Progress In Electromagnetics Research, PIER 60, 143–152, 2006

MICROSTRIPLINE FED CYLINDRICAL DIELECTRIC RESONATOR ANTENNA WITH A COPLANAR PARASITIC STRIP

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Abstract—The paper discusses the experimental analysis on a cylindrical dielectric resonator antenna (DRA) with a parasitic conducting strip, loaded coplanar with the 50Ω microstripline feed. The antenna offers an impedance bandwidth as high as 17.33% at a centre frequency of 2.77 GHz, as a result of the enhanced coupling produced by the coplanar strip. The return loss, impedance, polarization and radiation characteristics of the antenna are studied. The radiation patterns are broad and the low cross-polarisation levels confirm that the antenna is linearly polarised over the entire impedance bandwidth.

1. INTRODUCTION

Dielectric resonators (DR), by virtue of their high Q-factor and very low conduction loss have been found worthy of applications such as microwave and millimeter wave filters and antennas. An interesting feature of DR is that certain low-Q modes can be excited, which can radiate energy rather than confining it over a considerable frequency band [1, 2]. Radiation characteristics of various modes can be different. For example, modes like $HEM_{11\delta}$, $TE_{01\delta}$ and $TM_{11\delta}$ radiate maximum power in the bore sight direction but $TM_{01\delta}$ operation produce a null in that direction. Excitation of a mode depends on the DR geometry, feed structure and the feed location. Among various feed structures [3, 4], the simplest one is an open-ended microstrip transmission line [5, 6] to excite the DRA. The amount of coupling depends on the distance between the tip of the strip and the centre of the DR which may be defined as the overlapping distance. This is one way of tuning a DR where the resonant frequency is a function of its position on the feed. Section of a nonresonant microstrip line coupled to the DR has been shown as an effective tuning element [7]. By correctly selecting the length of the microstrip tuning line, a known range of reactance can be added to the resonator. It has been shown [8, 9] that conducting strip loading on the DR surface can enhance the impedance bandwidth and can change the polarization characteristics.

The present design shows how the impedance bandwidth of a cylindrical DRA can be enhanced by adding a parasitic coplanar strip adjacent to the microstrip feed. At an optimum strip position and dimensions, dual radiating modes of similar polarizations are excited in close vicinity to form a linearly polarized, wide impedance band.

2. ANTENNA STRUCTURE AND MEASUREMENT SETUP

The antenna structure is shown in Fig. 1. A cylindrical DR of permittivity $\varepsilon_{r1} = 20.8$, diameter $2a = 27.3\,\text{mm}$ and height $h = 8.4\,\text{mm}$ is fed with a 50Ω microstrip transmission line of $80\,\text{mm}$ (length) $\times$ $3\,\text{mm}$ (width), fabricated on a microwave substrate of permittivity $\varepsilon_{r2} = 4$ and size $140\,\text{mm}$ (length) $\times$ $110\,\text{mm}$ (breadth) $\times$ 1.64mm(thickness). The condition that $\varepsilon_r 1 \gg \varepsilon_r 2$ for efficient coupling between the stripline and the DR is satisfied here. The microstrip feed provides a much easier means of optimizing the feed position. The transmission line is excited via a 50Ω SMA connector soldered to its one end. Reflections from the open end of the microstripline produce standing waves of wavelength $\lambda_o/\sqrt{\varepsilon_{r2}}$ where λ_o is the operating wavelength. If the DR is located at the point of maximum electric field on the feed, maximum energy is coupled capacitively [10].

Antenna measurements are performed with HP 8510C Vector Network Analyzer. The reflection (S_{11}), impedance (Z) and radiation (S_{12}) characteristics of the DRA are measured and discussed in the following sections.

3. RESULTS AND DISCUSSION

The DR is placed off-centered on the microstrip feed line which excites the broadside HEM_{11d} mode. The theoretical resonant frequency of $HEM_{11\delta}$ mode is given as [2]

$$f_o = \frac{6.324c}{2\pi a}\left[0.27 + 0.36\left(\frac{a}{2h}\right) + 0.02\left(\frac{a}{2h}\right)^2\right]$$

