The Analysis of U Slotted Rectangular Patch with Geometric Series DGS for Triple Band Applications

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Abstract. In this paper U shaped slotted on rectangular patch with geometric series defected ground structure (DGS) has been proposed. The proposed antenna has operated at three different operating frequencies of 8.3 GHz, 11.8 GHz, 14.3 GHz with return losses are −20.67 dB, −22 dB, −45.23 dB. The triple band has wide impedance bandwidth and maximum gain at operating frequencies. The co polarization and cross polarization of E plane and H plane are measured, the current distributions of U slotted rectangular patch antenna is measured.

Keywords: Defected ground structure · Circular ring patch antenna
Slots in ground plane

1 Introduction

The microstrip patch antennas (MSPA) is a essential device in the modern communication and radar systems. The provocative characteristics of MSPA are low cost, easy to design and conformability of the object. However the multi-band antennas has widely used in wireless and satellite communications.

[1–6] the different shape of defected ground structures (DGS) at ground plane to improve the impedance bandwidth, integration of microstrip lines and reduce the cross polarization. Liu proposed the planar monopole antenna with inverted L shaped DGS for wireless local area networks (WLAN) 2.4/5.2/5.8 GHz, WiMAX 3.5/5.5 GHz applications [1]. The spiral shape of the defected ground structure for dual polarized isolation, high input impedance 75 Ω, 150 Ω, and 100 Ω effectively [2], the monopole antenna with double U shaped DGS for improve impedance bandwidth of 112.4% over the traditional design [3]. The arc shape of DGS [4] and rectangular patch of asymmetric DGS [5] for reduce the cross polarization. The Zig Zag shaped rectangular patch with circular DGS for 2.45/5.28-GHz WLAN bands and the 3.5-GHz WiMAX and resonate at three resonant frequencies with gain of 4–6 dB [6]. The center fed circular ring patch with annular ring introduced for monopole radiation pattern, gain of 5.7 dB at resonant frequency 5.8 GHz [7]. Coupled-fed stacked microstrip monopolar patch antenna for monopole like radiation pattern are obtained in the dual bands

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(2.28–2.55 GHz, 5.15–5.9 GHz) for wireless local area network (WLAN) applications [8]. Soodmand [9] proposed breach coupled circular ring patch with four port dual band dual polarized for global system for mobile communication (GSM) and distributed control system (DCS) applications. Compact circular ring patch antenna for dual and triple band antennas resonate at fourth generation (4G) band [10]. Liu et al. [11] has reported tri-band monopole antenna with protrudent strips cross-shaped DGS for operate at UWB, WiMAX, WLAN and using for low pass filters [12–14].

In commercial antennas such as rectangular, triangular and other shapes are having low gain. In the view of that the ring antennas has been proposed to operate with high gain. But the ring patch has cross polarization problem. So, to improve that two concentric rings has been consider in this proposed design. The proposed U shaped slotted rectangle patch antenna with geometric series DGS has operated with triple bands are 8.3 GHz, 11.8 GHz and 14.3 GHz with return loss of −20.67 dB, 11.80 dB, 14.3 dB at three resonant frequencies. This triple bands are very much useful at WLAN, WiMAX applications to protect the cross polarization.

2 Antenna Design

Figure 1 shows the proposed U shaped slot on rectangular patch with geometric series factor DGS. The RCUS substrate dimensions has consider length (L_1) and width (W_1) are 70 × 50 mm^2 shown in Fig. 1. The substrate dielectric constant Fr4 epoxy (ε_r = 4.4) with thickness is 1.6 mm. The top layer of substrate is patch and ground patch with geometric series defected ground structure.

