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DETERMINATION OF A PERIODIC SEQUENCE SURFACE IMPEDANCE OF THE RECTANGULAR WAVEGUIDES JUNCTIONS

Determination of a periodic sequence surface impedance of the rectangular waveguides junctions

The development of effective analytical-numerical models of basic inhomogeneities in waveguide structures (diaphragms, pins, and waveguide joints), which allow programmatically to implement theoretical developments in the field of computer modeling of various inhomogeneities of microwave nodes, is an urgent scientific and applied problem, the solution of which this work is dedicated to.

Most of the problems of the diffraction mathematical theory and electromagnetic waves propagation were solved thanks to the introduction of equivalent boundary conditions that roughly describe the effect of a real obstacle on wave propagation. Impedance boundary conditions [1] are a vivid example of such boundary conditions. Their introduction and use made it possible to build effective methods and algorithms for solving a large number of diffraction theory problems.

This paper considers a calculation model of a rectangular waveguide with a periodic sequence of secondary waveguides along a narrow wall, which are elements of a filter of harmonics with wave leakage (Fig. 1).

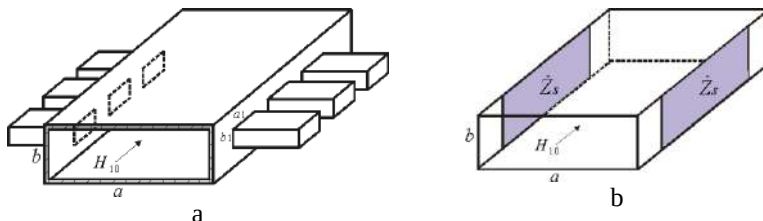


Figure 1 – Section of a waveguide path with secondary waveguides along narrow walls (a) and its calculation model (b) – a waveguide with impedance narrow walls.

It is assumed that the H_{10} wave falls on the interface between a regular rectangular waveguide with ideal metal walls and a rectangular waveguide on the narrow walls of which secondary rectangular waveguides are located (Fig. 1a). The medium inside the waveguides has the following parameters: $\mu_r = \varepsilon_r = 1$.

In order to be able to apply the approximate boundary conditions, the periodic sequence of secondary rectangular waveguides is replaced by a smooth impedance surface with a homogeneous isotropic impedance $\tilde{Z}_s$.

In Fig. 1 b) provides a calculation model of the junction of a regular and irregular waveguide with impedance narrow walls. In the general case, the surface impedance of irregular narrow walls is a complex value, which allows taking into account losses in the waveguide.

Taking into account the geometry of the problem (Fig. 2), the surface impedance is represented as a decomposition of the equivalent surface impedance $\tilde{Z}_{eq}$ of a separate hole into a double Fourier series.

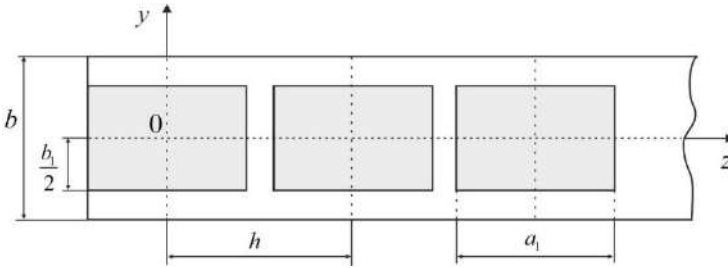


Figure 2 – Geometry of the problem

$$\begin{aligned} \dot{Z}(y,z) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \delta_{mn} \{ & A_{mn} \cos(k_y y) \cos(k_z z) + B_{mn} \sin(k_y y) \cos(k_z z) + \\ & + C_{mn} \cos(k_y y) \sin(k_z z) + D_{mn} \sin(k_y y) \sin(k_z z) \} \end{aligned} \quad , \quad (1)$$

where δ_{mn} - normalizing coefficient,

$k_y = m\pi/b$, $k_z = n\pi/h$ - transverse wavenumbers along the y and z axis, respectively,

$\varphi_{mn}(y,z)$ - eigen-functions of in the waveguide area under study.

