Methods of information systems synthesis

UDC 519.62:614.8.086 **doi:** https://doi.org/10.20998/2522-9052.2026.1.05

Larysa Levchenko[1], Nataliia Burdeina[2], Valentyn Glyva[2], Grygorii Krasnianskyi[2], Oleksandr Tokarskiy[3]

[1] National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
[2] National University of Construction and Architecture, Kyiv, Ukraine
[3] Main Directorate of the SE Service of Ukraine in the Zakarpattia Oblast, Mukacheve, Ukraine

AUTOMATION OF DESIGNING COMPOSITE ELECTROMAGNETIC SCREENS OF SPECIFIED EFFICIENCY

Abstract. Relevance. Shielding is the most effective means of improving electromagnetic safety for people and electromagnetic compatibility for electronic equipment. Only composite materials can control the protective properties (ratio of reflection, absorption and transmission coefficients) of electromagnetic waves. However, designing materials with the required protective properties is complex and requires large amounts of calculations. This makes it expedient to automate these processes by creating application software. **The aim of this work** is to automate the design processes of composite materials with controllable protective properties. **Research results**. Mathematical functions are provided to determine the effectiveness of electromagnetic radiation shielding by reflection and absorption of electromagnetic waves. It is shown that it is advisable to use fundamental relations of electrodynamics of continuous media to automate the design processes of composite protective materials. A list of theoretical and experimental data necessary for the design of protective materials is determined. Applied software has been developed that allows obtaining data on the effectiveness of electromagnetic radiation shielding by reflection and absorption of electromagnetic waves depending on the electrophysical parameters of the composite components and the volume content of the electrically conductive filler in the dielectric matrix. Using the example of a silicate material with a granulated copper filler, dependencies of the effectiveness of shielding ultra-high frequency electromagnetic radiation on the filler content were obtained. A comparison of the obtained data with the experiment shows their acceptable convergence. To accelerate the design of protective materials, a generalised function of the dependence of the electrical conductivity of the composite on the filler content was obtained. This allows reducing the amount of experimental work to obtain the initial data. **Conclusions**. The creation of application software for automating the design processes of composite materials allows optimising the effectiveness of protective materials by selecting the most acceptable components and the content of electrically conductive material in the dielectric matrix.

Keywords: automation; electromagnetic radiation; composite material; shielding effectiveness.

Introduction

A steady trend today is the increase in electromagnetic pollution of the environment. This is due to the increase in the number of sources of electromagnetic radiation and the increase in the operating frequencies of wireless communication devices. With the gradual transition to the 5G standard, the task arises of simultaneously ensuring high-quality communication and protecting people from ultra-high, ultra-high and extremely high frequency electromagnetic radiation.

Traditional metal protective screens do not meet these requirements. They completely shield electromagnetic radiation and block traffic, and have high electromagnetic wave reflection coefficients. This leads to an undesirable redistribution of electromagnetic energy flows. In such conditions, composite materials are the most suitable protective materials. Their use allows for the rationalisation of the ratio of reflection, absorption and transmission coefficients of electromagnetic waves. However, the design of such materials is very complex. Their effectiveness depends on the electrophysical and magnetic properties of the matrix and shielding filler, as well as the thickness of the material. At the same time, the dielectric and magnetic permeabilities of the components and the composite have frequency dependencies.

Therefore, the process of designing a protective composite material requires large amounts of calculations even for known amplitude-frequency characteristics of electromagnetic radiation. Under conditions of alternating electromagnetic load on the environment, it is practically impossible to rationalise the material parameters using traditional methods. Therefore, it is advisable to determine the most acceptable mathematical apparatus for designing protective compositions and to create application software for automating the design of materials with the required efficiency.

Literature review. The use of electromagnetic shields is regulated by international standard [1]. It specifies the maximum permissible levels of electromagnetic fields and emissions in industrial and domestic environments under identical electromagnetic loads outside buildings. This means that different levels of protection must be provided depending on the purpose of the building. Therefore, much attention is paid to the development of protective materials.

A review paper [2] presents the results of the development and application of all classes of shielding materials. However, the mathematical functions used to predict shielding effectiveness are semi-empirical and unsuitable for the automation of material design.

The complexity of this process is the reason why most of the work on the development of composite

© Levchenko L., Burdeina N., Glyva V., Krasnianskyi G., Tokarskiy O., 2026

shielding materials is entirely experimental [3, 4]. At the same time, the use of metasurfaces does not have wide practical application due to the complexity of their production.

The paper [5] presents the results of predicting the magnetic field shielding coefficient based on the results of modelling its propagation using COMSOL.