The rectangular patch length (L_2) is 40 mm and width (W_2) is 30 mm and concentric circles are slotted on the rectangular patch with outer circle and inner circle of radius (R_1) 13 mm, radius (R_2) 11.5 mm, radius (R_3) 6.5 mm, radius (R_4) 5.5 mm, width of the ring ($d_1 = d_2$) 1.5 mm. The U shaped slots are placed at corners of rectangular patch for improve the bandwidth of proposed antenna and length (L_4), width (W_4) of U shape are 3.8 mm, 3.8 mm and thickness (d_3) of slot is 0.5 mm is shown in Fig. 1(a). The input impedance of feed line is 50 ohms and length (L_3) and width (W_3) of feed line is 20 × 2 mm^2. The ground patch has equally subdivided into three parts with length (L_5) 23.2 mm, width (W_5) 16.53 mm is shown in Fig. 1(b), again second part and third part equally subdivided into three parts with length (L_6) and width (W_6) are 7.6 ×5.38 mm^2. To improve bandwidth, reduce size of antenna, again the third part is equally subdivided into three part with length (L_7) 2.40 mm and width (W_7) 1.66 mm shown in Fig. 1(b). Slot ($S_1 = S_2$) of 0.2 mm for equally subdivided the ground plane. The each rectangle is connected to another rectangle with equal dimensions ($S_3 = S_4 = S_5 = S_6$) of 0.2 mm. The with DGS and Without DGS are shown in Fig. 2.

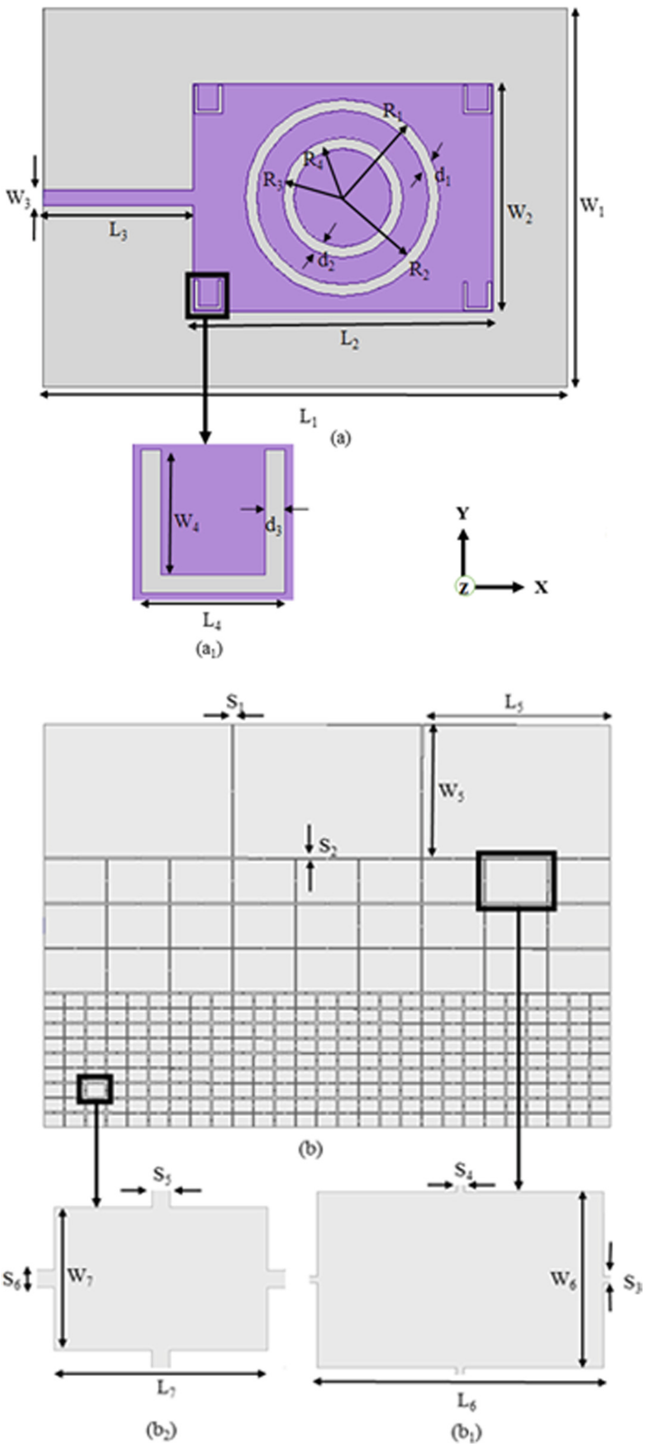


Fig. 1. (a) Patch of the rectangle circular with U shaped slots (b) Ground patch of geometric series factor DGS

