.

High-frequency electromagnetic radiation ionizes atoms or molecules in somatic cells and thereby disrupt the processes occurring in them. Electromagnetic oscillations heating cells, put molecules in thermal motion, which leads to insufficient flow of substances through membrane, and consequently, to metabolic disorders. The most sensitive to the action of electromagnetic fields are the neuroendocrinal and central nervous systems. In the latter case, there are subjective perceptions in the form of the increased fatigue and headaches. Neuroendocrinal regulation disorder affects the cardiovascular system, blood system, immunity, metabolism, reproductive function. There may also be changes in the heart rate and vascular reactions.

The literature describes changes in hematopoiesis, endocrine system, metabolic processes, and visual organs diseases. In the latter case, the thermal effect of radio-frequency radiation and microwaves leads to heating of the lens to the temperature exceeding the physiological norm, which causes the development of cataracts. This is one of the specific lesions of the electromagnetic field in the frequency range from 1.5 to 10 GHz. High-frequency electromagnetic waves also affect biological processes, breaking hydrogen bonds, which leads to the reorientation of DNA and RNA macromolecules [1].

Television transmitting center (television center) of Rostov-on-Don is a complex of technical means, providing television signals broadcast on the territory of the Rostov region, with the radius of reliable reception of about 80 km. Rostov television center is typical broadcast tower of project 3803 KM, located in Zheleznodorozhny district of Rostov-on-Don on Barrikadnaya street. The TV tower is the tallest building in the city. Its height is 195 meters. The existing network of transmitting devices of the regional radio-television transmitting center consists of six powerful and thirty-eight low-power stations. The power of television transmitters ranges from 0.01 to 50 kW.

The aim of the work is a theoretical assessment of the electromagnetic situation near Rostov-on-Don television center, followed by the vertex outcome realization on the basis of the parametric criterion "impact is greater than susceptibility", taking into account the classification of working conditions.

The object of the research — the television center of Rostov-on-Don.

The subject of the research is the electromagnetic field of the Rostov-on-Don television center.

Research problems:

1. to find the intensity of the electric field, taking into account the power of the transmitters of the television center, amplification of antennas and the distance to residential facilities;

2. to determine radiant exposures at different distances from the television center;

3. to compare the obtained results with the maximum permissible level (MPL) of EMF radiant exposures taking into account sanitary and epidemiological requirements;

4. to establish the measures of certainty of the vertex outcome on the basis of the parametric criterion "impact is greater than susceptibility".

At the first stage, we find the values of the intensity and density of the EMF energy flow when exposed to radiation on a nearby residential object, which is a residential nine-storey house located on 1st Barrikadnaya street at a distance of 80 m from the television center. We estimate the electromagnetic impact on the areas of 80 m and 300 m from the television center.

The electric field strength E, V/m, in the far zone of the antenna is associated with the transmitter power, antenna amplification and the distance from the antenna [2, 3]:

$$E = \frac{1}{D}(\sqrt{30 * P * Ga}),$$

where P — the input power of the antenna, W; Ga — the degree of antenna amplification in power in a given direction, which is determined from the antenna radiation pattern.

Next, we find the radiant exposure in the frequency range 30 kHz–300 MHz according to the formulas [4]:

$$ЭЭ_E = E^2 * T, \text{ (В/м)}^2\cdot\text{ч};$$

$$ЭЭ_H = H^2 * T, \text{ (А/м)}^2\text{·ч},$$

where H — the magnetic field strength, A/m; T — the time of exposure per shift, h.

Calculation of radiant exposure $ЭЭ_E$ is carried out at distances of 80 and 300 m from the radiation source. Here T = 24 h, since the impact of the electromagnetic field is around the clock.

Next, we find the energy flux density $ППЭ$, W/m, and the radiant exposure $ЭЭППЭ$, (μW /cm²)·h, in the frequency range of 300 MHz–300 GHz according to the formulas [6]:

$$ППЭ = \frac{P_{вых}}{4 * \pi * r^2};$$

$$ЭЭППЭ = ППЭ * T.$$

Fig. 1 presents the scheme of electromagnetic radiation effect in the frequency range of 470-862 MHz on a house located at a distance of about 80 m from the antennas to calculate the $ППЭ$ parameter.