However, these results are based on experimental data and only take into account the thickness of the protective layer.

A similar determination of the initial data for calculating the effectiveness of electromagnetic shields is given in [6]. However, the use of Maxwell-Garnett relations gives large errors.

Even the use of Brugeman's relations for high concentrations of shielding filler in a composite does not always give an adequate result [7].

Effective protective compositions have a complex structure, so the use of traditional approaches for calculating their electrophysical and magnetic properties does not give an acceptable result [8, 9].

Works [10, 11] shows that the use of fundamental electrodynamic relations for continuous media ensures a minimum error in the calculation of shielding coefficients.

This approach was used in study [12, 13]. A comparison of the calculated and experimental data shows their acceptable convergence. The corresponding analytical functions are given in complex form. Therefore, for the development of application software, it is advisable to convert the corresponding electrodynamic relations into real form.

A similar approach has been used in modelling the propagation of electromagnetic fields and emissions, which indicates the feasibility of its application and makes it possible to additionally determine the most rational location of the shielding material [14, 15].

This will reduce the amount of calculations and allow the selection of rational critical parameters of the composite material without solving optimization problems.

The aim of the work is to develop the principles of automation of the design processes for composite electromagnetic screens of a given efficiency.

Research results

Calculations of shielding effectiveness are based on fundamental electrodynamic relationships in continuous media. Most composite materials used for shielding electromagnetic radiation are metal-dielectrics.

However, the filler in the dielectric matrix does not necessarily have to be metallic. It must have sufficiently high electrical conductivity, which is found in graphite, carbon nanotubes, etc.

The proposed calculation method has limitations:

– only electrically conductive fillers are used;

– the calculation method is only applicable to quasi-stationary fields.

The condition of quasi-stationarity is:

$$\nu \ll \frac{c}{d},$$

where ν is the frequency of electromagnetic radiation, c is the speed of light in a vacuum, d is the thickness of the screen.

For example, for a material thickness of 5 mm, the critical frequency is 60 GHz. That is, the calculations will be correct for the ultra-high and ultra-high frequency ranges and part of the extremely high frequency range.

The final task is to calculate the effectiveness of electromagnetic radiation shielding by SE_T material:

$$SE_T = 10\log\left(1/T\right),\ dB,$$

where T is the coefficient of transmission of an electromagnetic wave incident on a plane-parallel screen located between air and an arbitrary medium;

SE_T is the total effectiveness of electromagnetic radiation shielding by the material, dB.

SE_R is the effectiveness of shielding due to reflection

$$SE_R = \log\left(1/\left(1-R\right)\right),\ dB,$$

where R is the reflection coefficient.

Efficiency due to absorption:

$$SE_A = SE_T - SE_R,$$

that is

$$SE_T = SE_R + SE_A.$$

The main task is to calculate the shielding effectiveness depending on the volume fraction of the electrically conductive filler.

That is, the effectiveness of electromagnetic radiation shielding by SE_T material and the effectiveness of shielding by SE_R reflection must be expressed in terms of volume components.

The solution of Maxwell's equations for the amplitude of a plane wave in a plane with the z-coordinate of an absorbing medium is as follows:

$$E_0 = e^{-az},$$

where E_0 is the electric field intensity at $z=0$;

α is amplitude coefficient of electromagnetic wave absorption, $\alpha = (\omega \cdot k)/c$.

ω is the cyclic frequency of radiation, $\omega = 2\pi\nu$, where ν is the frequency of periodic oscillations,

k is the extinction coefficient (an indicator of the rate of light wave attenuation in a medium), imaginary frequency,

c is the speed of light in a vacuum.

Complex dielectric permeability of screen material containing electrically conductive additives, $\sqrt{\hat{\varepsilon}}$

$$\sqrt{\hat{\varepsilon}} = n + ik, \qquad (1)$$

where n is the wave refraction coefficient;

$$\hat{\varepsilon} = \varepsilon' + i\varepsilon'',$$

where ε' is the real component, ε'' is the imaginary component, $i = \sqrt{-1}$;

$$\hat{\varepsilon} = \varepsilon' + i\varepsilon'' = \varepsilon + i\frac{\sigma}{\omega\varepsilon_0}, \qquad (2)$$

that is

$$\varepsilon'' = \frac{\sigma}{\omega\varepsilon_0},$$

where ε is the dielectric permeability,

ω is the cyclic frequency,

σ is the electrical conductivity of the material, the values of which depend on the volume content of the electrically conductive additive;

$\varepsilon_0 = 8{,}85\cdot 10^{-12}$ F/m – electric constant.

