Enhancement of the Performance Parameters of Microstrip Slotted Patch Antenna using Defected Ground Structure

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Abstract

This article represents the Microstrip patch antenna with corner slots in the patch and the corner slots in the ground plane. The antenna is developed on Rogers RT Duroid having Dielectric constant 2.2 with height of 1.6 mm fed with coaxial feed at optimized location. The performance parameters of the proposed patch antenna are characterized by measuring Return Loss, Gain, Efficiency, Axial Ratio, Radiation Pattern and Directivity. The presented antenna has low profile and resonates at 12 GHz which can be operated in X-band and Ku-Band applications like Terrestrial communications and Networking, Motion detectors, Traffic light crossing detectors, Fixed Satellite service and Broadcast satellite service, VSAT etc.

Keywords: *DGS, Slotted Patch, X-band, Ku-Band, Gain, Circular Polarization*

I. INTRODUCTION

From Last few years tremendous growth has been seen in the field of Wireless Communication and antenna is the most vital component of the Wireless communication. Microstrip patch antenna has been always the prime choice among the researchers due to their various advantages like small size, low cost, desired shape, less weight, easy fabrication process and integration with the Monolithic integrated circuit. However, there are some disadvantages of the patch antenna like narrow Bandwidth and low gain [1-3]. Various methods have been adopted by the researchers to improve the performance parameters of the patch antenna. One such technique is called defected ground structure (DGS). Ground plane lies on the bottom of the substrate material and etching of the ground plane in any desired pattern leads to the improvement of performance parameters of the patch antenna. The defect in the ground disturbs the current distribution in the circuit. Also, Capacitance and inductance characteristics of transmission line disturbs i.e increases effective capacitance and inductance [4-5]. There are numerous advantages has been observed with the application of defected ground structure like miniaturization of the patch antenna, Harmonics Reductions, Cross- Polarization reduction, Mutual Coupling reduction in case patch antenna array, helps in achieve circular polarization, Broadband Radar Cross Section Reduction [6-8]. There are many shapes of the ground plane like concentric rings, Dumbbell Shape, Arrow-head dumbbell, Spiral shape, U-shaped, Circular head, Split-ring resonators, H-shaped dumbbell, Cross-shaped, Meander Line have been observed in the literature [9-10]. From last Couple of years a significant modification can be seen in the DGS structures. A 2X2 patch array has been designed with circular ring DGS structure resonating at 5.8 GHz having -36dB of return loss achieving 530 MHz of Bandwidth [11]. A concentric ring shaped with a rectangular slot has been etched from the ground plane to achieve the 3.5GHz resonating frequency with a bandwidth of 400 MHz and the gain of 2.26 dB [12]. An I-shaped slot DGS has been cut in the diamond shaped patch antenna. The design operates at 3.675 GHz and 10.35 GHz frequencies with a return loss of -14.63 dB and -11.91 dB respectively [13]. An E-shaped Ground slot has been cut in the slotted patch. There is a significant improvement in the bandwidth i.e performing dual band operation in the frequency bands of 3.2 to 3.5 GHz and 5.6 to 5.8 GHz [14]. Rectangular patch antenna is designed with the various slots in the ground plane resonating at two frequencies i.e. 6.1 and 8.9 GHz leads to improvement in the bandwidth and gain with DGS [15]. Partial ground plane with triangular slot has been cut from the ground to achieve the multiband operation. The design covers the ultra-wide band (UWB) ranging from 3.58-9.93 GHz with a gain of 3.124 dB [16]. A review has been presented regarding various shapes, applications and disadvantages of the defected ground structure in the patch antenna [17]. In this article, the ground is etched from the corners to achieve the circular polarization in the patch antenna and also patch is slotted from the corners to achieve the desired resonating frequency and Return Loss.

II. ANTENNA DESIGN

The proposed antennas are designed using IE3D Software. The proposed antenna is developed on a substrate of height of 1.588mm with dielectric constant, 2.2. A CPW fed is used having feed position

(3, -4). The antennas is a small size planer patch antenna with length L=9.06 mm and width W=11.85 mm using equations (3) and (1) respectively. Also the Length of the ground is L_g = 18.588mm and Width of the ground is W_g = 21.378 mm is calculated using equations (5) and (6) respectively [18]. The conventional Rectangular patch antenna is shown in fig 1.

