The Impact of Higher Order Modes on the Cross Polarization Levels of a Rectangular Patch Antenna

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Abstract

This paper examines the impact of higher modes on the cross-polarization performance of rectangular microstrip patch antennas with different aspect ratios. The amplitude coefficients of the higher-order modes are employed for calculating the excited modes. Calculated, simulated and measured results are presented to illustrate the impact of the higher modes of a microstrip patch antenna on the cross polarization levels. It is demonstrated that the inherently excited higher-modes have a significant impact in the cross-polar patterns. Using this simple technique will help antenna designers to specify the excited higher order modes, identify their contributions to the cross polarization, and choose the appropriate way to suppress those modes that are undesired. This paper is focused on providing a better understanding of the effects of the higher modes. A full characterization of the influence of the higher modes on the cross polarization levels of microstrip patch antennas is included. The use of a cavity model to analyze microstrip patch antenna performance in terms of the cross polarization levels and higher-order modes is presented.

I. Introduction

In the early 1970s, interest in microstrip patch antennas increased dramatically, however, the concept of microstrip antennas was first proposed in the 1950s. These antennas began to be developed rapidly because of the availability of good substrate with low loss tangent and attractive thermal and mechanical properties. They have recently attracted much attention and are used extensively in government and commercial applications because of their inherent advantages. Despite the many advantages of basic microstrip patch antennas compared to conventional antennas, they also possess fundamental disadvantages. The primary disadvantage is that of poor polarization purity; relatively high level of cross polarization radiation. Dual-polarized antennas with high polarization purity are required to enhance the performance of polarization diversity systems. Rectangular patch antennas resonating in the fundamental mode radiate along the broadside of the element with linear polarization along the resonating dimension. However, in reality, cross-polarized radiation takes place, especially off the main planes.

There are several sources of cross polarization. The first source is the asymmetric fringing fields along the non-radiating edges of the patch antenna because of the asymmetry of the probe location. As a consequence of disturbances in the near field of the antenna, cross polarized radiation will be generated in the H-plane. Unwanted higher order modes are a second source of cross polarization, since their transverse current distributions result in high polarization impurity. In addition to the dominant mode, other higher modes will also be excited and contribute to undesirable cross-polarized fields. The cross polarization level depends on the aspect ratio. For rectangular microstrip patch antennas, cross polarization in the H-plane is mainly due to higher-mode orthogonal modes, particularly TM02 mode, as the antenna radiates at its dominant TM10 mode. However, in the diagonal plane, even the ideal single-mode microstrip patch antenna will radiate cross-polarized fields.

Although much successful, intensive research has been done in recent years to analyze microstrip patch antennas, there remains a need for additional analytical investigation of higher modes and cross polarization levels. Specifically, the impact of the higher modes on cross polarization levels needs to be clarified and simplified. In this paper, the amplitude coefficients of the excited higher modes in the cavity of the patch antenna are used to calculate the energy coupled to these modes and their impact on the radiation patterns of the dominant mode. Based on the cavity size, dielectric of the substrate, and feed position, all excited modes and their coefficients will be calculated. These coefficients have been used to successively calculate other parameters, such as input impedance and return loss.

Although the higher mode radiations of conventional microstrip patch antennas are not widely used, a theoretical analysis using a cavity model shows that the rectangular patch antenna also has higher order resonances at the multiples of its fundamental mode frequency. Electromagnetic fields within the cavity show multiple cycles of sinusoidal distribution. This distribution makes each two edges of patch either co-phase or anti-phase.

Since the aspect ratio R (width to length ratio) affects the radiation characteristics of a rectangular microstrip antenna, several antenna designs with different ratios and feed positions are investigated in this work. The corresponding return loss of these antennas is calculated to show the fundamental mode frequency and the higher mode resonances, depending on the patch size and feed position. All these antennas are designed to operate at a frequency of 3 GHz in the dominant mode and fed at the optimum matched location by a coaxial probe. To include the higher mode contribution to the dominant mode radiation patterns, the coefficient amplitude values of these modes need to be calculated.