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INCREASING THE SAFETY OF WIRELESS COMMUNICATION

У роботі обґрунтовано проблеми захисту від електромагнітних випромінювань ультрависоких частот для забезпечення безпеки людей та прийнятної якості зв'язку. Доведено, що найбільш ефективним методом зниження електромагнітного фону є екранування зовнішніх випромінювань та зниження рівнів випромінювань внутрішніх джерел. Розроблено і досліджено захисні властивості металополімерних електромагнітних екранів. Встановлено, що підвищення дисперсності металовмісних наночастинок у 2–4 рази знижує коефіцієнт відбиття на 0,15–0,20.

Ключові слова: *електромагнітне випромінювання, випромінювання ультрависоких частот, екранування, металовмісні наночастинки.*

В работе обоснованы проблемы защиты от электромагнитных излучений ультравысоких частот для обеспечения безопасности людей и приемлемого качества связи. Доказано, что наиболее эффективным методом снижения электромагнитного фона является экранирование внешних излучений и снижения уровней излучений внутренних источников. Разработаны и исследованы защитные свойства металлополимерных электромагнитных экранов. Установлено, что повышение дисперсности металлосодержащих наночастиц в 2–4 раза снижает коэффициент отражения на 0,15–0,20.

Ключевые слова: *электромагнитное излучение, излучение ультравысоких частот, экранирование, металлосодержащие наночастицы.*

In this paper the problem of protection from electromagnetic radiation of ultrahigh frequencies to ensure the safety of people and an acceptable quality of communication, have been substantiated. The most effective way to reduce electromagnetic background it's shielding is external radiation and reduce the levels of internal radiation sources. We developed and examined protective properties of the metal polymeric electromagnetic screens. It was found that increasing the dispersion of particles by 2–4 times reduces reflection coefficient by 0,15–0,20.

Keywords: *electromagnetic radiation, radiation of ultrahigh frequency, shielding, metal-containing nanoparticles.*

Introduction. Radio signals are part of everyday life that are created by both natural and artificial sources, such as base stations of mobile communication, radar installations, remote controls, medical, electrical and electronic equipment. The level of electromagnetic radiation from the source grows exponentially, popularity of wireless technology and Wi-Fi are also increasing. In Ukraine the impact on public health associated with the effect of electromagnetic radiation (EMR) of ultra-high and higher frequency is growing as well.

Literature review and problem statement. Despite the considerable attention paid to applied research and development of protecting means from the effects of high radiation for people under the production and living conditions, problems related to this issue are far from the final solution. Ukraine has risen the maximum permissible levels of radiation frequency for base stations by four times (10 $\mu W/cm^2$, corresponding to general European standards) , which will partially reduce the severity of the problem, but will also put forward new tasks associated with redistribution of radiation in space.

Most studies on protection of people from the exposure to electromagnetic fields of ultra-high and higher frequency (mobile, wireless computer networks, microwave technology for various purposes, radio facilities of civil aviation, etc.) are limited to testing certain areas, buildings, premises and ascertain the specific fact of exceeded or acceptable levels of radiation [1, 2]. Considerable number of work is devoted to the experimental study of the levels of radiation, development of actual distribution diagrams and definition of sanitary protecting zones, zones of building restrictions, etc. [3, 4]. In recent years, a series of experimental and theoretical researches on reducing radiation exposure of workers to ultra-high and extremely ultra-high frequency by the means of shielding with protective materials of various compositions and configurations has been made [5].

Results of research. The most common and widely applied methods of protecting workers are reduction of equipment radiating capacity, increase of the distance between the source and employees and reduction of working time in the area of radiation. In modern terms, these methods are of limited use or not efficient at all. Approaches to protect workers from exposure to certain radiation sources (sources group) are significantly different.

Capacity of some power sources can be reduced. This includes UHF equipment that is used in the production and spurious emissions of many electronic devices. This method is used to reduce the impact on personnel operating radio equipment in civil aviation. But virtually all wireless devices (both indoor and mobile base stations) must operate at nominal capacity. This capacity reduction and increase equally result in unstable operation. The limitation of time of exposure to radiation is problematic given that person is exposed during the working day at the workplace, and in many cases further under domestic environment, making recovery time insufficient.

The most acceptable method of reducing the impact of high radiation on workers is their shielding. But there is a problem of losing connection used for industrial purposes or its insufficient quality.

It was established that under the conditions of partial screening areas poor passing radio waves causes significant increase in radiation intensity due to reflection of waves from the internal sources (Table 1).

Table 1

The levels of energy flux density in different rooms with the same generation of ultra-high frequency radiation

Number	Energy flux density W, μW/cm^2	
	Background radiation level of external radiation source	Radiation level at switched source
1	0,20	2,3
2	0,19	2,5
3	0,20	4,3
4	0,25	2,8
5	0,22	3,6
6	0,20	7,8
7	0,24	12,5
8	0,20	16,7

Thus, the cell phone radiation significantly increases the lower the level of base station signal.

Our experimental studies have shown that the intensity of radiation of mobile communication devices increases dramatically when the signal from the base stations to reduces to 0,2–0,1 μW/cm^2. But the real radiators of ultrahigh and super high frequencies are very sensitive to mechanical and other influences (even humidity and pollution of surface antenna affect them) that leads to origination of side radiation (spurious emissions).

