Progress In Electromagnetics Research M, Vol. 20, 171–177, 2011

RECTANGULAR RING-SLOT DIELECTRIC RESONATOR ANTENNA WITH SMALL METALLIC PATCH

R. G. Madhuri* **and P. M. Hadalgi**

Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga, Karnataka 585106, India

Abstract—This paper presents an innovative design approach that improves the characteristics of rectangular dielectric resonator antenna (RDRA). In this design the dielectric resonator (DR) fed by microstrip line feed through a rectangular ring slot. This slot represents the coupling mechanism between the resonator and microstrip line. Both DR and slot are resonant structures. Further a comparative study is made by depicting a metallic patch over the DR. The antenna has been fabricated and measured for the study, such as impedance bandwidth, return loss, radiation pattern and antenna gain. Measurement results show dual band property with an achievable impedance bandwidth of 63.67% with return loss of −34.3 dB and antenna gain 2.32 dB.

1. INTRODUCTION

DRA is an excellent radiator as it has negligible metallic loss. It offers advantages such as small size, wide bandwidth, and low cost with the exciting feeding techniques when operating at millimeter and microwave frequencies. Some common feeding mechanisms such as probe feed, aperture slot, microstrip line and coplanar line can be used with the DRAs [1]. DR of any shape can be used for antennas such as cylindrical, hemispherical, rectangular etc. [2–4]. The rectangular DRA offers practical advantages over the spherical and cylindrical shapes, due to flexibility in choosing aspect ratio [5]. There are many papers and investigations, which have been reported on wideband DRA operation [6, 7]. Bandwidth enhancement techniques to improve the bandwidth of dielectric resonator antennas, such as, stacking multiple DRAs [8], using parasitic dielectric resonator elements [9], thick substrate, utilizing special dielectric resonator geometries [10],

Received 12 April 2011, Accepted 23 August 2011, Scheduled 29 August 2011

* Corresponding author: R. G. Madhuri (rg_madhuriv@rediffmail.com).

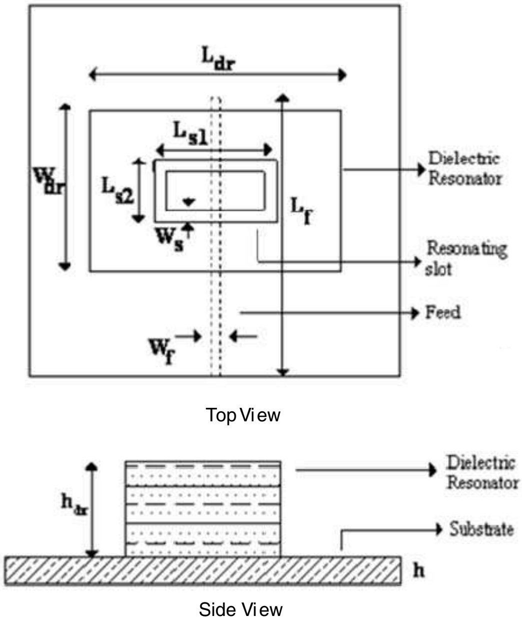
slot coupling etc are reported. Microstrip lines also offer a degree of impedance matching not available with coaxial lines or wave-guides. As the microstrip line can be extended by a distance beyond slot, this extension behaves like an open stub. By adjusting the length of stub, impedance match to microstrip line can be improved[6]. When ε_r of DR is above certain value, say $\varepsilon_r \geq 9.5$, the highest cross polar discrimination occurs and very strong cross-polarized fields are produced for $\varepsilon_r < 2$. This is important information as one may use very small ε_r to push up operating frequency without realizing the increase in the cross-polarization level [11]. In this study, a comparative study is made between rectangular ring slot-fed DRA (RDRA) and metal plate DRA (MPDRA). It is seen that by placing a small metal plate over the DR increases the bandwidth and also reduces the resonant frequency. The DR is centered over a rectangular ring slot, which represents coupling mechanism between resonator and microstrip line. The shape and size of the slot has the significant impact on the strength of the coupling between feed line and DR. The improvement in bandwidth is due to the flexibility offered by the slot length and coupling slot size [12].