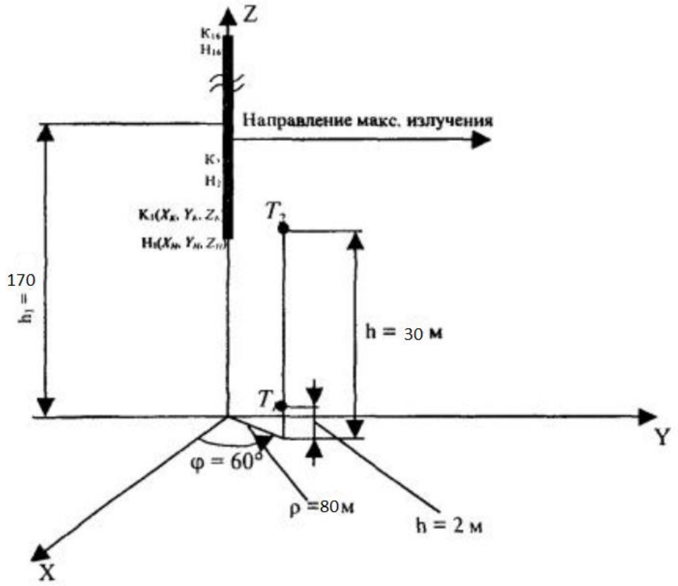

Fig. 1. Scheme of electromagnetic radiation effect of the antenna on a house located at a distance of about 80 m

The calculation of the $ЭЭППЭ$ parameter is made taking into account the electromagnetic effect on the first and the ninth floors of a nine-storey building. During the calculation, we take into account the antennas height.

We use the following technical characteristics of the antennas in the calculations:

1. for corner antennas operating frequency ranges: 66-74 MHz, 87.5–108 MHz; maximum input power — 10 kW;

2. for vibrator 4-storey broadband antennas operating frequency ranges: 66-74 MHz, 87.5 -108 MHz; maximum input power — 5 kW;

3. for four-storey panel antennas "Sivash-Skuy" series operating frequency range: 470-862 MHz; height — 4.2 m; maximum input power — 32 kW;

4. for two-storey antennas "LPA-G" operating frequency ranges: 66-74 MHz, 87.5–108 MHz, maximum input power — 20 kW;

5. for wideband eight-storey panel antennas "SIVASH-2TS" series operating frequency range: 470-860 MHz, input power up to 40 kW.

Table 1 presents the calculation results for the television center of Rostov-on-Don.

Table 1

Values of parameters of electromagnetic influence of the television center

No.	Antenna type, control conditions	Electric field intensity *E*, V/m, at a distance to the place of control		Radiant exposure at a distance to the place of control	
		80 m	300 m	80 m	300 m
1.	Corner antennas	12.89	3.4	ЭЭ=3987 (V/m)·h	ЭЭ=277.4 (V/m)·h
2.	Vibrator 4-storey broadband antennas	12.16	3.24	ЭЭ=3548.77 (V/m)·h	ЭЭ=251.94 (V/m)·h
3.	Four-storey panel antennas "Sivash-Skyu" series At the level of the 1st floor of a nine-storey building	–	–	*ЭЭппэ*=2544 μW /cm^2·h	–
	Four-storey panel antennas "Sivash-Skyu" series At the level of the 9th floor of a nine-storey building	–	–	*ЭЭппэ*=3352.8 μW /cm^2·h	–
4.	Two-storey "LPA-G" antennas	13.67	3.65	ЭЭ=4484.85 (V/m)·h	ЭЭ=319.7 (V/m)·h
5.	Broadband eight-storey panel antennas "SIVASH-2TS" series At the level of the 1st floor of a nine-storey building	–	–	*ЭЭппэ*=3504 μW /cm^2·h	–
	Broadband eight-storey panel antennas "SIVASH-2TS" series At the level of the 9th floor of a nine-storey building	–	–	*ЭЭппэ*=4672.8 μW /cm^2·h	–

At the second stage of problems solving, the radiant exposure on the magnetic component is not considered, due to the fact that the maximum permissible levels for the frequency range 50 MHz–300 GHz are not established according to Sanitary Regulations and Norms SanPiN 2.2.4.3359–16 "Sanitary and epidemiological requirements for physical factors in the workplace" of June 21, 2016 No. 81.