(a) Computation of Width

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{c}{f_r}\sqrt{\frac{2}{\epsilon_r+1}} \qquad (1)$$

(b) The effective dielectric constant of rectangular microstrip patch antenna is given by

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W}}}\right) \qquad (2)$$

(c) The actual length of patch (L)

$$L = L_{eff} - 2\Delta L \qquad (3)$$

Where $L_{eff} = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$

(d)Computation of Length Extension

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad (4)$$

(e) Computation of Ground Length

Lg = 6h + L (5)

(f) Computation of Ground Width

Wg = 6h + W (6)

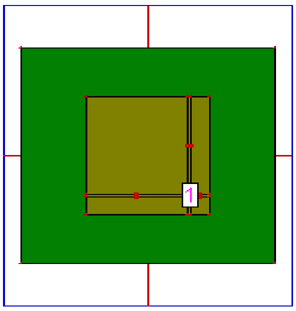

Fig. 1 Conventional Patch

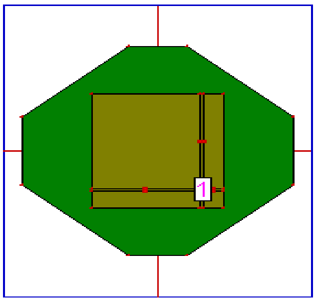

Fig. 2 Patch Antenna with DGS

The Presented second antenna has Defected ground structure as shown in figure 2. DGS makes the above antenna low profile, improved return loss and enhanced directivity.

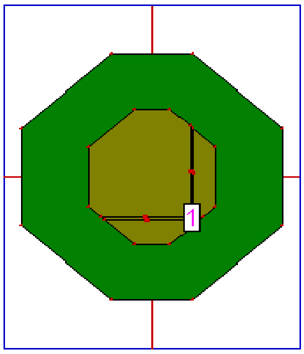

Fig .3 Microstrip Patch Antenna with DGS and Slotted Patch

Fig .3 illustrates the third design having DGS and slotted patch for the improved return loss, Enhanced gain and promising directivity.

III. RESULTS AND DISCUSSION

A. Return Loss V/S Frequency

The simulation of the proposed antenna has been completed using ie3d software. this software is based on the method of the moment's technique. the return loss graphs for the three designs are shown in fig. 4, 5 & 6. It has been observed from the graphs that resonant frequency of all the designs is about near to 12 GHz. but conventional rectangular patch antenna has return loss about-16db at 11.9 GHz having bandwidth (7.4 GHz - 16 GHz) , second design has return loss about -22.5 db at 12.3 GHz having bandwidth (10 GHz -18 GHz) with the notching of 11.5 GHz band and third design has return loss of -27db at 12.3 GHz having bandwidth 8.5 GHz -15 GHz.

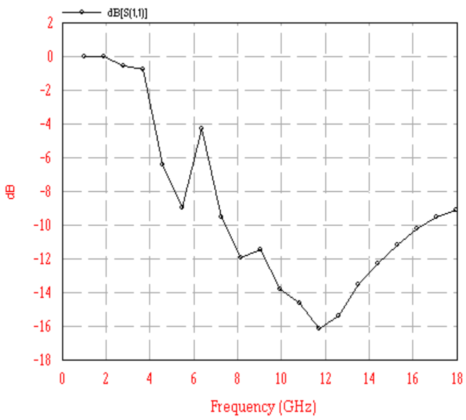

Fig. 4 Return loss of Conventional Patch Antenna

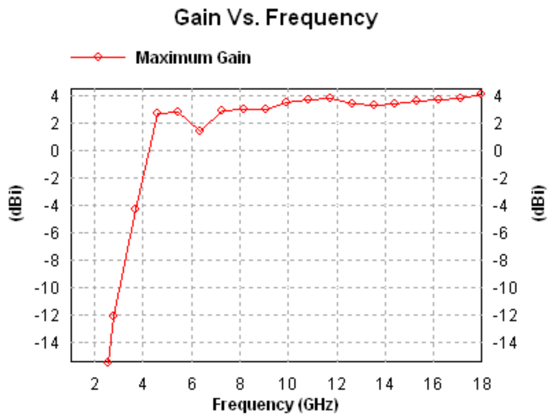

Fig .7 Gain of Conventional Patch Antenna

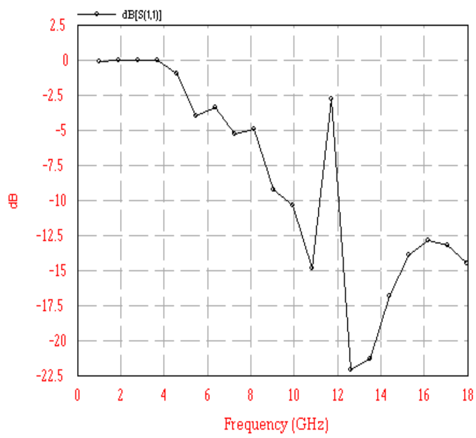

Fig. 5 Return Loss of Rectangular Patch antenna with Defected Ground Structure (DGS)