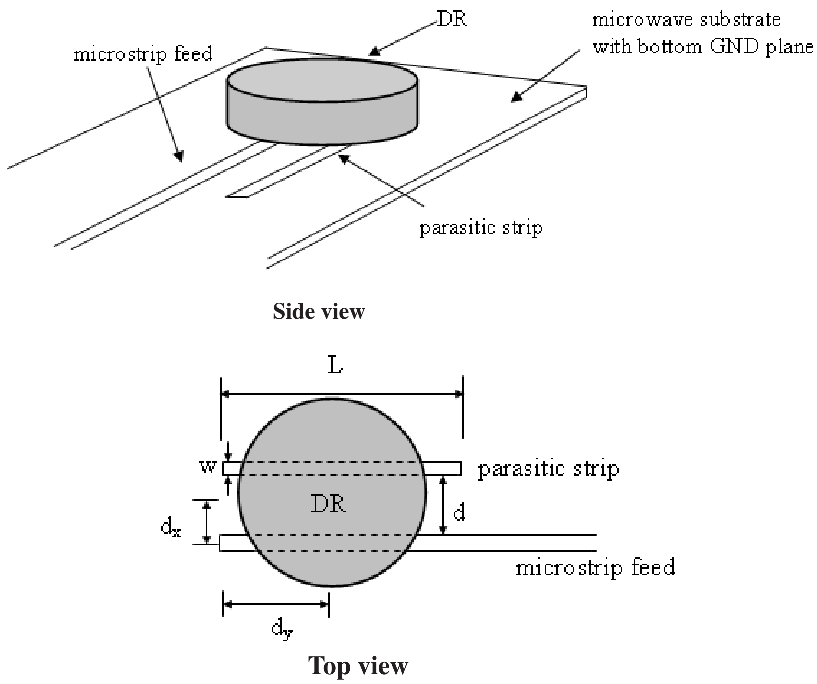

Figure 1. Antenna structure.

where c is the velocity of light. The frequency is calculated as 2.67 GHz which is quite close to the measured value of 2.605 GHz as shown in Fig. 2. It is clear from the figure that the return loss is below -10 dB over a bandwidth of 7.37% ranging from 2.545 to 2.74 GHz. This wide impedance bandwidth is the result of the low Q-factor of the excited $HEM_{11\delta}$ mode. The measured input impedance as a function of frequency shows relatively good and uniform impedance matching throughout the band.

4. EFFECT OF PARASITIC STRIP LOADING

A metallic strip of length L and width w is adhered at a distance of d from the microstripline to modify the feed for the DR as shown in Fig. 1. The length of the strip is chosen slightly higher than half the feed strip length i.e., $L = 45$ mm and a width of $w = 1$ mm to start with. The resulting reflection characteristics, measured for various values of the distance d from the feed strip are shown in Fig. 3. When the strip is kept at a distance $d = 2.5$ mm from the feed strip,

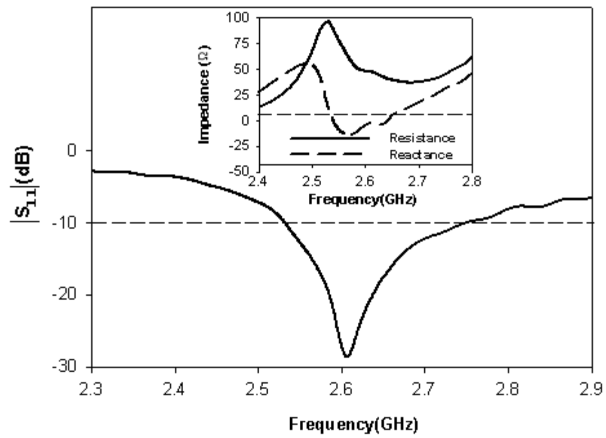

Figure 2. Return loss and input impedance (inset) of the DRA with microstrip feed only.

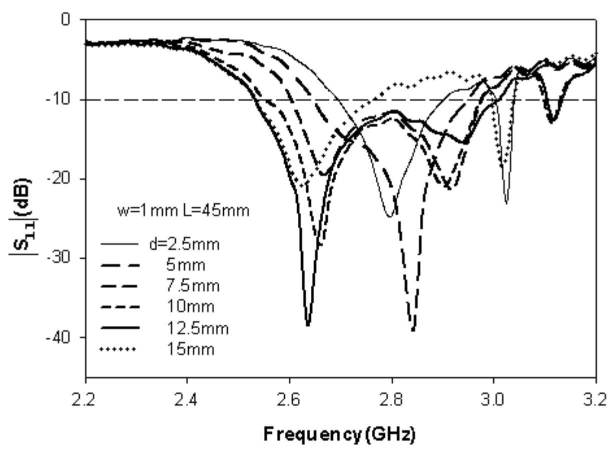

Figure 3. Return loss of the loaded DRA for various parasitic strip positions (d).