3 Results and Discussion

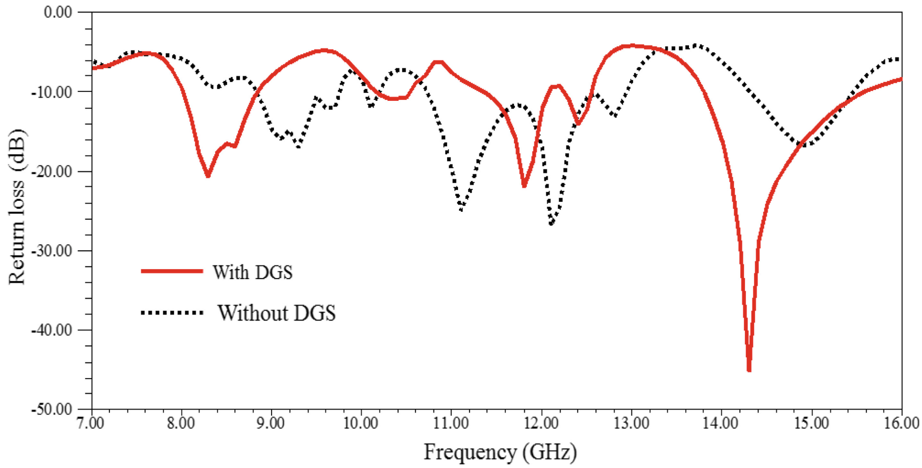


Fig. 2. Comparison of with DGS and without DGS of rectangular circular slot antenna

3.1 Parametric Analysis

The rectangular of concentric circles and U shaped slots (RCUS) patch shown in Fig. 1 (a). The ground plane is equally subdivided into three parts is shown in Fig. 3(a). The simulation results of RCUS with 3 × 3 cells ground plane shows the multi bands with lower bandwidth. The triple band is obtained for RCUS with 9 ×9 cells ground plane and triple bandwidths are 1 GHz, 0.6 GHz, 1.86 GHz with lower gain at resonant frequencies is shown in Fig. 4. In order to improve the bandwidth and gain of proposed antenna with ground 3 has dual bands. The reflection coefficients of ground 3 are −37.5 dB (7.8 GHz), −15.8 dB (15.2 GHz) with lower bandwidth compare to ground 1 and ground 2 is shown in Fig. 4.

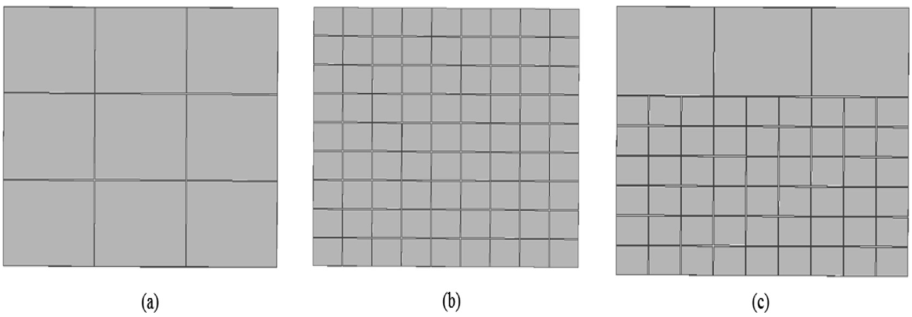


Fig. 3. The proposed antenna configurations (a) ground 1 (b) ground 2 (c) ground 3

