DESIGN AND ANALYSIS OF DEFECTED GROUND STRUCTURE BASED CIRCULAR PATCH ULTRA WIDE BAND ANTENNA FOR HIGH FREQUENCY APPLICATIONS

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ABSTRACT

In this paper, the development of a compact circular microstrip patch based Ultra-Wideband (UWB) antenna with the inclusion of a regular Defected Ground Structure has been presented. Firstly, a primary UWB circular patch antenna with resonant frequency of 7.5 GHz is designed with FR4 substrate. DGS has been incorporated to this antenna in multiple levels by varying the shape of DGS. It is observed that the primary antenna with final modified ground plane shows a better performance with reference to operating frequency range. The proposed antenna is designed to operate from 3.1 to 20 GHz frequencies. The proposed circular patch antenna shows enhanced bandwidth, when compared to the basic circular patch antenna with rectangular DGS. The antenna uses low cost laminate of FR4 with thickness of 1.6 mm and dielectric constant of 4.4. The simulations are carried out using 3D EM Simulator. The details of proposed circular patch antenna with partial ground plane design and measured results are presented and discussed. The simulated results are in good agreement with the fabricated UWB antenna.

Keywords: ultra wideband antenna, circular patch antenna, defected ground structure.

1. INTRODUCTION

Radio communication systems are progressing at a rapid rate of late. The future developments of the wireless devices will mainly focus on the transfer of data, speech, and images from anywhere in the entire globe. Ultra-Wideband (UWB) technology has merits such as low cost, less complex, and supports very high data rates. Due to these advantages this technology is largely used in communication systems. Federal Communication Commission (FCC) enabled 3.1 to 10.6 GHz frequency band with an effective isotropic radiated power level less than 241.3 dBm/MHz for UWB implementations in the year 2002 [1-4]. UWB denotes the occupied fractional bandwidth as >20% of or greater than 500 MHz of the bandwidth. Devashree S. Marotkar *et al.* [5] presented a rectangular microstrip patch antenna with U shape DGS to get high bandwidth and this study is done for a 2.4 GHz microstrip patch antenna which is not suitable for ultra wideband frequencies. In this paper, this drawback has been addressed which can be overcome by the proposed antenna and it has been implemented for UWB frequency range. Another aspect is that circular patch has been considered in this paper. Lei Tao *et al.* [6] proposed a microstrip patch antenna with complementary rhombus resonator for widening the bandwidth to 200% but a more simple DGS arrangement has been implemented in this paper which has many advantages. Many UWB planar broadband antennas have been implemented with reduced size and enhanced bandwidth [7-12]. These existing methods are a little complicated and implemented for specific band applications. A novel compact UWB planar monopole antenna by progressively making various changes in Defected Ground Structure (DGS) is studied in this paper. The antenna is a simple circular patch with DGS structure. For better impedance matching, several modifications of DGS are performed for enhancing the bandwidth. The proposed prototype antenna has been manufactured and put to various tests. The performance details such as VSWR return loss and radiation pattern of both the predicted and measured antenna are given and discussed. Section II gives the antenna design details. Section III discusses their simulations and measured results and paper ends with the conclusion given in section IV.

2. ANTENNA DESIGN

The mathematical equation for designing the circular patch antenna using resonant frequency [4] is

$$f_r = \frac{1.84118c}{2\pi r\sqrt{\varepsilon_r}} \quad ---(1)$$

Here, f_r represents the resonant frequency, c is velocity of light, r is the radius of patch and ε_r refers to the dielectric constant. Based on the given equation, the resonant frequency is selected as 7.5 GHz. The circular patch antenna configuration is given in Figure-1 and calculated parameters are tabulated in Table-1. Figure-1 shows the basic circular patch antenna with partial ground plane. The overall size of antenna is 30mm x 35mm x 1.6 mm, which is printed on a low cost laminate of FR4 with dielectric constant of 4.4. The radiating element of circular patch is 9 mm in radius. A 50 ohm microstrip line is used for feeder of the circular patch antenna with width of 2.6 mm. The partial ground plane is used for bandwidth improvement of circular patch antenna and their dimensions are 9mm x 35 mm. By modifying the partial ground plane for improving bandwidth and impedance matching, three slots are etched on the ground plane underneath of the feed is presented in Figure-4. The

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proposed antenna is shown in Figure-7 with corner etched ground plane for enhancing bandwidth as well as better impedance matching.

