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Design and Development of Microstrip Patch fed Dielectric Resonator Antennas for 8 -16 GHz Frequency

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ABSTRACT: A hemisphere dielectric resonator antenna (HSDRA) is designed and developed. The measurements are taken for the frequency range of 8-16 GHz. The proposed antennas are fed by using microstrip patch fabricated using glass epoxy substrate material of permittivity Єr = 4.4 (FR4 material) with thickness h = 1.66 mm. The experimental results shows the HDRA with radius 0.8 cm resonates for triple band of frequencies with the impedance bandwidth of 900 MHz(9.81%), 1350 MHz (12.47%) and 2820 MHz (20.82%) respectively and the HDRA with radius 1.6 cm operates for single wide band with impedance bandwidth of 6530 MHz (55.36%) also the minimum reflection coefficient is found to be -42.74 dB. Further the antenna parameters such as gain, VSWR, HPBW and radiation pattern are also presented. The proposed antenna finds application in Radar communication and in modern communication systems.

KEYWORDS: Hemisphere dielectric resonator antenna, bandwidth, minimum reflection coefficient, gain.

I.INTRODUCTION

Antenna is one such device, which acts as both sensor and transducer that converts free space waves into electrical signal and vice versa. In the event there is a power failure the sensors will shut down a certain distribution system and restore power along an alternative route. To establish a direct line of sight high gain data communication link between a sensor and the central station the device should have adequate gain and bandwidth to handle data at desired frequency range. On the other hand, modern communication system, such as those for satellite links often require antennas with wide band and high gain [1]. For this, a new motivation is given for research on innovative solutions that overcome the bandwidth limitations of antennas.

Dielectric resonator (DR) is a ceramic puck characterised by a definite volume, shape, high dielectric constant and low loss. Radiation from open DRs was realized by *Richtmyer* in 1939 [2]. But the first theoretical and experimental analysis of a cylindrical DR antenna was carried out by *Long et.al.* in 1983 [3]. Since then, DRAs transformed into a fast growing focus among the antenna researchers so that new DR geometries like rectangle, hemispherical, triangular, ring etc. were evolved and studied extensively [4-8]

A hemisphere dielectric resonator antenna (HSDRA) is designed; the measurements are taken for the frequency range of 8-16 GHz show that the HSDRA offers multi-frequencies. The HSDRA is further developed, which results into improvement in antenna parameters such as single wide bandwidth, reflection coefficient, gain and radiation pattern. The proposed antenna finds application in Radar communication and in modern communication systems.

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II.ANTENNA DESIGN

Fig. 1 shows the geometry of Hemisphere DRA.

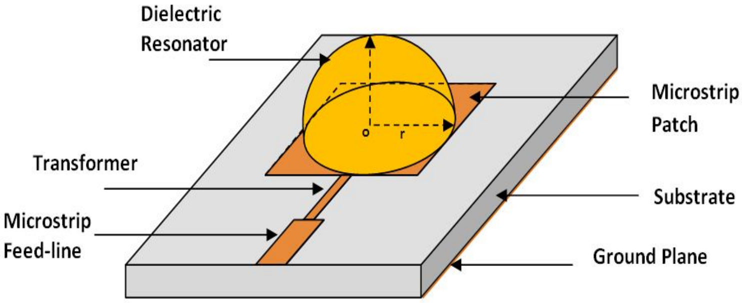

Fig. 1 Geometry of DRA

The Rectangular Microstrip patch is designed using the equations provided in literature which is shown below;

$$L = \left[\frac{C}{2f_r(\varepsilon_e)^{\frac{1}{2}}}\right] - 2\Delta l \qquad (1)$$

where,

$$\Delta l = 0.412\, h \left[\frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \qquad (2)$$

$$\varepsilon_e = \left[\frac{(\varepsilon_r + 1)}{2}\right] + \left[\frac{(\varepsilon_r \; +1)}{2}\right]\left[\frac{1 + 12h}{W}\right]^{\frac{1}{2}} \qquad (3)$$

and

$$W = \left[\frac{C}{2f_r}\right]\left[\frac{(\varepsilon_r \; +1)}{2}\right]^{\frac{1}{2}} \qquad (4)$$

The Microstrip patch is etched on a low cost glass epoxy substrate material with dielectric constant ε_r = 4.2 and its dimensions are tabulated in Table 1. An optimized Hemisphere Dielectric Resonator is designed and its dimensions are given in Table 2 with dielectric constant ε_r = 8.2 is placed on the rectangular microstrip patch. The designed hemisphere is calculated using the following equations.

