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Slot-fed wideband dielectric resonator antenna for wireless applications

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In this paper, a slot-fed dielectric resonator antenna (DRA) with wideband operations in 4-6 GHz frequency band is presented. Slot represents coupling mechanism between resonators and the microstrip line. The DRA and slot are both resonant structures. The microstrip feed line is positioned at right angle to the center of the slot for efficient coupling. Together they yield a double resonant structure with low cross-polarization levels and identical radiation patterns. With proper design, the two resonances can be merged to achieve wide bandwidth. The rectangular dielectric resonator placed at the center of the rectangular ring slot provides an impedance bandwidth of 42.1%. The return loss and radiation patterns of these are presented.

Keywords: Dielectric resonator antenna, Slot-fed wideband antenna

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1 Introduction

The wireless communication applications such as blue tooth, GPS, direct digital broadcast, satellite communication, etc. require wide band operation of antennas to accommodate large data rates[1]. The continuing growth in electronic systems has resulted in development of antennas that can be embedded into wireless products. Dielectric resonator antenna (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[2]. Dielectric resonator (DR) of any shape can be used for antennas such as cylindrical, hemispherical, rectangular, etc.[3-5]

The rectangular DRA offers practical advantages over the spherical and cylindrical shapes due to flexibility in choosing aspect ratio[6]. There are a number of papers and investigations, which have been reported on wideband DRA operation[7,8]. The bandwidth enhancement techniques to improve the bandwidth of dielectric resonator antennas, such as stacking multiple DRAs[9], using parasitic dielectric resonator elements[10], thick substrate, utilizing special dielectric resonator geometries[11], slot coupling, etc. are reported. The microstrip lines also offer a degree of impedance matching not available with coaxial lines or waveguides. 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[12]. In this study of slot-fed DRA, it has been shown that by increasing the thickness of DR, wide bandwidth can be achieved. 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 significant impact on the strength of coupling between feed line and DR. The improvement in bandwidth is due to the flexibility offered by the slot length and coupling slot size[13]. The dielectric constant is not the only factor determining the bandwidth of a DRA. The 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 increases resulting increase in the DRA bandwidth[14]. This study is carried out by using four thicknesses of DR, h_{dr} (3, 6, 9 and 12 mm), providing enhancement in bandwidth[15,16]. The return loss and radiation patterns are measured and presented.

2 Antenna configurations

Figure 1 shows the geometry of DRA. A rectangular DR of dimension L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 0.3, 0.6, 0.9 and 1.2 cm and dielectric constant ε_{dr} = 11.9, is fed by a slot of dimension L_{s1} = 2 cm, L_{s2}= 1 cm and width of ring, W_s = 0.2 cm, which is etched on the ground plane of low cost glass epoxy substrate material having dielectric constant ε_r = 4.2 and thickness h = 0.16 cm. The slot dimensions are taken in terms of λ_0, where λ_0 is free space wavelength in cm (i.e. 6 cm). A 50 Ω microstrip feed line with L_f = 3 cm and W_f = 0.157 cm with stub length taken in terms of $\lambda_0/6$ is used for impedance matching. At the tip of microstrip feed line, a 50 Ω 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. If the dimensions of the DR are chosen such that L_{dr}, W_{dr} >> h_{dr}, then the simple relation for h_{dr} in terms of resonance frequency f_o is given as[14]:

$$h_{dr} = \frac{C}{4 f_o \sqrt{\in_r}} = \frac{\lambda_o}{4\sqrt{\in_r}}$$

3 Experimental results

This experimental work was carried out by varying the thickness of dielectric resonator. DRA_1, with dimensions of DR as (L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 0.3 cm) and DRA_2, with dimensions (L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 0.6 cm), DRA_3 with dimensions (L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 0.9 cm) and DRA_4 with dimensions (L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 1.2 cm) are studied. DR is placed at the center of the rectangular ring slot in order to achieve maximum impedance bandwidth. The size and position of the slot are selected in order to improve matching and control resonance frequency[13].

The impedance bandwidth over return loss less than –10 dB for the proposed antennas is measured using Vector Network Analyzer (Rohde & Schwarz, German make ZVK model 1127.8651). Figure 2 shows the return loss versus frequency graph of DRA_1, DRA_2, DRA_3 and DRA_4. From these figures, the impedance bandwidth is calculated by using the equation:

$$BW = \left[\frac{f_H - f_L}{f_C}\right] \times 100\%$$

where, f_H and f_L, are higher and lower cut-off frequencies of the band, respectively, and f_c is the center frequency. It is clear from Fig. 2 that DRA_1 is resonating for dual frequencies with impedance bandwidth of 140 MHz (3.2%) at 4.38 GHz and 280 MHz (4.7%) at 5.96 GHz. DRA_2 is resonating with 980 MHz (17.6%) at 5.43 GHz, which is almost 5.5 times more than DRA_1. DRA_3 is resonating with 1960 MHz (37.7%), which is nearly 12 times more than DRA_1 and the impedance bandwidth of DRA_4 is 2170 MHz (42.1%), which is almost 13 times more than DRA_1.

