Development of Absorbing Coatings for Protection Against Electromagnetic Pollution of the Environment

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Abstract. Radioabsorbing materials are materials whose composition and structure provides effective absorption (with little reflection) of electromagnetic energy in a certain range of radio wavelengths. The paper investigates the weakening effects of screens of various kinds on the electromagnetic waves passing through them. With such solutions, it is possible to make estimates for the weakening effect of electromagnetic screens of arbitrary shape and for radiation with arbitrarily given characteristics.

1. Introduction
Radioabsorbing materials are materials whose composition and structure ensures effective absorption (with little reflection) of electromagnetic energy in a certain range of radio wavelengths. There is no universal classification of radioabsorbing materials. Conventionally, they can be classified by composition and principle of action.

In modern developments of radioabsorbing materials for absorption of energy of electromagnetic waves the traditional electroconducting disperse (soot, graphite, metal particles), fibrous (carbon, metal, metallized polymeric) and magnetic (sintered ferrite plates, powders of ferrites, carbonyl iron, etc.) fillers applied both separately, and together are used for absorption, forming difficult composite structures. Radioabsorbing materials made in the form of varnishes, paints, sealants, polymers, fabrics, tiles, foams, filled rubbers, building slabs, loose mixtures and other variants of various compositions are the main components in the creation of electromagnetic wave absorbers, which are used for the equipment of anechoic chambers.

In the simplest case, the screens are the windows and walls of the room where the device is working; in other cases, the role of the screen will perform specially created for this design.

In this regard, there is an urgent task to study the weakening effects of screens of various kinds on the electromagnetic waves passing through them. The solution of such problems depends on the characteristics spurious emissions, primarily from wave, its spectral composition and the radiation pattern and characteristics, namely its geometry and electromagnetic parameters of the material from which it is made.

Mathematically, problems of this kind are extremely complex and, in General, can only be solved approximately by numerical methods.

Accurate analytical solutions can be obtained only in the analysis of the simplest situations, such as the normal incidence of a plane harmonic linearly polarized wave on the screen in the form of a homogeneous plate.
2. Mathematical model

We formulate the initial relations of electrodynamics and the approximations that will be used in the calculations. All space we will divide into three areas - the material of the screen and the air environment on both sides of it.

An important characteristic of radioabsorbing materials is the absorption coefficient \( A \), which is found by formula 1:

\[
A = 1 - R \cdot T; \tag{1}
\]

\( R \) and \( T \) are the reflection and absorption coefficients, respectively, and are found by formulas 2 and 3.

\[
R = \frac{U_R}{U_i} \tag{2}
\]

\[
T = \frac{U_T}{U_i} \tag{3}
\]

\( U_i \) is the tension of the amplitude of the incident wave; \( U_R \) is the tension of the amplitude of the reflected wave; \( U_T \) is the tension of the amplitude of the transmitted wave.

Relationship between electric \( E(x) \) and magnetic \( H(x) \) field functions at the outer boundaries of the plate:

\[
E^i(-0) = A, \quad E^r(-0) = R, \quad E^p(d+0) = T
\]

\[
H^i(-0) = A/Z_0, \quad H^r(-0) = -R/Z_0, \quad H^p(d+0) = T/Z_0 \tag{5}
\]

\( Z_0 \) is characteristic impedance of vacuum

\[
Z_0 = \sqrt{\mu_0/\varepsilon_0} \tag{6}
\]

\( \varepsilon_0 \) is dielectric capacititivity, \( \mu_0 \) is magnetic permeability.

Conjugation conditions for functions \( E(x) \) and \( H(x) \) at plate boundaries:

\[
A + R = E(+0); \quad A - R = Z_0 H(+0); \quad T = E(d-0); \quad T = Z_0 H(d-0) \tag{7}
\]

The amplitude reflection \( r_a \) and transmission \( t_a \) coefficients are calculated by the formulas:
Here for brevity symbols $m_{ij}$ denote elements of the Cauchy matrix $M$:

$$m_{11} = \cos k_0 nd; \quad m_{12} = -\frac{iZ_0}{n} \sin k_0 nd; \quad m_{21} = -\frac{in}{Z_0} \sin k_0 nd; \quad m_{22} = \cos k_0 nd.$$  

The reflection $r_e$ and transmittance $t_e$ energy coefficients can be defined as:

$$r_e = \left| \frac{S^r}{S^i} \right|^2; \quad t_e = \left| \frac{S^p}{S^i} \right|^2$$  

$S$ is Poynting vector for the corresponding wave.

### 3. Discussion

An example of the reflection and transmission coefficients calculation is shown in figures 2 and 3. The graphs are constructed as a function of the ratio $d/\lambda$ at a constant real part of the refractive index $n$ for three values of the imaginary part of this index ($n = 0; 3.5; 7$).

Thus, the graphs give an idea of the behavior of the reflection and transmission coefficients depending on the wavelength of radiation and the absorption capacity of the material.

![Figure 2](image_url). The calculation of the reflection coefficient.
4. Conclusion
The proposed algorithm for calculating the reflection and transmission coefficients is easily
generalized to the case where instead of a plate we have a layered medium. Thus, it is possible to solve
the problem of calculating the coefficients of attenuation of electromagnetic radiation by dielectric
screens of different designs.

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