Vol. 1, No. 1, 2016

METHODOLOGICAL PRINCIPLES OF ELECTROMAGNETIC SCREENS APPLICATION FOR PUBLIC PROTECTION FROM ELECTROMAGNETIC FIELDS AND RADIATION

Valentyn Glyva[1], Olena Panova[2], Olena Voloshkina[3]

[1]*National Aviation University, Ukraine, Kyiv, larlevch@mail.ru*
[2]*Kyiv National University of Construction and Architecture, Ukraine, Kyiv, elena_panova@list.ru*
[3]*Kyiv National University of Construction and Architecture, Ukraine, Kyiv, stf@knuba.edu.ua*

Received: 30.11.2015

Abstract. The growing levels of electromagnetic fields require the improvement of protective shielding methods. Frequency and amplitude parameters of fields have been analyzed according to national and international standards of electromagnetic safety and guidelines on shielding application have been given. The methodological principles of choosing and applying electromagnetic screens depending on radiation parameters and the required protection efficiency have been developed.

Key words: shielding; electromagnetic field; reflection coefficient.

1. Introduction

The increasing electromagnetic impact on the environment, growing number of electric and electronic facilities applied in industry and households raise the question of protection people from negative impact of electromagnetic fields and radiation. The complexity of solving this task is caused by a wide permanent frequency range of electromagnetic impact: from quasi-stationary electromagnetic fields of power line frequency to microwave frequency radiation of communication equipment. As a result, different technical approaches must be applied to electromagnetic protection. Traditional protection approaches (protection with distance and time) are depleted or not efficient enough.

Nowadays electromagnetic shielding is under detailed investigation, but technique and conditions of various shielding materials application, as well as providing optimal efficiency of shielding are not sufficiently determined.

These tasks are also urgent because of gradual implementation of the European Council Directive on electromagnetic safety and enactment according to the Decree of the Cabinet of Ministers of Ukraine (№ 1483 КМ 29.12.2014) of a range of common European standards on electromagnetic safety and compatibility of technical facilities, that in many cases are stricter than Ukrainian national standards.

2. Problem formulation

Electromagnetic screens application for public protection from electromagnetic fields and radiation impact is regulated by both international [1, 2] and national standard acts [3, 4]. At the same time, none of them characterize the application conditions and screen parameters depending on shielded field frequency and amplitude values. For example, sanitary norms [3] recommend application of bars and solid surfaces made of aluminum and copper alloys, electro-technical steels and permalloys as protective screens without setting efficiency criteria under various conditions.

In the recent years a great number of studies on electromagnetic screens efficiency have been conducted [5–7]. Most of them are experimental because theoretical studies in this area are a bit abstractive and they are not suitable for application [8, 9]. Study and development of modern protective materials [10, 11] proved the possibility of protective properties management, i.e. production of screens with required shielding factor, in particular, protective electromagnetic screens with regulated protective properties [12]. Studies of shielding efficiency have been conducted mainly in lab conditions and their results are not completely matched with the measured results at real objects, which is conditioned, in our opinion, by both final dimensions of screens and external sources and over-radiation impact. Our previous studies [13] have shown that shielding efficiency depends not only on the chosen material properties, but also on the screen dimensions, its allocation relatively to the source of field and radiation, diffraction phenomenon etc. These aspects have not been studied enough yet.

The aim of the study is to determine the electromagnetic screens application depending on frequency and amplitude of shielded field or radiation, their sources allocation and provision of practical guidelines on regulation of protective materials selection.

Electromagnetic shielding is the most urgent for the provision of standard electromagnetic environment in buildings and constructions (except certain objects, for example, civil aviation enterprises), i.e. for electromagnetic ecology of premises. It is also necessary to take into account the presence of both internal and external sources of fields and radiation. External sources are generally radio-technical objects of communication facilities with extremely low radiation wavelength (to 1 centimeter) and power supply objects – transmission facilities, transforming station and open switching centers with extremely wide wavelength (6000 kilometers). It's obvious that protective methods for different types of radiation must be different. The internal sources are power supply systems with power line frequency electromagnetic fields and electromagnetic fields of industrial or household equipment, which have various and unpredictable frequency spectrum in many cases.

