EFFECT OF THE OPTICAL AXIS ORIENTATION ON THE PROPERTIES OF MICROSTRIP PATCHES ON ANISOTROPIC LAYERS

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ABSTRACT

The effect of the substrate dielectric anisotropy on the resonant frequency behavior of microstrip patches is investigated. In the analysis, the Hertz vector potentials in the spectral domain are used to determine the expressions for the field components and the moment (Galerkin) method is used to obtain the determinantal equation for the resonant frequency. A two layers uniaxial anisotropic dielectric substrate is considered. Numerical results are presented for the resonant frequency as function of the anisotropy ratio of one of the dielectric layers. Agreement with the results available in the literature for several particular cases was observed.

INTRODUCTION

The study of microstrip patches on anisotropic dielectric layers has been performed by several authors [1]-[4]. It has been pointed out that the dielectric anisotropy cannot be neglected, once that some of the dielectric material used in microwave integrated circuit applications are, in fact, anisotropic ones.

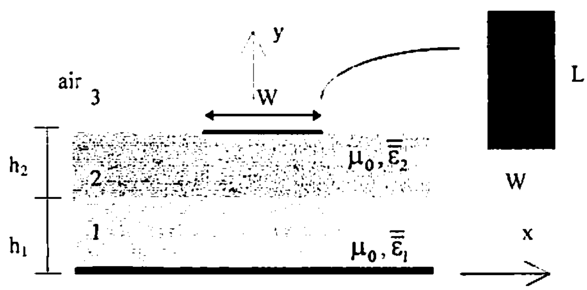

Fig. 1 - Microstrip patch on anisotropic layers.

Nevertheless, most of the studies were developed for microstrip patches on a single layer mounted on a ground plane [1],[2]. Furthermore, the optical axis is assumed to be oriented perpendicularly to the ground plane, which is the y-direction in Fig. 1 [1]-[4].

This work describes a fullwave analysis for the microstrip patch antenna on anisotropic dielectric layers (Fig. 1). A combination of Hertz vector potentials and Galerkin method is used in the Fourier domain. The optical axes orientation is considered to be along the η (η = x, y, z) direction, as shown in Fig. 1. A comparison between the results for the three different axes orientations is presented, showing how the optical axes orientation affects the properties of microstrip patches on anisotropic layers.

THEORY

The structure considered in this analysis is shown in Fig. 1. Dielectric region j (j = 1,2) in Fig. 1 is anisotropic. Region 3 is air. Conductor losses and conducting strip thickness are neglected.

In the anisotropic dielectric region j (j = 1,2), the optical axes are assumed to be oriented along the η (η = x, y, or z) direction. Thus, the permittivity tensor, $\bar{\bar{\varepsilon}}_j$, is given by

$$\overline{\overline{\varepsilon}}_j = \begin{bmatrix} \varepsilon_{xxj} & 0 & 0 \\ 0 & \varepsilon_{yyj} & 0 \\ 0 & 0 & \varepsilon_{zzj} \end{bmatrix} \varepsilon_0 \qquad (j = 1,2) \tag{1}$$

where $\varepsilon_{yyj} = \varepsilon_{zzj}$, for $\eta = x$, $\varepsilon_{xxj} = \varepsilon_{zzj}$, for $\eta = y$, and $\varepsilon_{xxj} = \varepsilon_{yyj}$, for $\eta = z$.

The anisotropy ratio, n_η (η = x, y, or z), is defined according to the assumed optical axes orientation, giving

$$n_x = \sqrt{\varepsilon_{yy}/\varepsilon_{xx}} \qquad ; \eta = x \tag{2}$$

$$n_y = \sqrt{\varepsilon_{xx}/\varepsilon_{yy}} \qquad ; \eta = y \tag{3}$$

$$n_z = \sqrt{\varepsilon_{xx}/\varepsilon_{zz}} \qquad ; \eta = z \tag{4}$$

To determine the electric and magnetic field components in dielectric region (Fig. 1), the Hertz vector potentials are assumed to be along η (η = x, y, or z) direction, so that

$$\overline{\Pi}_{ej} = \Pi_{ej} \hat{a}_\eta \qquad (j = 1, 2) \tag{5}$$

$$\overline{\Pi}_{hj} = \Pi_{hj} \hat{a}_\eta \qquad (j = 1, 2) \tag{6}$$

Using (5), (6) and Maxwell's equations, the wave equations for $\overline{\Pi}_{ej}$ and $\overline{\Pi}_{hj}$ are derived, as well as the expressions for the electric and magnetic fields as functions of $\overline{\Pi}_{ej}$ and $\overline{\Pi}_{hj}$, in the anisotropic dielectric layer j (j = 1, 2), in Fig. 1.

