Characteristics of Cylindrical Dielectric Resonator Antenna

Nisha Gupta[1], S. K. Rout[2], K. Sivaji[1]

Abstract- **In this paper characteristics of cylindrical Dielectric Resonator Antenna (DRA) fabricated using BaZrO3 material, are studied. The DRA antenna is designed by using FIDELITY software from Zeland USA, which employs the FDTD method for solution. The characteristics of these antennas are investigated with both co-axial feeding and microstrip line feeding mechanism used for exciting the DRA. The experiment is performed on cylindrical DRA shape fed by coaxial and microstrip line feed and fabricated from BaZrO3 material of dielectric constant 27.**

I. Introduction

Future smaller spacecraft requirement would lead to innovative antenna designs. Dielectric Resonator Antennas (DRAs) may be one of the solutions. The dielectric contains the antenna's near field and therefore prevents it from interfering with other nearby antennas or circuits, making it suitable for miniature and compact equipments. DRAs have attracted the antenna designers in microwave and millimeter wave band due to its features like high radiation efficiency, light weight, small size, low profile, low temperature coefficient of frequency, zero conductor losses and suitable scale in microwave band. DRs of low loss dielectric material, having dielectric constant as $10 < \varepsilon r < 100$ are ideally suitable for antenna applications, so that a compromise can be made between size, operating frequency and other antenna radiation characteristics. These antennas can also be easily integrated into portable communication devices.

A substantial amount of research effort has been devoted to the study of DR antennas in the last decade. It has been demonstrated that dielectric blocks of cylindrical [1], rectangular parallelepiped [2], hemispherical [3], half-split cylindrical [4], equilateral triangular [5] shapes can be designed to radiate efficiently through proper choices of feed location and feed dimensions. Different types of feeding structures such as coaxial probe [1], microstrip line [6], microstrip fed aperture [7], and coplanar waveguide [8] have been proposed. In this paper, the cylindrical dielectric resonator antenna using Barium Zriconate Trioxide (BAZrO3) ceramic with the permittivity 27 is designed and fabricated in order to determine its characteristics.

[1] N. Gupta and K. Sivaji are with the Department of Electronics and Communication Engineering, Birla Institute of Technology, Mesra Ranchi (Jharkhand) 835 215 INDIA,
Email: ngupta@bitmesra.ac.in
[2] S. K. Raut is with the Department of Applied Physics Birla Institute of Technology, Mesra, Ranchi (Jharkhand) 835 215 INDIA

II. Antenna Design

A. Antenna configuration

The antenna configuration of the cylindrical DRA is shown in Figure 1. The DRA is placed above a conducting ground plane. In the present work, the ground plane size of 8 cm×8cm is considered and a coaxial probe excitation is used for feeding the DRA. The ceramics used in this work is Barium Zirconate Trioxide (BaZrO3) with the dielectric constant of 30. The measured permittivity of the ceramic is 27. Loss tangent [6] of this material is 0.005 in the 1GHz to 10 GHz frequency range.

The dimensional parameters of the DRA are radius a=12mm, height h=5mm. The probe is located on the x-axis at x=6.5, y=0, z=3.5. For microstrip line feed, the substrate Dielectric Constant as 3.2, and substrate thickness as 0.76 mm.