In step 3, measures of certainty of the vertex outcome are established on the basis of the parametric criterion "impact is greater than susceptibility". The vertex outcome realization is measured at the condition of parameter overriding, or the magnitude of the impact *s* on the susceptibility *r*: ($s \ge r$). "The probability of the condition realization ($s \ge r$) is found by construction of a probabilistic parametric model "impact *s* — susceptibility *r*" using a model where the impact is greater than the susceptibility" [5].

We construct a probabilistic parametric model "impact *s* — susceptibility *r*" (Fig. 2). At the same time, the parameters m_r, m_s, σ_r, σ_s were selected in accordance with the classification of working conditions for the vertex outcome calculation [3].

For feature selection of m_r and σ_r of the susceptibility parameter, we use SanPiN 2.2.4.3359–16. Moreover, the values of MPL are determined taking into account the time of the impact of the factor during the working day in accordance with SanPiN 2.2.4.1191–03.

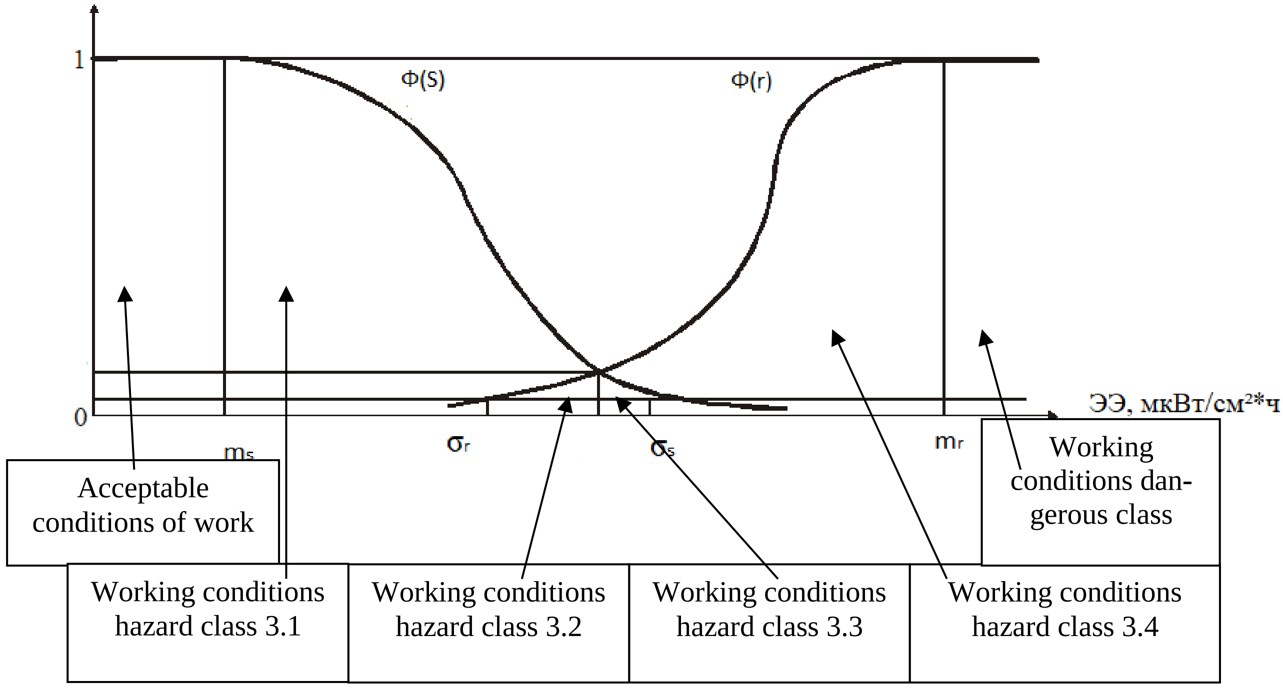

Fig. 2. Parametric models of impact and susceptibility taking into account the special assessment of working conditions

Further, taking into account the impact characteristics m_s and σ_s of radiant exposure of electromagnetic radiation, we determine the class of working conditions as follows.

