

Surface Wave Mode Reduction For Rectangular Microstrip Antennas

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I. Introduction

Rectangular microstrip antennas are being used for several years in communication systems and other applications (radars, telemetry, navigation, biomedicine), due to their advantages over conventional antennas [1]. With the recent development of micromachining technology, there is an increased interest in incorporating patch antennas with other components fabricated with this technology. However, micromachined circuits are usually fabricated on high dielectric constant substrates, such as Silicon, and are required to operate in high frequencies. Under these conditions, the excitation of surface waves is pronounced, thus leading to lower efficiency, degradation of the antenna radiation pattern and polarization characteristics and undesired coupling between array elements. Several approaches have been proposed in order to reduce surface wave power excitation [2-3]. In [3], Jackson et al. achieved a complete elimination of the dominant T_{M0} surface wave mode for circular patches, by use of a specific design of the antenna element. In this paper, a similar approach will be followed for the rectangular patch, in an effort to reduce significantly the T_{M0} surface wave mode.

II. Analysis

Our purpose is to design a rectangular patch antenna operating at $f=23$ GHz (K-band), with a dielectric constant of $\epsilon_r = 10.8$ and thickness of $h=25$ mils, with a suppressed T_{M0} surface wave mode. Since for the given substrate, higher order modes exist at frequencies above 40 GHz, only the dominant mode needs to be eliminated.

According to the equivalence principle and the cavity model, in terms of radiation a rectangular microstrip patch can be modeled as a rectangular loop of magnetic current. From the cavity model, the electric field of the dominant TM_{10} mode for the geometry shown in Fig.1 is given by:

$$E_z = A \cos(\pi y / b) \quad (II.1)$$

where a,b are the width and the resonant length of the patch, respectively. Here the assumption is made that the patch is fed in such a way that only the TM_{10} mode is excited. Thus, the radiating edges will be at $y=0,b$. The equivalent magnetic current at these two edges is: $\vec{M} = 2\vec{E} \times \hat{n} = 2A\hat{x}$ ($y=0,b$).

As it is known, a single Hertzian magnetic dipole, oriented in the x direction at a height z' above the ground, will give rise to a TM_0 surface wave field given by:

$$\Psi = K(z, z') H_1^{(2)}(\beta_{TM_0} \rho) \sin \phi \quad (II.2)$$

where β_{TM_0} is the propagation constant of the TM_0 mode and $K(z, z')$ is an amplitude factor that depends on the height of the source and the observation point. By integrating over the two radiating edges of the rectangular patch for the magnetic current distribution, the total surface wave field radiated by the magnetic currents takes the form:

$$\Psi = -4A \frac{B(z)}{\beta_{TM_0}} H_1^{(2)}(\beta_{TM_0} \rho) \tan \phi \cos(\beta_{TM_0} \frac{b}{2} \sin \phi) \sin(\beta_{TM_0} \frac{a}{2} \cos \phi) \quad (II.3)$$

where $B(z) = \int_0^h K(z, z') dz'$.

In order to derive the above expression the far field approximation for the phase of the radiated surface wave is used. The pattern of (II.3) is shown in Fig. 2

(dashed line). By setting $b = \frac{\pi}{\beta_{TM_0}}$ nulls are placed at the location of the peaks of

the lobes at $\phi = \frac{\pi}{2}, \frac{3\pi}{2}$ so that four minor lobes replace the two major lobes (Fig.

2- solid line). As a result, the surface wave pattern is reduced.

Choosing b according to the above formula, results in greater resonant length than the one chosen for the design frequency. In order to overcome this decrease in operating frequency, the material in a rectangular region under the patch is removed (Fig. 3a,b), thus creating a lower effective dielectric constant which will permit the

desired increase in operating frequency. The length of this "cored" region is found from the transcendental equation, which is derived from the field expressions of the dominant mode of the cavity, after applying the boundary conditions at the various interfaces.

III. Results

In order to test the accuracy of this analysis, an antenna was designed according to the above procedure and was compared with a conventional patch. Simulations were run using the FDTD method [4]. Measurement of the field inside the dielectric region showed a suppressed electric field for the reduced-surface-wave (RSW) antenna, which was more than 10 db lower than the field of the conventional patch (Fig. 4). Measurement of the reflection coefficient also with the help of FDTD, showed good agreement between the resonant frequencies of the cored patch and the conventional patch.

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References

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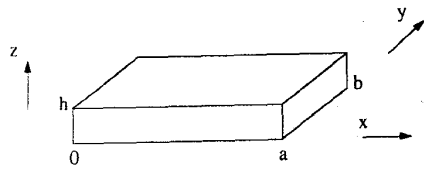


Fig. 1

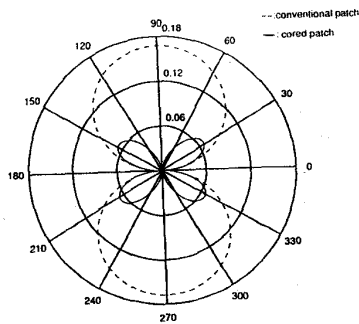


Fig. 2

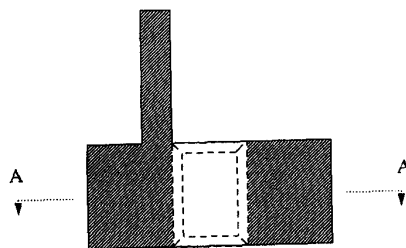


Fig. 3a

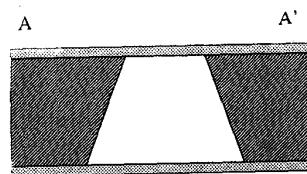


Fig. 3b

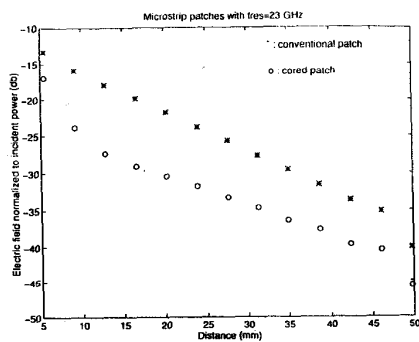


Fig. 4