International Journal of Microwave and Wireless Technologies, page 1 of 5.
doi:10.1017/S1759078714001433

RESEARCH PAPER

Analysis of elliptical-disk microstrip patch printed on isotropic or anisotropic substrate materials

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This paper presents a simple approach for accurate determination of the resonant frequency of an elliptical microstrip patch printed on isotropic or anisotropic substrate materials. In this approach, some modifications are made to account for fringe fields, dispersion effects, and losses by calculating effective dimensions, effective permittivity of anisotropy in the layer, and effective loss tangent, respectively. The theoretical resonant frequency results are in very good agreement with the experimental results reported elsewhere. Numerical results show that the change in the resonant frequency of the antenna is due primarily to a small disturbance of the substrate's nature. Then the effect of the uniaxial anisotropic materials is a significant parameter and most essential on the microstrip antenna characterization.

Keywords: Elliptical-disk antenna, Anisotropic substrate, Cavity method, Fringe fields, Circular polarizations

Received 27 May 2014; Revised 12 September 2014; Accepted 18 October 2014

I. INTRODUCTION

Microstrip antennas are widely used in high-performance aircraft, spacecraft, satellites, and some other applications due to their advantages of low profile, conformable to planar and non-planar surfaces, simple and low cost to manufacture [1–3]. The choice of shape of an antenna opens a whole new aspect of exploration in the field [4]. Extensive work on rectangular and circular geometries can be easily found in available literature. However, these geometries are not suitable for every application [5]. Conventional circular and rectangular microstrip antennas operate at the single-resonant frequency and radiate the linear polarization. In many practical applications, the dual-resonant frequency and circular polarizations (CPs) are required for a number of radar, communication, telecommunication, and navigation systems [6]. Various patch configurations implemented on different types of substrates have been tested and investigated. In practice, it was found that the choice of the substrate material is of a great importance and plays a significant role in achieving the optimum radiation characteristics of the antenna [7, 8].

Some substrate materials used for integrated microwave circuits or printed antennas exhibit dielectric anisotropy. This phenomenon occurs either naturally in the material or is introduced during the manufacturing process [9]. In addition, anisotropic substrates have become popular in the design of microwave integrated circuit components and microstrip antennas [9, 10]. Uniaxial substrates have drawn more attention due to their availability in materials such as sapphire, boron nitride and E-10 ceramic-impregnated Teflon. Previous studies of anisotropic materials used in microwave devices indicate that the effects of anisotropy on the performance of such structures particularly in high frequencies cannot be ignored [9–12]. Furthermore, it has been shown that the performance of directional couplers can be improved using the anisotropic substrates to equalize the even and odd mode phase velocities [9, 10]. Therefore, many investigations have examined the effects of substrate anisotropy in microwave components performance.

The elliptical patch has been analyzed extensively using the cavity model [4, 10–12], generalized transmission line model [13, 14], analysis in the Fourier–Hankel transform domain [5]. The method of moments (MoM) [14], other full-wave analyses [10, 15], and commercial software does not provide closed-form expressions and take a long computational time. So, full-wave analysis and commercial software are not useful for direct synthesis of the patch antenna. The computer-aided design (CAD) oriented cavity model is ideal for design purposes, because it involves fewer mathematical steps than full-wave models; takes less computational times and gives results with accuracy equivalent to that of full-wave models; cost effectiveness, easy to implement, and provides close-form expressions, since the client can use a simple PC for implantation. Another advantage of the proposed model is that it takes into account the uniaxial anisotropy in the substrate.

The cavity model has been chosen as a simple alternative to analyze and predict the behavior of elliptical microstrip antennas (EMAs). Furthermore, some modifications are made to

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