3. RESULTS AND DISCUSSIONS

The proposed antenna is connected with a 50Ω SMA connector for excitation and the feeding point is selected as the reference plane. The microstrip feedline dimensions can be expressed as a transmission line with characteristic impedance of Z_O. According to the transmission line theory, the input impedance of the given reference plane is

$$Z_{input} = Z_0 \frac{1+\Gamma}{1-\Gamma} \qquad ---(2)$$

Where, Z_0 is the characteristic impedance and Γ is the reflection coefficient. In an ideal case, Z_{input} will be zero if the radiating patch and the feed line impedances are matching.

In first step, a circular patch antenna using a partial ground plane is developed and simulated using CST Microwave Studio. Figure-2 shows the simulated return loss and VSWR. In Figure-2 (a) at 9 GHz frequency the return loss graph touches the - 10dB points. The corresponding radiation patterns at various resonating frequencies are shown in Figure-3. The range of operating frequency is from 3.37 GHz to 14.04 GHz and is not covering the overall UWB region.

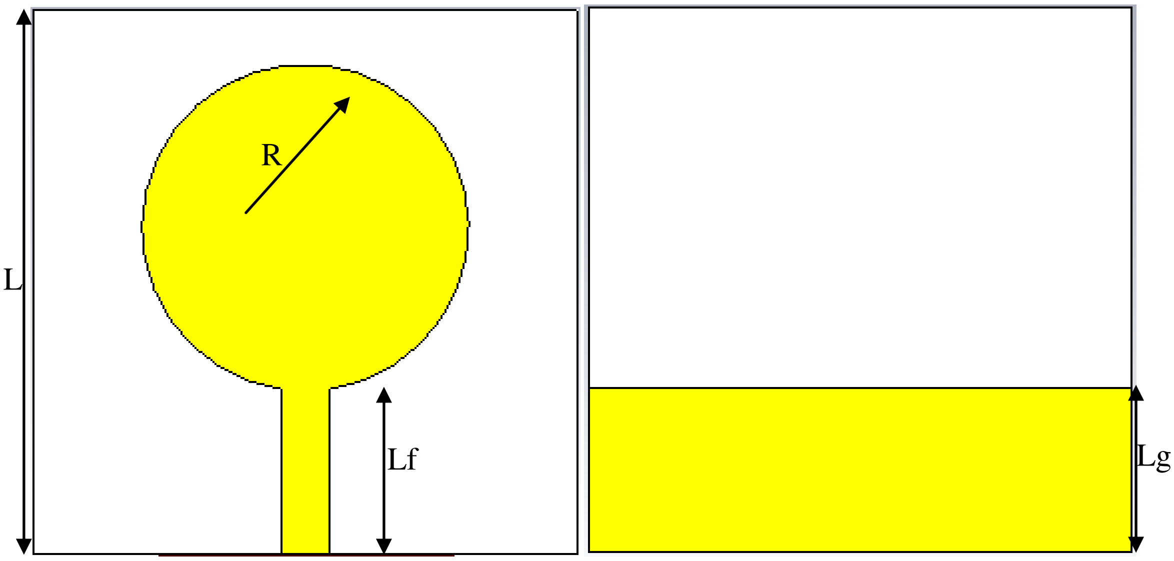

Figure-1. Basic circular patch antenna with DGS.

Table-1. Antenna Parameters.

S. No	Parameter	Value in mm
1	L (Length of the Substrate)	30
2	W (Width of the substrate)	35
3	Lf (Length of the feed)	10.2
4	Wf (Width of the feed)	2.6
5	Lg (Length of the ground)	10.6
6	R (Radius of the patch)	9
7	L1 (Length of the slot 1)	2.6
8	W1 (Width of the slot 1)	0.8
9	L2 (Length of the slot 2)	2.2
10	W2 (Width of the slot 2)	1.2
11	L3(Length of the slant edge)	5

