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Design and Performance Analysis of Wideband Hexagonal Ring Antenna with Defected Ground Structure

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Abstract: ***In this paper, a wideband hexagonal ring antenna with defected ground structure (DGS) which is suitable for wide band applications is designed. The proposed structure has overall dimensions of 50mm×42mm×1.6mm made on the readily available FR4 substrate having permittivity ε_r 4.4. Later a DGS is introduced on the ground. This antenna operates in wide band starting from 2.4 GHz to 9.8GHz below - 10db. The proposed design supports wireless communication applications such as Bluetooth (2.4GHz), WiMAX (3.5/5.5GHz), WLAN(5.2/5.8 GHz) and C-band applications. Parametric analysis of the design is carried out by the varying radius of circular slot and also by varying the gap between ground and patch there by creating a provision to improve bandwidth. The performance of the proposed design is analyzed with return loss, VSWR, radiation pattern, gain characteristics, current and field distributions. This design is also compared with existing designs and it was found that proposed design shows good result than existing one. The design antenna gives excellent agreement between measured and fabricated results.***

Keywords: Circular ring, Defected Ground Structure, MicroStrip, Wideband.

I. INTRODUCTION

Microstrip patch antenna has great demand over conventional antennas because of its advantages such as low size, low weight, low profile and low fabrication cost [1][2].These antennas are mostly used in the field wireless communications such as RADAR and satellite communications [3][4]. These microstrip patch antennas are available with different shapes like square, circular, ring, elliptical, pentagonal, hexagonal[5-8]. In this paper a hexagonal circular ring patch antenna is designed [9-11]. UWG antennas are widely used in wireless communication systems because of their tremendous advantages like high data rate, low power consumption and low cost.

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A multi narrow band antenna can be replaced by a single UWG antenna which effectively reduces the antenna number. UWG technology can be useful for all the mobile and wireless transceiver manufacturers to upadate their products[12].

In this paper, a wideband hexagonal ring antenna with DGS is designed. Operating range of this antenna is 2.4 to 9.8GHz. It supports various wireless communication applications like Bluetooth(2.4GHz),Wi-Fi(5GHz) and WLAN(5.2/5.8GHz), Wi-Max(5.5GHz)[13]-[15].

By introducing a defected ground structure to the design the narrow bandwidth of microstrip patch antenna can be resolved. Higher data rate and greater bandwidth can be obtained by using defected ground structure[16]-[18]. In this design a rectangular slot is introduced in the ground to make defect on it and a circular slot is made on hexagonal patch to enhance bandwidth.

The presented works are structured as follows

Section 1 deals with introduction. Section 2 elaborates the designing of antenna. Section 3 have parametric analysis. Section4 have obtained results and discussions. Finally conclusions is done in section 5.

II. PROPOSED DESIGN

A hexagonal ring antenna is designed by the arrangement of partial slotted ground structure and hexagonal ring is shown in figure1(a). The hexagonal patch is created by inserting polygon into a circle of radius R1=10mm after that by making a defect on hexagonal patch in the shape of circle with radius R2=3mm as shown in figure1(b). It is fabricated on FR-4 substrate with dielectric constant of ε_r=4.4. The dimensions of the antenna are L=50mm and W=42mm respectively. On the back side of the substrate a partial ground plane is kept having length and width are L_g=20.8mm and W_g=42mm respectively.

The width of the microstrip line is fixed on W_f=2mm to achieve proper impedance matching.

The length of the feed line is L = 20.8mm. Further to achieve better impedance bandwidth the inner radius R2 is inserted in hexagonal pattern. The simulation is done by HFSS(High Frequency Structural Simulator). The inner and outer radius of the proposed antenna is calculated based on the equations [16].

$$R_1 = \frac{58X10^9}{f_r\sqrt{\varepsilon_{reff}}}$$

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$$R_2 = 0.30R_1$$

Where, R_1 and R_2 are outer and inner radius, respectively, f_r is the resonant frequency of antenna

$$\varepsilon_{reff} = \sqrt{\frac{\varepsilon_r + 1}{2}}$$

and effective dielectric constant of substrate. The lower resonant frequency of the proposed design was found to be 2.4GHz. The design parameters of hexagonal patch antenna are given in table 1.