2. DESIGN AND EXPERIMENTAL DETAILS

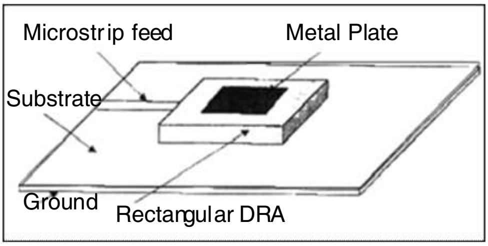
Figure 1 depicts the layout of proposed antenna. The structure in Figure 1(a), incorporates a rectangular DR of dimension $L_{dr} = 3.12\,\text{cm}$, $W_{dr} = 2.44\,\text{cm}$, $h_{dr} = 0.6\,\text{cm}$ and dielectric constant $\varepsilon_{dr} = 11.9$, is fed by a slot of dimension $L_{s1} = 2\,\text{cm}$, $L_{s2} = 1\,\text{cm}$ and width of ring, $W_s = 0.2\,\text{cm}$ which is etched on the ground plane of low cost glass epoxy substrate material having dielectric constant $\varepsilon_r = 4.2$ and thickness $h = 0.16\,\text{cm}$. The slot dimensions are taken in terms of λ_0, where λ_0 is free space wavelength in cm. A $50\,\Omega$ microstrip feed line with $L_f = 3\,\text{cm}$ and $W_f = 0.157\,\text{cm}$ with stub taken in terms of $\lambda_0/6$ is used for impedance matching. At the tip of microstrip feed line a $50\,\Omega$ coaxial SMA connector is connected for feeding microwave power. Slot coupling offers the advantage of having the feed network located below the ground plane, isolating the radiating slot from any unwanted coupling from the feed. Figure 1(b) shows the geometry of MPDRA, a metal plate is placed over the DR.

2.1. Results & Discussion

The resonant properties of the proposed antenna have been experimentally tested on Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651). Figure 2 illustrate



(a) Geometry of RDRA



(b) Geometry of MPDRA

Figure 1. Geometry of Proposed DRA (a) RDRA, (b) MPRDA.

the measured results of the return loss (RL) versus frequency for RDRA wherein, it is observed that two distinct operating frequencies are excited which will result in dual frequency operation (TE^x_{111}). This is due to the fact that TE^x_{111} mode would be resonant at a different frequencies. Here, the slot on the substrate creates first lower resonance frequency at 5.43 GHz and second resonance at 8.72 GHz is due to the DR placed on the slot. The impedance bandwidth of 17.6% (5.08–6.06 GHz) is achieved at 10 dB return loss (for VSWR < 1.5) while other Bandwidth of 25.2% (7.67–9.88 GHz). Figure 3 shows the

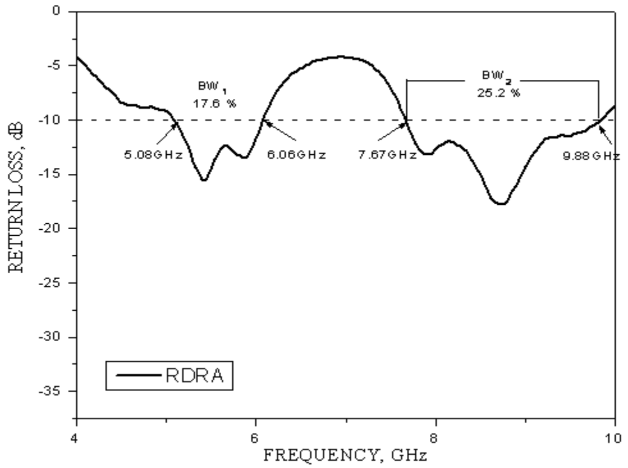


Figure 2. Plot of return loss (RL) versus frequency (GHz) response of RDRA ($h_{dr} = 6\,\mathrm{mm}$).