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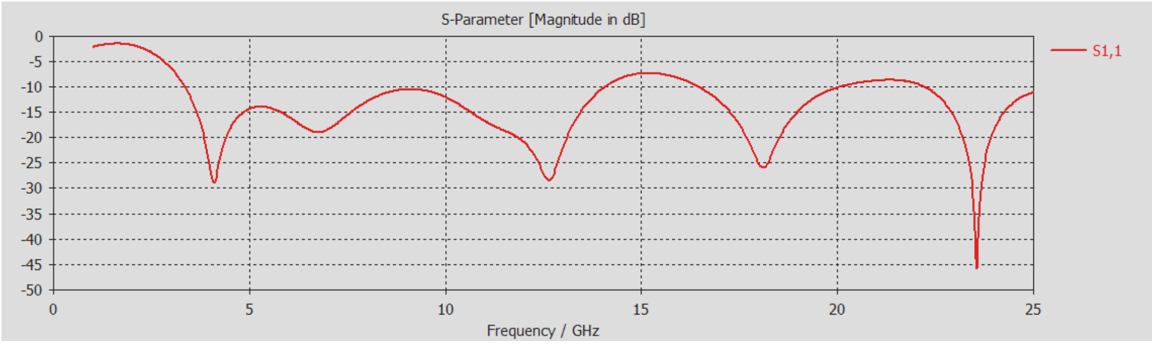
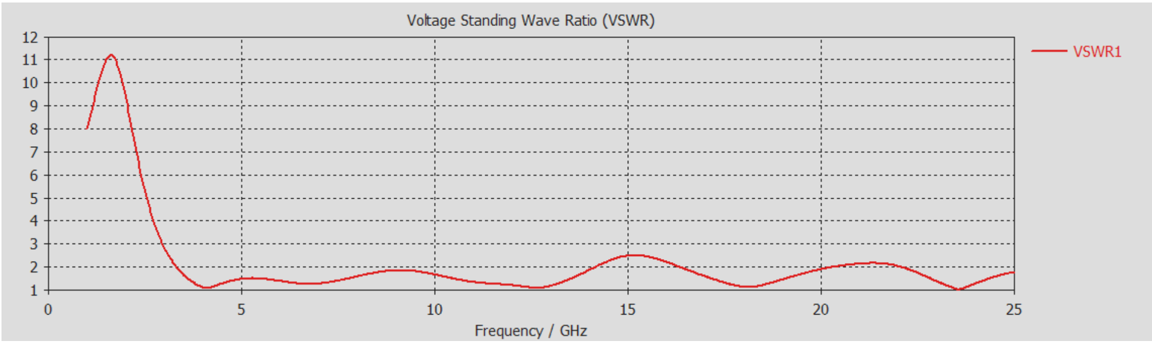
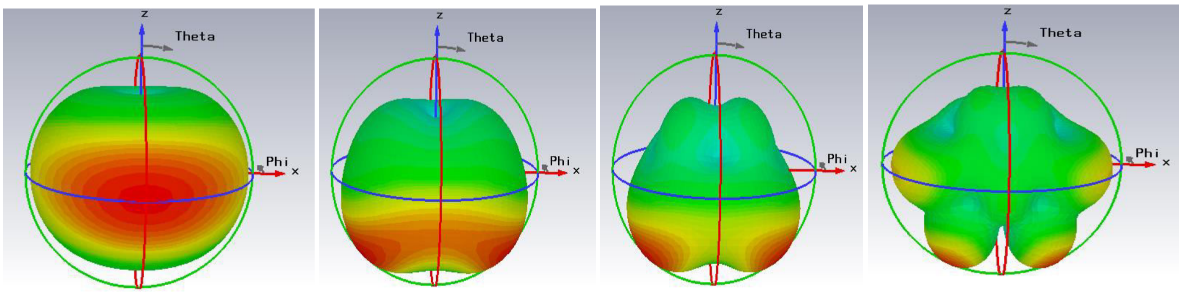


(a)

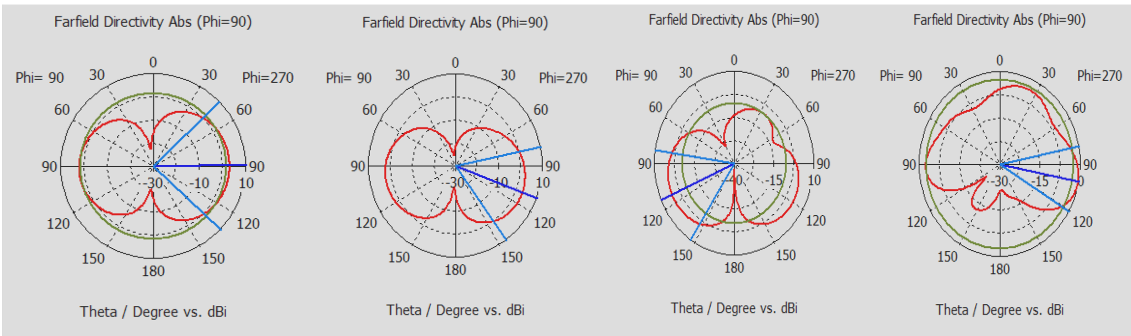


(b)

Figure-2. Simulated Results (a) Return Loss (b) VSWR.



