THE CONDITIONS OF THE FULL ABSORPTION OF THE ELECTROMAGNETIC RADIATION OF THE TWO-LAYERED SYSTEM DIELECTRIC-METAL AT THE PRESENCE OF THE RESISTANCE TRANSFORMER

M.A. SADIKHOV, S.T. AZIZOV
Institute of Physics, Azerbaijan National Academy of Sciences
Baku, Az-1143, H. Javid ave., 33

Equations describing conditions of preferential non-reflecting (full) absorption of electromagnetic radiation into dielectric-metal system with covered arbitrary number of quarter-wave none-absorbing layers on it has been obtained. The Influence of such multilayer resistance transformer on band of preferential absorption of radiation is shown.

In the refs [1,2] the existence of the non-reflecting (full) absorption of the electromagnetic radiation in the plane two-layered system polar dielectric-metal had been theoretically predicted and experimentally proved. This effect appears in the dispersion region of the material of the dielectric covering at the discrete values of incident radiation wavelength λ_0, thickness l_0 of the reflecting layer of the covering. The obtained spectrum λ_0 and l_0 has a resonance character, it is individual for the covering substance and defined by its static and dynamical properties. The spectral values λ_0 and l_0 correspond to the appearing once so-called zero minimums of the dependence of the module of wave reflection coefficient ρ on the thickness l of composition layer. Moreover, the obtained values l_0 are close, but don't equal to the values, which are multiple once to the quarter - wave length λ_g in the dielectric covering. The specified theoretical and practical interest is the investigation of this phenomenon at the presence of the additional plane quarter-wave layers from the non-reflecting materials, which situate upper than the absorption dielectric of the two-layered system dielectric-metal [1,2]. The presence of such additional layers can influence on the selective absorption band of wave in the same way, as it is in the tasks of the optic's antireflection.

Let's consider the general task of the reflection of the plane-reflected wave, falling normally on the plane multi-layered system, which can be presented in the capacity of the two-layered absorption system dielectric-metal, connected with the air part of the radiation space with the help of resistance transformer, which in the general case presents by itself the m successively covered quarter-wave layers from the non-reflecting dielectrics. The transformation ratio of such layered resistance transformer is equal to

$$k = \left[\frac{Z_2, Z_4, Z_6 . . . .}{Z_1, Z_3, Z_5 . . . .} \right]^2 \tag{1}$$

where Z_1, Z_2, ... Z_n are wave resistances of the direction system, filled by the materials of m successively applied layers of resistance transformer, accordingly.

The complex value of the wave reflection coefficient of the system, absorbing the dielectric-metal, taking into consideration the resistance transformer, is equal to

$$\rho = \frac{Zkth\ \gamma l - Z_0}{Zkth\ \gamma l + Z_0} \tag{2}$$

where $\gamma = i \frac{2\pi}{\lambda} \sqrt{\varepsilon - p}$; Z, Z_0 are the wave propagation constant and the wave resistance of the directing system, filled by the material of the main absorbing layer; $\varepsilon=\varepsilon' -i\varepsilon''$; ε', ε'' -are values of the dielectric constant and dielectric loss of the material of the absorbing layer, accordingly; l is the thickness of the layer of the absorbing dielectric, $\rho= (\lambda/\lambda_{cr})^2$; λ-is the wavelength; λ_{cr} is the critical wavelength, defined by the measures of the directing system.

The values ε^I and ε^{II} of the absorbing coefficient, including in the equation (2), connect with its wave refraction coefficient n and factor of dielectric loss with the known ratios

$$\varepsilon^I = n^2 (1-y^2) ; \qquad \varepsilon^{II} = 2 n^2 y \tag{3}$$

For the convenience of the later considering, let's introduce the mention of the given values of wave refraction coefficients $\tilde{n}$ and factor of the dielectric loss $\tilde{y}$, which are differ from n and y in the case of the usage of the direction system, when value p differs from 0.

