DESIGN, FABRICATION AND ANALYSIS OF WIDEBAND HIGH GAIN DIELECTRIC RESONATOR ANTENNAS

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ABSTRACT

In this paper, a technique is proposed to enhance the impedance bandwidth of microstrip antenna. When a dielectric resonator of thickness 3 mm is placed at the center of the patch, the bandwidth of the antenna increases compared to conventional antenna. The obtained bandwidth is 24.10 times more when compared to conventional rectangular microstrip antenna without changing the broad side radiation characteristics. Further a comparative study is made by increasing the thickness of the dielectric resonator. Thus, in this study, it reveals that the bandwidth of antenna can be increased by increasing the thickness of the dielectric resonator. The measured gain, VSWR, reflection coefficient and HPBW are presented. These antennas are suitable for wide single band application.

Keywords: Dielectric Resonator, Impedance Bandwidth, Microstrip, Reflection Coefficient, VSWR.

1. INTRODUCTION

The wireless communication applications such as Bluetooth, 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. When \( \varepsilon_r \) of DR is above certain value, say \( \varepsilon_r = 9.5 \), the highest cross polar discrimination occurs and very strong cross-polarized fields are produced for \( \varepsilon_r \gg 2 \). 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[12]. In this study, it has been shown that by increasing the thickness of DR, wide bandwidth can be achieved. The DR is centered over a rectangular radiating patch, which represents coupling mechanism between resonator and patch. 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 in an increase in the DRA bandwidth[13-14]. This study is carried out by increasing thicknesses of dielectric resonator in terms of 0.3, 0.6 and 0.9 cms. The reflection coefficient and radiation patterns are measured and obtained results are presented.

2. ANTENNA CONFIGURATIONS

Figure 1 shows the geometry of DRA. An optimized rectangular DR of dimension \( L_{dr} = 2.2 \text{ cm.} \) \((\lambda_0/3.8)\), \( W_{dr} = 2.8 \text{ cm.} \) \((\lambda_0/3)\), \( h_{dr} = 0.3 \text{ cm.} \) \((\lambda_0/283.3)\) with dielectric constant \( \varepsilon_r = 8.2 \) is placed on the rectangular microstrip patch of dimension \( L = 1.38 \text{ cm.} \) and width \( W = 2.24 \text{ cm.} \). Microstrip patch is etched on a low cost glass epoxy substrate material with dielectric constant \( \varepsilon_r = 4.2 \) and thickness \( h= 0.16 \text{ cm.} \) A 50 \( \Omega \) microstrip feed line with \( L_t = 0.61 \text{ cm.} \) and \( W_t = 0.32 \text{ cm.} \) with quarter wave transformer with length \( L_q = 0.72 \text{ cm.} \) and width \( W_q = 0.82 \text{ cm.} \) is taken in terms for impedance matching. At the tip of microstrip feed line, a 50\( \Omega \) coaxial SMA connector is connected for feeding microwave power. 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 \( f_0 \) is given in equation (1):

\[
h_{dr} = \frac{c}{4f_0\sqrt{\varepsilon_r}} = \frac{\lambda_0}{4\sqrt{\varepsilon_r}}
\]

\[\text{........... (1)}\]
3. EXPERIMENTAL RESULTS

The experimental study is carried out by varying the thickness of dielectric resonator as $h_1$, $h_2$ and $h_3$, where $h_1$ is 0.3 cm, $h_2$ is 0.6 cm and $h_3$ is 0.9 cm. DR is placed at the center of the rectangular patch in order to achieve maximum impedance bandwidth.

The impedance bandwidth over reflection coefficient less than $-10$ dB for the proposed antennas is measured. The resonant properties of the proposed antennas are experimentally measured on Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651). Fig. 2 shows the reflection coefficient versus frequency graph of DRA with thickness $h_1$. Fig. 3 shows the reflection coefficient versus frequency graph of DRA with thickness $h_2$ and Fig. 4 shows the reflection coefficient versus frequency graph of DRA with thickness $h_3$. From these figures the impedance bandwidth is calculated by using the equation (2);

$$BW = \frac{f_H - f_L}{f_c} \quad \ldots \ldots \quad (2)$$

where $f_H$ and $f_L$ are higher and lower cut-off frequencies of the band, respectively, and $f_c$ is the center frequency.

From Fig. 2, 3 and 4 it is observed that DRA with $h_1$ offers single wide band (BW$_1$) at 9.92 GHz, with a magnitude of 7800 MHz (70.39%) which is 24.10 times more as compared to conventional microstrip antenna 140 MHz (2.92%). The minimum reflection coefficient is found to be -56.06 dB.

Similarly, from the Fig. 3, it is observed that DRA with $h_2$ is also resonating for single wide band (BW$_2$) at 9.91 GHz, with a magnitude of 10640 MHz (83.91%). When compared to DRA with $h_1$, the impedance bandwidth of DRA with $h_2$ is 1.19 times more and 28.73 times more when compared to conventional microstrip antenna. The minimum reflection coefficient of this antenna is found to be -20.86 dB.

Further, from the Fig. 4, it is seen that DRA with $h_3$ is also resonating for a single wide band (BW$_3$) at 8.2 GHz, with a magnitude of 11340 MHz (91.97%). When compared with earlier resonators the impedance bandwidth is 1.30 times and 1.09 times more respectively. Similarly, 31.49
times more when compared to the conventional microstrip antenna and the minimum reflection coefficient for this antenna is found to be -20.67 dB.

Fig. 3: Reflection coefficient versus frequency graph of DRA with thickness $h_2$

Fig. 4: Reflection coefficient versus frequency graph of DRA with thickness $h_3$

The VSWR of the proposed antennas is also measured using VNA and are found to be 1.011 for DRA with thickness $h_1$, 1.198 for DRA with thickness $h_2$ and 1.204 for DRA with thickness $h_3$.

The X-Y plane co-polar and cross-polar radiation patterns of the proposed antennas are measured at their resonating frequencies and are shown in Figs. 5 to 7. From Figs. 5 to 7, it is clear that the measured radiation patterns are almost similar and cross-polar levels in all cases are very low. From the radiation pattern the half power beam width (HPBW) is calculated and are found to be 90°, 76° and 50° respectively for DRA with $h_1$, $h_2$ and $h_3$. 
To find the gain, the power transmitted ($P_t$) by the pyramidal horn antenna and the power received ($P_s$) by proposed antenna is measured separately. Gain of antenna under test ($G_T$) in dB is calculated using the formula:

$$(G_T) \ dB = (G_S) \ dB + 10 \log \left( \frac{P_t}{P_s} \right)$$

where $G_s$ is the gain of pyramidal horn antenna. From the analysis obtained, gains of the proposed antennas are 9.80 dB, 12.78 dB and 4.68 dB respectively. When compared with the gain of DRA with $h_1$, the gain of DRA $h_2$ has improved. This shows that gain of the antenna can be improved by increasing the thickness from 0.3 cm to 0.6 cm. Whereas the gain of DRA with $h_3$ is decreased and this is due to the side lobes in the radiation pattern.

Further, as DRA with $h_3$ 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 antennas are quite simple in design and fabrication and good in enhancing the impedance bandwidth. A wide bandwidth is obtained by increasing the thickness of dielectric resonator placed at the center of rectangular microstrip patch. The experimental results show that among the proposed antennas, DRA with \( h_3 \) offer a bandwidth of 91.97% with better gain without changing the nature of radiation characteristics at the resonating frequency. The proposed antennas are useful for modern broadband wireless communication systems.

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REFERENCES