Technical approaches to the protection from the impact of these two categories of sources differ substantially. In many cases efficient protection from the impact of external sources can worsen electromagnetic environment as a result of internal sources impact. The cause of it is that internal source radiation reflection from electromagnetic screen into the room increases electromagnetic background level. This also partially refers to external sources. Our measurements have shown that reflection of base station electromagnetic radiation from well-shielded construction surfaces (metal decorative coats) significantly worsens electromagnetic environment in adjacent areas. Sometimes this worsening makes up 70–80 %. Partial reflection is observed even from concrete construction. It is important to note that this parameter depends substantially on weather conditions, for example, the electromagnetic fields reflection index on the surfaces of roofs and buildings changes significantly in the presence of precipitation. Neighboring buildings orientation in relation to the incident and reflected waves is also important.

In any case, reflection phenomenon has unfavorable character in terms of human safety. Therefore, it is necessary to determine the maximum permissible reflection coefficient while selecting the material for electromagnetic screen production, if the required general screening coefficient is known. As for separate premises their full shielding, even at minimum reflection coefficient, can cause certain inconveniences, for example, blocking of communication with base stations, experienced by citizens. It can block the activity of wireless computer net within a certain building.

Another problem is magnetization of ferromagnetic screen in an external magnetic field, which may cause the increase of field level while approaching it. Our study has proved that ferromagnetic electromagnetic screens have to be applied as entirely closed screens around high-power electro-technical facilities or as the screens developed on the basis of the specular reflection phenomenon, which is a fundamental physical principle. Such screen is located at the back of the source, instead of being placed between the source and the public zone. Depending on relative distances in the public area, the decrease of power line frequency and other low-frequency magnetic fields level by 16–17 % is achieved which is confirmed by the results of the conducted experiments.

The benefit of such shielding is that its efficiency can be accurately calculated [14]. The exception is ferromagnetic and magnetic screens made of soft magnetic amorphous alloys, but their application is limited by the high cost of these materials due to complex production technology. The most efficient screens for protection from both external and internal sources impact are flexible metal-polymeric materials with managed protective properties. Determination of frequency and amplitude characteristics of radiation, to be shielded, must precede screen production, and required screen parameters are determined from the developed dependencies (Fig. 1).

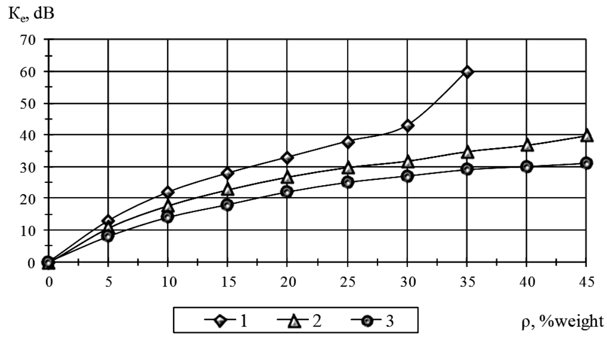

Fig. 1. Dependence of shielding coefficient of flexible protective material on conductive component content: thickness 1 – 5,0 mm; 2 – 3,0 mm; 3 – 1,0 mm

Reflection coefficients can be determined according to ratios in Fig. 2.

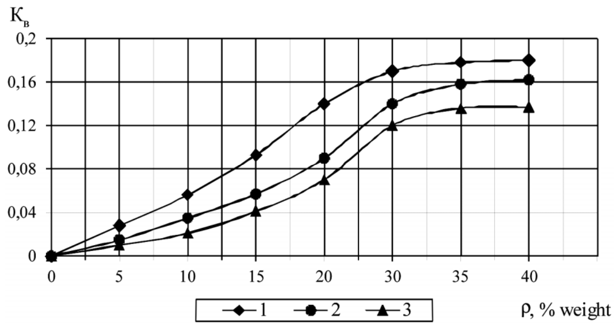

Fig. 2. Dependence of reflection coefficient of flexible protective material on conductive component content: thickness 1 – 5,0 mm; 2 – 3,0 mm; 3 – 1,0 mm

To determine the efficiency of electromagnetic screens for the provision of required parameters it is necessary to take into account a range of factors: reflection level, attenuation, caused by energy penetration through the screen material, and diffraction phenomena. The last issue is applied to perforated and latticed surfaces and screens with limited dimensions (length and width). Additionally it is important to take into account separately located big radio-reflective surfaces and certain emitters, which sometimes increase the level of the field in the radio shadow zone. The solution of these tasks will be efficient with application of both theoretical and experimental methods. Application of mathematic models with acceptable accuracy for the selection of protection methods provides significant reduction of time and costs used for the provision of required protection levels. To fulfill such work it is necessary to apply fundamentals of geometry [14]. The scheme to calculate the impact of the screen geometric configuration, taking into account the diffraction phenomena, is given in Fig. 3.