Let's square equations (1) and (2):

$$\hat{\varepsilon} = (n+ik)(n+ik) =$$
$$= n^2 + ink + ink - k^2 = \left(n^2 - k^2\right) + i\cdot 2nk,$$

That is, the real component $\varepsilon = n^2 - k^2$, imaginary component – $2nk$.

Thus, the complex part

$$\varepsilon'' \frac{\sigma}{\omega\varepsilon_0} = 2nk.$$

From this equation, n and k can be found.

Multiple reflections are taken into account by the following relationships.

$$R = R_{12}\begin{pmatrix} 1 + (1-R_{12})^2 \exp(-4\alpha d)\times \\ \times\left(1 - R_{12}^2 \exp(-4\alpha d)\right)^{-1} \end{pmatrix}, \quad (3)$$

$$T = (1-R_{12})^2 \exp(-2\alpha d)\times$$
$$\times\left(1 - R_{12}^2 \exp(-4\alpha d)\right)^{-1}, \quad (4)$$

$$A = (1-R_{12})(1-\exp(-2\alpha d))\times$$
$$\times\left(1 - R_{12} \exp(-2\alpha d)\right)^{-1}. \quad (5)$$

where R is the multiple reflection coefficient,

R_{12} is the reflection coefficient from the material,

d is the screen thickness,

α is the amplitude coefficient of electromagnetic wave absorption,

T is the electromagnetic wave transmission coefficient,

A is the electromagnetic wave absorption coefficient.

For normal wave incidence, R_{12} is determined by the ratio:

$$R_{12} = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}. \quad (6)$$

The multiple reflection coefficient R is taken into account under certain conditions; the screen thickness d must be small.

The condition for taking into account multiple reflections from the inner surfaces of the screen, which significantly affects the values of R, T and A, is:

$$d < 3\delta,$$

where $\delta = 1/\alpha$ – the thickness of the layer at which the wave amplitude decreases by a factor of e.

That is, the wave amplitude is reduced by 3δ, in which case multiple reflections must be taken into account. This is done under the condition: $\delta = \frac{c}{\omega k}$, that is $d < \frac{3C}{\omega k}$.

This corresponds to small values of k (weak absorption of radiation by the material) or low frequencies of incident radiation – ω.

Otherwise, multiple reflections can be ignored, i.e. R_{12} (6) is not taken into account. Then the wave reflected from the rear surface of the screen is completely absorbed by the substance, expressions (3), (4), (5) for the values of R, T and A are simplified and take the form:

$$R = R_{12}\left(1 + (1-R_{12})\exp(-2\alpha d)\right), \quad (7)$$

$$T = (1-R_{12})^2 \exp(-2\alpha d), \quad (8)$$

$$A = (1-R_{12})\left(1-\exp(-2\alpha d)\right). \quad (9)$$

If the condition $d < 3\delta$ is not met, wave reflection from the inner surface can be disregarded.

Then the reflection coefficient in formula (7) is simplified and we have:

$$R = R_{12}, \quad (10)$$

The electromagnetic wave transmission coefficient T in formula (8) is simplified:

$$T = (1-R_{12})\exp(-2\alpha d). \quad (11)$$

Absorption coefficient A, which in this case is calculated as follows:

$$A = (1-R_{12})\left(1-\exp(-2\alpha d)\right)$$

according to (9), and shows the proportion of incident radiation power absorbed by the shielding layer.

Effectiveness of electromagnetic radiation shielding by material:

$$SE_T = 10\log\left(\frac{(n+1)^2 + k^2}{4n}\right) + 20\alpha d \log e, \quad (12)$$

Shielding effectiveness due to electromagnetic wave reflection:

$$SE_R = 10\log\left(\frac{(n+1)^2 + k^2}{4n}\right), \quad (13)$$

Efficiency through absorption of electromagnetic energy:

$$SE_A = SE_T - SE_R = 20\alpha d \log e, \quad (14)$$

where the values of n and k, as follows from (1), are determined by the relations:

$$n = \sqrt{\frac{\varepsilon' + \sqrt{\varepsilon'^2 + \varepsilon''^2}}{2}}, \quad (15)$$

$$k = \sqrt{\frac{-\varepsilon' + \sqrt{\varepsilon'^2 + \varepsilon''^2}}{2}}. \quad (16)$$

If the values of the real and imaginary components of the complex dielectric permittivity of the material are available, all the necessary indicators can be calculated.

The values of the dielectric permittivity of the composite depend on the radiation frequency ω and the volume content of the electrically conductive filler θ.

