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Electrodynamical Model of Composite Cylindrical Structure with Laminated Dielectric

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Abstract—The article is devoted to the problem of the natural electromagnetic modes, the regions of their existence and the relationship with all possible types of resonances in the waveguide junction of a cylindrical and radial waveguides with a layered (laminated) filling of the radial waveguide with dielectric material. An electrodynamic model is created on the basis of a rigorous method of modal matching technique, with the separation of the common waveguide coupling region and the representation of the field in it in the form of a superposition of the fields of the partial waveguide eigenmodes. The structure under investigation can be used to measure the electrical parameters of dielectric samples of a cylindrical cross-section. It is shown that the measurements will have a local character, since the spectral characteristics of the junctions are determined mainly by the size of the central coupling region of the waveguides and by the electrical parameters of the dielectric that is in the junction. The problem of edge effects for samples of finite length (partial filling of a radial waveguide with dielectric) is investigated. Taking into account the edge effect enables reducing the error in measuring the permittivity for samples of arbitrary sizes in the investigated structure.

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1. INTRODUCTION

A considerable number of studies have been devoted to electromagnetic modes in waveguide junctions [1–5]. This is due to their extensive use in microwave region: as components of passive and active devices [6], measuring/sensing devices for non-destructive determination of electrical parameters of dielectrics [7, 8]. The investigated waveguide structures with dielectric filling possess the advantages of both open dielectric and closed resonator systems: a sufficiently high Q-factor with a sparse frequency spectrum of eigenmodes, and also the possibility of free access to the resonance region through the open ends of the waveguide arms.

Earlier, characteristic modes in cylindrical, rectangular and planar unfilled waveguide junctions [1–3] or with homogeneous filling [4] were considered. The aim of this paper is to investigate the "edge" effect when the radial waveguide is partially filled with a dielectric of finite length. This will reduce the error in measuring the permittivity of samples of arbitrary sizes in the investigated structure.

2. ELECTRODYNAMIC ANALYSIS

The investigated structure (Fig. 1) is a junction of cylindrical waveguide with transverse dimension of $2a$ and radial waveguide with a transverse dimension of l. We consider axially symmetric modes ($\partial/\partial\varphi = 0$) of the H_{oms} type, where the indices indicate the number of field variations with respect to the coordinates φ, r, z, respectively. We separate the coupling region I, which is common for the round (II) and radial (III, IV) waveguides. Each of the regions is filled with a dielectric of permittivity ε_1, ε_2, ε_3, ε_4, respectively. The solution is carried out using modal matching technique, representing the fields in regions II, III and IV in the form of an expansion in terms of the evanescent eigenmodes of cylindrical and radial waveguides.

In the waveguide coupling region I, the field is represented in the form of superposition of the eigenfunctions of regions II and III. The only component of the electric field E_φ in regions I–IV takes the form of:

region II ($0 \le r \le a$, $|z| > l/2$)—cylindrical waveguide of radius a:

REFERENCES

1. Yu. G. Makeev, L. A. Rud', S. Yu. Ostritskaya, "Axially-symmetric eigenmodes of circular and radial waveguides junction," *Radiotekh. Elektron.* **39**, No. 5, 1497 (1994).
2. S. L. Berdnik, V. A. Katrich, M. V. Nesterenko, Yu. M. Penkin, "E-plane T-junction of rectangular waveguides with vibrator-slot coupling between arms," *Telecom. Radio Eng*. **74**, No. 14, 1225 (2015). DOI: 10.1615/TelecomRadEng.v74.i14.10.
3. S. O. Steshenko, "An algorithm for analyzing planar junctions of waveguides of arbitrary cross-section with the use of eigenfunctions of the common aperture," *Telecom. Radio Eng.* **73**, No. 10, 851 (2014). DOI: 10.1615/TelecomRadEng.v73.i10.10.
4. A. A. Zvyagintsev, A. V. Strizhachenko, D. F. Furman, "Natural electromagnetic modes in cylindrical waveguide junctions and their use for nondestructive microwave measurements of electromagnetic characteristics of materials," *Int. J. Infrared Milli. Waves* **16**, No. 5, 965 (1995). DOI: 10.1007/BF02066670.
5. Yu. G. Makeev, A. P. Motornenko, N. T. Cherpak, I. P. Babiichuk, M. B. Kosmyna, "On the anisotropy of dielectric permittivity in single crystal lanthanum aluminate substrates," *Tech. Phys. Lett*. **28**, No. 3, 221 (2002). DOI: 10.1134/1.1467281.
6. K.-L. Wu, M. Yu, A. Sivadas, "Novel modal analysis of a circular-to-rectangular waveguide T-junction and its application to design of circular dual-mode filters," *IEEE Trans. Microwave Theory Tech.* **50**, No. 2, 465 (2002). DOI: 10.1109/22.982225.
7. M. Ilchenko, Yu. Poplavko, A. Yuschenko, et al. "The nondestructive MV test of extended dielectric and metallized dielectric structures parameters by the method of electromagnetic resonances of waveguide junctions," *Proc. of 5th Int. Symp. on Recent Advances in Microwave Technology*, 11-14 Sept. 1995, Kiev, Ukraine (Kiev, 1996), pp. 707-710.
8. A. V. Strizhachenko, "The measurement of permittivity tensor of uniaxial crystals with tetragonal and hexagonal symmetry at microwaves," *Electrical Power Eng. Frontier* **2**, No. 1, 17 (2013). URI: http://www.academicpub.org/epef/paperInfo.aspx?PaperID=13820.