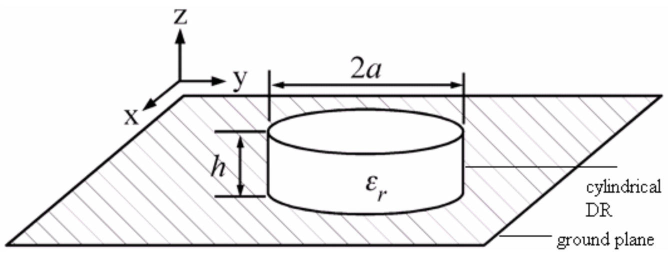


Fig. 1 Antenna configuration of cylindrical DRA with Coaxial feed

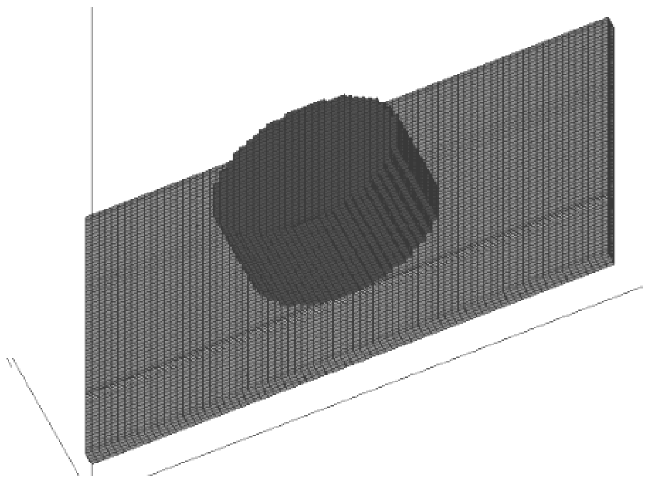


Fig. 2 3-D view of a Cylindrical DRA with Microstrip line feed

The cylindrical DRA is fed to excite HE11δ mode [9]. The theoretical formula of cylindrical DRA for resonant frequency is given in equation 1.

$$f_0 = \frac{3\times10^8}{2\pi\sqrt{\varepsilon_r}}\sqrt{2\left(\frac{\pi}{a}\right)^2 + \frac{\pi^2}{2h}} \quad (1)$$

III. RESULTS AND DISCUSSION

B. Simulated and Measured results of CDRA

First the comparison of the simulated and experimental results is shown for the CDRA with coaxial feed. The return loss was measured using vector network analyzer. The measured return loss and simulated return loss vs. frequency of CDRA are shown in Figure 3. The antenna mainly resonates at three frequency bands as evident from the measured return loss characteristic because of the fact that the feeding mechanism excites more than one mode.

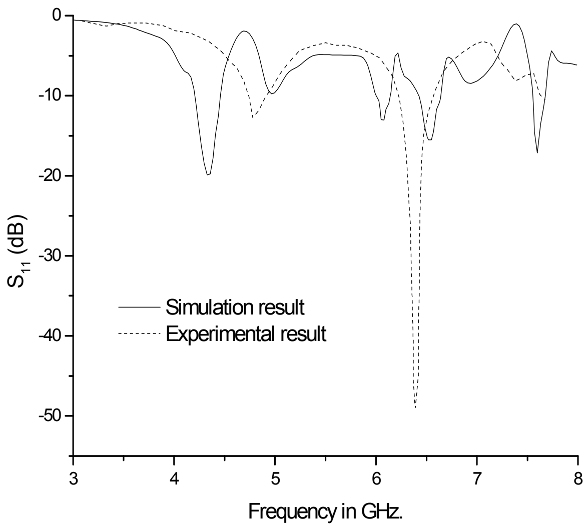


Fig. 3 Measured and Simulated Return loss vs. Frequency of CDRA with Coaxial Feed

Next the return loss characteristics are obtained for CDRA with microstrip line feed. A comparison of the simulation result with experimental result is shown in Figure 4. As evident the cylindrical DRA with microstrip feed shows a wide band characteristic over 5.2 to 5.9 GHz. band which differs from the co-axial feeding mechanism. This is because of the fact that in a Dielectric Resonator Antenna, the selection of the feed and that of its location both play an important role in determining which modes are excited. This, in turn determines the input impedance and radiation characteristics of the DRAs.

