CHARACTERISTICS OF A MICROSTRIP-EXCITED HIGH-PERMITTIVITY RECTANGULAR DIELECTRIC RESONATOR ANTENNA

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1. INTRODUCTION

Shielded dielectric resonators have been traditionally used as circuit elements for the miniaturization of filters, oscillators, and so forth by virtue of their high Q. A dielectric resonator (DR) placed over a ground plane can serve as an effective radiator, since the electromagnetic fields extend beyond the geometrical boundary of the cavity [1]. The dielectric resonator antenna (DRA) is of small size and light weight, is devoid of conductor losses, can be easily excited, and is capable of producing a variety of radiation patterns through excitation of its different resonant modes. Moreover, it can be easily integrated with active circuitry. The main restriction in the miniaturization of the DRA is the availability and cost of suitable low-loss high ε_r materials. Of the various geometries possible, rectangular DR is of practical interest because of the ease of fabrication, and the potential for choosing the aspect ratios (height/length, height/width) in a desired manner [2]. A high-permittivity low-loss cylindrical dielectric resonator was proposed by P. V. Bijumon et al. to enhance the bandwidth of a microstrip patch antenna [3]. In this paper, we report the outcome of the experimental studies performed on a rectangular DR of similar material excited by a microstrip line. It was previously demonstrated that the variations of the antenna dimensions introduce drastic changes in the nature of the excited modes [4]. Also, the desired mode can be excited efficiently with proper orientation of the DR [5]. Therefore, the DR is placed in different orientations upon the feed line and the resultant effect on the reflection and radiation characteristics of the antenna configuration is studied in

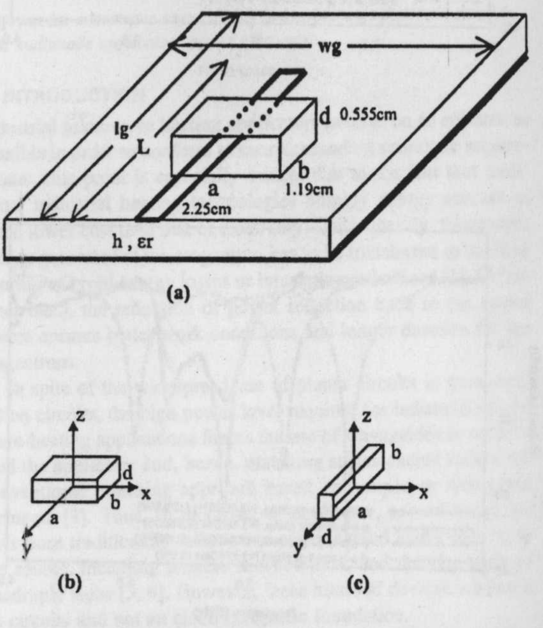
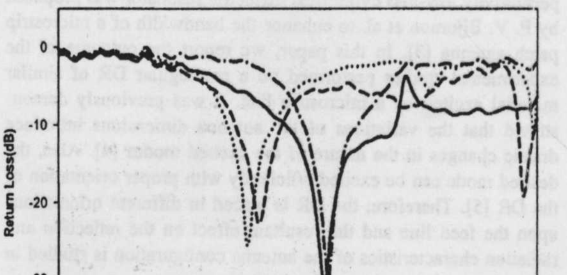


Figure 1 (a) Microstrip excitation of the DRA placed in the *a-b-d* orientation; (b) *a-b-d* orientation of the DR upon the feed; (c) *d-a-b* orientation of the DR upon the feed

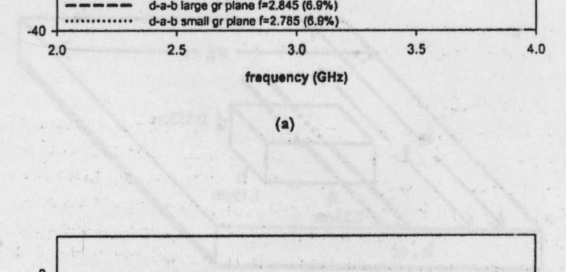
detail. The occurrence of various modes for different feed positions and orientation is also observed.

2. ANTENNA GEOMETRY

The antenna is comprised of a rectangular dielectric resonator with dimensions $(a \times b \times d) = 2.25$ cm $\times$ 1.19 cm $\times$ 0.555 cm, composed of low-loss ceramic material $Ca_5NB_2TiO_{12}$. The DR is prepared using the conventional solid-state ceramic method. The material has a dielectric constant of 48 with a quality factor $Q_u \times f > 26000$ GHz and low temperature variation of resonant frequency τ_f (+40 ppm/°C). The relatively low density (4.19 g/cm^3) of the material ensures lightweight of the antenna configuration. The DR is excited directly by a microstrip line of 3-mm width, fabricated on a substrate of dielectric constant $\varepsilon_r = 4.28$ and 1.6-mm thickness, in order to provide a characteristic impedance of 50Ω. The geometry of the antenna configuration is shown in Figure 1(a). Two of the six possible orientations of the DR are also illustrated in Figure 1(b) and (c) for better understanding of the geometry.