From the expressions for $\tilde{n}$, taking into consideration (3), it follows, that

$$n = \frac{n}{\sqrt{1 - p}} ; y = tg\, \Delta/2 ; \Delta = arctg\ \varepsilon'' /(\varepsilon' -p) \tag{4}$$

where $\tilde{n}= \lambda_{в}/\lambda_g$; $\lambda_{в} = \lambda / \sqrt{1 - p}$ is the wavelength in the empty directing system and direction one, filled by the absorbing dielectric, accordingly.

Applying such output process that was in the ref [4] we obtain the following equations, defining the conditions of the full non-reflecting wave absorption in the considered multi-layered system.

$$\left.\begin{aligned}\pi(2N-1)+\operatorname{arcng}\frac{2nyk}{n^2(1+y^2)-k^2}&=\frac{1}{2y}\ln\frac{(k+n)^2+n^2\tilde{y}^2}{(k-n)^2+n^2y^2}\\ \frac{l}{\lambda_b}&=\frac{1}{kn}\left(\frac{2N-1}{4}+\frac{1}{4\pi}\operatorname{arctg}\frac{2nyk}{n^2(1+y^2)-k^2}\right.\end{aligned}\right\}\qquad(5)$$

where N is the number of the zero minimum of dependence of ρ on l.

The equations (5) establish the connection between values n, y, N, at which in the considered multi-layered system the full non-reflecting wave absorption appears. At $p=0$ and $k=1$, they are equal by form with the analogical equations, obtained at the consideration of the conditions of the non-reflecting wave absorption in the two-layered system dielectric-metal in the free space.

The equation (5) doesn't take into consideration the change character with the frequencies ε', ε'' of dielectric material, which is the absorbing layer of the considered multi-layered system. For the concretization of the appearing conditions of the non-reflecting wave absorption for the real polar compositions, let's take into consideration, that their dielectric properties in the region of wave dispersion are well enough described by Debye equation

$$\varepsilon=\varepsilon'-i\varepsilon''=\varepsilon_\infty+\frac{\varepsilon_0-\varepsilon_\infty}{1+i\omega\tau}\qquad(6)$$

where ε_0, ε_∞ are extra dispersion statistic and high-frequency dielectric constants of composition; ω is circular frequency; τ is the relaxation time[3].

The combine solution of the equations(5) allows to find the functional connection between ε_0, ε_∞ and τ of material of the covering absorbing layer, wavelength λ_0, thickness l_0 of the covering absorption layer, transformation coefficient k, at which the non-reflecting wave-absorption in the multi-layered system will take place. For the finding of this connection the iterating process of the solution of the initial equations has been applied.

The results of the carried out calculations for the case of the first five zero minimums of function ρ(l) are given on the figure 1 in the generalized coordinate planes $\left[\lg\omega\tau,\ \frac{l}{\lambda}\right]$ and $\left[\lg\omega\tau,\ \varepsilon_0\right]$. Taking into consideration, that ε_∞ of the more polar compositions within 2-3 units, was equal to 2 at the carrying out of the given calculations. The obtained dependences ε_0 on $\lg\omega\tau$ at different N of the zero minimum of the function $\rho(l)$, and their vertexes achieve to the value $\omega\tau=1$, according to the center of the dielectric dispersion region. The value l_0/λ_B increases with the increase of lg $\omega\tau$ and stabilizes at $\omega\tau>1$.