The importance of taking into account the spurious radiation is conditioned by the fact that current regulations allow the installation of antennas of base stations on the roofs of buildings. In general, it is safe because the building itself is in radiation shadow ("dead zone") relative to the main lobe. But side emission can significantly exceed the electromagnetic fields in the building. The most effective means of reducing their impact is shielding. But there is a problem with the focusing of the reflected radiation in unwanted directions. This imposes certain requirements for protective surfaces: they must ensure overall screening rates, leaving the level of radiation sufficient for industrial needs and have minimal reflection indices. Metal and polymer composite electromagnetic screens with adjustable protective properties are proved to meet the mentioned requirements.

Receiving a composite material with the required concentration of nanoparticles is possible using two methods. The first is the synthesis of particles directly in a polymeric material from appropriate additives (in situ). The second implies the addition to the solution or melt of ready metal-containing finely dispersed particles. The first method was sufficiently developed [6]. However, obtaining the samples with large areas for testing proved to be quite problematic. To receive the examined samples, we used finely dispersed iron oxides Fe_2O_3 and Fe_3O_4 of average size 50–300 nm. This minimizes the effects of reflection, which manifested themselves at application of aluminum powder (petals of thickness 0,25–0,50 μm with average minimum size 20–50 μm). We chose the epoxy resin with subsequent polymerization using a polyamide hardener as a matrix (model material). The amount of a metal component was determined by weight. Measurement of the total shielding coefficient and the contribution of the shielding due to reflection to it was conducted on the samples the size 0,75×0,75 m. Penetration of radiation beyond the screen was excluded. We used a high-frequency generator and antenna as the radiation source. The tests were carried out for samples with the dispersion of a metal-containing component of 50–100 nm and 200–300 nm, and a thickness of 5 mm.

Earlier studies [7, 8] indicate that the protective properties of materials depend on their electrical-physical properties. We measured electrical conductivity of the received materials. It was conducted using the compensation method by bridge circuit.

The results show that the growth of protective properties occurs at the border of the electric current flow. In this case, reflection coefficient rises as well; however, the presence of such data allows us to optimize the ratio of coefficients of absorption and reflection, depending on the required levels of protection under actual conditions. The required coefficients can be determined in advance based on the electrical-physical properties of materials.

Results of the calculation of reflection coefficient are presented in Table 2.

In the course of calculation, we employed the parameters of starting materials from reference sources. Electrical conductivity of epoxy resin is

~10^{-8}–10^{-7} S/m, ε~14. Electrical conductivity of the mixture of iron and iron oxides is ~10^5–10^6 S/m.

Table 2

Dependence of reflection coefficient of the electromagnetic screen on the concentration of a metal-containing component

ρ, %	5	10	11	12	13	14
K_r	0,18–0,22	0,2–0,33	0,27–0,35	0,38–0,42	0,48–0,52	0,68–0,76

An analysis of the results obtained indicates that the differences between experiments and calculations are satisfactory, at least in terms of the requirements for electromagnetic safety. Given the errors of field measurements these results can be considered acceptable. A necessary condition of stability of the protective properties of a material is the uniformity of distribution of the particles, which influence this parameter, in the body of the matrix. This was verified using a raster electron microscope. The result received testifies to the possibility of fabricating a material with the required protective properties without the use of complicated technology for the synthesis of nanostructures in the body of the matrix, which limits the size of the screen [9].

Theoretical considerations indicate that it is thus possible to obtain a material with the concentration of particles in the body of the material variable by depth. This will make it possible to manufacture a gradient type screen without the use of multiple layers of material, which is always associated with the problems of adhesion between layers and the degradation of materials.

Results of the tests confirm the prospects of the chosen path in the development of electromagnetic screens. However, the examined material can be considered as a model only. Because of the fragility of the matrix, it possesses large thickness, which is not convenient for practical application while specialized obtaining of finely dispersed metal-containing particles is complex and expensive in large quantities.

At the same time, effectiveness of using local means for the protection of people from the radiation of communication means is questionable. A special feature in the formation of electromagnetic background of radiation of ultra-high and higher frequencies inside and outside the premises is its practical isotropy. One should not consider the sources of such radiation as pointed [10]. Under such conditions, electromagnetic screens must meet the following criteria to implement efficient protection:

- the possibility of fabricating a protective surface with a large area;
- manufacturability of material for lining the surfaces with complex configuration;

• acceptable cost of components and manufacturing technology.

That is, it is necessary to have sufficient amount of metal-containing finely dispersed powder and flexible polymer matrices with low cost.

Conclusions

Thus, the most efficient method of reducing electromagnetic fields of ultrahigh and super high frequencies is shielding external radiation with simultaneous reducing emissions of internal sources. Reduced levels of external radiation of mobile communication cannot exceed 0,2 $\mu W/cm^2$, that will ensure reliable mobile communications without excess radiation levels from cell phones themselves. The metal and polymer composite electromagnetic screens with minimal reflectance properties are efficient for the reduction of electromagnetic background.

The most promising materials for the protection of people against exposure to electromagnetic fields and ensuring the electromagnetic compatibility of technical means are metal polymer composites with a filler made of nanoscale particles. Protective properties of nanocomposite electromagnetic screens depend not only on the concentration of metal-containing particles, but on their dimensions. Increasing the dispersion of particles by 2–4 times reduces reflection coefficient by 0,15–0,20 at a satisfactory shielding coefficient of 7–8 dB. This provides control over protective properties of materials depending on the frequency-amplitude characteristics of the shielded field and on particular industrial needs.

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