In accordance with Federal law No. 426 of 28.12.2013 "On special assessment of working conditions", article 14 (classification of working conditions), we assign the values of the parametric model of impact and susceptibility:

ms — class 2 (acceptable conditions of work);
σr — subclass 3.1 (harmful working conditions of the 1st degree);
σ*s* — subclass 3.3 (harmful working conditions of the 3rd degree);
mr — class 4 (hazardous working conditions).

At the fourth stage of problems solving we find the vertex outcome probability (threat to the lives of residents of the area) under the influence of radiation on a nearby residential facility. The residential 9-storey building (1st Barrikadnaya street) is located at a distance of 80 m from the radiation source. Based on the calculated data, probabilistic parametric models "impact s — susceptibility r" were constructed: model ($s \geq r$) at a distance of 80 m (Fig. 3); model ($s \leq r$) at a distance of 300 m (Fig. 4).

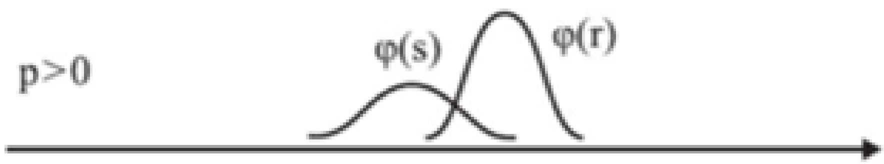

Fig. 3. Parametric model "impact s — susceptibility r" taking into account the distance of 80 m ($s \geq r$)

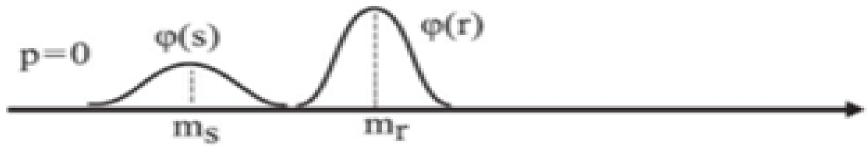

Fig. 4. Parametric model "impact s — susceptibility r" taking into account the distance of 300 m ($s \le r$)

Based on figures 3 and 4 of the parametric model, we determine the probability of exceeding the impact *s* over the susceptibility *r*: *Pro* ($s \ge r$) and the probability that the impact *s* is less than the susceptibility *r*: *Pro* ($s \le r$) [7].

For the case when the mathematical expectation of random impact is less than the mathematical expectation of random susceptibility, the probability that the action *s* is less than the susceptibility *r*: *Pro* ($s \le r$) is determined by the formula:

$$p1(u) = \mathrm{Pr}\,o(z \ge 0) = 0,5 - \Phi\left[\frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)}\right] = 0,5 - \Phi(u).$$

In this expression, the parameter is a probabilistic "reduced parametric safety margin" (RPSM), expressed by the ratio of the difference between the mathematical expectations of the impact and the susceptibility to their total standard deviation [5]:

$$u = \frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)}.$$

For the case when the mathematical expectation of random impact is greater than the mathematical expectation of random susceptibility, the probability of exceeding the impact *s* over the susceptibility *r*: *Pro* ($s \ge r$) is determined by the formula:

$$p2(u) = \mathrm{Pr}\,o(z \ge 0) = 0,5 + \Phi\left[\frac{ms - mr}{0,5(\sigma^2 r + \sigma^2 s)}\right] = 0,5 + \Phi(u).$$

Replacing the "less" condition with the "more" condition in the above expressions is accompanied by replacing the plus sign with a minus sign:

$$\frac{ms - mr}{0,5(\sigma^2 r + \sigma^2 s)} = -\frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)} = -u.$$

It is obvious that if the positive value (+*u*) is a characteristic of the "safety margin", then the negative value (–*u*) expresses the presence and increase of "danger" with a further increase in the magnitude of the impact [6].