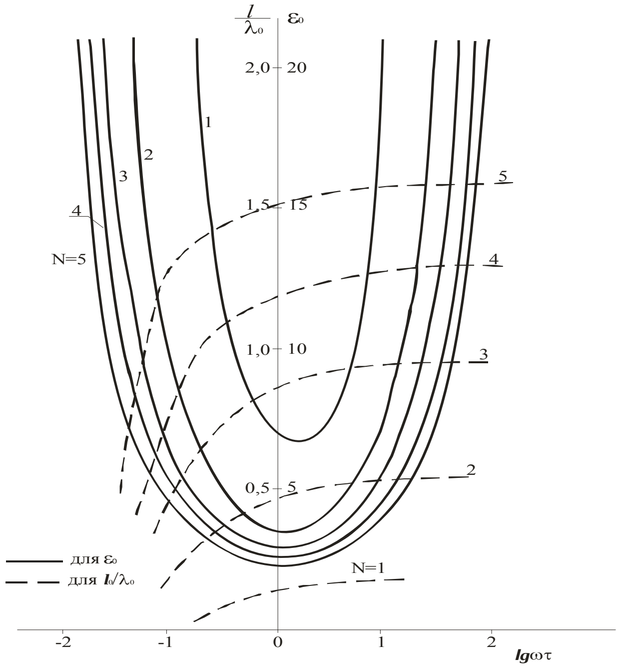

Fig.1. The dependence ε_0,ε_∞ and relaxational τ,ω characteristics of the selective wave absorption for the different numbers N of zero minimum of function $\rho(\ l)$.

As it follows from the fig.1, at the given N, ε_0, ε_∞ and τ can be two couples of values λ_0 and l_0, at which the conditions of non-reflecting wave absorption in the system dielectric-metal is carried out. The analysis of behaviour of functions ε_0, l_0/λ_0 on $\lg\omega\tau$ shows, that in the dispersion region of composition should be the spectrum of wavelength and the spectrum of the thickness of reflecting composition layer, corresponding to it. The character of these spectrums is strongly individual for every composition and is defined by its statistic and dynamic dielectric properties. The spectrums consist on two branches: low-frequency and high-frequency, differing by only change character of values of spectral wavelengths with the increase of the thickness of covering composition layer, corresponding to it. For the low-frequency spectrum arm the increase of λ_0 with he increase of N accompanies by the increase of l_0. It is characterized, that dielectrics with small values ε_0 may have the degeneration of absorption spectrums because of the disappearance of their spectral lines, corresponding to first zero minimums of the function $\rho(\ l)$.

[1] *R.M. Kasimov.* Injenerno-Fizicheskiy jurnal, 1994, t.66, N 5-6.
[2] *R.M. Kasimov, M.A. Kalafi, E.R. Kasimov,Ch.O.Kadjar, E. Yu. Salaev.* Jurnal Texnicheskoy Fiziki, 1996, t.67, 2.s.167.
[3] *A.F. Xarvey.* Texnika Sverxvisokix Chactot. M.,1965.

M.A.Sadıxov,S.T.Əzizov

TƏRKİBİNDƏ MÜGAVİMƏT TRANSFORMATORU JERLƏŞƏN DİELEKTRİK-METAL İKİLAYLİ SİSTEMİNDƏ ELEKTROMAGNİT ŞÜALANMASININ ŞƏRTLƏRİ

İki laylı dielektrik-metal sisteminin üzərinə dörtdəbir dalğa layı olan əks etdirməyən layları çəkilmiş əks etdirməyən (tam) udulmasının şərtlərinin tənlikləri alınıb. Bu çox laylı mügavimət transformatorun seçilmiş udulma zolağına tə'siri qöstərilib.

М.А. Садыхов,С.Т.Азизов

УСЛОВИЯ ПОЛНОГО ПОГЛОЩЕНИЯ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ ДВУХСЛОЙНОЙ СИСТЕМЫ ДИЕЛЕКТРИК-МЕТАЛЛ ПРИ НАЛИЧИИ ТРАНСФОРМАТОРА СОПРОТИВЛЕНИЯ

Получены уравнения, описывающие условия избирательного безотражательного (полного) поглощения электромагнитного излучения в системе диэлектрик - металл с нанесенным на него произвольным числом четвертьволновых непоглощающих слоев. Показано влияние такого многослойного трансформатора сопротивления на полосу избирательного поглощения излучения.

Received: 21.06.04