The *X*-*Y* plane co-polar and cross-polar radiation patterns of DRA_1, DRA_2, DRA_3 and DRA_4 are measured at their resonating frequencies and are shown in Figs 3-6.The half power beam widths (HPBWs) of the proposed antennas (DRA_1, DRA_2, DRA_3 and DRA_4) are calculated and are found to be 68^0, 78.5^0, 56^0 and 74^0, respectively. It is clear that the measured radiation patterns are almost similar and cross-polar levels in all cases are very low. As DRA_4

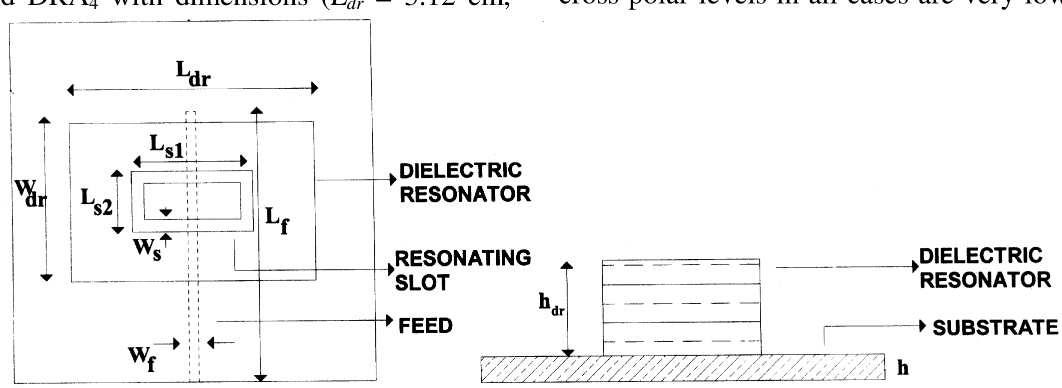

Fig. 1 — Geometry of DRA

gives maximum bandwidth among the proposed antennas, its variation of input impedance is shown in Fig. 7. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its wideband operation.

