THE FREQUENCY CHARACTERISTICS OF THE REFLECTION OF THE ELECTROMAGNETIC RADIATION IN THE LAYERED SYSTEMS

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In the ref the results of the investigation of the frequency characteristics of the layered systems, obtained by the way of the coating of the dielectric-metal of the quarter-wave-length layers from the non-absorptive material on the two-layered system.

The effect of the non-reflective absorption of the electromagnetic radiation in the two-layered systems of polar dielectric-metal, which is predicted and experimentally proved, appears in the dispersion region of the dielectric covering at the discrete values of the wave length of the incident radiation λ_0, the thickness l_0 of the reflective layer of the covering and the substance of the polar molecules in it [1]. This effect has resonance character and taking this under consideration, the investigations of the frequency characteristics of the reflection of the electromagnetic waves from such two-layered system, near resonance values λ_0 and l_0 present the definite interest.

The results of the investigations show the bandlimitedness of the frequency spectrum, at which the effect of total absorption carries out. For the increase of the frequency band of the non-reflective absorption it was supposed to use the quarter-wave-length layers from the non-absorptive material, coated on the two-layered system of dielectric-metal. The investigation of the frequency characteristics of such layered system has been showed, that the use of the quarter-wave-layers significantly changes the frequency range, at which the partial or total absorption of the electromagnetic waves in these systems is carried out.

For the calculation of the frequency characteristics of the reflection of such system the following expression for the module of standing-wave ratio was used near chosen values λ_0, l_0 [1,2]

$$\rho = \left| \frac{Z_{enm} - Z_0}{Z_{enm} + Z_0} \right| \qquad (1)$$

where Z_{enm} is the input resistance of the multi-layer system depending on the frequency, substance properties and geometric dimensions of the directed system.

Taking under the consideration such approach the input resistance of the system at the connection to it the *i*-additional layer of the covering is equal:

$$Z_{eni} = \frac{Z_{eni-1} + Z_i th\,\gamma_1 l}{1 + \frac{Z_{eni-1}}{Z_i} th\,\gamma_1 l}\ , \qquad (2)$$

where Z_{eni}, Z_{eni-1} are input resistances of the system at the existence of the i and i-1 layers; Z_i is wave resistance of i-layer; γ_i- is distribution constant in the substance of i-layer in it [3,4].

From the equation (2) it is followed, that the input resistance of the multi-layer system, consisting from the absorptive layer and one additional layer will have the form

$$Z_{en\,1} = \frac{Z_{en} + Z_1 th\,\gamma_1 l}{1 + \frac{Z_{en}}{Z_1} th\,\gamma_1 l} \qquad (3)$$

where Z_{en} is the input resistance of the absorptive layer.

According to the definition $Z_{en}=Zth\gamma l$. Using the expression for Z and γ, we obtain:

$$Z_{en}=M+iN\ , \qquad (4)$$

where

$$M = \frac{1}{n(1+y^2)} \frac{sh\,4\pi\overline{x}\overline{y} - y\,sin\,4\pi\overline{x}}{ch\,4\pi\overline{x}\overline{y} + cos\,4\pi\overline{x}}\ ;$$

$$N = \frac{1}{n(1+y^2)} \frac{\overline{y}sh\,4\pi\overline{x}\overline{y} + sin\,4\pi\overline{x}}{ch\,4\pi\overline{x}\overline{y} + cos\,4\pi\overline{x}}\ .$$

For the creation of the simple automatized calculation of the reflection frequency characteristics of the absorbent coverings with one or two quarter-wave-length additional layers from the lossless materials, coated on them, the investigated algorithm was applied. It allows to evaluate the influence of the matched layers on the behavior of the frequency characteristics, in particularly, wave absorption band, near the spectral values l_0, λ_0 in the dependence on the concerning substance properties and additional layers. The algorithm is constructed by the principle of the consistent calculations of the input resistances consisting the layer system during of their connection to the main layer.

The investigations of the frequency characteristics were carried out in the range of wave lengths 0,5-5 cm, moreover, it was considered, that dielectric properties of the adsorbent covering were described by Debye equation at the value

ε_∞=2. The values, ε_0, τ of the substance of the absorbent layer varied in the interval 5-20 units and 5-20·10^{-12}c correspondingly.