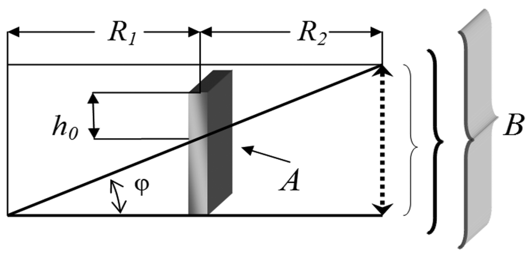

Fig. 3. Scheme of relative placement of electromagnetic screen *A* and field source. h_0 – distance between the screen edge and the source axis; R_1 – distance from the source to the screen; R_2 – distance from the screen to the protected zone *B*

To account the diffraction numerically it is useful to introduce the dimensionless parameter – screen efficiency factor η:

$$\eta = h_0 \cdot \cos\ \varphi = \sqrt{\frac{2}{\lambda} \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} \right)},$$

where h_0 – distance between the screen edge and the source axis, λ – wavelength, R_1 – distance from the source to the screen, R_2 – distance from the screen to the protected zone.

Experimental dependencies of diffraction attenuation depending on integral parameter η, which is determined by the distances from the screen to the source and the protected zone (R_1 R_2) and the length of the electromagnetic wave λ and the distances h_0 between the screen edge and the source axis – the border of the protected zone (Fig. 4).

Analysis of Fig. 4 proves that solid conductive screens give relatively high attenuation of electromagnetic radiation that is not always necessary for low amplitude and high frequency fields. Therefore, perforated surfaces and metal lattice which sufficiently reduce the levels of the field but have low weight and cost, can be applied for protection.

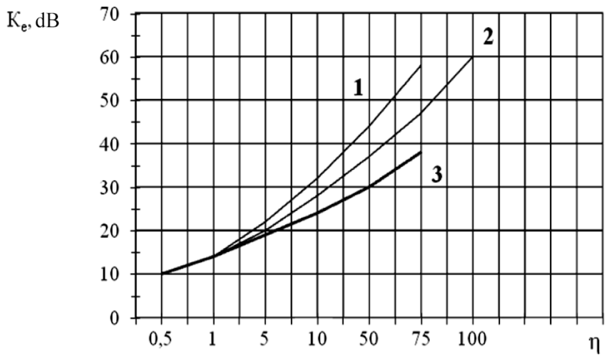

Fig. 4. Dependence of shielding coefficient on field source location and screen dimensions:
1– for field component, which is parallel to the screen;
2 – integral shielding; 3 – for field component, which is perpendicular to the screen

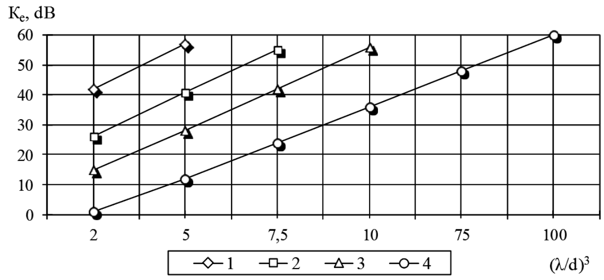

Fig. 5. Dependence of shielding properties of electromagnetic screen on perforation parameters ℓ:
1 – 50 mm, 2 – 20 mm, 3 – 10 mm, 4 – 5 mm

Perforated screens constructions have to meet the requirements of shielding minimum. Efficiency of such screens depends mainly on the diameter of holes *d* and distances between them ℓ. Experimental data on correlation between perforated surfaces shielding coefficient, the length of the electromagnetic wave λ and perforation parameters are given in Fig. 5.

Shielding coefficients for latticed and linear periodical structures (alternation of metal wires with a determined step) depend on wires diameters, distances between their axes and the length of a shielded wave.