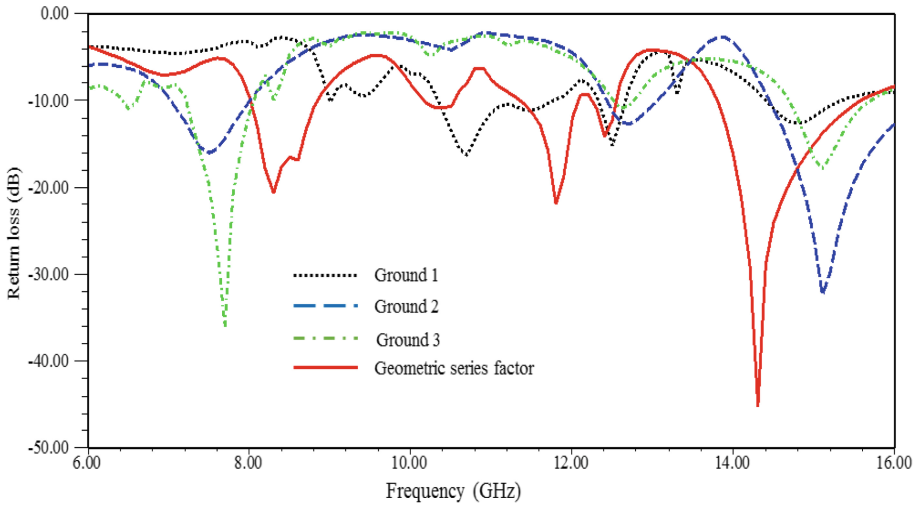


Fig. 4. Return loss of CCAP antenna for different values of (a) t_1 (b) t_2

3.2 Effect of S_1

Figure 5 shows the parametric analysis of proposed antenna by varying the slot (S_1) width as 0.2 mm, 0.3 mm, and 0.4 mm. When the slot size is increases, bandwidth of proposed antenna is decreases. From the observation slot size 0.2 mm shows the better result compared to 0.3 mm and 0.4 mm.

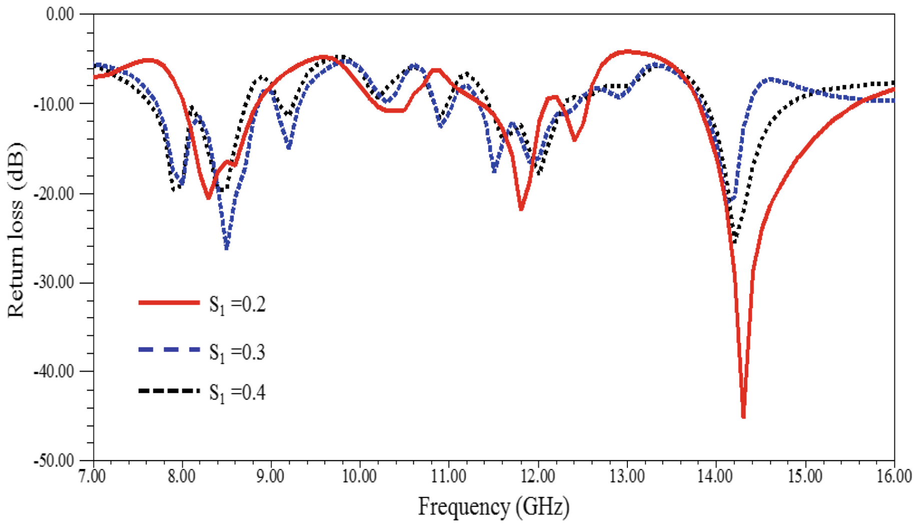


Fig. 5. Parametric analysis of proposed antenna by varying S_1

3.3 Effect of D_1

The width of ring (d_1) is decreases, bandwidth and gain of proposed antenna decreases. The parametric analysis on proposed antenna by varying ring (d_1) width as 1.1 mm, 1.3 mm and 1.5 mm. From the observation ring size of 1.5 mm shows the better result compare to 1.1 mm and 1.3 mm is shown in Fig. 6.

