Use of absorbent coatings based on composite materials

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The information sphere plays a growing role in ensuring the security of all areas of society. A significant part of the threats to the national security of the state is realized through this sphere. Therefore, the issues of protecting confidential information from leakage are quite relevant. One of the main sources of information leakage is electromagnetic fields resulting from the operation of modern radio-electronic means. Therefore, the problem of weakening unauthorized informational electromagnetic fields is currently receiving much attention.

An analysis of the relevant topics of publications shows that a promising direction for ensuring effective field attenuation is the use of composite materials that have high shielding properties and meet sanitary and hygienic requirements. To date, it is known about the effective use of composite materials as absorbers deposited on the leading surface. As for the attenuating properties of composites during the through passage of electromagnetic waves, this issue has not been studied enough.

The aim of the article is the synthesis of shielding composite materials for absorbing electromagnetic wave coatings with resonant dispersion of the permittivity. An example of such materials can be materials consisting of a dielectric matrix with leading inclusions, the absolute complex permittivity of which is described by the expression

$$\varepsilon_k(\omega) = \varepsilon_0\left(\varepsilon_\varepsilon + \sum_{i=1}^{N}\frac{(\mathrm{A}_{0i}-1)\omega_{0i}^2}{\omega_{0i}^2-\omega^2+j\omega\gamma_i}\right), \mathrm{A}_{0i}>1,\ \gamma_i>0, \tag{1}$$

where: ω - – current oscillation frequency; ω_{0i} - resonant frequencies; , $\mathrm{A}_{0i}, \gamma_i$ - parameters of the composite material, determined by the shape and properties of the leading inclusions; ε_0 - absolute permittivity of vacuum; ε_ε - relative permittivity of the dielectric matrix, which characterizes the static and optical permittivity of the composite; $\mathrm{i} = \overline{1, N}$, where the upper summation limit N is determined by the number of resonant frequencies of the composite material. By choosing the parameters $\varepsilon_\varepsilon, \mathrm{A}_{0з}, \omega_{0з}, {}_{,}\gamma_i, N$ one can achieve a significant weakening of the electromagnetic field. Let's consider the simplest case, when $N = 1$.

Our task is to determine the varied parameters ε_ε, $\mathrm{A}_{0i}, \omega_{0i}, \gamma_i$ (i = 1), at which in a given frequency range $\omega \in \omega_í \ldots \omega_â$ ($\omega_í$, $\omega_â$ - lower and upper limits of the frequency range) the shielding factor is implemented, not lower than the specified level. It is assumed that the thickness of the coating is also given $l = l_0$. The fact is that varying the thickness of the coating l it makes no sense, since by increasing the thickness of the coating, any value of the shielding factor can be obtained. According to the accepted terminology, a composite material with certain parameters ε_ε, A_{0i}, ω_{0i}, γ_i called synthesized material.

Based on the described algorithm, a composite coating was synthesized with subsequent initial data. Coating thickness $l_0 = 1$ см, frequency range $\mathrm{f_н}$ = 3000MHz, $\mathrm{f_в}$ = 5000MHz; $\varepsilon_\varepsilon = 1$. For advanced composite materials $1 < \mathrm{A}_{0i} < 20$. Therefore, we will use this restriction in optimization.

It is known that the shielding factor must be at least 10. On the image 1-3 the characteristics of the synthesized coatings are shown with one term in the formula (1) $(N = 1)$ and with two terms $(N = 2)$. In this case (Fig. 1), dependence 1 corresponds to the parameters of the composite : $A_{01} = 13{,}53$; resonant frequency $f_{01} = 3850\text{MHz}$ $(\omega_{01} = 2\pi f_{01})$; $\gamma_1 = 4{,}35 \cdot 10^9$. Dependencies 2 match parameters: $A_{01} = 5{,}33$; $A_{02} = 6{,}14$; resonant frequencies $f_{01} = 2437\text{MHz}$; $f_{02} = 4672\text{MHz}$; $\gamma_1 = 6{,}21 \cdot 10^9$; $\gamma_2 = 8{,}66 \cdot 10^9$.