To find the probabilities *p*1(*u*) and *p*2(*u*), we use the Laplace function Φ(*u*).

To find the probabilities p1(u) and p2(u), we use the Laplace function f(u).

The electromagnetic situation danger in the area of Rostov-on-Don television center. Tables 2-6 provide the calculation results of the probability values of realization of the vertex outcome Pro ($s \ge r$) in the function of the given parametric safety margin *u* for two variants of the ratios of mathematical expectations of impact and susceptibility (1): $(mr \ge ms)$ and (2): $(ms \ge mr)$.

Table 2

Energy characteristics of corner antennas
with frequency ranges: 66–74 MHz and 87.5–108 MHz

EE µW /cm²·h	*u*	Φ (*u*)	$p1\,(u)\|(mr \geq ms)$	$p2\,(u)\|(ms \geq mr)$
277.4	0.9896	0.33646	0.83646	0.16354
3987	1.037	0.35083	0.15	0.85

Table 3

Energy characteristics of vibratory 4-storey broadband antennas with frequency ranges: 66-74 MHz and 87.5–108 MHz

EE µW /cm²·h	*u*	Φ (*u*)	$p1\,(u)\|(mr \geq ms)$	$p2\,(u)\|(ms \geq mr)$
3548.77	1.031	0.34849	0.15151	0.84849
251.94	0.989	0.336	0.836	0.164

Table 4

Energy characteristics of four-storey panel antennas
with frequency range 470-862 MHz

EE µW /cm²·h	*u*	Φ (*u*)	$p1\,(u)\|(mr \geq ms)$	$p2\,(u)\|(ms \geq mr)$
2544	1.126	0.369	0.131	0.869
3352.8	1.179	0.38	0.12	0.88

Table 5

Energy characteristics of two-storey LPA-G antennas
with frequency ranges: 66-74 MHz and 87.5–108 MHz

EE µW /cm²·h	*u*	Φ (*u*)	$p1\,(u)\|(mr \geq ms)$	$p2\,(u)\|(ms \geq mr)$
4484.85	1.0436	0.35	0.15	0.85
319.7	0.99	0.33891	0.839	0.161

Table 6

Energy characteristics of broadband eight-storey panel antennas
with frequency range 470-860 MHz

EE µW /cm²·h	*u*	Φ (*u*)	$p1\,(u)\|(mr \geq ms)$	$p2\,(u)\|(ms \geq mr)$
3504	1.189	0.382	0.118	0.882
4672.8	1.278	0.398	0.102	0.898

The tables present the energy characteristics of the antennas of Rostov-on-Don television center and the probability of vertex outcomes realization taking into account the distance from the source of electromagnetic radiation.

Conclusion. The algorithm for calculation of probability of electromagnetic influence outcome realization on personnel in their labor activity is developed and approved. The scientific novelty of the method is in finding the probability of occupational disease based on the parametric criterion of "impact is greater than susceptibility", taking into account the classification of working conditions.

The algorithm allows us to calculate quantitative measures of occupational diseases assessment in accordance with the requirements of *OHSAS* 18001:2007 "Order of occupational safety and health assessment". A parametric model "impact of electromagnetic fields of different frequency ranges — susceptibility" was built and probabilities of occurrence of diseases were estimated on the example of the system "television center— the inhabitants of a residential nine-storey building on 1-st Barrikadnaya st. of Rostov-on-Don". At the same time, it is proved that the residents living in this house are exposed to electromagnetic influence, which corresponds to the harmful class of working conditions 3.4. With a probability of 0.9 (for nine out of ten people), there is a threat of the emergence and development of severe forms of diseases. Working personnel of the television center using PPE are exposed to electromagnetic influence, which corresponds to the harmful class of working conditions 3.3. With a probability of 0.9 (for nine out of ten employees of the television center), there is a threat of the emergence and development of occupational diseases of moderate severity. It is concluded that it is necessary to apply organizational and technical measures to reduce the radiation power. These theoretical calculations require confirmation in practice by measurements.

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