International Journal of Electronics Engineering, 1(2), 2009, pp. 269-271

Rectangular Dielectric Resonator Antenna for X-Band Applications

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Abstract: *In this paper a slot-fed rectangular dielectric resonator antenna is studied. A wideband operation is achieved by loading a rectangular dielectric resonator on the center of the rectangular ring slot. Dielectric resonators of two different size and thickness have been studied. In this configuration, slot acts as an effective radiator and the feeding structure of the dielectric resonator. The measured impedance bandwidth obtained is about 25.2%. The return loss, radiation pattern and half power beam widths are presented.*

Keywords: *Dielectric Resonator Antenna, Slot-fed, Bandwidth.*

1. INTRODUCTION

The dielectric resonator antenna (DRA) offers advantages such as small size, high efficiency, large bandwidth, low profile, ease of fabrication and low production cost. The feeding mechanisms such as probe feed, aperture slot, microstrip line and coplanar line etc can be used with the DRAs [1]. Several DRA standard shapes such as rectangular, cylindrical, hemispherical, circular are used. The rectangular DRA offers practical advantages over the spherical and cylindrical shapes, due to the flexibility in choosing the aspect ratios. In many communication applications, wideband antenna operation is useful to accommodate the increasing data rates required for services such as Video-Conferencing, direct digital broadband, EHF portable satellite communications, local multi-point communications etc. Some of these requirements may be met by the existing printed antenna technology also. Many researchers have experimentally investigated that wideband operation of DRA can be obtained by stacking two different DRAs [2], coplanar parasitic DR elements beside DRA [3-4] and some methods that need single DRA to achieve wideband operation is also reported [5-6]. In this paper, a DRA fed by rectangular ring slot is reported. In slot coupling method, the microstrip feed line is etched on the bottom of the feed substrate and a slot is made over the ground plane. This feed mechanism was initially proposed by Pozar [7] for microstrip patch antennas. The DR is placed on the top of the slot usually at the center. This coupling mechanism minimizes spurious radiation. The microstrip feed line should be positioned at right angles to the center of the slot for efficient coupling. The shape of the coupling slot has significant impact on the strength of the coupling between the feed line and DR. The rectangular coupling slots are commonly used, as they give better coupling than round slots. The dielectric constant is not only the factor determining the bandwidth of a DRA. The other factors affecting the bandwidth of DRA are its shape and aspect ratio height/ length (h/l). As the height of the DR increases, the aspect ratio decreases resulting in increase in the DRA bandwidth [8].

This paper reports two DRAs of slightly bigger dimensions giving out enhancement in the bandwidth. Measured results such as return loss, bandwidth and half power beam width are presented and discussed.

2. ANTENNA DESIGN

Figure 1, shows the geometry of DRA. The antenna comprises of rectangular dielectric resonator of diel ectric constant e_{dr} = 11.9. We have studied two antennas DRA_1, with DR_1 dimensions (L_{dr} = 2.21cm, W_{dr} = 1.64cm and thickness, h_{dr} = 0.3cm and 0.6mm) and DRA_2, with DR_2 dimensions (L_{dr} = 3.0cm, W_{dr} = 2.64cm, and thickness, h_{dr} = 0.3cm and 0.6mm) fed by a rectangular ring slot of dimension L_{s1} = 2cm, L_{s2} = 0.5cm, and width of ring, W_s = 0.2cm which is etched on the ground plane of low cost glass epoxy substrate material having dielectric constant, e_r = 4.2 and thickness, h = 0.16cm.

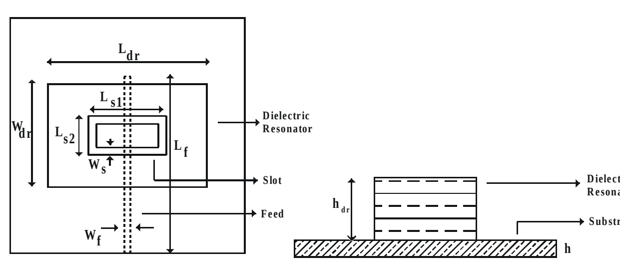

Figure 1: Geometry of DRA

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The slot dimensions are taken in terms of l_0, where l_0 is free space wavelength in cm. A 50W microstrip feed line with $L_{f=}$ 3 cm and $W_{f=}$ 0.157 cm with stub taken in terms of $l_0/6$ is used for impedance matching. At the tip of microstrip feed line a 50W 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.