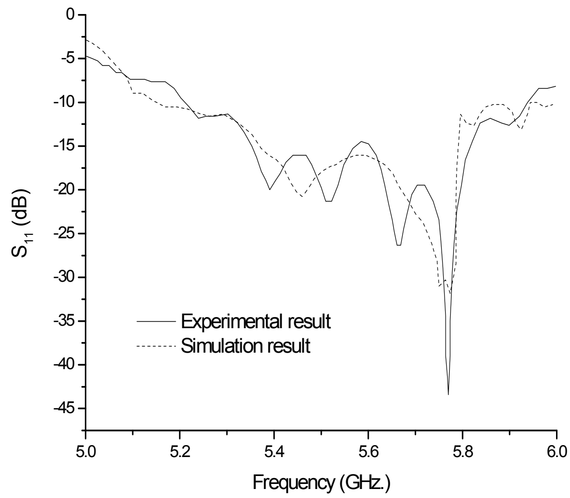


Fig. 4 Measured and Simulated Return loss vs. Frequency of CDRA with Microstrip line Feed

C.Radiation patterns of CDRA

Next the radiation characteristics of the CDRA with co-axial feed are obtained at all the three bands. The patterns are plotted in both the planes. A comparison of the simulation results with experimental results and the cross-polarization characteristics obtained experimentally are shown in Figure 5. The ideal characteristics in E-plane should look like a pattern of the half-wave dipole parallel to the ground plane. In practice, the feeding mechanism may excite more than one mode, so that the pattern will not look like the ideal one. Moreover the simulation and experimental characteristics at all the three frequencies show some radiation in the lower half of the plane which may be accounted for the finite size of the ground plane. The back radiation is more significant in the experimental results than the simulation results as the prototype model is built on a smaller ground plane. The H-plane characteristics show an omni-directional pattern as in the case of half-wave dipole at all the three frequencies. The gain of the antenna obtained at the dominant mode frequency is maximum but shows a decreasing trend at higher modes. The cross-polarization patterns obtained experimentally at all the three frequencies in E-plane show an acceptable cross-polarization level.

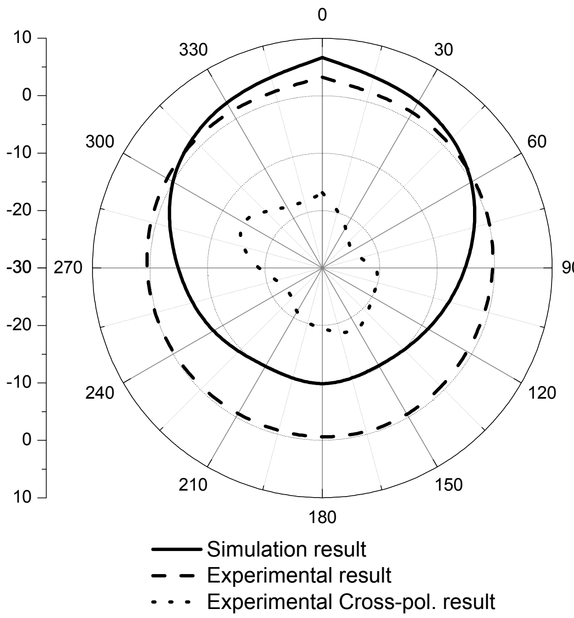
The simulation results of CDRA with coaxial feed are summarized in Table 1. As evident from the Table, the antenna has the moderate gain at all the four bands of frequencies and good antenna efficiency and radiation efficiency. The gain shows a decreasing pattern at higher order modes.

TABLE 1: CHARACTERISTICS OF THE CDRA WITH ER=27 WITH COAXIAL FEED

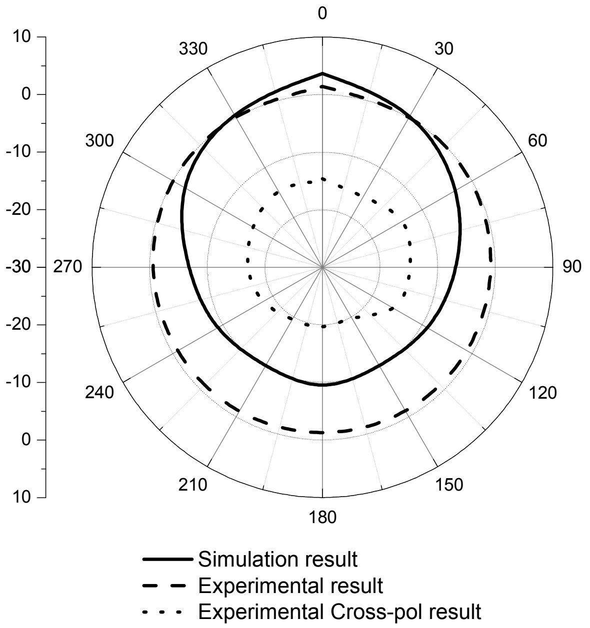
Resonant frequency ranges(GHz) S11<-10dB	Gain(dBi)	Antenna efficiency (%)	Radiation efficiency (%)
4.2-4.5	6.63-6.75	90.47-91.09	99
6.01-6.13	3.43-4.06	85.7-87.9	99
6.42-6.62	2.97-3.65	81.2-84.5	97
7.5-7.66	2.22-2.83	74.3-78.5	94