The criticality of the filler content is due to the percolation effect – a sharp increase in the electrical conductivity of the material – the threshold for the flow of electric current.

Consider θ_c – the flow threshold, θ_i – the threshold concentration, and τ – θ-θ_c – the distance from the flow threshold.

$$\varepsilon''(\omega,\theta) = \frac{\sigma_m}{\omega\varepsilon_0} \times$$

$$\times\left(\left(B_0 h(-\tau)^{-q} + B_1\left(h^2 - \left(\frac{\omega\varepsilon_0\varepsilon_d}{\sigma_m}\right)^2 (-\tau)^{-p}\right)\right)\right), \quad (17)$$

$$\varepsilon'(\omega,\theta) = B_0\varepsilon_d(-\tau)^{-q}, \quad (18)$$

where $h = \sigma_d / \sigma_m$;

σ_d and ε_d – electrical conductivity and dielectric permittivity of the matrix; σ_m – electrical conductivity of the filler; q and i – critical indices of percolation theory; $B_0 > 0$, $B_1 < 0$ – constants.

When the content of the conductive filler is above the threshold $(\tau > 0)$ – the subthreshold region ε'':

$$\varepsilon''(\omega,\theta) = A_0\frac{\sigma_m}{\omega\varepsilon_0}\tau^t, \quad (19)$$

$$\varepsilon'(\omega,\theta) = A_1\varepsilon_d\tau^{-q}, \quad (20)$$

where *t* is the critical index, A_0 and A_1 are constants.

To perform calculations, experimental determination of $\sigma(\theta)$ is required. Assuming uniform distribution of filler particles in the dielectric matrix, $t = 1.6;\ q = 1.0$.

All critical indices can be determined from the relationships given in [12].

Constants B_0, B_1, A_1 are determined from the conditions $\sigma(\theta) = \sigma_d;\ \varepsilon(\theta) = \varepsilon_d$ at $\theta = 0$, $A_1 = B_0$. A_0 is determined graphically from the dependence σ(τ), constructed on a logarithmic scale.

The automation of the design of composite material for shielding electromagnetic radiation was carried out for a model material consisting of calcium hydrosilicate (matrix) and granulated copper (dispersity – up to 60 μm). The frequency of the shielded radiation is 20 GHz. For this frequency, $\theta_c = 0.162$.

Output constants:

$\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m – electric constant,

$c = 3 \cdot 10^8$ m/s – speed of light in a vacuum,

$v = 20$ GHz – frequency of electromagnetic radiation,

ω – cyclic frequency of radiation, $\omega = 2\pi v$, $\omega = 1.26 \cdot 10^{11}$ Hz,

σ – electrical conductivity of the material, the value of which depends on the volume content of the electrically conductive filler,

$\sigma_m = 6 \cdot 10^7\ \Omega^{-1} \cdot m^{-1}$ – electrical conductivity of the filler,

$\varepsilon_d = 68.5$ – dielectric permeability of the matrix,

$d = 5 \cdot 10^{-3}$ m – screen thickness.

Experimental data on the dependence of the electrical conductivity of the composite on the content of the shielding filler are given in Table 1.

Table 1 – **Dependence of material electrical conductivity on the volume content of metal filler**

θ	0,165	0,170	0,175	0,180	0,185	0,190	0,195	0,200
σ, $\Omega^{-1} \cdot m^{-1}$	1,6	6,8	14,2	23,2	33,5	45,0	57,5	71,1

$$\sigma = A_0\sigma_m(\theta - \theta_c)^t.$$

Calculation procedure:

1. From the comparison of theoretical and experimental dependencies $\sigma(\theta)$, we find A_0 and θ_c. $\theta_c = 0.162$, $A_0 = 2.5 \cdot 10^{-4}$.

2. Calculate $\varepsilon''(\theta) = \dfrac{\sigma(\theta)}{\omega\varepsilon_0}$.

3. $\varepsilon'(\theta) = A_1\varepsilon_d(\theta - \theta_c)^{-q}$ A_1 find from the condition $\varepsilon(\theta) = \varepsilon_d$.

Consider that when $\theta < \theta_c$ $\varepsilon'(\theta) = B_0\varepsilon_d(\theta_c - \theta)^{-q}$.

We think that to assess $B_0 = A_1$, then the formula for determining $\varepsilon_d = A_1\varepsilon_d\theta_c^{-q}$, $A_1 = \theta_c$.

The final formula for $\varepsilon'(\theta) = \theta_c\varepsilon_d(\theta - \theta_c)^{-1}$.