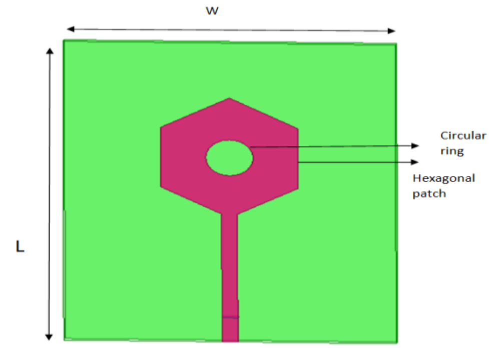

Fig . 1(a) Hexagonal ring Patch antenna.

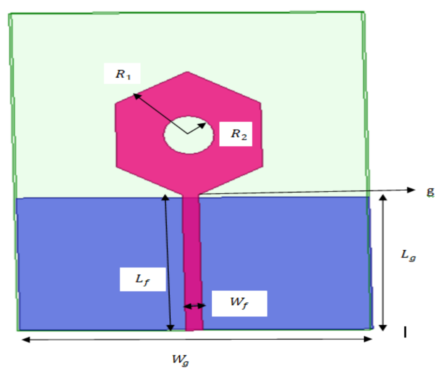

Fig . 1(b) Hexagonal ring Patch antenna with Defected ground structure.

Table 1.Design parameters of the antenna

Parameter	Description	In mm
L	Length of the antenna	50
W	Width of the antenna	42
h_s	Height of dielectric substrate	1.6
L_g	Length of ground	20.8
W_g	Width of ground	42
W_f	Width of MS feed line	2
L_f	Length of Ms feed line	20.8
R_1	Outer radius of patch	10
R_2	Inner radius of patch	3
G	Height of feed gap between feed line and ground	0.8

III. COMPARITIVE PARAMETRIC ANALYSIS

Return loss (S_{11} db) variations

The parametric analysis has been carried out by varying radius of inner circle (R_2) and separation between ground plane and hexagonal patch(g). The comparative return loss variation of hexagonal patch with DGS and hexagonal patch without DGS antennas are shown in figure 2. A hexagonal patch antenna bandwidth can be enhanced by inserting circular plotting radiating patch and making defect on the ground plane in the shape of rectangle as shown in figure1(b). The bandwidth of hexagonal antenna is obtaining 2.8-6.5 GHz below -10db. The return loss variations are calculated -15.4 db, -31.2 db, -13.2 db, -18.7 db, 17.2 db at 2.8 GHz, 4.7 GHz, 6.5 GHz, 8GHz, 9.6 GHz resonant frequency respectively. Further to improve the bandwidth of antenna, a circular slot of radius R_2 is 3mm has been introduced in hexagonal patch and making rectangular defects on ground. By inserting a slot and DGS , lower cutoff frequency 2.8 GHz is shifted to 2.4 GHz and higher cut off frequency of 6.5 GHz is 9.8 GHz and frequency band of 2.4-9.8 GHz has been obtained at 2.8 GHz, 4.5 GHz, 6.4 GHz, 8.2 GHz and 9.4 GHz resonant frequencies. The proposed design achieves the fractional bandwidth of 125% there by it is suitable for RADAR , medical imaging , wall imaging and ground penetrating.

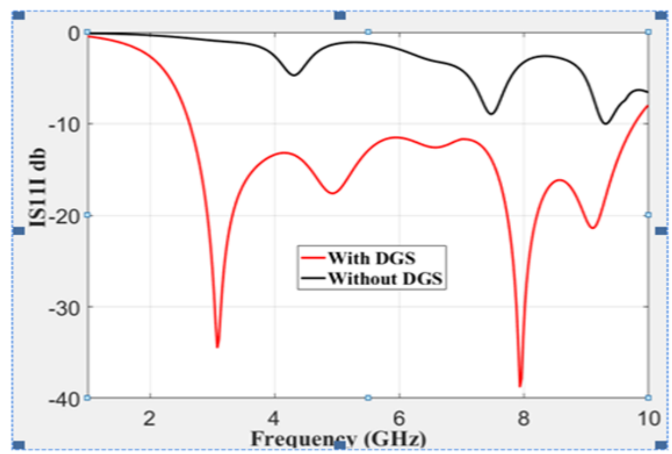

Fig. 2 Simulated Return loss curve for with and without DGS

Return loss variation with inner radius (R_2)

The comparative return loss variations for circular ring on the hexagonal patch antenna is shown in figure 3. It is observed that the impedance bandwidth has been improved by varying the radius of the inner circle on the hexagonal patch. Therefore, impedance bandwidth achieves the frequency in the band of 2.4 - 9.8 GHz. Also impedance matching has been improving in entire specified WB band by inserting a circular plot in the patch.