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Volume of a hemisphere

$$V = \left(\frac{2}{3}\right)\pi r^3 \quad (5)$$

Circumference of the base of a hemisphere

$$C = 2\pi r \quad (6)$$

Curved surface area and base surface area of hemisphere

$$A = 2\pi r^2 \ \& \ B = \pi r^2 \quad (7)$$

The total surface area of a hemisphere is given by

$$K = (2\pi r^2) + (\pi r^2) \quad (8)$$

Table 1: Dimensions of the rectangular microstrip antenna

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

Table 2: Dimensions of hemisphere dielectric resonator

Parameters of hemisphere material	Dimensions with radius r = 0.8 cm	Dimensions with radius r = 1.6 cm
Volume, V	1.07 cm^3	8.57 cm^3
Circumference, C	5.02 cm	10.05 cm
Curved surface area, A	4.02 cm^2	16.08 cm^2
Base surface area, B	2.01 cm^2	8.04 cm^2
Total surface area, K=A+B	6.03 cm^2	24.12 cm^2

III.RESULTS AND DISCUSSION

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 Analyser (Rohde and Schwarz, Germany make ZVK model 1127.8651) which is as shown

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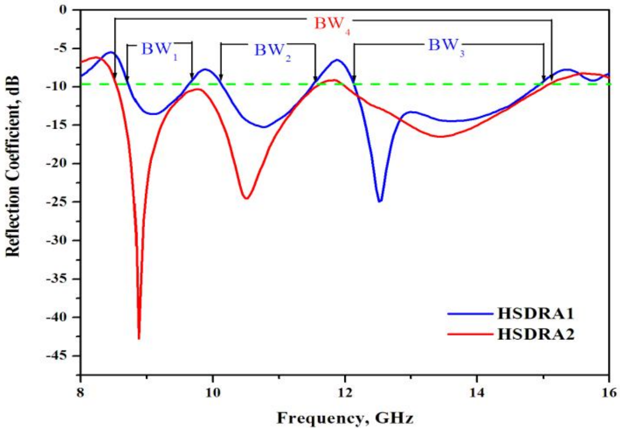

Fig. 2 Reflection coefficient versus frequency graph of HSDRA1 and HSDRA2

From *Fig.* 2, it is observed that HSDRA1 with radius r = 0.8 cm offers triple bands such as BW_1 resonates at 9.10 GHz, BW_2 at 10.78 GHz and BW_3 at 12.51 GHz with a magnitude of 900 MHz (9.81%), 1350 MHz (12.47%) and 2820 MHz (20.82%) respectively. The overall bandwidth is 14.60 times more when compared to conventional microstrip antenna 140 MHz (2.92%). Also the minimum reflection coefficient is found to be -13.55 dB, -15.23 dB and -24.93 dB respectively.

Similarly, from the graph the HSDRA2 with the radius r = 1.6 cm resonates for single wide band at 8.87 GHz with the magnitude bandwidth, BW_4 of 6530 MHz (55.36%). When compared to the conventional antenna it gives 18.95 times more bandwidth. And the minimum reflection coefficient is found to be -42.74 dB.

Further, the far-field H - plane co-polar and cross-polar radiation patterns of the proposed antennas are measured at their resonating frequencies. In this study the turn-table method is used to measure the radiation pattern of all the proposed antennas (AUT). *Fig.3* and *Fig. 4* show the radiation pattern of antenna HSDRA1 and HSDRA2.