4. Calculate $n(\theta)$ та $k(\theta)$.

5. Calculate SE_T, SE_R, SE_A

We take into account $k(\theta) = \dfrac{\omega k(\theta)}{c}$.

To automate the process of designing protective composite materials for shielding electromagnetic radiation, application software was developed consisting of a MySQL database, Microsoft Visual Studio programming environment, and *C#* programming language. Materials with electromagnetic field shielding functions (metal polymers) are entered into the interface.

The results of designing the specified shielding efficiency of the composite material are shown in Fig. 1.

The transmission coefficient *T* and reflection coefficient *R* of electromagnetic waves by protective material have practical significance in terms of their impact on people and ensuring the electromagnetic compatibility of electronic equipment.

A comparison was made between the calculated and measured coefficients for the material under consideration. The results are shown in Fig. 2.

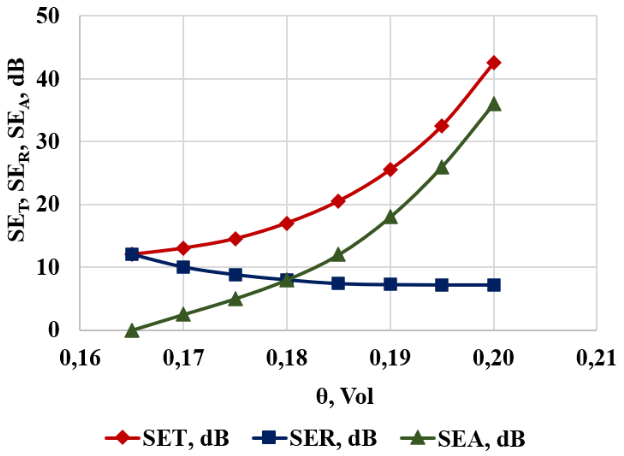
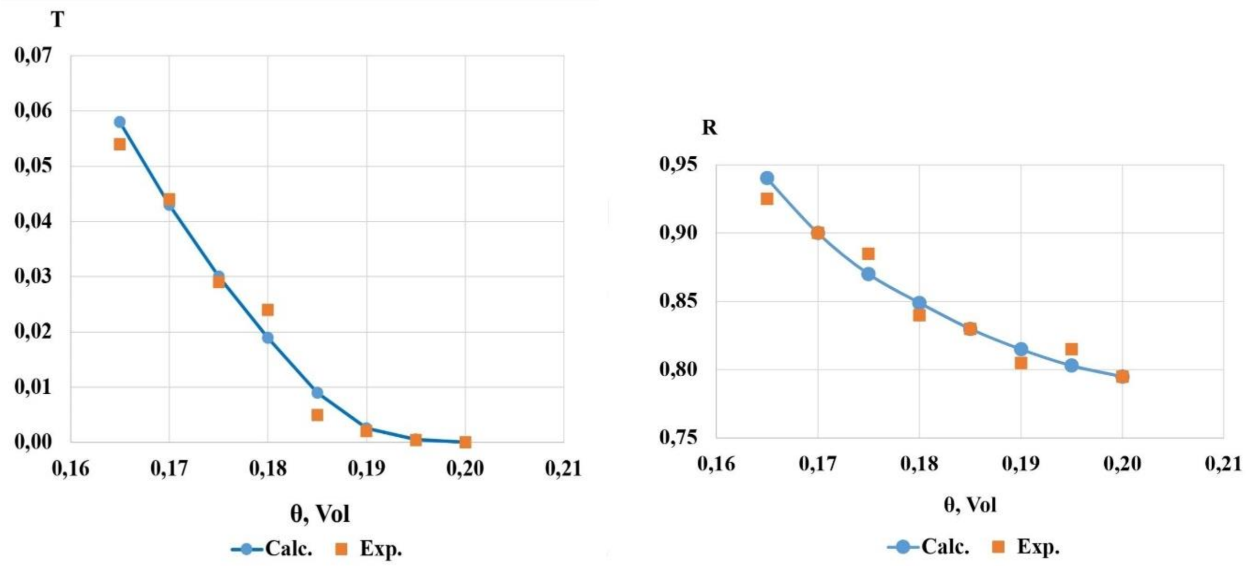


Fig. 1. Effectiveness of electromagnetic radiation shielding by composite metal-dielectric material: SE_T – total effectiveness of electromagnetic radiation shielding by material; SE_R – effectiveness of shielding by reflection; SE_A – effectiveness by absorption



a b

Fig. 2. Comparison of calculated and experimental coefficients: a – transmission T; b – reflection R of electromagnetic waves by composite material depending on the volume content of the filler

The data in Fig. 2 show that the convergence of calculated and experimental data is acceptable.