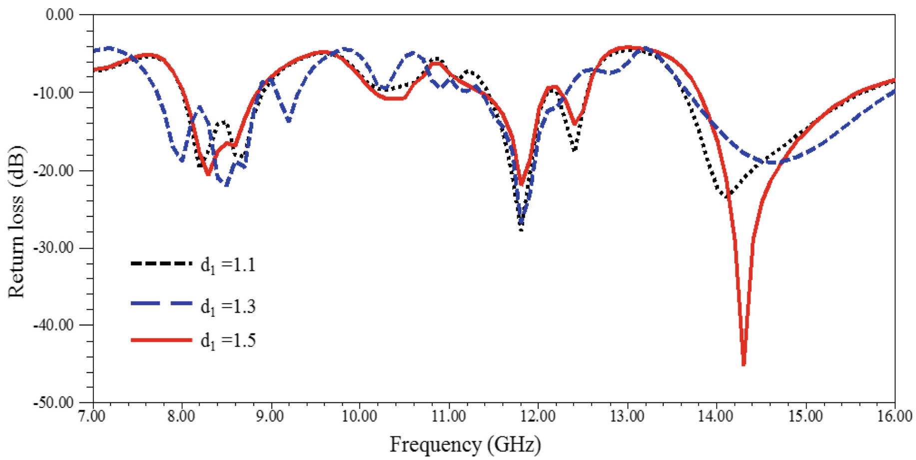


Fig. 6. Parametric analysis of proposed antenna by varying d_1

3.4 Radiation Patterns

The co polarization, cross polarization of E plane and H plane of the proposed antenna radiation characteristics shown in Fig. 7. The proposed antenna operated with three resonant frequencies are 8.3 GHz, 11.8 GHz, 14.3 GHz and The co polarization and cross polarization (XP) are observed and cross (XP) are found at is 0^0, −20 dB(xz plane) and −18 dB (yz plane) at is 90^0 for 8.3 GHz. The radiation patterns are observed at is 0^0 and is 90^0 in xz and yz plane for three resonance bands. The co and cross polarization has presented and cross polarization is found below 20 dB at one plane of each angle and operating frequency. The solid (black), dot (red) indicates the co and cross polarizations. The bi directional, omnidirectional radiation characteristics at resonant frequency of 8.3 GHz.

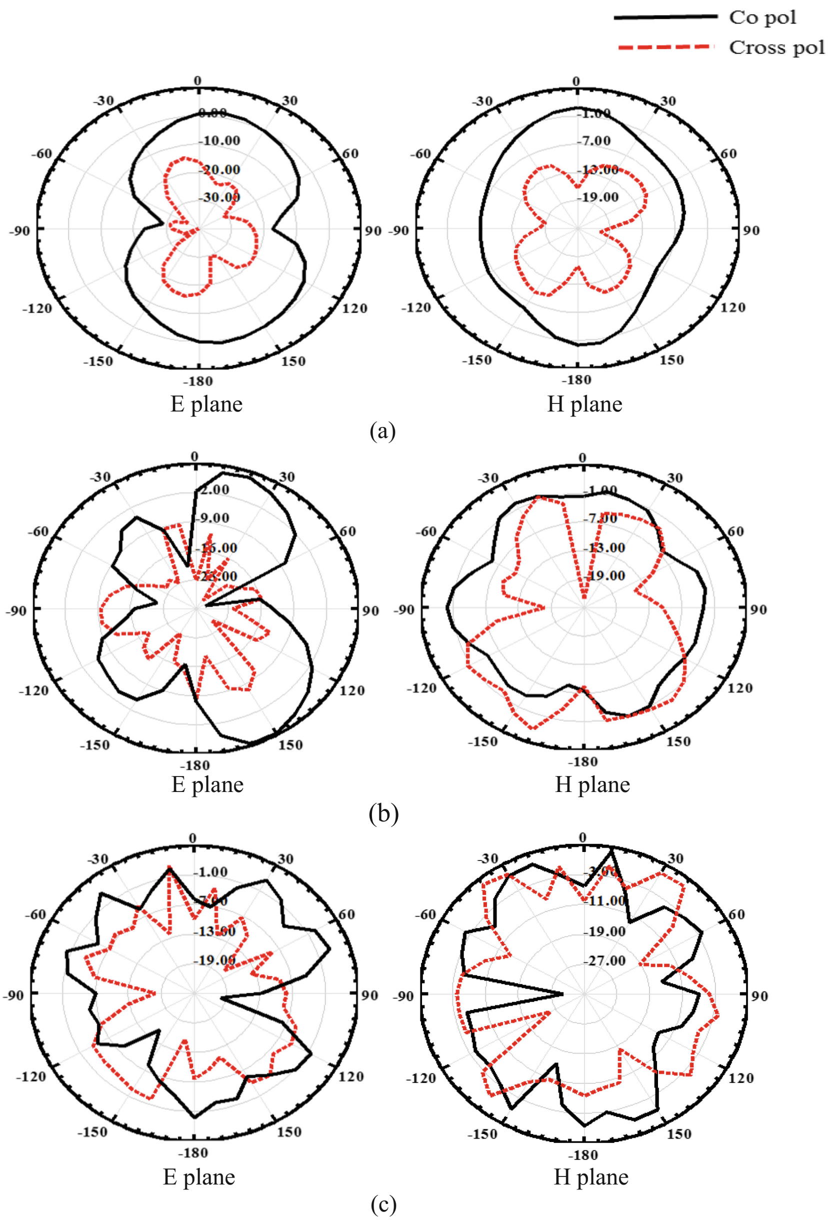
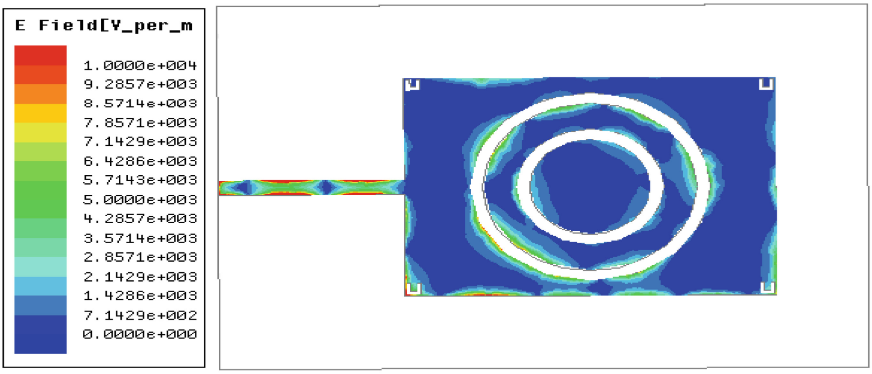