Hence, to optimize dimensions have been chosen for inner radius R_2=3mm respectively can be seen in figure 3.

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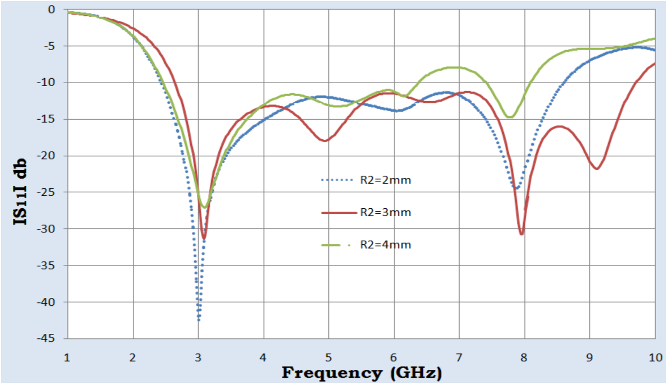

Fig. 3 Simulated Return loss variation for different values of R2.

Return loss variation with different values of gap between ground and patch(g)

The radiation in gap between ground and patch shows effect on return loss as shown in figure 4 for hexagonal patch antenna. It can be observed that by varying the gap (g) the impedance bandwidth is increased for the hexagonal patch antenna. The impedance matching has also been improved in the entire Wide band. Therefore the optimized dimension of the gap is taken as d=20.8mm

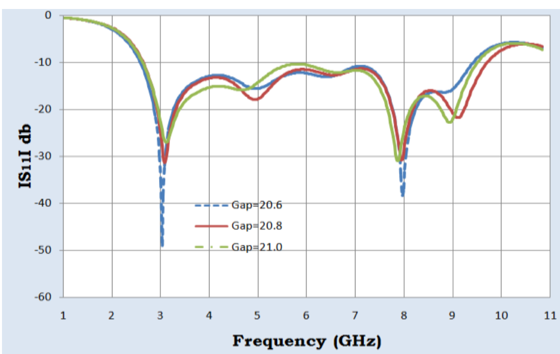

Fig. 4 Simulated Return loss variation for different values of gap(g)

VSWR

The mismatch power between antenna and feed line has been defined by VSWR of any antenna. The comparative simulated VSWR plot of hexagonal patch antenna with circular ring has been shown in Fig4.The value of VSWR of hexagonal antenna is found to be 1.5. Therefore, The proposed antenna gives the proper impedance matching between microstrip feedline and patch.

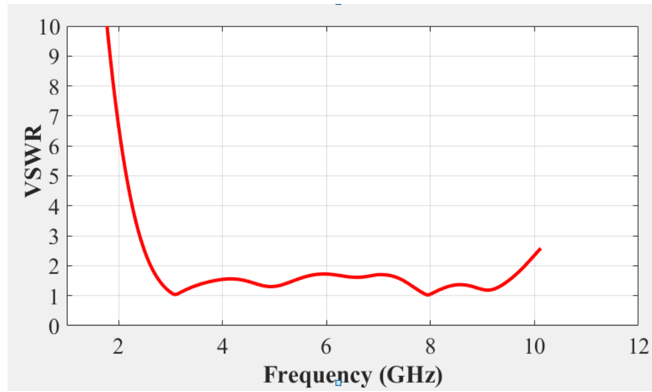

Fig. 5 VSWR plot of proposed design

GAIN

The simulated gain variation of proposed antenna is shown in fig 6. It is observed that proposed antenna gives maximum gain and it was found to be 7.2dB for hexagonal patch antenna with DGS at frequency 9.8GHz.

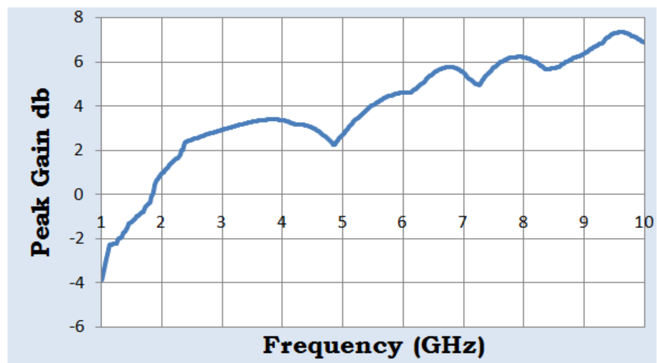

Fig. 6 Gain variation of antenna with respect to frequency

Surface Current Distributions

The simulated surface current distribution of the proposed antenna are shown in fig 7 at 2.4GHz. It is observed that the current is mainly concentrates on the edges of hexagonal patch, Microstrip feed line and ground plane which increases the path length of the current due to their symmetrical defected structures. The field distributions at E-Field and H-Fields are shown in Figure 8.