Automation of the design process for protective composite materials for shielding electromagnetic radiation allows optimising the ratio of *T*, *R*, and *A* indicators by adjusting the composition and thickness of composites depending on the needs and operating conditions of the materials.

However, the proposed approach has a certain drawback [16, 17].

Data is needed on the dependence of the electrical conductivity of the material on the volume content of the shielding material in the dielectric matrix. This requires a large number of measurements.

The patterns shown in Table 1 can be considered common for two-component compositions with an acceptable margin of error. Once an analytical function corresponding to the given relationships has been obtained, it is possible to limit oneself to measuring the specific electrical conductivity for a single filler concentration. The rest of the data is obtained by extrapolation. In this case, the dependence of σ on θ corresponds to the function:

$$\sigma = 2000x - 335, \ (R^2 = 0{,}98).$$

Therefore, it is advisable to enter this function and the corresponding data into the database for further determination of the effectiveness of electromagnetic radiation shielding. It should be noted that the proposed approach provides an acceptable calculation error, provided that the particles of the electrically conductive filler can be considered spherical. For more complex particle morphologies, it is necessary to improve the calculation apparatus and the corresponding software.

Conclusions

1. Mathematical functions have been defined for calculating the coefficients of reflection, transmission and absorption of electromagnetic radiation of ultra-high and higher frequencies. The smallest error is given by

calculations based on fundamental relations of electrodynamics of continuous media. Their application requires large amounts of calculations, which makes it expedient to automate this process.

2. Software has been developed to determine the protective properties of composite materials based on the electrophysical properties of the components and the volume content of the electrically conductive filler in the dielectric matrix. This allows the composition and thickness of the protective material to be optimised depending on the conditions of its application. The result obtained allows protecting people from the effects of electromagnetic radiation and ensuring the electromagnetic compatibility of electronic equipment based on the principles of reasonable sufficiency.

3. Comparison of the calculated and experimental data for the model material has proven their acceptable convergence. To reduce the measurement volumes to obtain the source data, a generalized function of the dependence of the electrical conductivity of the composite material on the voluminous content of the electrical filler is determined. This allows you to limit one measurement of electrical conductivity and get the rest of the data by extrapolation.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

