Slot-fed wideband dielectric resonator antenna for wireless applications

P M Hadalgi, R G Madhuri \textsuperscript{5,7} \& S L Mallikarjun

Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga 585 106, Karnataka, India

\textsuperscript{5}E-mail: rg_madhuriv@rediffmail.com

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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\textsuperscript{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\textsuperscript{2}. Dielectric resonator (DR) of any shape can be used for antennas such as cylindrical, hemispherical, rectangular, etc.\textsuperscript{3-5}

The rectangular DRA offers practical advantages over the spherical and cylindrical shapes due to flexibility in choosing aspect ratio\textsuperscript{6}. There are a number of papers and investigations, which have been reported on wideband DRA operation\textsuperscript{7,8}. The bandwidth enhancement techniques to improve the bandwidth of dielectric resonator antennas, such as stacking multiple DRAs\textsuperscript{9}, using parasitic dielectric resonator elements\textsuperscript{10}, thick substrate, utilizing special dielectric resonator geometries\textsuperscript{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\textsuperscript{6}. When $\varepsilon_r$ 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 $\varepsilon_r$ to push up operating frequency without realizing the increase in the cross-polarization level\textsuperscript{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\textsuperscript{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\textsuperscript{14}. This study is carried out by using four thicknesses of DR, $h_{dr}$ (3, 6,
9 and 12 mm), providing enhancement in bandwidth\textsuperscript{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 $\varepsilon_{dr} = 11.9$, 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 $\varepsilon_r = 4.2$ and thickness $h = 0.16$ cm. The slot dimensions are taken in terms of $\lambda_0$, where $\lambda_0$ is free space wavelength in cm (i.e. 6 cm). A 50 $\Omega$ 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 $\Omega$ 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. If the dimensions of the DR are chosen such that $L_{dr}, W_{dr} \gg h_{dr}$, then the simple relation for $h_{dr}$ in terms of resonance frequency $f_o$ is given as\textsuperscript{14}:

$$h_{dr} = \frac{C}{4f_o \sqrt{\varepsilon_r}} = \frac{\lambda_0}{4 \sqrt{\varepsilon_r}}.$$

3 Experimental results

This experimental work was carried out by varying the thickness of dielectric resonator. DRA\textsubscript{1}, with dimensions of DR as ($L_{dr} = 3.12$ cm, $W_{dr} = 2.44$ cm, $h_{dr} = 0.3$ cm) and DRA\textsubscript{2}, with dimensions ($L_{dr} = 3.12$ cm, $W_{dr} = 2.44$ cm, $h_{dr} = 0.6$ cm), DRA\textsubscript{3} with dimensions ($L_{dr} = 3.12$ cm, $W_{dr} = 2.44$ cm, $h_{dr} = 0.9$ cm) and DRA\textsubscript{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\textsuperscript{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\textsubscript{1}, DRA\textsubscript{2}, DRA\textsubscript{3} and DRA\textsubscript{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\textsubscript{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\textsubscript{2} is resonating with 980 MHz (17.6%) at 5.43 GHz, which is almost 5.5 times more than DRA\textsubscript{1}. DRA\textsubscript{3} is resonating with 1960 MHz (37.7%), which is nearly 12 times more than DRA\textsubscript{1} and the impedance bandwidth of DRA\textsubscript{4} is 2170 MHz (42.1%), which is almost 13 times more than DRA\textsubscript{1}.

The X-Y plane co-polar and cross-polar radiation patterns of DRA\textsubscript{1}, DRA\textsubscript{2}, DRA\textsubscript{3} and DRA\textsubscript{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\textsubscript{1}, DRA\textsubscript{2}, DRA\textsubscript{3} and DRA\textsubscript{4}) are calculated and are found to be 68\textdegree, 78.5\textdegree, 56\textdegree and 74\textdegree, respectively. It is clear that the measured radiation patterns are almost similar and cross-polar levels in all cases are very low. As DRA\textsubscript{4}

![Fig. 1 — Geometry of DRA](image-url)
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.

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
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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References