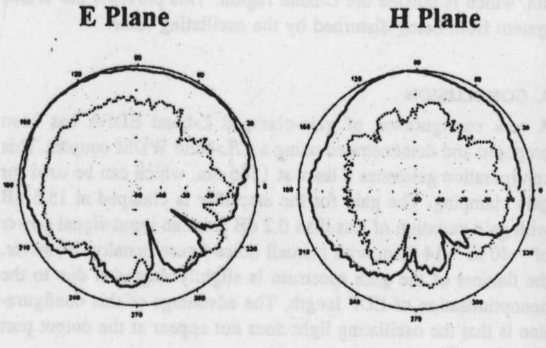


(a)

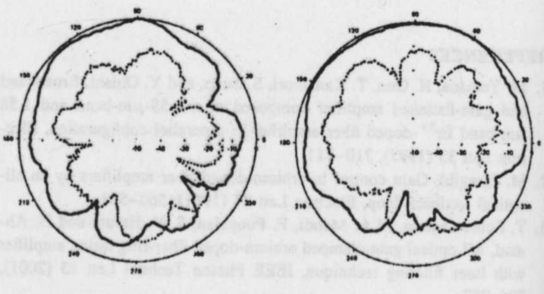


(b)

Figure 2 Reflection characteristics at the optimum bandwidth position of the DRA for the *d-b-a* and *d-a-b* orientations with respect to the feed: (a) feed length $L = 0.65\lambda_d$; (b) feed length $L = 1.08\lambda_d$



(a)



(b)

Figure 3 Radiation patterns in the *d-a-b* orientation of the DRA with respect to a feed line of length $L = 0.65\lambda_d$ for E and H planes (— co-polar, – – – cross-polar): (a) large ground plane ($l_g = 1.5\lambda_d$, $w_g = 1.3\lambda_d$) $f = 2.875$ GHz; (b) small ground plane ($l_g = 0.65\lambda_d$, $w_g = 0.73\lambda_d$) $f = 2.74$ GHz

3. EXPERIMENTAL RESULTS

Microstrip line of varying lengths is used to excite the rectangular DR under study. The variation in return loss as a function of frequency is observed for different positions of the DR along the feed line. The measurements are repeated for different orientations of the DR upon the feed line. In order to study the effect of the ground plane dimensions on the reflection and radiation characteristics of the antenna, different ground planes are also employed in this study. The position of the DR along the feed line is experimentally optimized for maximum bandwidth. The typical return loss at the optimum bandwidth position of the DR is plotted in Figure 2 for the *d-a-b* and *d-b-a* orientations, for two different ground-plane dimensions. It is inferred from the reflection characteristics that the *d-b-a* orientation gives the maximum bandwidth, for $l_g = 1.5\lambda_d$, $w_g = 1.3\lambda_d$, $a = 0.48\lambda_d$, and $L = 0.65\lambda_d$. Also, no resonance was observed in the *b-d-a* orientation of the DR in the observed frequency band. The change in feed length does not cause a considerable change in the resonant frequency of the optimum bandwidth position, although it excites different frequencies. The *a-d-b* orientation and the *d-a-b* orientation excite a mode of the lowest frequency for all ground-plane dimensions. This fact may be put to use while designing low-frequency antennas without compromising on the size. The fundamental mode for *d-b-a* orientation exhibits a 2:1 VSWR bandwidth of 14.9%, even though the frequency is slightly higher than that of the *d-a-b* orientation.

The radiation pattern of the DRA is measured for all orientations of the antenna. The measurements are done using an HP

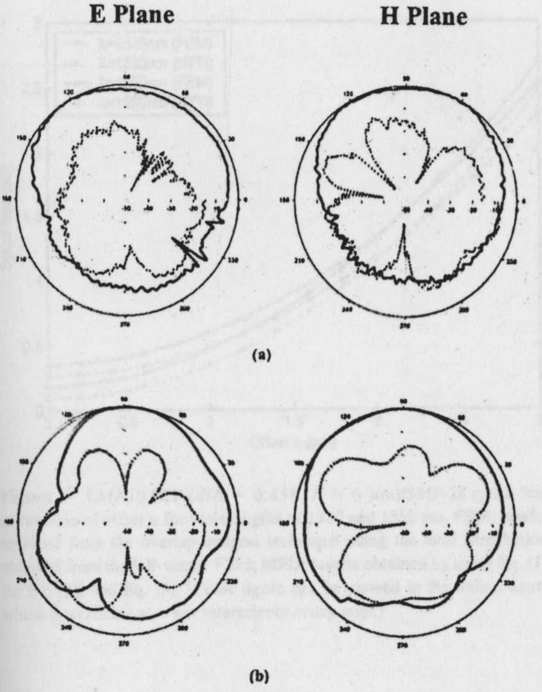


Figure 4 Radiation patterns in the d-a-b orientation of the DRA with respect to a feed line of length $L = 1.08\lambda_d$ for E and H planes (— co-polar, - - - cross-polar): (a) large ground plane ($l_g = 1.5\lambda_d$, $w_g = 1.08\lambda_d$) $f = 2.47$ GHz; (b) small ground plane ($l_g = 1.08\lambda_d$, $w_g = 0.65\lambda_d$) $f = 2.575$ GHz

8510C Network Analyser. Figures 3 and 4 show the measured radiation patterns in the d-a-b and d-b-a orientations of the DR. The patterns of all the orientations are reasonably broad in both E and H planes. The cross-polarization is ~ 20 dB, indicating the usefulness of the proposed antenna configuration for mobile communication. It is observed that the gain of the proposed antenna configuration is almost the same as that of a standard circular patch antenna with ± 0.5-dB variation.

4. CONCLUSION

Experiments were conducted on a high-permittivity rectangular DR excited by a 50Ω microstrip line. It was observed that different resonant modes are excited at different locations of the DR along the feed line. Broad radiation patterns were obtained in almost all orientations, with the main lobe of the radiation pattern remaining normal to the ground plane of the structure with variations in orientation and frequency.

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