(a) (b) (c) (d)



(e) (f) (g) (h)

Figure-3. (a)-(d) 3D Radiation patterns (e)-(h) 2D Radiation patterns at 4.1 GHz, 6.7 GHz, 7.5 GHz and 12.6 GHz frequency.

The Figure-4 is the modified partial ground plane underneath the feed for better impedance matching and bandwidth enhancement. The simulated return loss and VSWR of the antenna are displayed in Figure-5. The return loss and VSWR indicates that the antenna gives good performance in the frequency range of 3.37 GHz to 16.94 GHz but is not fulfilling the UWB applications. The 2D and 3D radiation patterns at various resonating frequencies are shown in Figure-6

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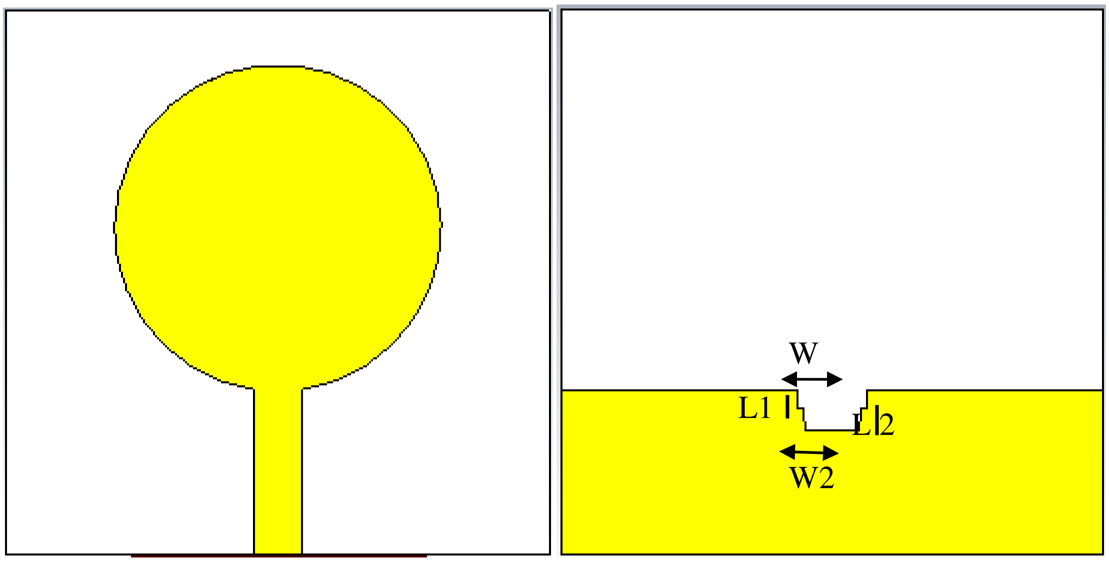
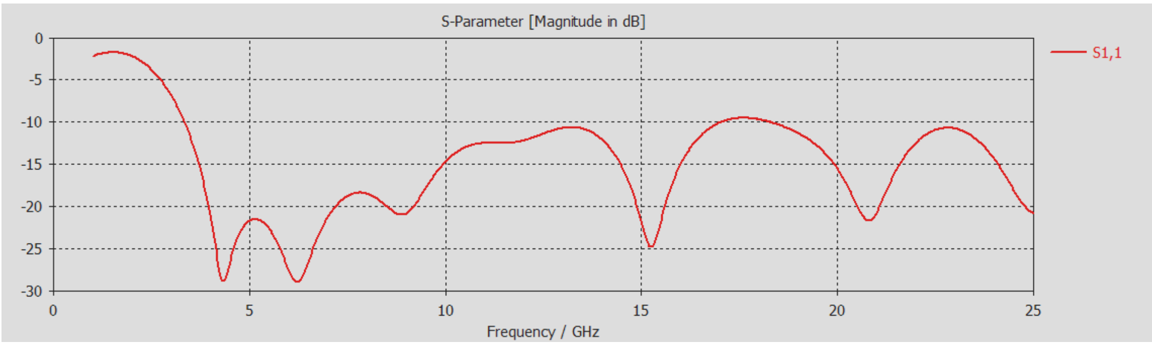
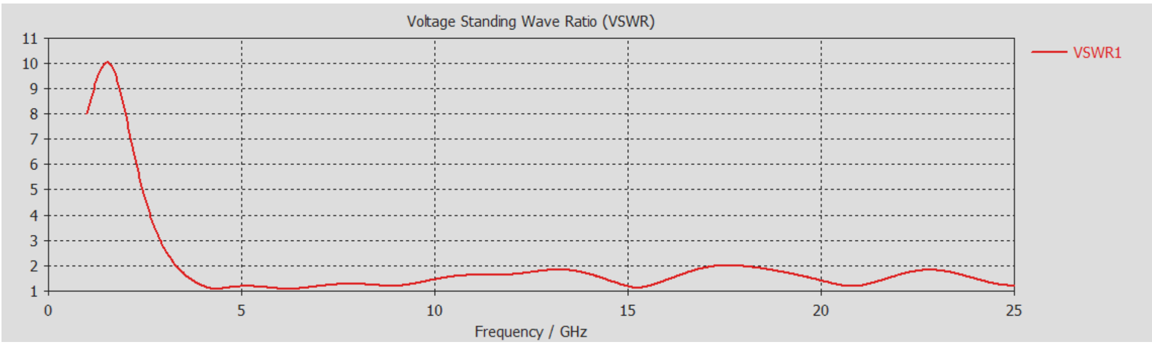


