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RESEARCH PAPER

Resonant characteristics of rectangular Microstrip antenna printed on electric–magnetic uniaxial anisotropic substrates

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In this paper, the resonant characteristics of the rectangular microstrip patch antenna on uniaxially anisotropic substrates are determined via spectral domain analysis. The anisotropic substrates are characterized by both permittivity and permeability tensors. Green's functions of the structure in Fourier transform domain are determined using the Galerkin's technique. The sinusoidal functions are selected as the basis function, which show fast numerical convergence. Numerical results concerning the effects of electric anisotropy and antenna parameters on the resonant characteristics of rectangular microstrip antenna are presented and discussed. Results are compared with previously published data and are found to be in good agreement.

Keywords: Rectangular patch, Electric and magnetic uniaxial anisotropy, Galerkin technique, Resonant characteristics

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I. INTRODUCTION

Microstrip structures of various shapes have recently received much attention due to the rapid growth in exploiting the millimeter-wave frequencies. They are very important in many commercial applications, such as mobile radio and wireless communications systems [1, 2].

During recent years, great interests have been shown in using a microstrip antenna deposited on the anisotropic substrate since the substrate anisotropy could have important applications for the operation of microstrip antennas [3–6]. With the increasing complexity of geometry and material property, designing these antennas requires more and more dedicated and sophisticated computer aided-design (CAD) tools to predict the characteristics. The method of moments (MoM) has been proven to be one of the most powerful CAD tools for solving this class of problems. By now, a number of microstrip antennas with the anisotropic substrate have been investigated using the MoM-based spectral domain analysis method [3–5].

In later studies on microstrip structures, anisotropic materials, especially the uniaxially anisotropic ones have been considered due to their advantages [7–12]. It is known that some metamaterials exhibit uniaxial-type anisotropy both in permittivity and permeability tensors [13]. In the following designs of the rectangular and circular microstrips, metamaterials and other uniaxially anisotropic substrates have been used to obtain special operational characteristics.

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In this paper, the effects of both electric and magnetic uniaxial anisotropy, in the substrate on resonant characteristics of the rectangular microstrip patch antenna are investigated. This subject has not been reported in the open literature: only the influence of the electric uniaxial anisotropy on the complex resonant frequency and bandwidth has been treated [4, 14, 15]. The present paper is organized as follows. In Section II, the derivations of the electric uniaxial Green's function in the spectral form, the associated moment method analysis of the complex resonant frequency of the printed antenna are presented. The calculation is performed by vector Fourier transforms, which gives rise to a diagonal form of the Green's function. The effects of the antenna parameters on resonant characteristics of the rectangular microstrip antenna are investigated in Section III. Variations in the permittivity perpendicular to the optical axis of the dielectric and along this axis are considered. Concluding remarks are summarized in Section IV.

II. SPECTRAL DOMAIN FORMULATION

The rectangular microstrip patch antenna is shown in Fig. 1, along with the coordinate system used in the analysis. The microstrip patch is printed on a grounded uniaxial anisotropic dielectric slab with the optical axis normal to the patch. The permittivity and permeability tensors in this anisotropic region are given by

$$\bar{\bar{\varepsilon}} = \varepsilon_0 \begin{bmatrix} \varepsilon_x & 0 & 0 \\ 0 & \varepsilon_x & 0 \\ 0 & 0 & \varepsilon_z \end{bmatrix}, \quad (1)$$