A QUASI-PLANAR WIDE BAND CONICAL ANTENNA

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1. INTRODUCTION

The conical antenna has wide input impedance bandwidth and omni-directional radiation pattern (Kawakami and Sato, 1987; Liang and Wah, 2000). This special property makes it irreplaceable in some modern applications, for instance, in portable or mobile communications requiring very wide-bandwidth channels or where continuous frequency coverage is needed. The prototype of the conical antenna has a three-dimensional structure. It is mechanically difficult to fabricate and integrate. In (Gentili et al., 2004), a dielectric loaded conical antenna is reported, where the dielectric loading mechanically stabilizes the conical antenna while maintaining wide band input impedance characteristics. However in (Gentili et al., 2004), the loading material is magnetic, hence not practical; and the antenna still has a three-dimensional configuration. In this study, a conical antenna with metallic cones coated on non-magnetic dielectric slab is proposed. The proposed antenna has a quasi-planar structure. It is mechanically stable, and easy to build and integrate with planar circuits. A full wave analysis code is developed to simulate this novel conical antenna. It is shown that the input impedance remains close to a constant value when the loading material’s dielectric constant is chosen within a wide range. A quasi-planar conical antenna is fabricated with high density polyurethane foam as the loading material. The measurement data verifies the simulation results. Techniques to reduce the antenna size and adjust the radiation pattern are also discussed.

2. ANTENNA DESIGN AND ANALYSIS

The proposed antenna is illustrated in Figure 1(a), and its cross section is shown in Figure 1(b). A cylindrical dielectric slab is made of homogeneous material with permittivity $\varepsilon_r\varepsilon_0$ and permeability $\mu_0$, where $\varepsilon_0$ and $\mu_0$ are the permittivity and

permeability of the free space, respectively. One side of the slab is coated by metal and behaves as the ground plane. A conical cavity is etched in the slab, and metal is coated on the cone wall. The antenna is fed at the tip of the cone. The dielectric material loading makes the antenna mechanically stable, quasi-planar, and easy to fabricate. Furthermore, if any planar circuits are on the other side of the ground plane, they can be simply connected to the antenna through a via hole.

\[
Z_0 = \frac{1}{\pi} \sqrt{\frac{\mu_0}{\varepsilon_r \varepsilon_0}} \ln \left(\cot \left(\frac{\psi}{2}\right)\right). \quad (1)
\]

In Eq. (1), \(\psi\) denotes the angle of the cone (Figure 1(b)). When the TEM wave hits the end of the cone, it is reflected and scattered. With the increase of frequency, the reflection and scattering attenuate, and the antenna behaves more and more like an infinitely long transmission line. Compared with the conventional conical antennas, the additional dielectric loading makes the wave’s behavior more complicated. Firstly, the wavelength within the dielectric material is shorter than that in the air. As a result, the electrical length of the transmission line is enlarged due to the dielectric loading, which is helpful to the high frequency input impedance performance. However secondly, because of the dielectric-air interface, the reflection and scattering at the end of the cone is larger in the dielectric loaded antenna, making the antenna less matched to free space. Thirdly, the dielectric material forms a cavity, like that underneath microstrip patch antennas (Richards et al., 1981). This cavity tends to store energy, hence would reduce the antenna’s bandwidth. Fourthly, a dielectric material’s electrical properties usually vary with respect to frequency. Specifically, the dielectric constant \(\varepsilon_r\) depends on frequency.

Figure 1. The quasi-planar conical antenna

The radiation mechanism of this quasi-planar conical antenna (Figure 1) is similar to the classical conical antenna (Kawakami and Sato, 1987; Liang and Wah, 2000). Since the feed is located at the center of a revolutionarily symmetric structure, a spherical transverse electromagnetic (TEM) wave is launched in the dielectric material. The cone and the ground plane can be considered constituting a piece of transmission line with characteristic impedance (Kawakami and Sato, 1987),