Figure-4. Circular patch antenna with modified DGS.



(a)



(b)

Figure-5. Simulated Results (a) Return Loss (b) VSWR.

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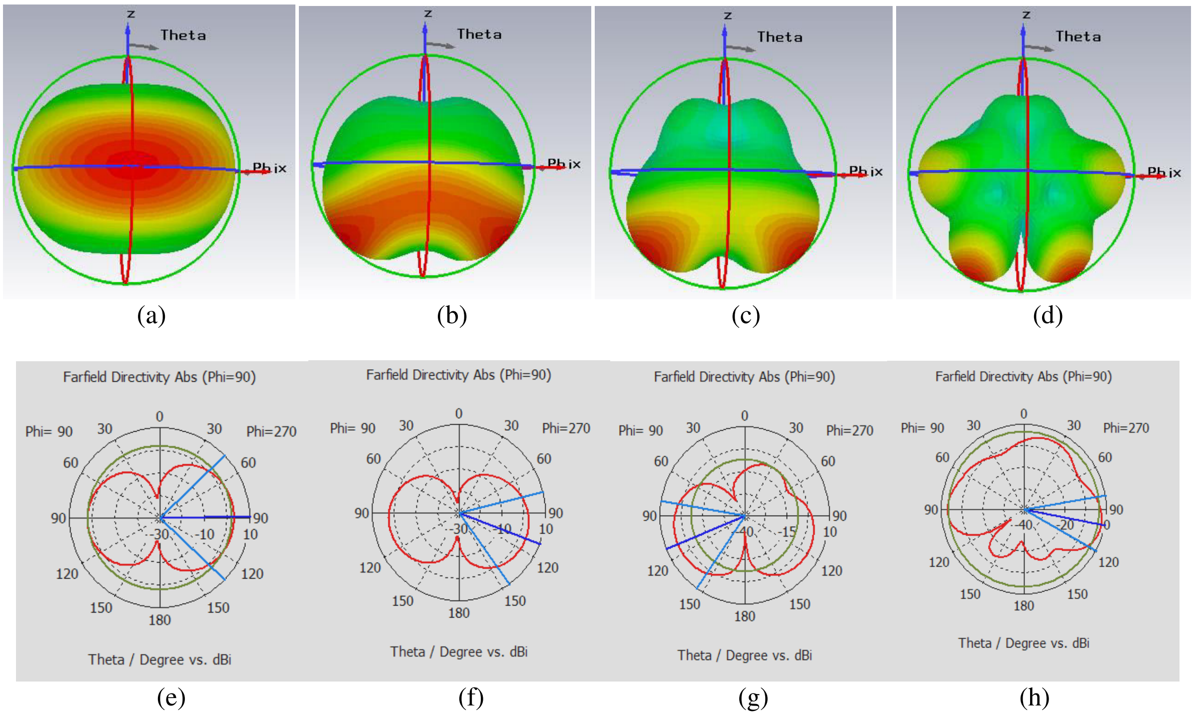

Figure-6. (a)-(d) 3D Radiation patterns (e)-(h) 2D Radiation patterns at 4.1 GHz, 6.7 GHz, 7.5 GHz and 12.6 GHz frequency.