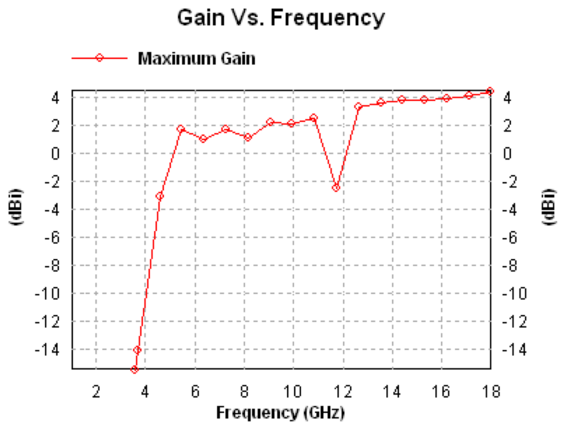

Fig .8 Gain of Patch Antenna with DGS

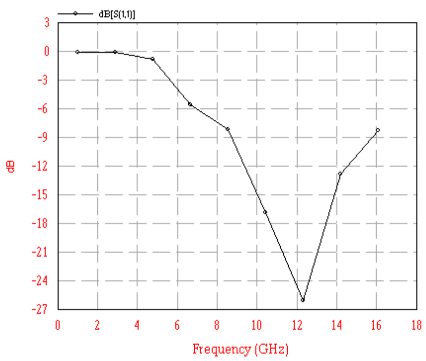

Fig. 6 Return Loss of Microstrip Patch antenna with DGS and slotted patch

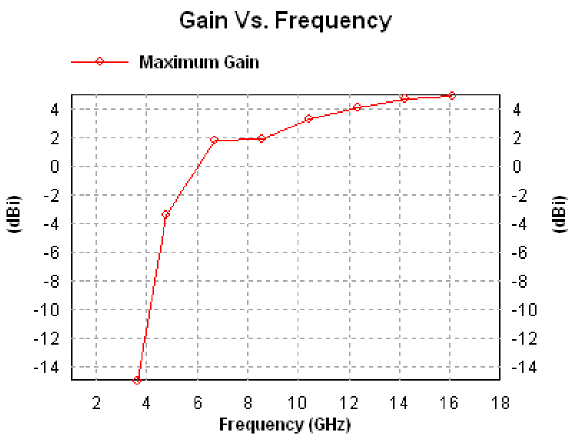

Fig. 9 Gain of Patch Antenna with DGS and slotted patch

B. Gain V/s Frequency

Gain vs Frequency graphs of all the designs are shown in fig. 7, 8 & 9. Gain can be measured in terms of the directivity and the radiation efficiency. Gain can be defined as the multiplication of directivity and radiation efficiency. From the graphs it has been observed that gain of three designs is 3.72dbi, 3.23dbi and 4.04dbi respectively.

C. Directivity v/s Frequency

Directivity vs. Frequency graphs of all the designs are shown in fig.10, 11 & 12. From the graphs it has been observed that directivity of three designs are 5dbi, 6dbi and 6dbi respectively.