In the Fourier domain, the wave equations for the transformed $\tilde{\Pi}_e$ and $\tilde{\Pi}_h$ (j = 1,2) are derived as

$$\frac{\partial^2 \tilde{\Pi}_{ej}}{\partial y^2} - \gamma_{ej}^2 \tilde{\Pi}_{ej} = 0 \quad (j=1,2) \tag{9}$$

$$\frac{\partial^2 \tilde{\Pi}_{hj}}{\partial y^2} - \gamma_{hj}^2 \tilde{\Pi}_{hj} = 0 \quad (j=1,2) \tag{10}$$

where

$$\gamma_{hj}^2 = \alpha^2 + \beta^2 - \omega^2 \mu_0 \varepsilon_0 \varepsilon_{j2} \quad ; \eta = x, y, \text{or } z \tag{11}$$

$$\gamma_{ej}^2 = \frac{\varepsilon_{xxj}}{\varepsilon_{yyj}} \alpha^2 + \beta^2 - \omega^2 \mu_0 \varepsilon_0 \varepsilon_{xxj} \quad ; \eta = x \tag{12}$$

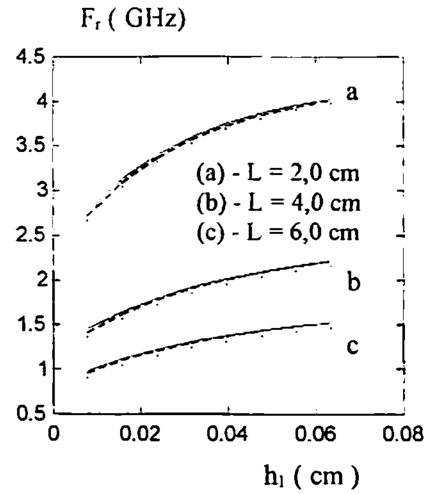

Fig. 2 - Reosnant Frequency versus h_1: w = 3.0 cm, h_2 = 0.127 cm, $\varepsilon_{xx1} = \varepsilon_{yy1} = \varepsilon_{zz1} = 1.0$.

________ $\varepsilon_{xx2} = \varepsilon_{zz2} = 11.22$, $\varepsilon_{yy2} = 10.2$

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$$\gamma_{ej}^2 = \frac{\varepsilon_{xxj}}{\varepsilon_{yyj}}(\alpha^2 + \beta^2 - \omega^2\mu_0\varepsilon_0\varepsilon_{jl}) \quad ; \eta = y \qquad (13)$$

$$\gamma_{ej}^2 = \alpha^2 + \frac{\varepsilon_{zzj}}{\varepsilon_{xxj}}\beta^2 - \omega^2\mu_0\varepsilon_0\varepsilon_{zzj} \quad ; \eta = z \qquad (14)$$

For region 3 (Fig. 1), equations (9) to (14) remain valid, by imposing $\varepsilon_{xx3} = \varepsilon_{yy3} = \varepsilon_{zz3} = 1$.

Solving the boundary value problem (Fig. 1), the transformed electric field components are expressed as functions of $\tilde{J}_x$ and $\tilde{J}_z$, which are the transformed electric current density components at $y = d_1 + d_2$, as

$$\tilde{E}_x = \tilde{Z}_{xx}\tilde{J}_x + \tilde{Z}_{xz}\tilde{J}_z \qquad (21)$$

$$\tilde{E}_z = \tilde{Z}_{zx}\tilde{J}_x + \tilde{Z}_{zz}\tilde{J}_z \qquad (22)$$

where $\tilde{Z}_{xx}$, $\tilde{Z}_{xz}$, $\tilde{Z}_{zx}$ and $\tilde{Z}_{zz}$ are the components of the impedance matrix $[\tilde{Z}]$, in the spectral domain.