Figure-7 shows the proposed circular patch antenna with slanted edge ground plane. The simulated results of proposed antenna show that it operates in the frequency range of 3.1 GHz to 20 GHz with good performance in terms of return loss, VSWR and radiation patterns which are presented in Figures 8 and 9. After simulating the antenna, the fabricated antenna is subjected to the concept of validation. Figure-10 presents measured radiation pattern for the proposed antenna. The proposed fabricated antenna is shown in Figure-11. The comparison of measured and simulated results for return loss and VSWR are shown in Figure-12.

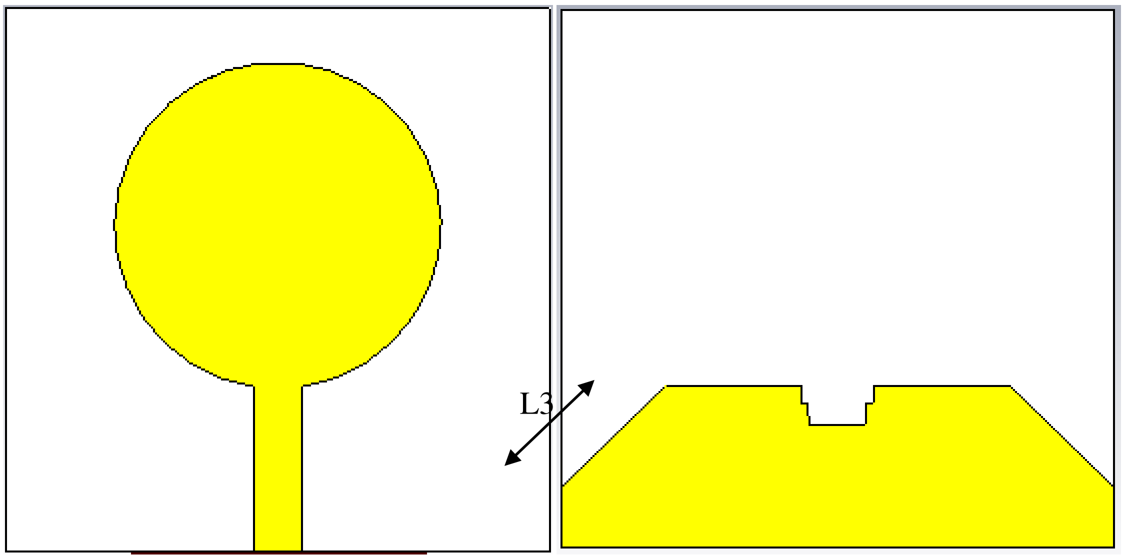

Figure-7. Proposed antenna.