The coefficients of the Fourier series are calculated from the ratio:

$$U_{mn} = \frac{4}{bh} \int_0^b \int_0^h \dot{Z}(y,z) \varphi_{mn}(y,z) dy dz \quad , \quad (2)$$

where U_{mn} – any of the coefficients A_{mn} , B_{mn} , C_{mn} , D_{mn} ; the function $\dot{Z}(y,z)$, which is included under the integral sign, is defined as:

$$\dot{Z}(y,z) = \begin{cases} \dot{Z}_{eq}, & \text{for } (y,z) \in S_1, \\ 0, & \text{for } (y,z) \notin S_1, \end{cases} \quad (3)$$

where S_1 - cross section $a_1 \times b_1$ of the secondary waveguide.

$$\dot{Z}_{eq} = \frac{\iint_{S_1} [\dot{E}, \dot{H}^*] \tilde{x}_0 dz dy}{\iint_{S_1} |\dot{H}_\perp|^2 dz dy} \quad (4)$$

The amplitudes of electric E and magnetic H fields are determined from the solution of the H_{10} wave diffraction problem at the junction of the primary and secondary waveguides [3]. In the proposed mathematical model of the waveguide, the impedance of narrow walls should be homogeneous and isotropic. For this, the concept of "average value of surface impedance" is introduced, which is defined as the average value of surface impedance over a period.

$$\dot{Z}_s = \frac{1}{bh} \int_0^b \int_0^h \dot{Z}(y,z) dy dz, \quad (5)$$

where $\dot{Z}(y,z)$ is determined from equation (1).

According to the obtained analytical expression (5), a numerical analysis of the dependence of the normalized value of the surface impedance $\tilde{Z}_S = \dot{Z}_S / \dot{Z}_0$ on the ratio a/λ for different values of the parameter $d=b_1/a_1$ (where a is the size of the wide wall of the main waveguide, $\dot{Z}_0$ is the wave impedance of free space).

In fig. 3, 4 are depicted the dependences of the real (active) and imaginary (reactive) parts of $\tilde{Z}_S$. The resonant nature of the active component of the surface impedance (Fig. 3) is related to the redistribution of energy between higher types of waves. Since the value of the active component of the impedance is completely determined by the field of waves propagating in the lateral waveguides, then at a wavelength longer than the critical one, lateral waveguides are out of bounds for the corresponding types of waves and, as a result, the active part of the impedance is zero. The reactive component of the surface impedance in the studied structure has an inductive nature. The value of the reactive component, as well as the active one, changes resonantly with the change in wavelength. The resonant nature of the curves in Fig. 4 is associated with the excitation of higher types of waves in the main waveguide, for which the secondary waveguides are below cutoff.

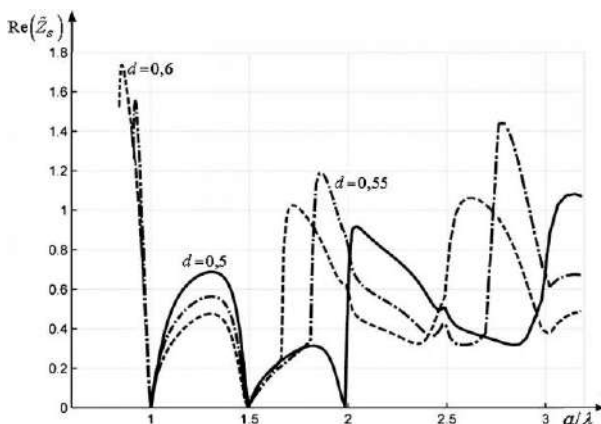


Figure 3 – Dependence of $\text{Re}(\tilde{Z}_s)$ on the ratio a/λ for different values of d

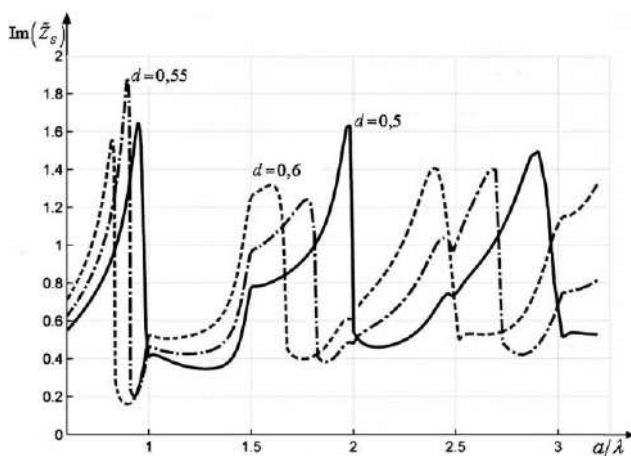


Figure 4 – Dependence of $\text{Im}(\tilde{Z}_s)$ on the ratio a/λ for different values of d

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