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Enhancement of Bandwidth Using Rectangular Shaped Dielectric Resonator Antenna

Shailashree S.[1], Dinesh B. Ganure[2], S.L. Mallikarjun[3] and P.M. Hadalgi[4]
[1,2]Research Scholar, Department of Applied Electronics, Gulbarga University, Kalaburagi, Karnataka, India
[3]Asst. Professor, Dept. of Physics and Electronics, Maharashtra Udayagiri Mahavidyala, Maharastra, India
[4]Professor, Department of Applied Electronics, Gulbarga University, Kalaburagi, Karnataka, India

Abstract: The paper presents the use of dielectric resonator material on the radiating patch of rectangular microstrip antenna in the frequency range of X- band. The material is made of Calcium carbonate ($CaCO_3$) in rectangular shape of thickness 1.5 mm with dielectric constant of 9.2. When this dielectric resonator is placed on the radiating patch of the rectangular microstrip antenna the antenna is enhanced with the impedance bandwidth with approximately 3.47 times more when compared to conventional microstrip antenna 140 MHz (2.92%). Similarly, the other antenna parameters such as reflection coefficient, VSWR, gain, Radiation pattern and HPBW are presented. Also, the proposed antenna finds the application in X –band applications.

Keywords: calcium carbonate ($CaCO_3$), dielectric resonator, microstrip antenna, wideband.

Introduction

A dielectric resonator antenna (DRA) is a radio antenna mostly used at microwave frequencies and higher, that consists of a block of non-conducting material of various shapes. Usually, the dielectric resonator, mounted on a radiating patch of an antenna or at a ground plane. Radio waves are introduced into the inside of the resonator material from the transmitter circuit and bounce back and forth between the resonator walls, forming standing waves. The walls of the resonator are partially transparent to radio waves, allowing the radio power to radiate into space. An advantage of dielectric resonator antennas is they lack metal parts, which become lossy at high frequencies, dissipating energy. So these antennas can have lower losses and be more efficient than metal antennas at high microwave and millimeter wave frequencies [1]. Dielectric resonators (DR's) have proved themselves to be ideal candidates for antenna applications by virtue of their high radiation efficiency, flexible feed arrangement, simple geometry, small size and the ability to produce different radiation pattern using different modes [2]. In the last decade, the demand of antennas miniaturization and the wide band had increased exponentially for that many antenna engineers have been tried to design compact size antennas with wide bandwidth performance, so the DRA is good for these requirements [3]. Moreover, the DRA's have higher bandwidth than conventional MSA and they do not use metallic radiators [4].

The DRA of any shape can be used for antennas such as cylindrical, hemispherical, rectangular, etc [5-7]. Here, for the present study a rectangular shaped DRA is used with the thickness of 1.5 mm. The advantage of this shape is that it offers a smaller area for a given thickness and resonant frequency. Moreover the size and operating bandwidth of a DRA can be easily varied by suitably choosing the dielectric constant of the resonator material and its dimensions [8].

Antenna Design

The Figure 1 shows the geometry of calcium carbonate ($CaCO_3$) DRA with rectangular shape. Here the DR material is in rectangular shape with dimension L x W = 2.2 x 2.8 cm and thickness h = 1.5 mm is designed and placed on the center of microstrip radiating rectangular patch. The antenna uses microstrip-line feeding technique which is connected to the radiating patch on one side and a ground plane at the other side separated by a glass epoxy dielectric material with $\varepsilon_r = 4.2$ and loss tangent, $\tan \delta = 0.02$. The details of the dimensions rectangular microstrip antenna are depicted in Table 1.

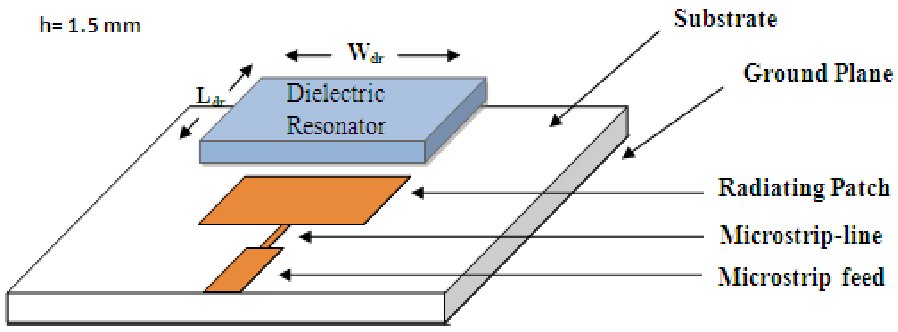

Figure 1. Geometry of rectangular dielectric resonator antenna

Table 1: Rectangular microstrip antenna dimensions

Antenna Parameters	Dimensions
Length of the patch, L	1.38 cm
Width of the patch, W	2.24 cm
Quarter wave length, L_t	0.72 cm
Quarter wave width, W_t	0.82 cm
Microstrip feed length, L_f	0.61cm
Microstrip feed width, W_f	0.32 cm

Experimental results

The impedance bandwidth over reflection coefficient less than -10 dB for the proposed antenna 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). Figure 2 shows the reflection coefficient versus frequency graph of $CaCO_3$ rectangular DRA with thickness h = 1.5 mm. The impedance bandwidth is calculated by using the equation (1).

$$\text{Impedance bandwidth (BW)} = \frac{f_H - f_L}{f_C} \qquad \text{............ (1)}$$

where f_H and f_L are higher and lower cutoff frequencies of the band respectively and f_C is the center frequency.