REFERENCES

1. (2020), “Guidelines for limiting exposure to electromagnetic fields (100 KHz to 300 GHz), *Health Physics*, vol. 118, no. 5, pp. 483–524, doi: https://doi.org/10.1097/HP.0000000000001210
2. González, M., Pozuelo, J. and Baselga, J. (2018), “Electromagnetic Shielding Materials in GHz Range”, *The Chemical Record*, vol.18, is. 7–8: Special Issue: Recent Advances on Nanostructured Functional Materials, pp. 1000–1009, doi: https://doi.org/10.1002/tcr.201700066
3. Kefeng, J.I., Jun, G.A.O., Xiangyu, C.A.O., Jiangfeng, H.A.N. and Huanhuan, Y.A.N.G. (2021), “Design of Ultra-wideband Low RCS Reflecting Screen Based on Phase Gradient Metasurface” *Radioengineering*, vol. 30, is. 2, pp. 314–322, doi: https://doi.org/10.13164/re.2021.0314
4. Kolcunová I., Zbojovský J., Pavlík M., Bucko S., Labun J., Hegedus M., Vavra M., Cimbala R., Kurimský J., Dolník B., Petráš J., Džmura J. Shielding Effectiveness of Electromagnetic Field by Specially Developed Shielding Coating. Acta Physica Polonica, A. May 2020, Vol. 137 Issue 5, p. 711-713, doi: http://doi.org/10.12693/APhysPolA.137.711
5. Kozirsky, V. V., Podoltsev, O. D. and Tregub, M. I. (2020), “Substantiation of magnetic system of switched reluctance generator with annular rotor for wind turbine”, *Machinery & Energetics*, no. 2, pp. 165–170, doi: https://doi.org/10.31548/machenergy2020.02.165
6. Shcherba, A. A., Podoltsev, O. D., and Kucheriava, I. M. (2020), “The study of magnetic field of power cables in polyethylene pipes with magnetic properties”, *Tekhnichna Elektrodynamika*, no. 3, pp. 15–21, doi: https://doi.org/10.15407/techned2020.03.015
7. Tudose, I.V., Mouratis, K., Ionescu, O.N., Romanitan, C., Pachiu, C., Popescu, M., Khomenko, V., Butenko, O., Chernysh, O., Kenanakis, G., Barsukov, V., Suchea, M., and Koudoumas, E. (2022), “Novel water-based paints for composite materials used in electromagnetic shielding applications”, *Nanomaterials*, vol. 12(3), 487, doi: https://doi.org/10.3390/nano12030487
8. Kochetov, G., Glyva, V., Malyshev, V., Gots, V., Samchenko, D., and Lastivka, O. (2024), “Application of Innovative Electromagnetic Screens for Reconstruction and Restoration of Buildings”, *International Journal of Conservation Science*, vol. 15, pp. 63–72, doi: https://doi.org/10.36868/IJCS.2024.SI.06
9. Senyk, I., Kuryptya, Y.A., Barsukov, V., Butenko, O.O. and Khomenko, V. (2020), “Development and Application of Thin Wide-Band Screening Composite Materials”, *Physics and Chemistry of Solid State*, vol. 21, pp. 771–778, doi: https://doi.org/10.15330/pcss.21.4.771-778
10. Grinchenko, V.S. (2018), “Mitigation of three-phase power line magnetic field by grid electromagnetic shield”, Tekhnichna Elektrodynamika, vol. 2018, is. 4, pp. 29–32, doi: https://doi.org/10.15407/techned2018.04.029
11. Xia, T., Zhang, C., Oyler, N.A., and Chen, X. (2013), “Hydrogenated TiO_2 nanocrystals: a novelmicrowave absorbing material”, Adv. Mater., vol. 25(47), pp. 6905-6910, doi: https://doi.org/10.1002/adma.201303088
12. Xu, J., Qi, X., Luo, C., Qiao, J., Xie, R., Sun, Y., Zhong, W., Fu, Q. and Pan, C. (2017), “Synthesis and enhanced microwave absorption properties: a strongly hydrogenated TiO_2 nanomaterial”, *Nanotechnology*, vol. 28, no. 42, 425701, doi: https://doi.org/10.1088/1361-6528/aa81ba
13. Krasnianskyi, G. V. Glyva, N. Burdeina, Y. Biruk, L. Levchenko, O. Tykhenko. Methodology For Designing Facing Building Materials with Electromagnetic Radiation Shielding Functions. International Journal of Conservation Science. Volume 15, Special Issue 1, 2024. Pp. 53-62, doi: https://doi.org/10.36868/IJCS.2024.si.05
14. Levchenko, L., Glyva, V., and Burdeina, N. (2022), “Mathematical apparatus for modeling of the propagation the magnetic field electric machines with a given accuracy”, *Advanced Information Systems*, vol. 6, no. 2, pp. 5–9, doi: https://doi.org/10.20998/2522-9052.2022.2.01
15. Levchenko, L., Bolibrukh, B., Kovalenko, O., Myshchenko, I. and Asieieva L. (2025), “Modeling of infrared radiation propagation through thermal insulation surfaces”, *Advanced Information Systems*, vol. 9, no. 1, pp. 43–48, doi: https://doi.org/10.20998/2522-9052.2025.1.05
16. Zhang, H., Zhao, Y., Yang, X., Zhao, G., Zhang, D., Huang, H., Yang, S., Wen, N., Javid, M., Fan, Z. and Pan, L. (2020), “A facile synthesis of novel amorphous TiO2 nanorodsdecorated rGO hybrid composites with wide band microwave absorption”, Nanomaterials, vol. 10, no. 11, 2141, doi: https://doi.org/10.3390/nano10112141
17. Shuo, Liu, Yaxi, Cheng, Wanui, Xiao Yaru, Li, Yidi, Lit, Jiajin, Li and Lixia, Bao (2025), “Tuning Oxygen Vacancy Concentration in Defect-EngineeredBlack TiO_2 Nanomaterials for Synergistically Enhanced Microwave Absorption Performance”, *ACS Applied Nano Materials,* vol. 8, is. 45, pp. 21938–21947, doi: https://doi.org/10.1021/acsanm.5c03969

Received (Надійшла) 25.09.2025
Accepted for publication (Прийнята до друку) 14.01.2026

ВІДОМОСТІ ПРО АВТОРІ.В/ ABOUT THE AUTHORS

Левченко Лариса Олексіївна – доктор технічних наук, професор, професор кафедри цифрових технологій в енергетиці, Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського, Київ, Україна;
Larysa Levchenko – Doctor of Technical Sciences, Professor, Professor of Department Digital Technologies in Energy, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine;
e-mail: larlevch@ukr.net; ORCID Author ID: http://orcid.org/0000-0002-7227-9472;
Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=57194577942.

