ISSN 0735-2727, Radioelectronics and Communications Systems, 2008, Vol. 51, No. 8, pp. 444–447. © Allerton Press, Inc., 2008.
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Electrodynamics of Waveguide Junctions with Anisotropic Loading

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Received in final form January 21, 2007

Abstract—An electrodynamic model for the calculation of waveguide junctions with anisotropic loading has been built in this study. A wave equation for longitudinal components of hybrid electromagnetic field and a system of linear algebraic equations (SLAE) were obtained. The conditions were found under which the SLAE for HE_{mnp}–oscillations (indexes indicate the number of variations of the field in terms of coordinates x, y, z, respectively) disintegrated into two independent systems corresponding to H_{mno}– and E_{klo}–oscillations. The developed algorithm and the software programs were used to carry out numerical analysis for these modes of oscillations that are of practical interest. The recommendations are given on the use of waveguide junctions for measuring components of the dielectric permittivity tensor of anisotropic crystals.

DOI: 10.3103/S0735272708080074

INTRODUCTION

Electrodynamics of anisotropic media is referred to the fundamental radiophysics and is also of practical interest, since all the known dielectrics (including the artificial ones) to one or another degree are anisotropic and the question is whether this anisotropy can be neglected at a certain stage of investigations. The knowledge of dielectric permittivity tensor ($\hat{\varepsilon}$) of anisotropic crystals plays an important role both for the metrological certification of the proper materials and for radio devices that contain such materials, since these parameters essentially affect their operation.

The interest in waveguide junctions is explained by their wide application in the microwave equipment: as frequency division devices designed for different purposes (for example, multiplexers of the systems of satellite communications and television), high Q-factor resonators, waveguide switches and wave-mode transducers, special devices of antenna feeders, etc.

STATEMENT OF THE PROBLEM. ELECTRODYNAMIC ANALYSIS

The structure represents an orthogonal junction of rectangular waveguides A and B with the transverse dimensions of $2a$ and $2b$, respectively. A metal screen is mounted at distance $\pm c/2$ from the center in waveguide A. One of the waveguides is completely loaded with dielectric, the dielectric permittivity tensor of which has a diagonal form (as is known any tensor can be reduced to the diagonal form):

$$\hat{\varepsilon} = \begin{vmatrix} \varepsilon_x & 0 & 0 \\ 0 & \varepsilon_y & 0 \\ 0 & 0 & \varepsilon_z \end{vmatrix}.$$

The following wave equation was derived from the Maxwell equations for longitudinal components of the hybrid electromagnetic field:

$$\begin{cases} \nabla^2 H_z + \left(\dfrac{k_0^2 \varepsilon_t}{2} - \beta^2 - 2\dfrac{\varepsilon_t^{*2}}{\varepsilon_t} \right) H_z = 2j\beta \dfrac{\varepsilon_t^* * \varepsilon_z}{\varepsilon_t} E_z, \\ \nabla^2 E_z + (k_0^2 \varepsilon_z - 2\beta^2 \dfrac{\varepsilon_z}{\varepsilon_t}) E_z = -2j\beta \dfrac{\varepsilon_t^*}{\varepsilon_t} H_z, \end{cases} \quad (1)$$