FREQUENCY CHARACTERISTICS OF THE PLANE-LAYERED MEDIUM TRANSFER FACTOR

G. D. Mikhailov and F. P. Astapenko

The relationships for the numerical calculation of a plane-layered controlled medium transmission factor are determined using the theories of periodic structures and the Green tensor functions of cylindrical areas. The results of calculations and a comparison with experimental data are presented.

The controlled plane-layered media (PLM) are intended to regulate the amplitude, phase, and polarization of the reflected and passed waves. The various centimeter, millimeter, and submillimeter wavelength devices can be realized on the basis of PLM [1–3].

At the present time the electrodynamic study is carried out only for a lattice of loaded thin rods placed into a homogeneous dielectric medium [4].

In this paper the problem of electromagnetic wave scattering on an endless (in a plane of the layers) PLM structure is considered to obtain the initial data for designing superhigh-frequency devices based on the controlled PLM as well as to establish the accessible characteristics of these devices.

The structure we study (Fig. 1) consists of a semi-infinite dielectric layer 1 having the permittivity ε₁, a second dielectric layer 2 (the permittivity is ε₂), which is h₂ in thickness, a third dielectric layer 5 (the thickness and the permittivity are h₃ and ε₃ respectively), and a fourth semi-infinite layer 6 having the permittivity ε₄. The periodic lattice of the conducting rods 3 and the cylindrical impedance loads 4 with a homogeneous distribution of the specific impedance Z_H, which are included in the gaps between the rods, are also elements of this structure.

Here we suppose that the vector of incident electromagnetic field \( \vec{E}_{ST} \) is parallel to the lattice rods.

Using the theory of periodic structure let us form a unit cell around one of the lattice elements (Fig. 1). The walls of the cell are perpendicular to the plane of the lattice, and produce a fictitious waveguide with the electric and magnetic walls [5, 6].

The continuity condition of the tangential components of the electric field at the grating (S₂ plane), and of the tangential components of the magnetic field at the interfaces of dielectrics S₁, S₃, S₄ can be written as

\[
\begin{align*}
\bar{H}_{ST} + \bar{H}^{II}(\bar{S}_{M1}) &= \bar{H}^{III}(\bar{S}_{M2}) + \bar{H}^{II}(\bar{S}_{M3}) + \bar{H}^{II}(\bar{I}_e); \\
\bar{E}^{II}(\bar{S}_{M2}) + \bar{E}^{II}(\bar{S}_{M3}) + \bar{E}^{II}(\bar{I}_e) &= \bar{E}_1; \\
\bar{H}^{II}(\bar{S}_{M2}) + \bar{H}^{II}(\bar{S}_{M3}) + \bar{H}^{II}(\bar{I}_e) &= \bar{H}^{III}(\bar{S}_{M4}) + \bar{H}^{III}(\bar{S}_{M5}); \\
\bar{H}^{III}(\bar{S}_{M4}) + \bar{H}^{III}(\bar{S}_{M5}) &= \bar{H}^{IV}(\bar{S}_{M6}),
\end{align*}
\]

where

\[
\begin{align*}
\bar{S}_{M1,2} &= \bar{n}_{1,2} \cdot \bar{E}_1; \quad \bar{S}_{M3,4} = \bar{n}_{3,4} \cdot \bar{E}_3; \quad \bar{S}_{M5,6} = \bar{n}_{5,6} \cdot \bar{E}_4
\end{align*}
\]

are the fictitious magnetic currents stemming from the distribution of the tangential components of the electric field at the dielectric layer interfaces, and

\[
E(I_e), \quad H(I_e), \quad E(S_M), \quad H(S_M)
\]

are the electric and magnetic fields induced by electric and magnetic currents in the 1, 2, 3, and 4 structures. Let us represent the external field as a sum of the direct and inverse waves [6]

\[ H_{ST} = \Psi_{00}\{\exp[-\gamma_{00}(z + h_2)] + \exp[\gamma_{00}(z + h_2)]\}, \]  
which is the most convenient form for the following transformations. Since the rod diameter \(2R\) is small in comparison with the wavelength, the field of an external source is constant near the rod. As a consequence we consider that the field of rod currents is induced by a rod-aligned imaginary thread of current \(I_n\) \[7\]. Taking into account that the rod gap \(\Delta\) is small in size, we can also specify the field at the rod surface and at the cylindrical loading as the averaged field

\[ E_1 = \left\{ \begin{array}{l}
Z'_{H} \int_{0}^{\Delta} I_e(x) \, dx, 0 \leq x \leq \Delta, y = \frac{1}{2} \pm R, \\
0, \Delta < x < A, y = \frac{1}{2} \pm R,
\end{array} \right. \]  

where

\[ Z'_H = Z_H/\Delta. \]

The boundary condition (3) is approximate and describes the effect of higher modes of oscillations near the load with low precision. This condition is intended for describing a field near the gap, is related to the theory of slot antennas \[8\], and gives good results in the case of thin (in comparison with the wavelength) slots. Physically the boundary condition means that the secondary field of the lattice with impedance loads is formed by only the currents induced by the metallic rods. This field does not harbor a component induced by the loads directly, and it