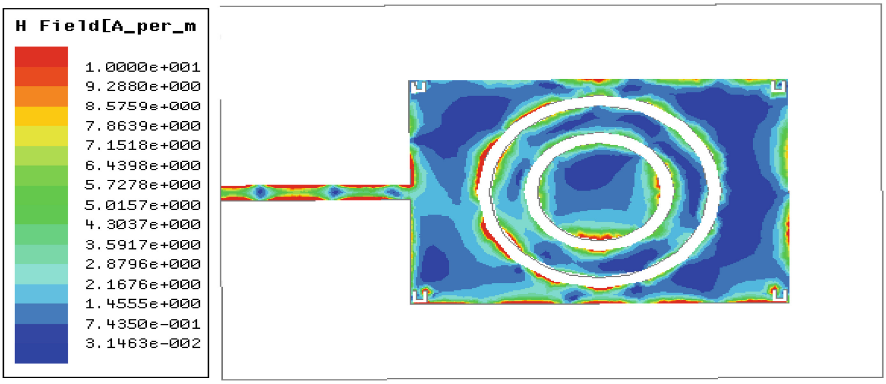
Fig. 7. The co polarization and cross polarization of E plane and H plane (a) 8.3 GHz (b) 11.8 GHz, (c) 14.3 GHz. (Color figure online)

3.5 Field Distributions of Proposed Antenna

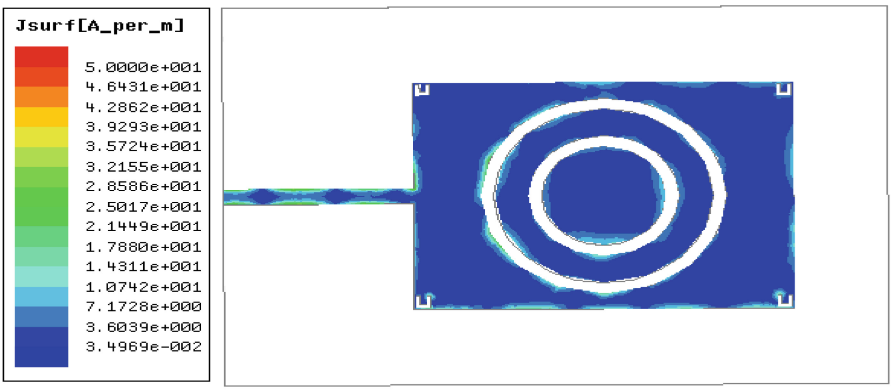
The field distributions of the proposed antenna at E field, H field and J field is shown in Fig. 8. The maximum E field distributions of the proposed antenna for adding



(a)



(b)



(c)

Fig. 8. The field distribution of star polygon antenna at (a) E field, (b) H field, (c) J field.