IV. CONCLUSION

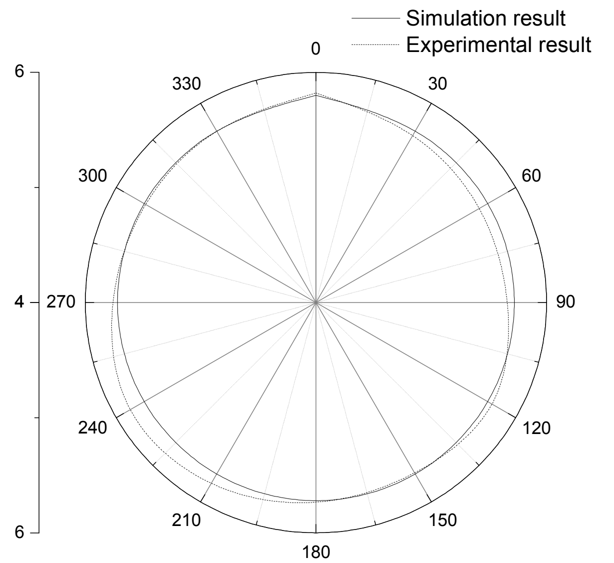
In this paper characteristics of Dielectric Resonator Antennas with co-axial feed and microstrip line feed are studied. CDRA is fabricated from the Barium Zirconate Trioxide (BaZrO3). Return loss characteristics are determined for both the configurations. A good agreement between the simulation and experimental results is obtained. Finally, radiation pattern of CDRA is also measured at different resonant frequencies for co-axial fed CDRA. It is evident that the Barium Zirconate Trioxide (BaZrO3) is a good candidate for realizing a DRA.



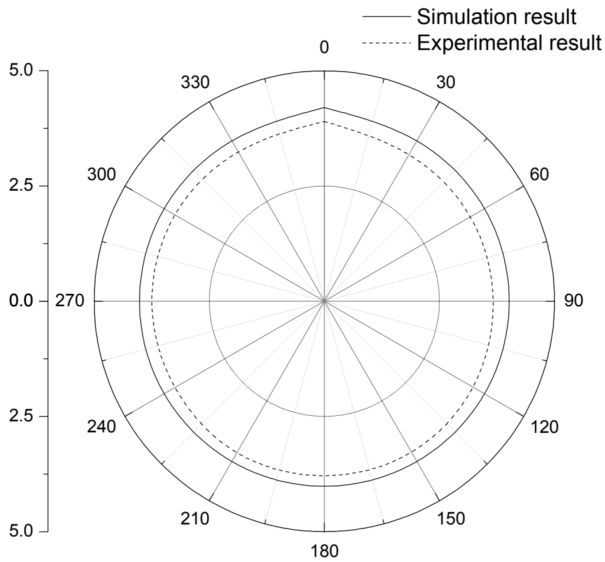
(a)