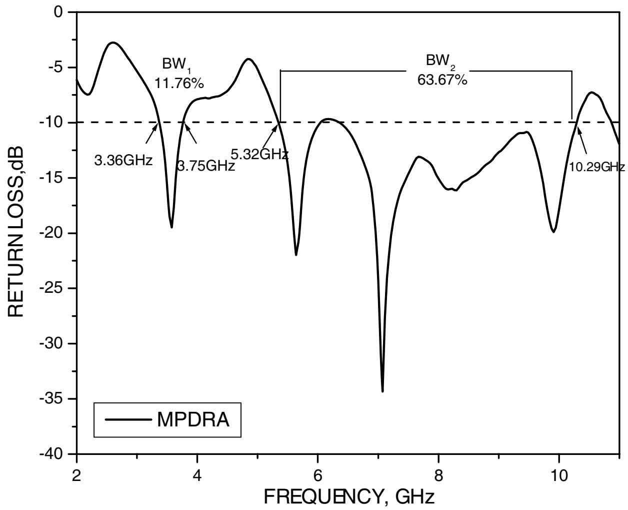


Figure 3. Plot of return loss (RL) versus frequency (GHz) response of MPDRA ($h_{dr} = 6\,\mathrm{mm}$).

measured results of return loss (RL) versus frequency for MPDRA results in dual frequency operating at 3.57 GHz and 7.07 GHz. The impedance bandwidth of 11.76% (3.36–3.75 GHz) is achieved at 10 dB return loss (for VSWR < 1.5) while other Bandwidth of 63.67% (5.32–10.29 GHz) with attained gain of 2.32 dB.

As compared to the RDRA, MPDRA with small metal plate there is reduction in resonant frequency. The improvement in impedance bandwidth at second resonance is due to the metal plate placed over the DR. The current distributions of the proposed antennas is high at the feed position and at the width of the dielectric resonator. And it is bit less at the width of the dielectric resonator.

Figures 4–7 show the measured radiation patterns of the proposed RDRA and MPDRA respectively with co-polar and cross-polar characteristics. The radiation patterns are measured and plotted at their resonant frequencies. As shown in Figures 4–7, the antenna exhibit good broadband radiation patterns with linear polarization characteristics. It is also noted that 3 dB beamwidth (HPBW) are 78° and 54° respectively for RDRA and 64° and 12° respectively for MPDRA. The cross polarization levels of the antennas are lower than the co-polarization levels by −20 dB in the E-plane.

As MPDRA gives maximum bandwidth among the proposed antennas, Figure 8 shows Smith chart plot of impedance locus versus

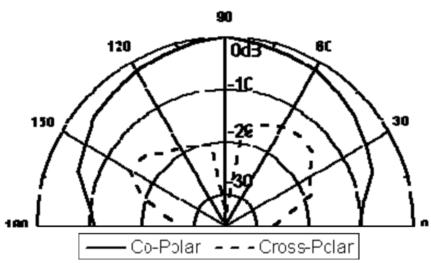


Figure 4. Radiation pattern of RDRA at 5.43 GHz.

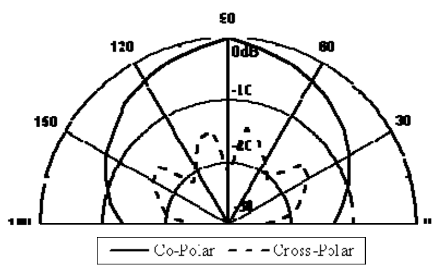


Figure 5. Radiation pattern of RDRA at 8.72 GHz.

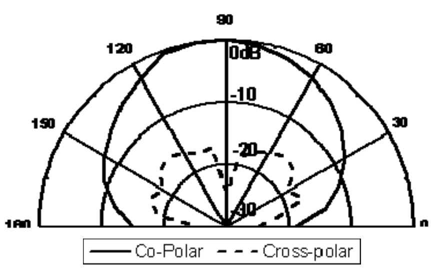


Figure 6. Radiation pattern of MPDRA at 3.57 GHz.

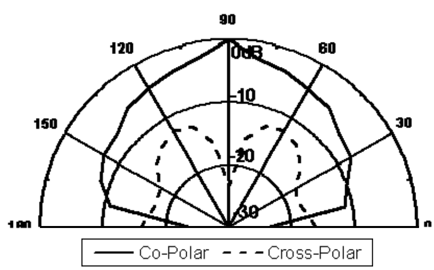


Figure 7. Radiation pattern of MPDRA at 7.07 GHz.