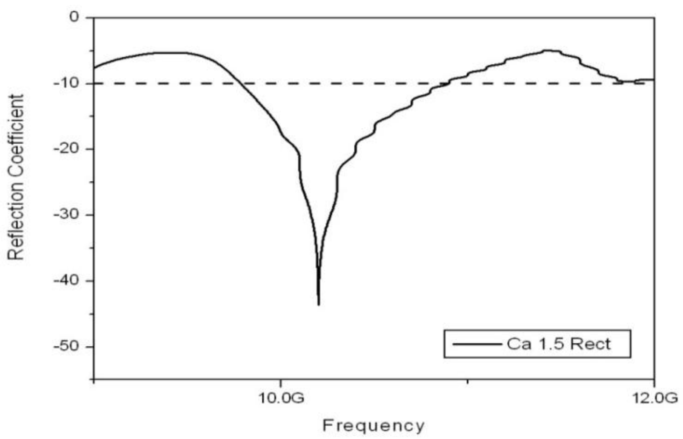

Figure2. Variation of reflection coefficient versus frequency of $CaCO_3$ Rectangular DRA with thickness h= 1.5 mm

From this graph the impedance bandwidth is found to be 1050 MHz (i.e. 10.15 %). This enhancement of impedance bandwidth is due to the use of Dielectric Resonator material on the radiating microstrip antenna element. The similar study was carried out without using the Dielectric material i.e., by using only the microstrip antenna, the bandwidth is found to be 2.85 % when compared with this and the antenna with DR used it shows 3.56 times more bandwidth. This indicates that, the use of Dielectric Resonator material on the radiating microstrip antenna element is quite effective in enhancing its impedance bandwidth. Also the minimum reflection coefficient of the antenna is found to be good that is -49.05 dB.

The VSWR of the proposed antenna is also measured using VNA and is given in Table 2. The X-Y plane co-polar and cross-polar radiation patterns of the proposed antenna are measured at the resonating frequency and are shown in Figure 3. From the figure, it is clear that the measured radiation patterns are nearly similar and cross-polar levels is low. From the radiation pattern the half power beam width (HPBW) and gain is calculated and presented in Table 2.

Table 2: Antenna parameters

Resonating Frequency	Min. Ref. Co-eff in dB	VSWR	HPBW in degrees	Gain in dB	Input Impedance
10.19 GHz	- 49.05	1.017	52	9.43	51.05 + j1.20

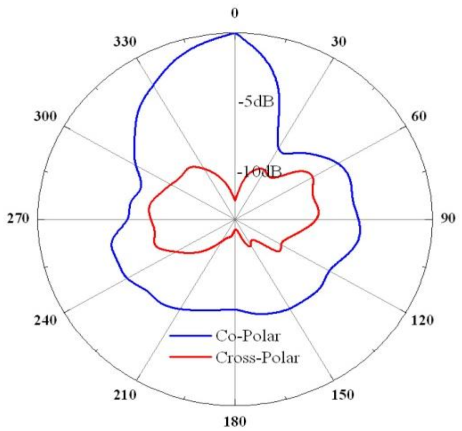

Figure 3. Radiation pattern of proposed antenna at 10.19 GHz

To find the gain, the power transmitted (Pt) by the pyramidal horn antenna and the power received (Ps) by proposed antenna is measured separately. Gain of antenna under test (G_T) in dB is calculated using the formula:

$$(G_T)\ dB = (Gs)\ dB + 10\log\ (Pt\ /Ps) \qquad \text{.........(2)}$$

where Gs is the gain of pyramidal horn antenna. The calculated gain of the proposed antenna is given in Table-2.

Further, the proposed antenna gives maximum bandwidth; its variation of input impedance is shown in Figure 4 and its input impedance is shown in Table 2. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its wideband operation [9].

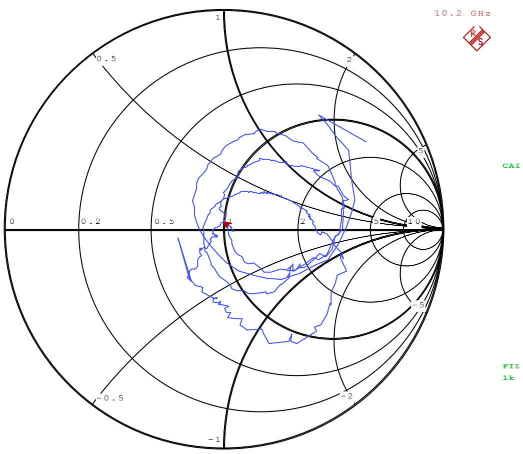

Figure 4. Input impedance profile

Conclusion

The proposed antenna is quite simple in design and fabrication and good in enhancing the impedance bandwidth. A wide bandwidth is obtained by dielectric resonator placed at the center of rectangular microstrip patch. The experimental results show that the proposed antenna i.e., $CaCO_3$ rectangular DRA with thickness h = 1.5 mm is resonating for a single wideband of 10.15% with the gain of 9.43 dB. Also, HPBW, input impedance and the nature of radiation characteristics at the resonating frequency is found to be good. Since, the antenna is resonating for single wideband frequency covering X band range. The frequency operation of the antenna may find application in modern radars and satellite communication systems. This would reduce weight and surface area, thus improving the possibilities of accommodation under the launcher fairing.

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