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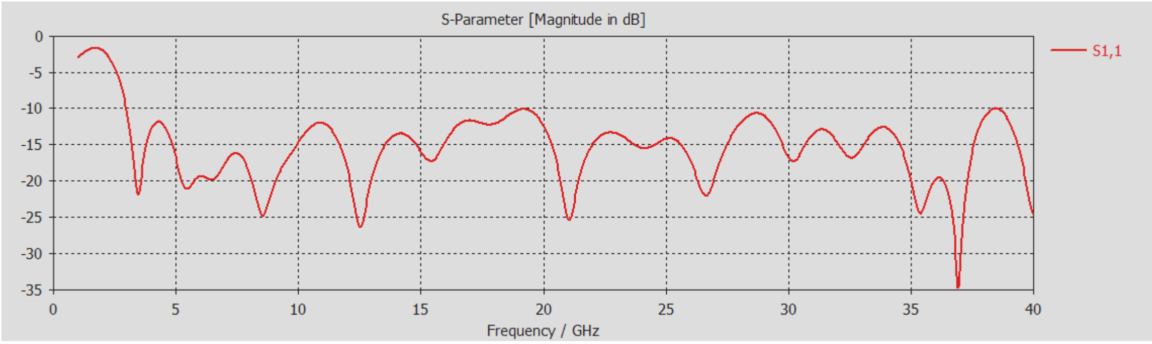
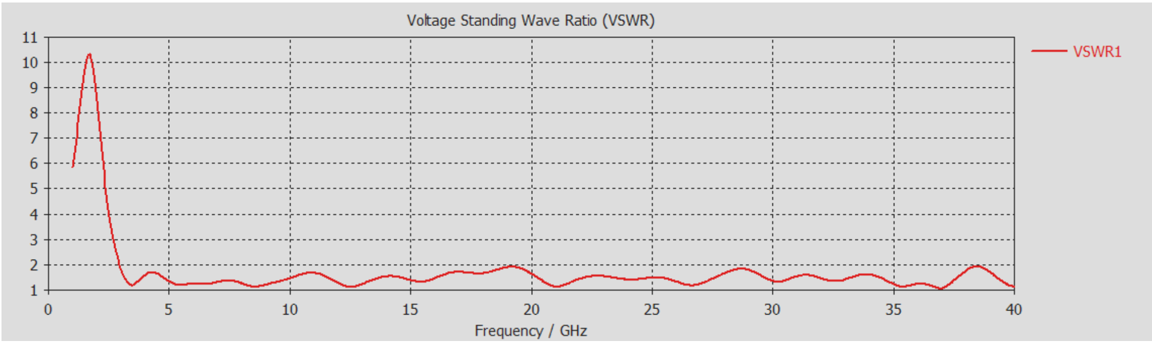
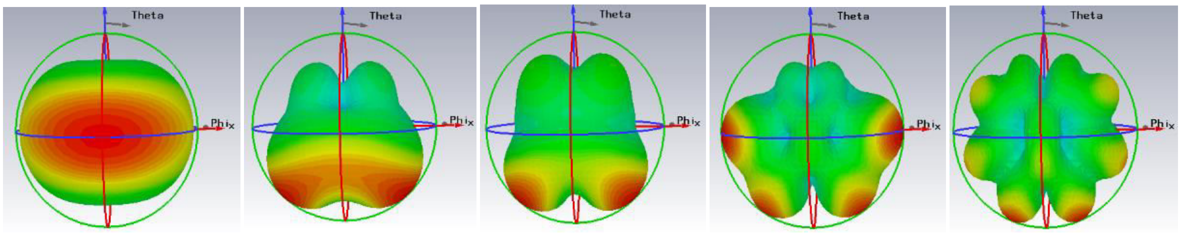


(a)

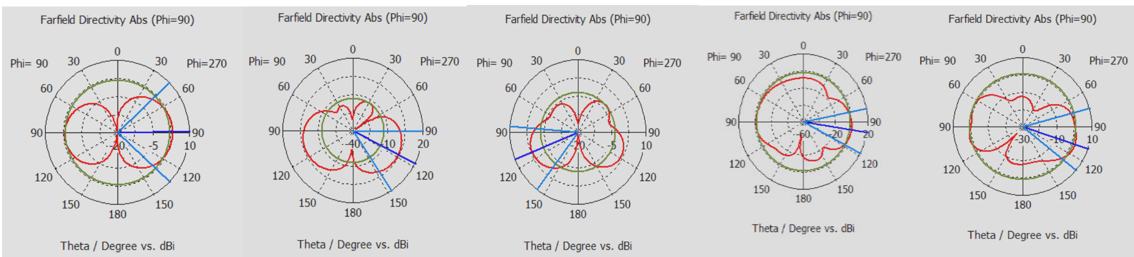


(b)

Figure-8. Simulation results (a) Return Loss (b) VSWR.



(a) (b) (c) (d) (e)



(f) (g) (h) (i) (j)

Figure-9. (a)-(e) 3D radiation patterns (f)-(j)2D radiation patterns of proposed antenna at4.1 GHz, 7.5 GHz, 8.5 GHz, 12.5 GHz and 15.4 GHz respectively.