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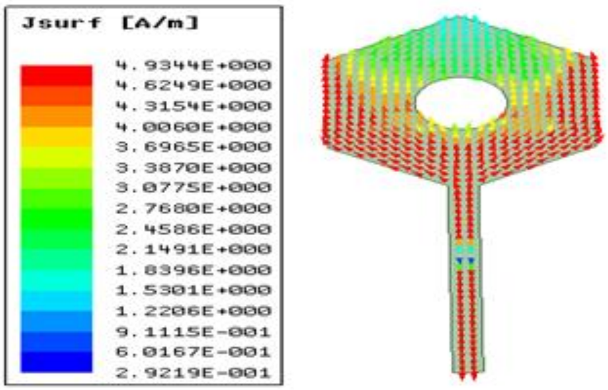

Fig. 7 The surface current analysis at 2.4GHz

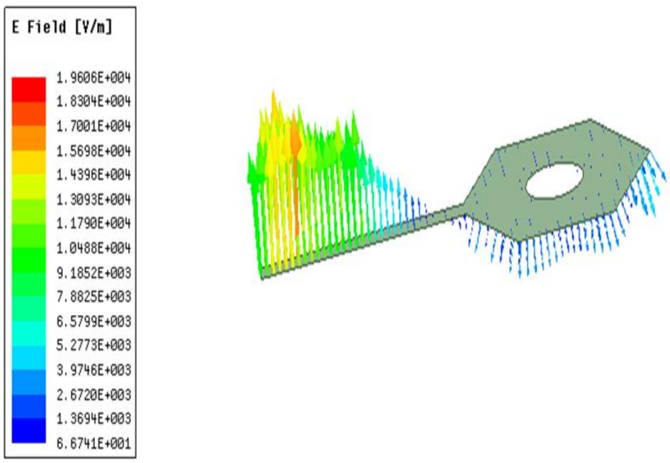

Fig. 8 (a) Field distribution at E-Field

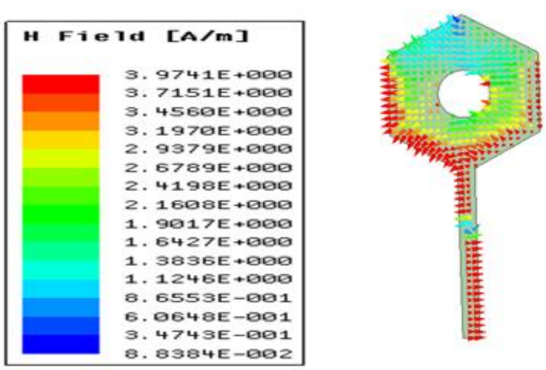

Fig. 8 (b) Field distribution at H-Field

Performance of the proposed hexagonal patch antenna has been affected mainly due to inner radius and separation between ground and patch. The detailed comprehensive study has discussed in section 3.Therefore proposed hexagonal patch antenna has been simulated with optimized dimensions as given in Table 1.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Performance of the proposed hexagonal patch antenna has been affected mainly due to inner radius and separation between ground and patch. The detailed comprehensive study has discussed in section 3.Therefore proposed hexagonal patch antenna has been simulated with optimized dimensions as given in Table 1. It has been observed that 112% of bandwidth is achieved by measurements in the frequency band of 2.4-9.8GHz below -10dB.The simulated radiation pattern of hexagonal patch antenna are shown in figure 9 at different resonant frequencies. Further the performance analysis of hexagonal patch antenna is measured in terms of bandwidth, gain, surface current analysis and field distribution. The field distribution of antenna in E-Field and H-Field are shown in figure 8. The radiation pattern of hexagonal ring antenna is shown in figure 9.The proposed hexagonal ring antenna has been fabricated with optimized dimensions and measurement has been carried out on Vector Network Analyzer(VNA) as shown in the figure 10. Excellent agreement is achieved between simulated and fabricated results as shown in figure 11.