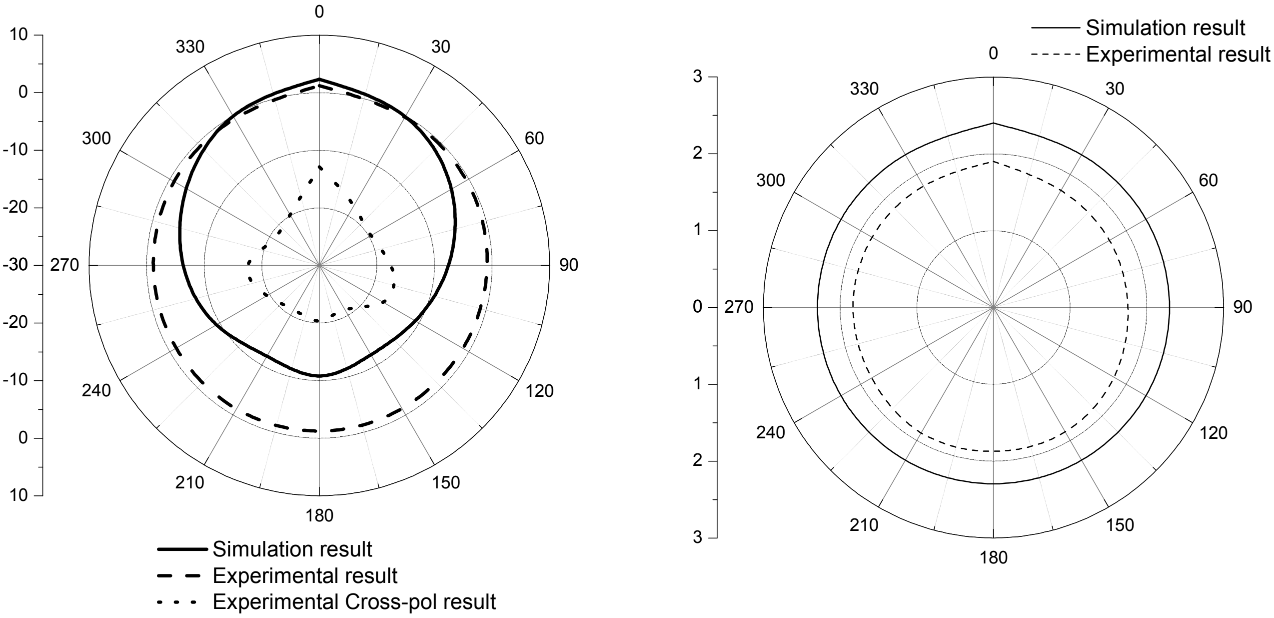
(b)



(d)



(e)



(c) (f)

Fig. 5 Radiation pattern of CDRA with co-axial feed at 4.33GHz, 6.55GHz and 7.57GHz, (a, b, c) Elevation pattern (d, e, f) Azimuth pattern

REFERENCES

[1] S. A. Long, M. W. McAllister, and L. C. Shen, "The Resonant Cylindrical Dielectric Cavity Antenna," *IEEE Transactions on Antennas and Propagation*, AP-31,3, 1983, pp. 406-412.

[2] M. W. McAllister, S. A. Long, "Rectangular Dielectric-Resonator Antenna," *IEE Electronics Letters*, 19, March 1983, pp. 218-219.

[3] M. McAllister, S. A. Long, "Resonant Hemispherical Dielectric Antenna," *IEE Electronics Letters*, 20, Aug. 1984, pp. 657-659.

[4] R. K. Mongia, "Half-split dielectric resonator placed on metallic plane for antenna applications," *IEE Electronics Letters*, 25, 1989, pp. 462-464.

[5] Lo, H. Y., Leung, K. W., Luk, K. M., and Yung, E. K. N., *Electron. Lett*., 35, 1999, pp. 2164–2166.

[6] R. A. Kranenburg, S. A. Long, "Microstrip Transmission Line Excitation of Dielectric Resonator Antennas," *IEE Electronics Letters*, 24, 18, Sept. 1988, pp. 1156-1157.

[7] Robert E. Collin, "Foundations for Microwave Engineering", IEEE Press, 2001.

[8] R. Kranenberg, S. A. Long, J. T. Williams, "Coplanar Waveguide Excitation of Dielectric-Resonator Antennas," IEEE Transactions on Antennas and Propagation, AP-39, 1, 1991, pp.1 19-122.

[9] Petosa Aldo, "Dielectric Resonator Antenna Handbook", Artech House publications