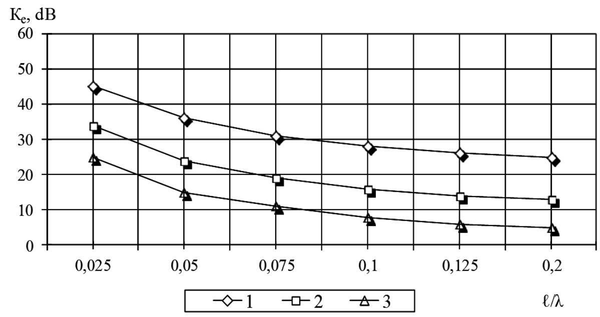

Fig. 6. Dependence of shielding coefficient of electromagnetic field on latticed structure parameters:
ℓ– distance between wire axes, *d* – diameter of wires,
λ – wavelength; 1, 2 and 3 – represent the following rations of ℓ/*d*=2; 5; 10

Dependences of protective properties of such screens on the mentioned parameters are given in Fig. 6.

Material of wires doesn't have noticeable influence on shielding coefficients in a high-frequency range; therefore, wires conductivity can be neglected in practice. Therefore, material selection is conditioned by economic reasons. Copper and aluminum structures are more efficient than steel constructions due to higher specific conductivity for low and super-low frequencies.

In all cases, electromagnetic screen functioning efficiency is provided with reliable galvanic contact in the places of certain lattice element connections.

3. Conclusions

1. Assessment of electromagnetic environment has to be conducted prior to screen material and structure selection; it includes determination of frequency and amplitude parameters of electromagnetic fields and external and internal sources of radiation.

2. It is necessary to choose reasonable correlation of attenuation and reflection screen parameters for maximum reduction of this physical factor impact on the human. It is efficient to apply graphic dependencies given in this paper.

3. Ferromagnetic electromagnetic screens application is most acceptable under the condition of full blocking of field source or taking into account reflection effect that enables preliminary calculation of shielding efficiency based on geometric issues exclusively.

4. Variability of shielding coefficients has to be taken into account at electromagnetic shielding application because of diffraction phenomena at the screen edges.

5. Perforation parameters and screen lattices have to be taken into account at high frequencies of electromagnetic radiation, it is reasonable to apply given graphic dependencies for this aim.

6. In all cases it is necessary to take into account the feasibility of screen production and installation, as well as its cost, which is provided by rationalization of shielding and reflection coefficients selection (i.e. according to the principle of reasonable adequacy).

References

[1] Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)/-International Commission on Non-Ionizing Radiation Protection // Health Physics, 1998, No. 74, 494–522.

[2] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

[3] Derzhavni sanitarni pravyla pry roboti z dzherelamy elektromagnitnykh poliv: DSanPin 3.3.6.096-2002. [Valid from 2003-0104], К.: MOZ Ukrainy, 2003, 16 p.

[4] Derzhavni sanitarni normy i pravyla zakhystu naselennia vid vplyvu elektromagnitnykh vyprominuvan: DSN 239-96, К.: MOZ Ukrainy, 1996, 28 p.

[5] Lynkov L. M., Bogush V. A., Borbotko P.V. *et al*. Doklady NAN Belarusi, 2004, **3**, 152.

[6] Zaporozhets O. I., Lukianchikov A. V., Glyva V. A. *et al*. Problemy okhorony praci v Ukraini, 2007, **14**, 35.

[7] Levchenko O. G., Levchuk V. K., Tymoshenko O. N. Avtomaticheskaia svarka, 2011, **3**, 49.

[8] Rezinkina M. M. Zhurnal tekhnicheskoi fiziki, 2007, **77(11)**, 17.

[9] Model ekranirovania postoiannykh magnitnykh polei mnogosloinym tsilindricheskim ekranom / [V. T. Erofeenko, G. Ch. Shushkevich, S. S. Grabchikov, V. F. Bondarenko]. – Minsk, NPTs NAN Belarusi po materialovedeniu, 2012, No. 3, 80–93.

[10] Klapchenko V. I., Krasnianskii G. E., Glyva V. A., Aznaurian I. A. Gigiena naselennykh mists, 2010, **56**, 219.

[11] Panova O. V. Tekhnika budivnytstva, 2010, **24**, 56.

[12] Glyva V. A., Nazarenko M. V., Podobed I. M., Matvyeyeva O. L., Panova O. V. Pat. 74857 Ukraine, МПК G12B17/00. Publ. 12.11.2912. Bul. № 21.

[13] Glyva V. A., Panova E. V. Tekhnologii technosfernoi bezopasnosti, 2014, **1 (53)**, 222-227.

[14] Panova O. V. Zakhyst pratsuuchykh vid vplyvu elektromagnithykh poliv ekranuvanniam: diss. … Cand. Tech. Sc.: 05.26.01 / Panova Olena Vasylivna – K., 2014. – 151 p.