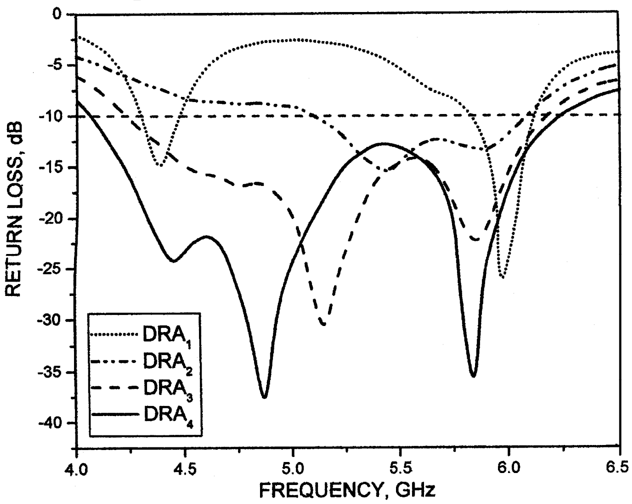

Fig. 2 — Return loss verses frequency of DRA_1, DRA_2, DRA_3 and DRA_4

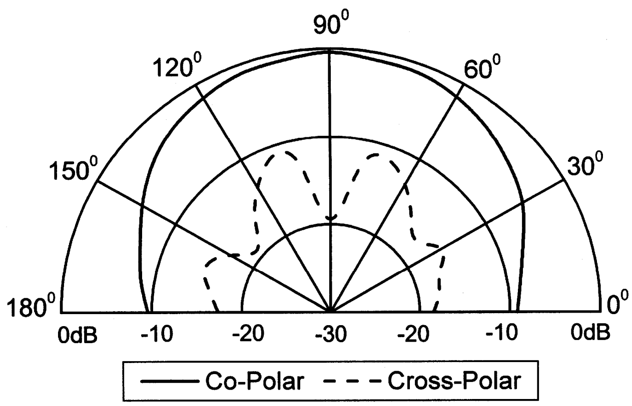

Fig. 3 — Radiation patterns of DRA_1 at 5.96 GHz

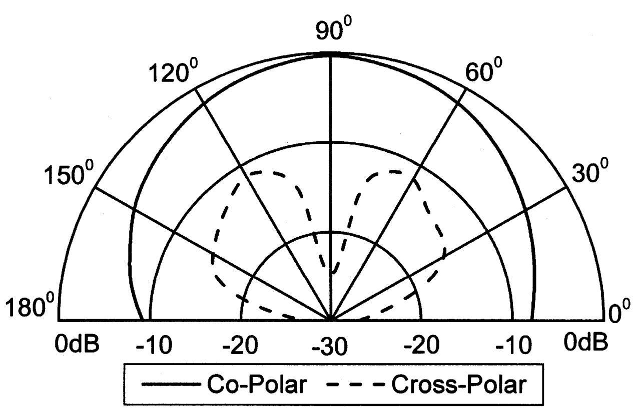

Fig. 4 — Radiation patterns of DRA_2 at 5.43 GHz

4 Conclusions

From the study, it is clear that the proposed antenna is quite simple in design and fabrication and good in enhancing the bandwidth. A large bandwidth is obtained by increasing the thickness of dielectric

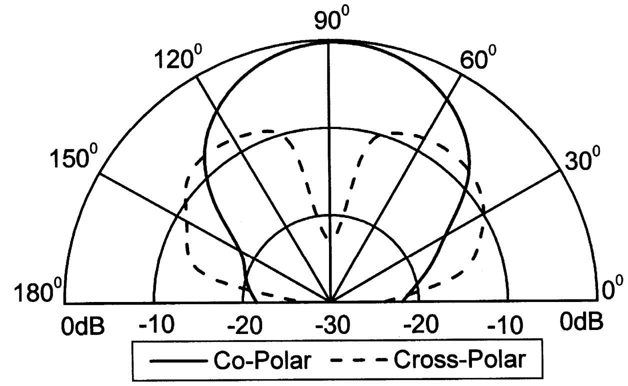

Fig. 5 — Radiation patterns of DRA_3 at 5.15 GHz

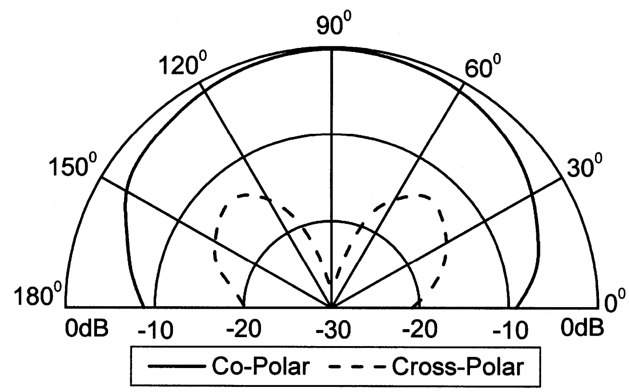

Fig. 6 — Radiation patterns of DRA_4 at 4.87 GHz

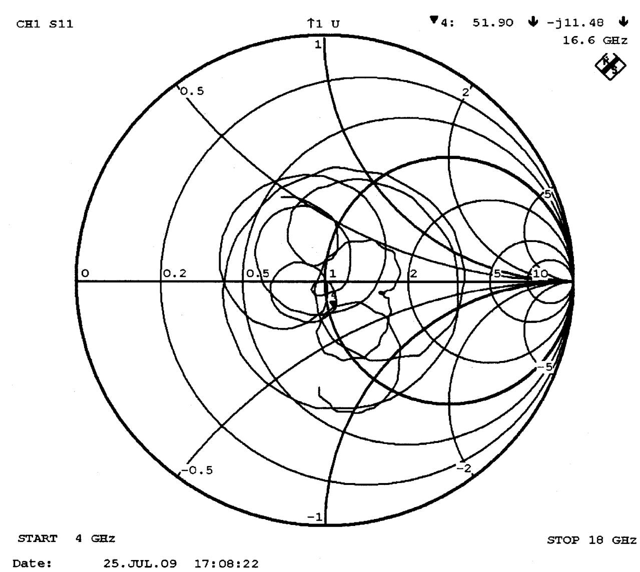

Fig. 7 — Input impedance profile of DRA_4

resonator placed over the rectangular ring-slot. The experimental results show that among the proposed antennas, DRA_4 with dimensions (L_{dr} = 3.12 cm, W_{dr} = 2.44 cm, h_{dr} = 1.2 cm) can offer a bandwidth of 42.1% with return losses less than –10 dB without changing the nature of radiation characteristics across the resonating frequencies. With these features, this antenna is useful for broadband wireless communication.

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