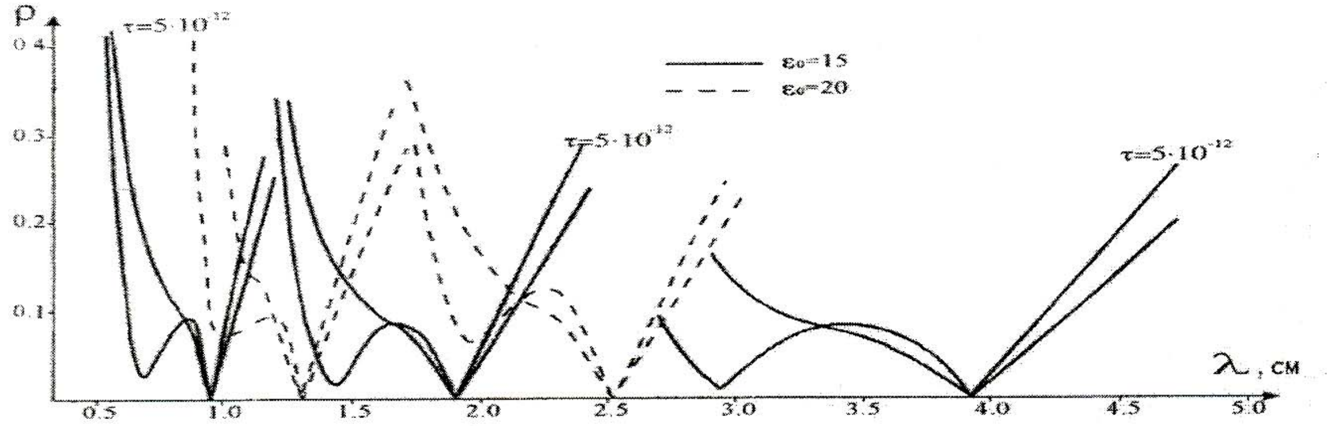

Fig.1. The reflection frequency characteristics of the three-layered system with the values of the dielectric constant ε_1, which are equal to 2(a,c) and 1,5 (b).

The reflection frequency characteristics of the three-layered system with the value of the dielectric constants ε of the additional quarter-wave-length layer, which are equal to 1,5 and 2,0, are presented on the fig.1. As in the case of the two-layered system dielectric-metal, ε_0 of the absorbent layer of the given system at the constancy of the τ value leads to the decrease of the relative band of the wave selective absorption for the low-frequency spectrum arm and some its stabilization for the high-frequency spectrum arm (see table 1). Moreover, the increase of the *N* number of zero minimum of ρ value relatively the bans is decreased. However, in the difference from the system dielectric-metal in the given three-layered system the input of the additional quarter-wave-length layer causes to the expansion of the relative band of the selective wave absorption. The variety of the value τ at the constancy ε_0 influences on the absorption band insignificantly.

Table 1.

The values of the statistical dielectric constant ε_0, relaxation time τ, thickness l_0, the covering layer, wave length λ_0, relative absorption band $\Delta\lambda/\lambda_0$ on the level ρ_l=0,1 of the three-layered absorbent system at ε_∞, and different values of the dielectric constants of the additional layer ε_1, *N* is number of dependence minimum of ρ on *l*.

Low-frequency branch N=1 k=2				
$\tau 10^{-12}$	ε_0	Λ_0	$\Delta\lambda/\lambda$ at $\varepsilon_1 = 4; \varepsilon_2 = 2$	$\Delta\lambda/\lambda$ at $\varepsilon_1 = 3; \varepsilon_2 = 1,5$
5	15	0,97	0,37	0,31
	20	1,28	0,37	0,21
10	15	1,93	0,35	0,33
	20	2,55	0,14	0,18
20	15	3,87	0,37	0,32