Then, using Galerkin method and Parserval's theorem [2], the characteristic equation for the resonant frequency is determined, allowing the determination of Q-factor.

Furthermore, by using the phase stationary condition [5], the radiation pattern for the structure considered is obtained.

RESULTS

Fig. 2 shows the resonant frequency versus the region 1 (in Fig. 1) substrate height for suspended microstrip patches on uniaxial anisotropic layers. In this case, region 1 is assumed to be air-filled.

Figs. 3 shows the resonant frequency versus the anisotropy ratio for a microstrip patch on a single uniaxial anisotropic layer. The result from reference [2], shown in Fig. 3, was obtained for a microstrip patch on a single isotropic layer. In Fig. 3 , about the same result were obtained for the cases where $\eta = x$ and $\eta = z$. Fig. 4 shows the E-plane pattern diagram for L = 4.0 cm.

In Fig. 5, we present the resonant frequency versus the patch length for three values of the anisotropy ratio in region 2.

CONCLUSION

The analysis of single microstrip patches on a two layers uniaxial anisotropic substrate was performed by using a combination of Hertz vector potentials and Galerkin method, in the spectral domain. Numerical results for suspended structures were shown for three different orientations of the anisotropic dielectric material optical axis. It was shown that this optical axis orientation choice changes the characteristics of microstrip patches with biaxial anisotropic layers.

This analysis is general and can be used to determine the properties of others planar structures, including those obtained by coupling microstrip patch antennas.

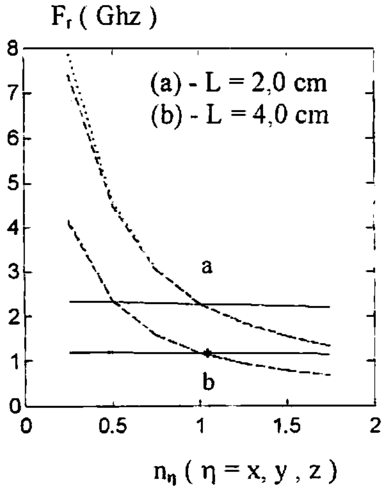

Fig. 3 - Resonant frequency versus anisotropy ratio: w = 3.0 cm, ε_{yy2} = 10.2, h_2 = 0.127 cm, h_1 = 0.0, ε_{xx2} = 10.2, ε_{zz2} = 10.2. * - Ref [2].

.... $\varepsilon_{yy2} = \varepsilon_{zz2} = 10{,}2$ ($\eta = x$)

\- - - - - - $\varepsilon_{xx2} = \varepsilon_{yy2} = 10{,}2$ ($\eta = z$)

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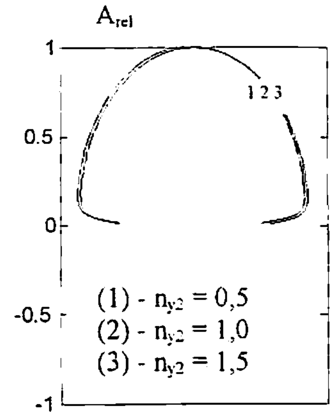

Fig. 4 - Radiation pattern (E-plane): w = 3.0 cm, h_1 = 0.0, h_2 = 0.127 cm, L = 4.0 cm, ε_{yy2} = 10.2.

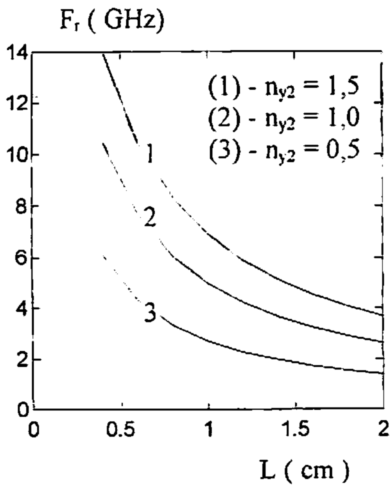

Fig. 5 - Resonant frequency versus patch length: w = 0.4 cm, h_1 = 0.0, h_2 = 0.127 cm, $\varepsilon_{xx2} = \varepsilon_{zz2} = 9.6$.

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