the original DRA mode is shifted from 2.605 GHz to 2.8 GH. As the parasitic strip is moved farther, a dip is formed at the the lower end of the impedance band and shifts to the left. The original mode is shifted to the right, until $d = 12.5$ mm or $\sim 0.1\lambda_o$. At this point the impedance bandwidth ranges from 2.545 to 3.01 GHz or 16.74%. The influence of the parasitic strip length L on the reflection characteristics is studied and is shown in Fig. 4. As the length L is reduced, the

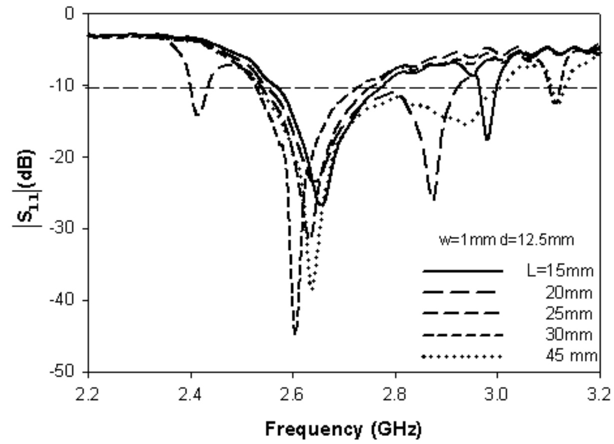

Figure 4. Return loss for various parasitic strip lengths (L).

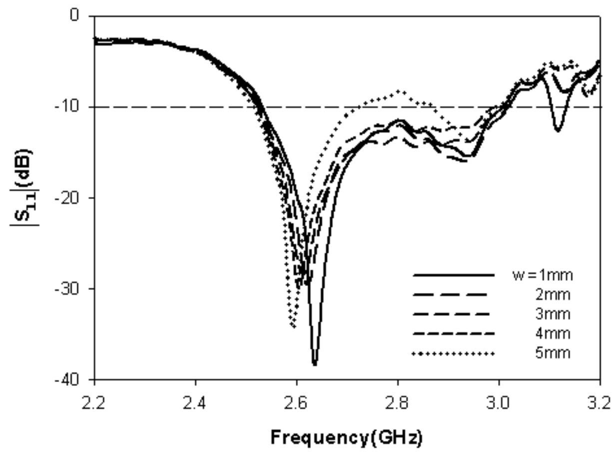

Figure 5. Effect of parasitic strip (w) on return loss.

wideband nature of the antenna disappears and a single resonance close to the $HEM_{11\delta}$ frequency of 2.605 GHz is exhibited. Effect of parasitic strip width w is shown in Fig. 5 where the individual responses do not vary appreciably from one another except for a slight down-shift, up to $w = 4$ mm. Maximum bandwidth is 17.33% obtained for $w = 2$ mm. This enhancement in bandwidth is the result of dual radiating modes excited in close vicinity as a result of the strip loading. Depending on the dimensions and the relative position of the parasitic strip, the

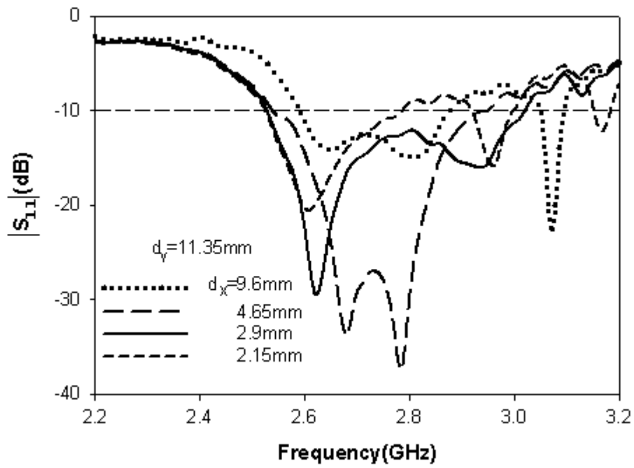

Figure 6. Measured return loss for various d_x.