3. EXPERIMENTAL RESULTS

A DR_1 is placed at the center of the rectangular ring slot in order to achieve maximum impedance bandwidth. The impedance bandwidth over return loss less than–10dB for the proposed antennas is measured using Vector Network Analyzer (Rohde & Schwarz, German make ZVK model 1127.8651). Figure 2 and 3, show the return loss versus frequency graph of DRA_1 and DRA_2 respectively. The impedance bandwidth of DRA_1 is found to be 520MHz (5.5%) at 9.42GHz for h_{dr} = 0.3cm and 1370MHz (14.7%) at 8.97GHz for h_{dr} = 0.6cm. And the impedance bandwidth of DRA_2 is found to be 1230MHz (13.2%) at 9.21GHz for h_{dr} = 0.3cm and 2210MHz (25.2%) at 8.72GHz for h_{dr} = 0.6cm.

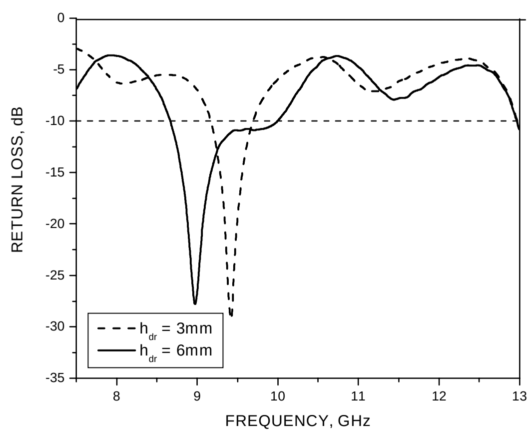

Figure 2: Variation of Return Loss versus Frequency of DRA_1

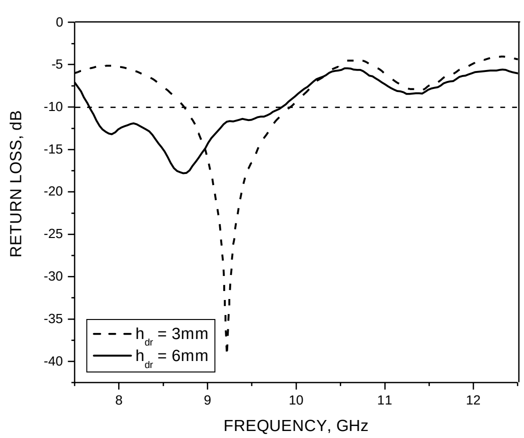

Figure 3: Variation of Return Loss versus Frequency of DRA_2

The *X*-*Y* plane co-polar and cross-polar radiation patterns of DRA_1 and DRA_2 are measured at their resonating frequencies and are shown in Figure 4 to Figure 7. The half power beam width (HPBW) of the proposed antennas is calculated and is found to be 85^0 and 115^0 for DRA_1 and 55^0 and 74^0 for DRA_2. Hence it is clear that, DRA_2 improves the sharpness of the beam by reducing HPBW.