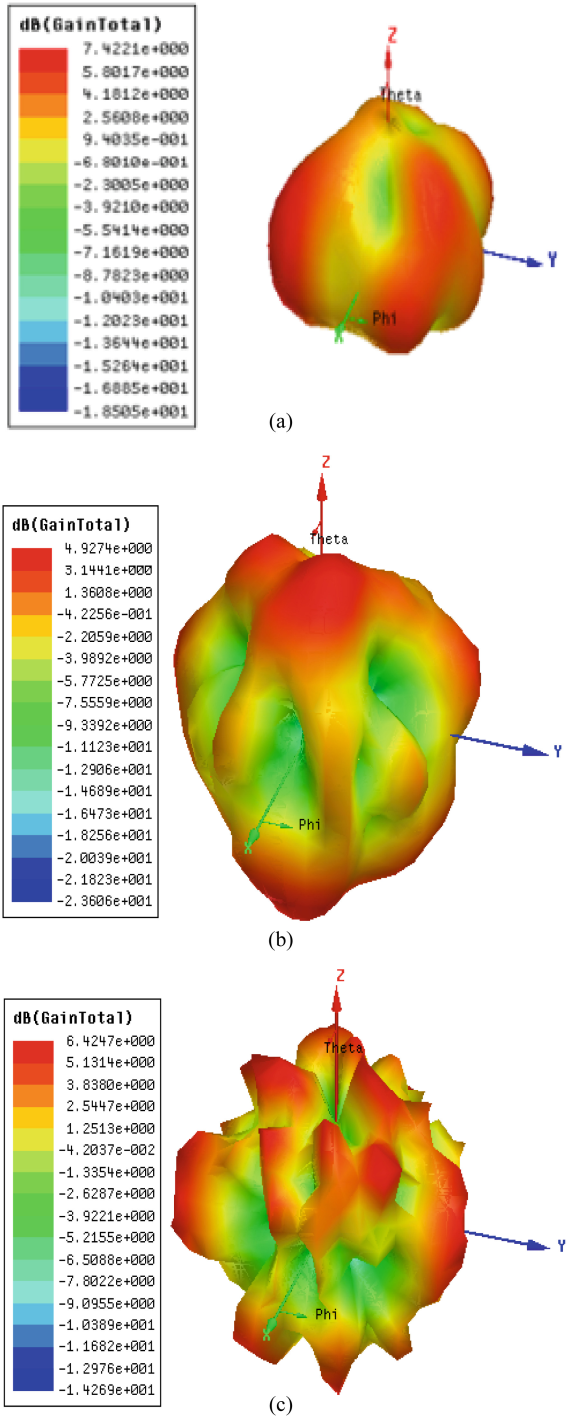


Fig. 9. The maximum gain at three resonant frequencies (a) 8.3 GHz (b) 11.8 GHz (c) 14.3 GHz

concentric circular slot, U shaped slots. The maximum electric field is 101 V/m at three resonant frequencies. The magnetic and J field are 10 A/m, 50 A/m.

3.6 Maximum Gain

The maximum gain of the proposed antenna at three resonant frequencies are shown in Fig. 9. The gain of 7.42 dB, 4.92 dB and 6.42 dB at resonant frequencies are 8.3 GHz, 11.8 GHz and 14.3 GHz. The maximum gain observed at 8.3 GHz compared to the other two frequencies. The U shaped slot rectangular patch with concentric circular slot for increasing the maximum gain of proposed antenna, the impedance bandwidth is increased by using geometric series defected ground structure.

4 Conclusion

In this paper the geometry shaped DGS is introduced for wide bandwidth and triple band applications. The U shaped slot on rectangular patch antenna with geometric series DGS is operating at three resonant frequencies are 8.3 GHz, 11.8 GHz, 14.3 GHz with return loss of −20.67 dB, −22 dB and −45.23 dB. The use of new geometric series DGS for improve the bandwidth, reduction size of antenna. The field distributions, radiation characteristics of the proposed antenna has been measured with minimum cross polarization and used for multi band, UWB, Ku band applications.

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