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DISPERSION IN ANISOTROPIC NRD WAVEGUIDE

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ABSTRACT

NRD waveguide is a proposed structure for millimeter wave applications. In this paper, the isotropic dielectric of this structure is replaced by a longitudinally magnetized ferrite, allowing the implementation of NRD non-reciprocal devices. Numerical results for the dispersion of the first few propagation modes in this structure is presented.

INTRODUCTION

Nonradiative dielectric (NRD) waveguide is a structure proposed by Yoneyama and Nishida (1) for millimeter wave applications. Since then, several devices using this structure, like filters, junctions, couplers and antennas have been investigated (2). On the other hand, equally important non-reciprocal devices have not yet been analysed.

The objective of this paper is to extend the analysis of NRD waveguides to the case where the isotropic dielectric of this structure is replaced by a longitudinally magnetized ferrite, allowing the implementation of NRD non-reciprocal and electronically tuned NRD devices.

THEORY

An NRD structure is shown in Fig. 1, where the isotropic dielectric placed between two perfect conducting planes and separated by less than half wavelength, is replaced by a ferrite magnetized in the "z" direction. The propagation of magnetostatic modes in ferrites placed between parallel metallic planes was investigated in the past (3).

In this work, the electromagnetic fields were supposed to be proportional to exp $(-j\beta z)$ and to exp $(j\omega t)$ inside the ferrite slab (dimensions a,b) and evanescent outside of the slab. For a saturated and lossless ferrite subjected to a "z" directed static magnetization and to small signals, the magnetic properties of this ferrite (dielectric contant ε, Landé factor g, saturation magnetization $4\pi M_s$) can be described by the Polder tensor:

$$\mu_r = \begin{bmatrix} \mu & -j\delta & 0 \\ j\delta & \mu & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad (1)$$

Using this tensor and the procedures suggested by Kales (4), components of electric and magnetic fields were obtained. The application of boundary conditions at the perfect conducting walls and at the air-ferrite interface results in a system of equations for the coefficients of the field components. The resulting characteristic equation can be placed in the following form:

$$(C_1 - C_3 \operatorname{tg} \phi_1 + 0.5\, C_5 \sec \phi_1) \sec \phi_2 + (C_2 - C_4 \operatorname{tg} \phi_2 + 0.5\, C_5 \sec \phi_2) \sec \phi_1 = 0 \qquad (2)$$

where $C_i (i = 1,2,3,4,5)$ and $\phi_j (j = 1,2)$ are functions of the propagation constant β, geometry of the structure and ferrite parameters. Numerical solutions of equation (2) was obtained, furnishing dispersion relations for several modes. All the modes are hybrids and were classified as HE_{mn}, where "n" is the n^{th} root of equation (2) for the m^{th} mode.

A numerical check of equation (2) was made in the limiting case where the ferrite parameters were modified to simulate an isotropic dielectric. Agreement was excellent.

Fig. 2 shows dispersion curves for the first few hybrid modes for a commercial ferrite operating at 30 GHz, under 15 kOe of external field and with a shape factor $[\sqrt{\mu}\, b/a]$ equal to 0.35. The dominant mode is HE_{11}. The horizontal axis gives the thickness of the ferrite slab for the given frequency while the vertical axis gives the normalized propagation constant. For example, if a = 3.43mm, then for b = 1.00mm, the value of the normalized propagation constant $\beta_+/(\sqrt{\mu\, \varepsilon_r}\, k_o)$ is 0.59. k_o and λ_o are the wavenumber and wavelength in air, respectively.

Fig. 3 shows how the dispersion curves for the dominant mode HE_{11} changes with the static external magnetic field H_{dc}. As shown, for lower values of

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H_{dc} there is a decrease in the propagation constant, for a given geometry and frequency.

CONCLUSIONS

The propagation of the electromagnetic waves in anisotropic NRD waveguide was investigated allowing numerical reuslts to be obtained. Some representative dispersion curves are presented. To our knowledge, this has been done for the first time.

REFERENCES

(1) T. Yoneyama and S. Nishida, "Nonradiative dielectric waveguide for millimeter-wave integrated circuits", IEEE Trans. Microwave Theory Tech., vol. MTT-29, nº 11, pp. 1188-1192, November 1981.

(2) T. Yoneyama and S. Nishida, "Nonradiative dielectric waveguide circuit components", Int. J. Infrared and Millimeter Waves, vol. 4, nº 3, pp. 439-449, 1983.

(3) B.A. Auld, "Walker modes in large ferrite samples", J. Applied Physics, vol. 31, nº 9, pp. 1642-1647, September 1960.

(4) M.L. Kales, "Modes in wave guides containing ferrites", J. Applied Physics, vol. 24, nº 5, pp. 604-608, May 1953.

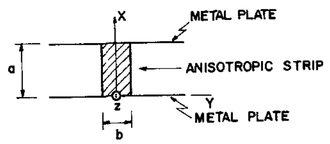

Fig. 1 - Geometry of an NRD waveguide with anisotropic strip

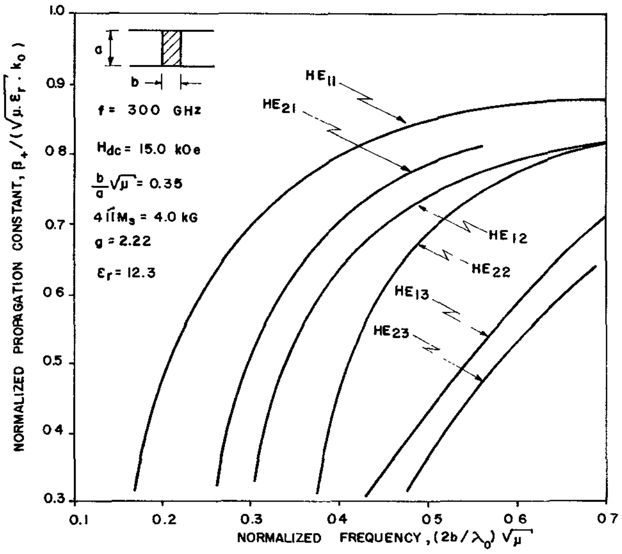

Fig. 2 - Normalized dispersion curves for a few hybrid modes.

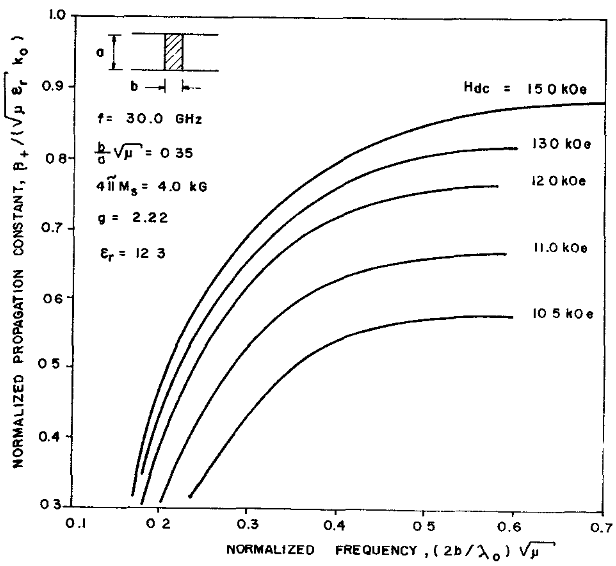

Fig. 3 - Influence of the static external magnetic field (H_{dc}) on the dispersion relation for the HE_{11} mode.