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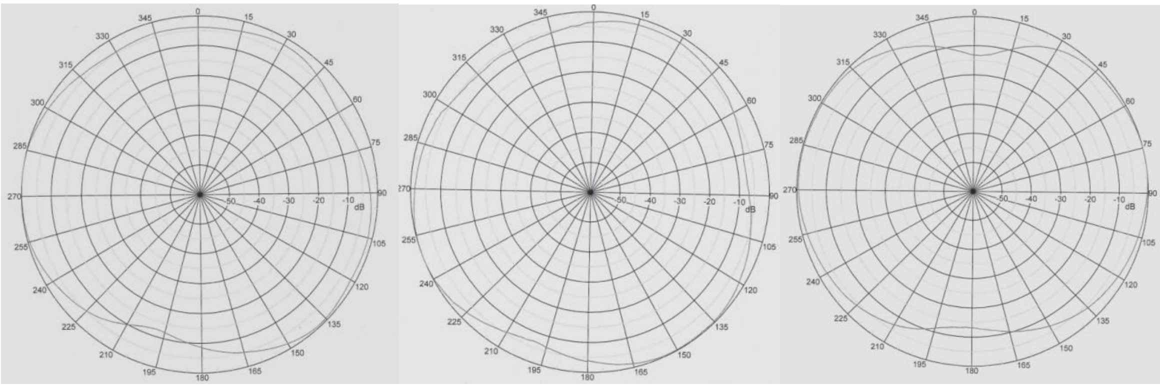
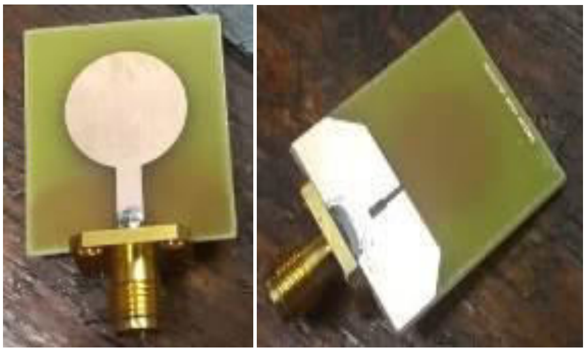


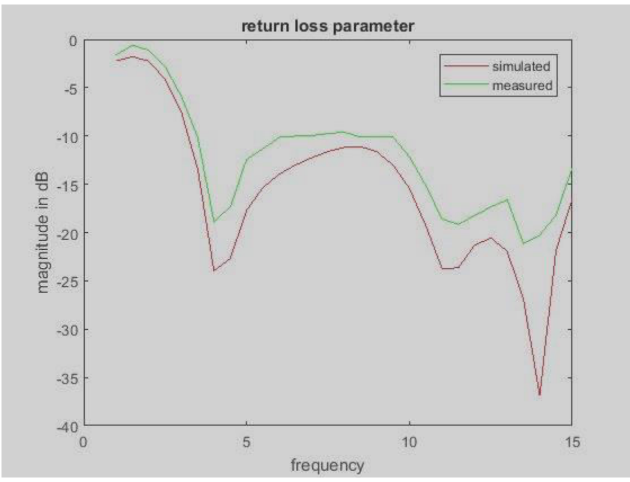
(a) (b) (c)

Figure-10. (a)-(c) Measured radiation patterns of proposed antenna at 5.0 GHz, 8.0 GHz, 12.0 GHz respectively.

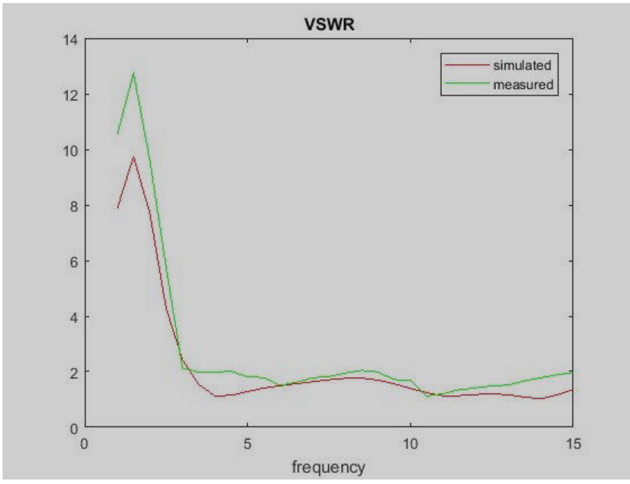


(a) (b)

Figure-11. Fabricated Prototype of proposed antenna (a) Front view (b) back view.



(a)



(b)

Figure-12. Comparison of parameters (a) Return loss (b) VSWR

4. CONCLUSIONS

In this paper, a compact circular patch with slanted edge rectangular DGS antenna is designed and manufactured. The simulated results show better performance for the proposed antenna when compared to the basic rectangular ground plane antennas. The proposed antenna is operating from 3.1 to 20 GHz with good performance in terms of return loss, VSWR and radiation pattern in both simulation and validation.

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