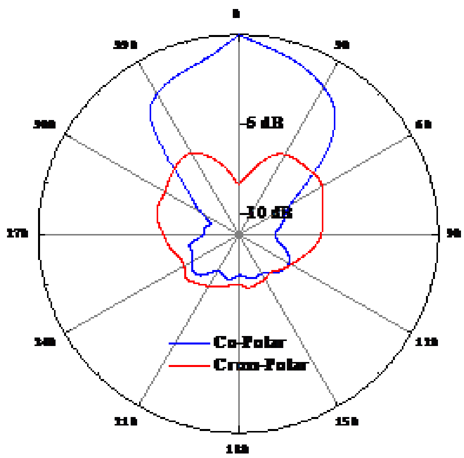

Fig. 3 Radiation Pattern of HDDRA1 at 12.51 GHz

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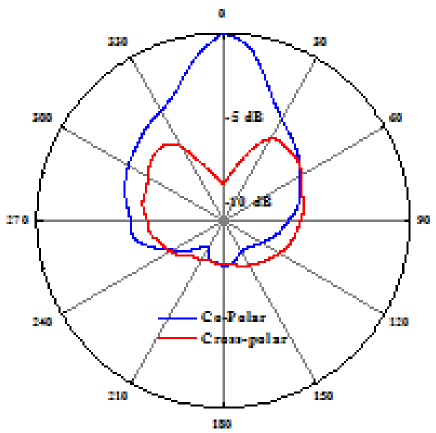

Fig. 4 Radiation Pattern of HDDRA2 at 8.87 GHz

The Half Power Beam Width at 3 dB is found and is tabulated in Table 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: [9]

$$(G_T)\ dB = (Gs)\ dB + 10\log\ (P_t / P_s)$$

where Gs is the gain of pyramidal horn antenna. The obtained gain is mentioned in Table 3. Similarly, The VSWR of the proposed antennas is also measured using VNA and is given in Table 3 and the diagram of HSDRA2 is shown in the *Fig.* 5.

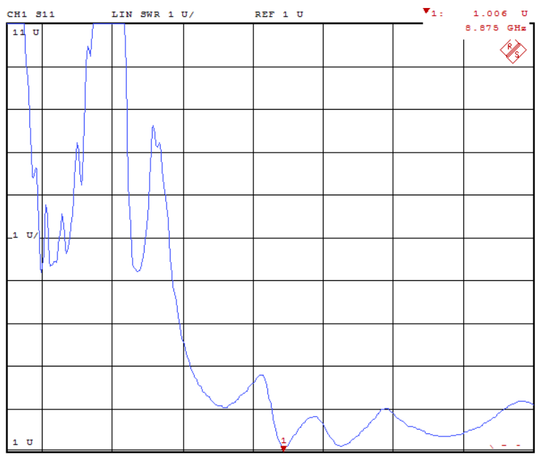

Fig. 5 VSWR of $HSDRA_2$

Table 3: Calculated Gain, HPBW and VSWR

Antenna	Gain	HPBW	VSWR
HSDRA1	09.42 dB	74^{0}	1.410
HSDRA2	12.57 dB	32^{0}	1.006

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Further, as HSDRA2 gives maximum bandwidth among the proposed antennas, its variation of input impedance is 50.19-j38.93 and is shown in *Fig. 6*. It is seen that the input impedance has multiple loops at the centre of Smith chart that validates its wideband operation [10].

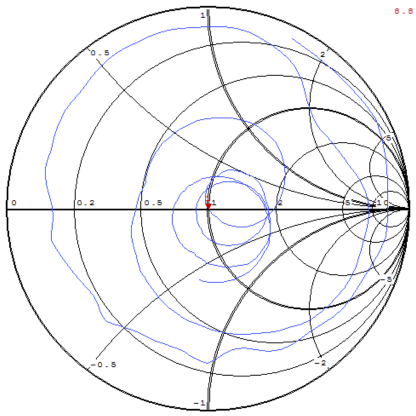

Fig. 6 Smith chart of HSDRA2

IV.CONCLUSION

From the detailed 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 radius of hemi-sphere dielectric resonator placed at the centre of rectangular microstrip patch. The experimental results show that HSDRA with r =1.5 cm offer a maximum bandwidth of 55.36% without changing the radiation characteristics at the resonating frequency and shows improvement in gain which is found to be 12.57 dB. The proposed antennas are useful for modern broadband wireless communication systems and radar applications in the range of 8-16 GHz.

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