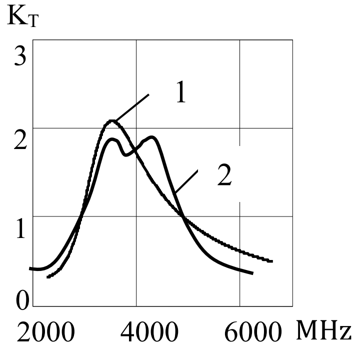

Fig. 1. Screening factor versus frequency: 1 - N=1; 2 - N=2

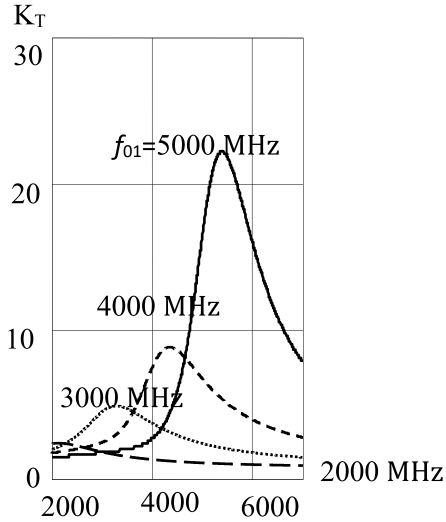

Fig. 2. Screening factor versus frequency at different resonant frequencies f_{01} composite coating material: $A_{01} = 5, \gamma_1 = 10 \cdot 10^9$

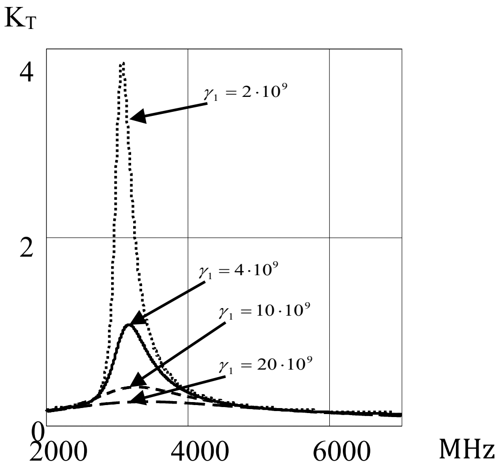

Fig. 3. The dependence of the shielding factor on frequency at different values of the material percolation parameter $\gamma_1 : A_{01} = 5,\ f_{01} = 3000$MHz

It follows from the obtained characteristics that with an increase in the number of terms in the expression for the permittivity (1), the dependence of the shielding factor on frequency takes the form of the Chebyshev characteristic.

As follows from the dependences of the screening factor on frequency for various percolation parameters (Fig. 3), the solution of optimization problems is multivalued, since many combinations of parameters of composite materials correspond to the given initial data. Therefore, when choosing the final solution, one should be guided by additional restrictions. For example, based on the manufacturability of the implementation of the composite, it is advisable to take the parameters A_{0i} as little as possible.

Theoretically, an increase in A_{0i} can provide any screening in an arbitrary frequency range, so optimization by the parameters A_{0i} without additional restrictions is meaningless.

A more detailed analysis of the screening factor shows that

1) the resonant frequencies of the composite must be within (or near) the specified screening range;

2) in the region of resonant frequencies, a sharp increase in the screening coefficient is observed, and with an increase in the resonant frequency, its value increases;

3) a change in the parameter A_{01} has little effect on the frequency position of the maximum of the screening coefficient: with an increase in A_{01}, both the degree of screening and the frequency region of screening increase;

4) with an increase in γ_1, the position of the maximum of the screening coefficient practically does not change. However, the degree of screening is reduced.

Conclusion. Based on the results obtained, the influence of the parameters of percolation materials on the screening coefficient is analyzed. It has been established that by choosing the percolation parameters it is possible to achieve a significant increase in the shielding factor of electromagnetic waves in a given frequency range.

The results obtained in the article can be used in the development of new absorbing electromagnetic wave coatings**.** It follows from the analysis of the research results that an improvement in the quality of shielding can be achieved using multilevel (N>1) composite materials. This direction is promising for further research.