Бурдейна Наталія Борисівна – доктор технічних наук, доцент, професор кафедри фізики, Київський національний університет будівництва та архітектури, Київ, Україна;
Nataliia Burdeina – Doctor of Technical Sciences, Associate Professor, Professor of the Department of Physics, Kyiv National University of Construction and Architecture, Kyiv, Ukraine;
e-mail: burdeina.nb@knuba.edu.ua; ORCID Author ID: orcid.org/0000-0002-2812-1387;
Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=57220047954.

Глива Валентин Анатолійович – доктор технічних наук, професор, завідувач кафедри фізики, Київський національний університет будівництва та архітектури, Київ, Україна;
Valentyn Glyva – Doctor of Technical Sciences, Professor, Head of the Department of Physics, Kyiv National University of Construction and Architecture, Kyiv, Ukraine;
e-mail: hlyva.va@knuba.edu.ua; ORCID Author ID: https://orcid.org/0000-0003-1257-3351;
Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=57210185162.

Краснянський Григорій Юхимович – кандидат фізико-математичних наук, доцент кафедри фізики, Київський національний університет будівництва та архітектури, Київ, Україна;
Grygorii Krasnianskyi – Candidate of Physical and Mathematical Sciences, Associate Professor of the Department of Physics, Kyiv National University of Construction and Architecture, Kyiv, Ukraine;
e-mail: krasnianskyi.giu@knuba.edu.ua; ORCID Author ID: https://orcid.org/0000-0002-2421-1270;
Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=6507131193.

Токарський Олександр Іванович – доктор філософії, начальник, 2 Державний пожежно-рятувальний загін головного управління державної служби України з надзвичайних ситуацій у Закарпатській області, м. Мукачеве, Україна*;*
Oleksandr Tokarskiy – PhD, chief, 2 State Fire and Rescue Detachment of the Main Directorate of the State Emergency Service of Ukraine in the Zakarpattia Oblast, Mukacheve, Ukraine;
e-mail: tokarskiyoleksandr@ukr.net; ORCID Author ID: https://orcid.org/0000-0001-6683-8437;
Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=57963188000&origin=resultslist.

Автоматизація проєктування композиційних електромагнітних екранів заданої ефективності

Л. О. Левченко, Н. Б. Бурдейна, В. А. Глива, Г. Ю. Краснянський, О. І. Токарський

Анотація. Актуальність. Найбільш ефективним засобом підвищення електромагнітної безпеки людей та електромагнітної сумісності електронного обладнання є екранування. Керованість захисних властивостей (співвідношення коефіцієнтів відбиття, поглинання проходження) електромагнітних хвиль мають тільки композиційні матеріали. Але проєктування матеріалів з потрібними захисними властивостями складне й потребує великих обсягів обчислень. Це обумовлює доцільність автоматизації цих процесів шляхом створення прикладного програмного забезпечення. **Метою роботи** є автоматизація процесів проєктування композиційних матеріалів з керованими захисними властивостями. **Результати дослідження**. Надано математичні функції для визначення ефективності екранування електромагнітних випромінювань за рахунок відбиття й поглинання електромагнітних хвиль. Показано, що для автоматизації процесів проєктування композиційних захисних матеріалів доцільно застосовувати фундаментальні співвідношення електродинаміки суцільних середовищ. Визначено перелік теоретичних та експериментальних даних, необхідних для проєктування захисних матеріалів. Розроблене прикладне програмне забезпечення, яке дозволяє отримати дані щодо ефективності екранування електромагнітного випромінювання за рахунок відбиття та поглинання електромагнітних хвиль у залежності від електрофізичних параметрів компонентів композиту та об'ємного вмісту електропровідного наповнювача у діелектричній матриці. На прикладі силікатного матеріалу з наповнювачем із гранульованої міді отримані залежності ефективності екранування електромагнітного випромінювання надвисокої частоти від вмісту наповнювача. Порівняння отриманих даних з експериментом свідчить про їх прийнятну збіжність. Для прискорення процесів проєктування захисних матеріалів отримано узагальнену функцію залежності електропровідності композиту від вмісту наповнювача. Це дозволяє зменшити обсяг експериментальних робіт для отримання вихідних даних. **Висновки.** Створення прикладного програмного забезпечення для автоматизації процесів проєктування композиційних матеріалів дозволяє оптимізувати ефективність захисних матеріалів за рахунок обирання найбільш прийнятних компонентів та вмісту електропровідного матеріалу у діелектричній матриці.

Ключові слова: автоматизація; електромагнітне випромінювання; композиційний матеріал; ефективність екранування.