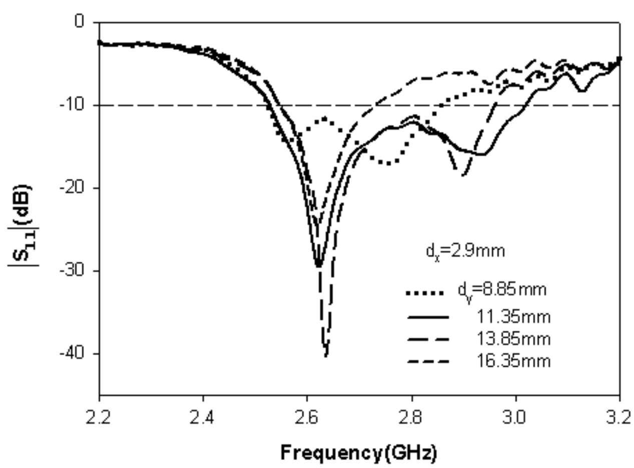

Figure 7. Measured return loss for various d_y.

magnitude and phase of the energy coupled to the strip vary, which excites an additional radiating mode of higher frequency. Effect of the DR position (d_x, d_y) on the reflection characteristics is also studied. It is clear from Figs. 6 and 7 that the maximum bandwidth corresponds to a feed position of $d_x = 2.9\,\text{mm}$ and $d_y = 11.35\,\text{mm}$ with respect to the centre of the DR. The impedance variation in the maximum band is also studied and is shown in Fig. 8.

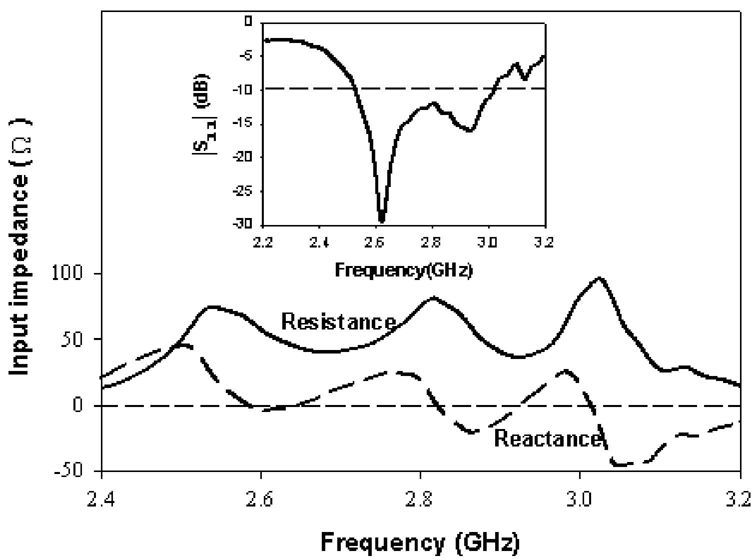

Figure 8. Measured input impedance corresponding to the return loss plot shown in inset for optimum values of $L = 45$ mm, $w = 2$ mm and $d = 12.5$ mm.

5. FAR FIELD

Far-field radiation patterns ($S_{12} \times$ Angle) within the operating band are measured by configuring a standard broad band H-plane horn antenna as the transmitter and the DRA as the receiver, i.e., in the receiving mode. Radiation patterns are measured for the two principal planes viz X-Z and Y-Z planes. Fig. 9 shows the radiation patterns at 2.62, 2.77 and 2.935 GHz i.e., in the neighbourhood of the lower, centre and upper ends of the operating band respectively. The co-polar patterns are broad and similar, but at the upper end of the band, the cross-polarisation of the X-Z plane goes below -30 dB. On the other hand, the Y-Z plane shows good cross-polarisation at the lower end of the band. The small degree of asymmetry in the patterns is due to the effects of the SMA connector and feed cable on one side of the antenna. Half power beam widths (HPBW) measured from the radiation patterns are 97° and 90° respectively in the X-Z and Y-Z planes at 2.77 GHz. Also an average gain of 5 dBi has been measured in the operating band.