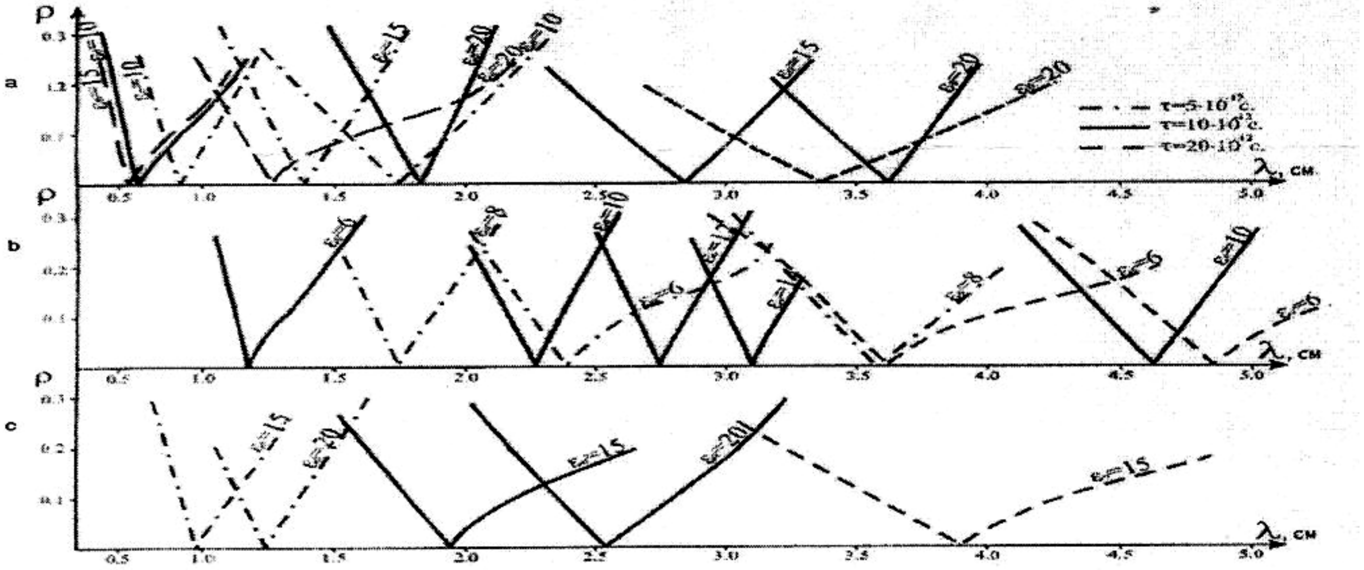

Fig.2. The reflection frequency characteristics of the four-layered system with the values of the dielectric constant ε_0, which are equal to 20 and 15 and values of the dielectric constants of the additional layers.

The input of the second additional quarter-wave-length layer significantly changes the frequency characteristic of the wave reflection from such four-layered absorbent system. The families of the reflection frequency characteristics for the four-layered systems, consisting the additional layers with the value $\varepsilon_1=4$; $\varepsilon_2=2$ and $\varepsilon_1=3$; $\varepsilon_2=1,5$ correspondingly are given on the fig.2.

The resistance transformer of these systems, appearing because of the two additional layers has the one and the same value of the transformation ratio $k=2$.

At the wave distribution in the waveguide and other direction system, the structure of the given algorithm of the calculation of the reflection frequency characteristics of the multi-layered system is saved. In this case it is need to make the change of the used values ε_0, ε_∞, τ, ε_1, ε_2, $\ldots\varepsilon_m$, λ on their reduced values $\frac{\varepsilon_0 - p}{1 - p}$; $\frac{\varepsilon_\infty - p}{1 - p}$; $\tau\sqrt{1 - p}$; $\frac{\varepsilon_1 - p}{1 - p}$; $\frac{\varepsilon_2 - p}{1 - p}$; $\frac{\varepsilon_n - p}{1 - p}$.

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LAYLI SİSTEMLƏRDƏ ELEKTROMAQNİT ŞÜALANMANIN ƏKSOLUNMASININ TEZLİKLİ XÜSUSİYYƏTLƏRİ

Məqalədə laylı sistemlərin, dielektrik-metal iki laylı sistemlərin dördəbirdalğalı udmayan materialdan layları üstünə çəkilmiş, tezlikliklərin xarakteristikalarının tədqiqinin nəticələri verilib.

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ЧАСТОТНЫЕ ХАРАКТЕРИСТИКИ ОТРАЖЕНИЯ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ В СЛОИСТЫХ СИСТЕМАХ

В статье представлены результаты исследования частотных характеристик слоистых систем, полученных путем нанесения на двухслойную систему диэлектрик-металл четвертьволновых слоев из непоглощающего материала.

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