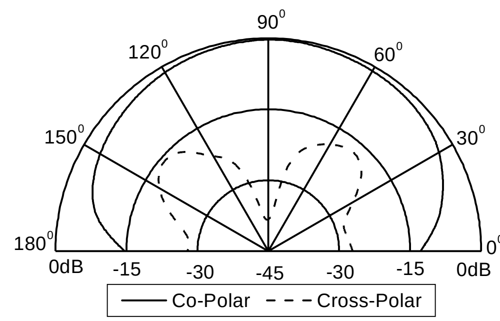

Figure 4: Radiation Pattern of DRA $_1$ at 9.42 GHz

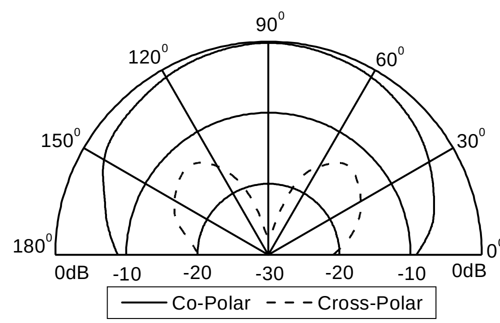

Figure 5: Radiation Pattern of DRA_2 at 8.97 GHz

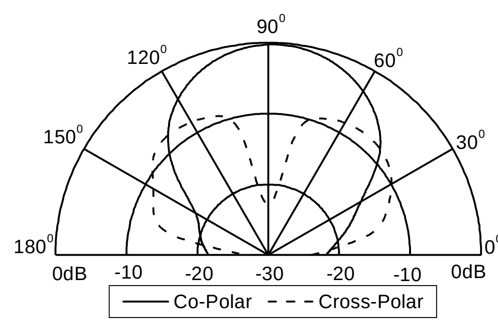

Figure 6: Radiation Pattern of DRA $_1$ at 9.21 GHz

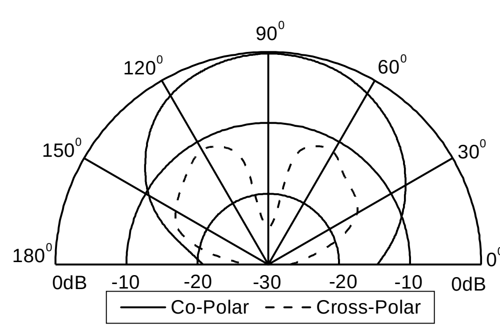

Figure 7: Radiation Pattern of DRA_2 at 8.72 GHz

For calculating the gain, the power received (P_r) by the proposed antenna and power received by the standard X-band pyramidal horn antenna (P_s) is measured separately. With the help of these experimental data the gain (G_T) in dB is calculated using the formula [9],

$$(G_T)_{dB} = (G_s)_{dB} + 10\log\left(\frac{P_r}{P_s}\right)$$

where, G_s is the gain of pyramidal horn antenna. From the measured results it is seen that the gain of the antenna measured at resonating frequencies is found to be 1.48dB at 9.42GHz and 3.56dB at 8.97 GHz for DRA_1. And 2.21dB at 9.21GHz and 5.04dB at 8.72GHz. Various antenna parameters measured are given in Table 1.

Table 1
Antenna Parameters

Antenna	*Thickness of DR (mm)*	*Resonating Frequency (GHz)*	*Bandwidth (%)*	*Gain, G_T (dB)*	*HPBW (deg)*
DRA_1	$h_{dr} = 3$	9.42	5.5	1.48	85
$h_{dr} = 6$	8.97	14.7	3.56	115	
DRA_2	$h_{dr} = 3$	9.21	13.2	2.21	55
$h_{dr} = 6$	8.72	25.2	5.04	74	

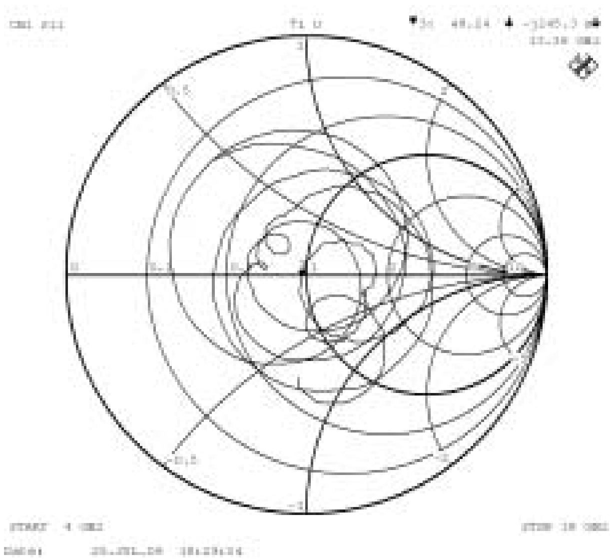

Figure 8: Variation of Input Impedance of DRA_2

As DRA_2 gives maximum bandwidth among the proposed antennas, its variation of input impedance is measured and is shown in Figure 8. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its wide band.

4. CONCLUSION

From the detailed experimental study it is clear that, the proposed antenna is quite simple in design and fabrication and good in enhancing the bandwidth. By increasing the size and thickness of the dielectric resonator placed over the rectangular ring slot shows improvement in the antenna parameters. An impedance bandwidth of 25.2 % for DRA_2 is achieved at X-band frequencies with improved broadside-radiation characteristics when compared to DRA_1. With these features, this antenna may find applications in broadband wireless communication.

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