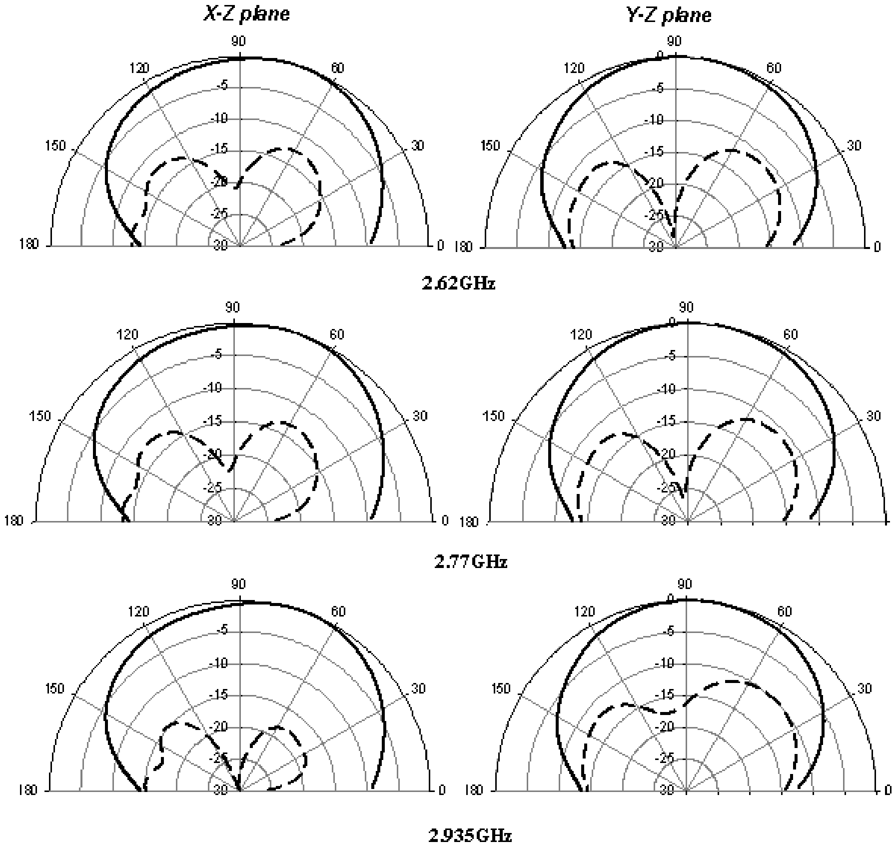

Figure 9. Measured radiation pattern.

6. CONCLUSION

A coplanar parasitic strip loaded DRA has been presented in this paper. The antenna offers an impedance bandwidth of 17.33% at the centre frequency of 2.77 GHz and linear polarization of the radiation throughout the band. The wide impedance bandwidth is the result of dual radiating modes, which are excited in close vicinity as a result of the strip loading. Radiation patterns are found to be broad over the entire bandwidth with good cross-polarisation levels. The possibility of shifting the operating band to the wireless application band is under investigation.

ACKNOWLEDGMENT

The authors acknowledge State Council for Science, Technology and Environment, Government of Kerala, India, University Grants Commission, India and Council of Scientific and Industrial Research, India for providing financial assistance.

REFERENCES

1. Long, S. A., M. McAllister, and L. C. Shen, "The resonant cylindrical dielectric cavity antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 31, No. 3, 406–412, 1983.
2. Mongia, R. K. and P. Bhartia, "Dielectric resonator antennas — A review and general design relations for resonant frequency and bandwidth," *Inter. J. Microwave and Millimeter-Wave Computer-Aided Engineering*, Vol. 4, No. 3, 230–247, 1994.
3. Petosa, A., A. Ittipiboon, Y. M. M Antar, D. Roscoe, and M. Cuchaci, "Recent advances in dielectric resonator antenna technology," *IEEE Antennas and Propagation Magazine*, Vol. 40, No. 3, 35–48, 1998.
4. Saed, M. and R. Yadla, "Microstrip-fed low profile and compact dielectric resonator antennas," *Progress In Electromagnetics Research*, PIER 56, 151–162, 2006.
5. Kranenberg, R. A. and S. A. Long, "Microstrip transmission line excitation of dielectric resonator antennas," *Electronics Letters*, Vol. 24, No. 18, 1156–1157, 1988.
6. Leung, K. W., K. Y. Chow, K. M. Luk, and E. K. N. Yung, "Low-profile circular disk DR antenna of very high permittivity excited by a microstripline," *Electronics Letters*, Vol. 33, No. 12, 1004–1005, 1997.
7. Kenneth, V., Buer, El-Badawy, and El-Sharawy, "A novel technique for tuning dielectric resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 43, No. 1, 36–41, 1995.
8. Long, R. T., R. J. Dorris, S. A. Long, M. A. Khayat, and J. T. Williams, "Use of parasitic strip to produce circular polarisation and increased bandwidth for cylindrical dielectric resonator antenna," *Electronics Letters*, Vol. 37, No.7, 406–408, 2001.
9. Leung, K. W. and H. K. Ng, "The slot-coupled Hemispherical dielectric resonator antenna with a parasitic patch: Applications to the circularly polarised antenna and wide-band antenna," *IEEE*

Antennas and Propagation Magazine, Vol. 53, No. 5, 1762–1769, 2005.

10. Mongia, R. K. and A. Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator antennas," *IEEE Trans. Antennas and Propagation*, Vol. 45, No. 9, 1348–1356, 1997.