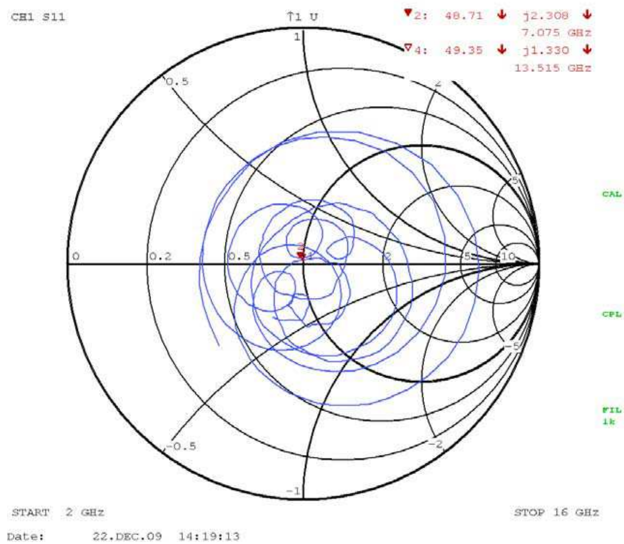


Figure 8. Measured input impedance characteristics on Smith chart.

frequency of the proposed antenna wherein it validates that presence of two loops on the Smith chart proves dual frequency functionality with better impedance matching characteristics between the input and the load.

3. CONCLUSION

The proposed antenna is quite simple in design and fabrication and good in enhancing the bandwidth. A large bandwidth is obtained by placing a metal plate on dielectric resonator depicted over the rectangular ring-slot. Experimental results show that the proposed antenna can offer a bandwidth of 63%, with return losses less than −10 dB, with slightly changing the nature of radiation characteristics across the resonating frequencies. With these features, this antenna is useful for broadband wireless communications for both S-band and X-band.

ACKNOWLEDGMENT

The authors thank the Department of Science & Technology (DST), Government of India, New Delhi, for sanctioning Network Analyzer to this Department under FIST project.

REFERENCES

1. Kishk, A. A., "Applications of rotated sequential feeding for circular polarization bandwidth enhancement for planar arrays with single-fed dielectric resonator antenna element," *IEEE Ant. Propag. Soc. Int. Sym.*, Vol. 4, 664–667, 2003.
2. Rao, Q. and T. A. Denidni, "Study of broadband dielectric resonator antennas," *PIERS Online*, Vol. 1, No. 2, 137–141, 2005.
3. Kumar, A. V. P., V. Hamasakutty, J. Yohannan, and K. T. Mathew, "Microstrip fed cylindrical dielectric resonator antenna with a coplanar parasitic strip," *Progress In Electromagnetics Research*, Vol. 60, 143–152, 2006.
4. Leung, K. W. and H. K. Ng, "The slot-coupled hemispherical dielectric resonator antenna with a parasitic patch: Applications to the circularly polarized antenna and wide-band antenna," *IEEE Antennas and Propagation Magazine*, Vol. 53, No. 5, 1762–1769, 2005.
5. Luk, K. M. and K. W. Leung, *Dielectric Resonator Antennas*, Research Studies Press Ltd., Hertfordshir, England, UK, 2003.
6. Rezaei, P., M. Hakkak, and K. Foreoraghi, " Design of wideband dielectric resonator antenna with a two segment structure," *Progress In Electromagnetics Research*, Vol. 66, 111–124, 2006.
7. Chair, R., A. A. Kishk, and K. F. Lee, "Wideband simple cylindrical dielectric resonator antennas," *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 4, 241–243, 2005.
8. Petosa, A., et al., "Design and analysis of multisegment dielectric resonator antenna," *IEEE Trans. Antennas Propag.*, Vol. 48, No. 5, 738–742, 2000.
9. Clent, M. and L. Shafi, "Wideband single layer microstrip antenna for array applications," *Electronics Lett.*, Vol. 25, No. 16, 1292–1293, 1999.
10. Kishk, A. A., et al., "Conical dielectric resonator antennas for wideband applications," *IEEE Trans. Antennas Propag.*, Vol. 50, No. 4, 469–474, 2002.
11. Leung, K. W. S., K. K. Tse, K. M. Luk, and E. K. N. Yung, "Cross-polarization characteristics of a probe-fed hemispherical dielectric resonator antenna," *IEEE Trans. Antennas Propag.*, Vol. 47, No. 7, 1228–1230, 1999.
12. Amelia, B., S. Kamal, and H. Mosallaei, "Compact slot and dielectric resonator antenna with dual-resonance, broadband characteristics," *IEEE Trans. Antennas Propag.,* Vol. 53, 1020–1026, 2005.