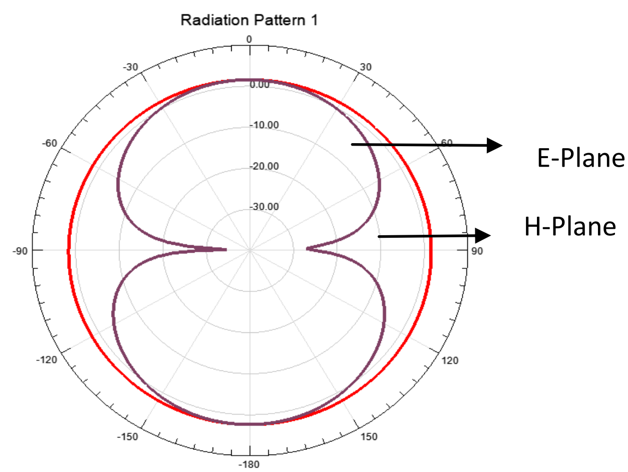

Fig. 9 (a) Radiation pattern at 3GHz.

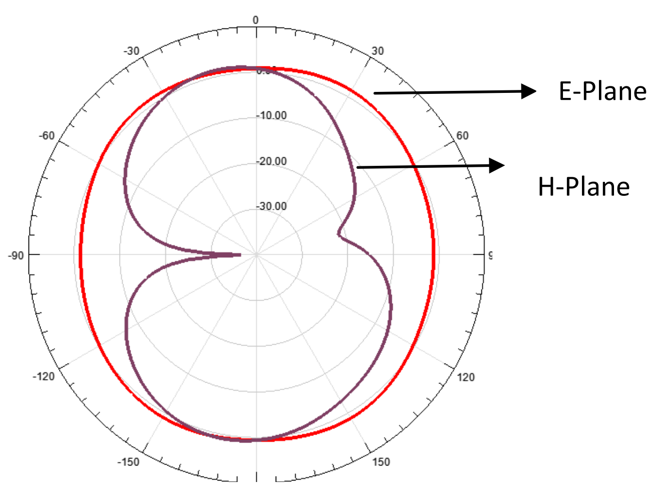

Fig. 9 (b) Radiation pattern at 5GHz

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Fig. 10(a) Fabricated Hexagonal Ring antenna top view

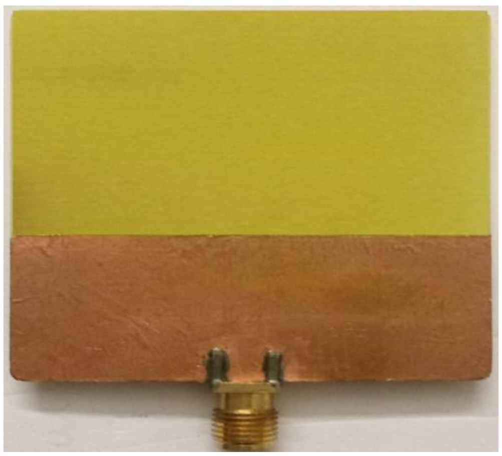

Fig. 10 (b) Fabricated Hexagonal Ring Antenna bottom view

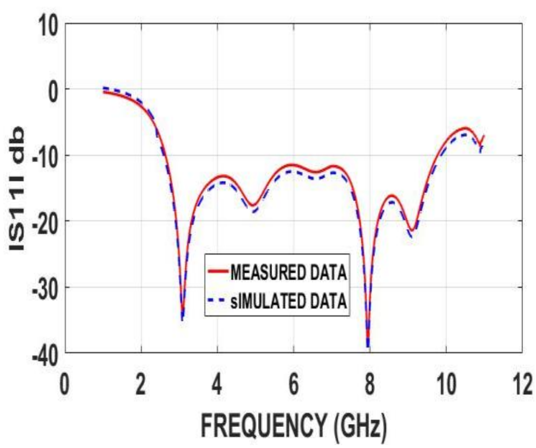

Fig. 11 Measured and Simulated Return loss plot for the fabricated antenna

V. CONCLUSION

In this work, the performance analysis of wideband hexagonal patch antenna having partial ground plane has presented. To achieve the proper impedance matching and bandwidth the optimized dimensions of antenna are found to be inner radius as 3mm and separation between ground and patch is 0.8 mm. The design antenna achieves 112% of fractional bandwidth in the wideband operating from 2.4GHz to 9.8GHz.The hexagonal patch antenna operates at 5 resonant frequencies 2.8,4.5,6.4,8.2 and 9.6GHz in the specified WB. The design antenna gives excellent agreement between measured and fabricated results. Further, the antenna size, gain characteristics, bandwidth of the proposed antenna have also been compared with other existing antennas. It is found that the proposed design shows better results than existing ones.

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