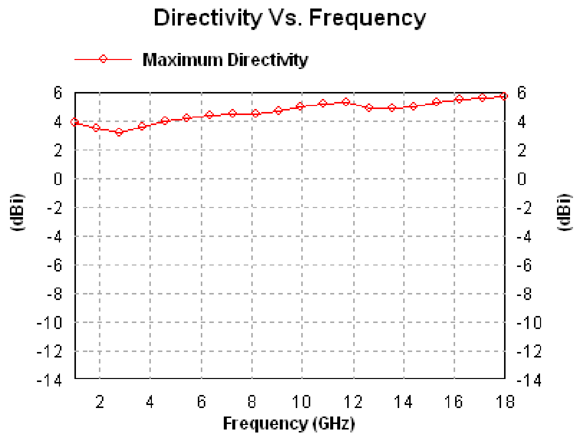

Fig 10. Directivity of Conventional Patch Antenna

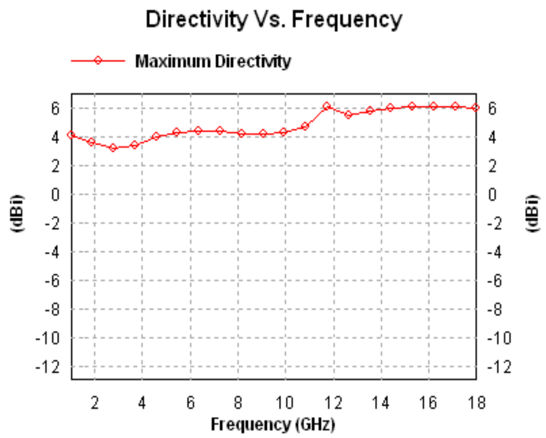

Fig 11. Directivity of Patch Antenna with DGS

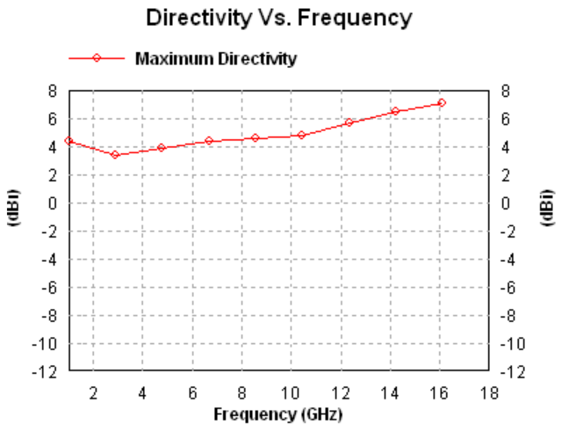

Fig. 12 Directivity of Microstrip Patch Antenna with DGS and Slotted Patch

D. Axial Ration v/s Frequency

Type of Polarization is determined by the calculation of Axial Ratio. From fig. 13, 14 & 15 depicts the axial ratio which is less than 3db that can be considered as the circular polarization type antenna [1-2].

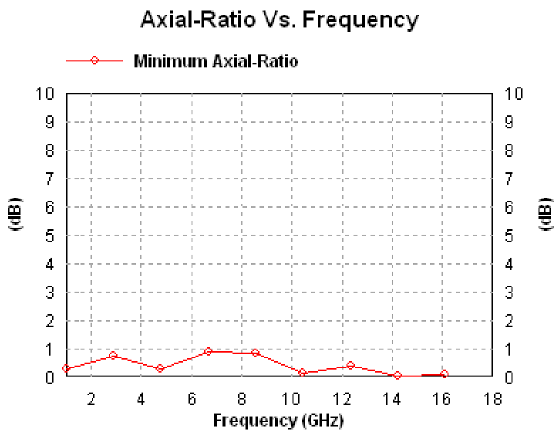

Fig 13. Axial Ratio of Conventional Patch Antenna

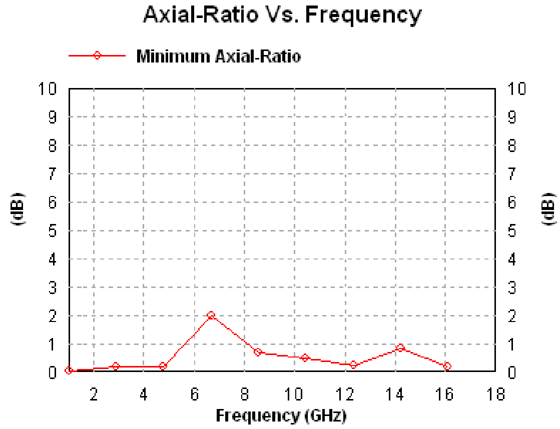

Fig .14 Axial Ratio of Patch Antenna with DGS

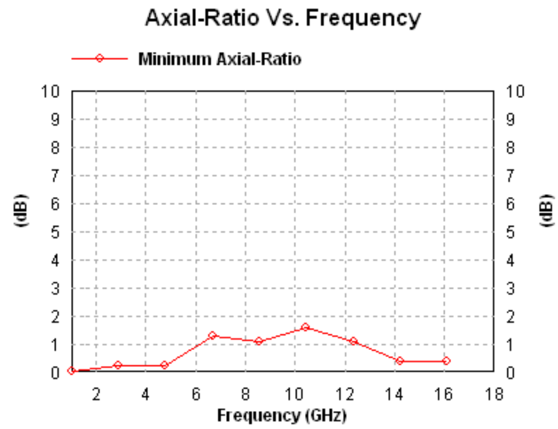

Fig. 15 Axial Ratio of Microstrip Patch Antenna with DGS and Slotted Patch

E. Elevation and Azimuth Radiation Pattern

Elevation Pattern and Azimuth Pattern of the proposed design are compared with the conventional rectangular Microstrip patch antenna are shown in Figure 16-21, Which shows the Promising Results of all the three proposed antennas.

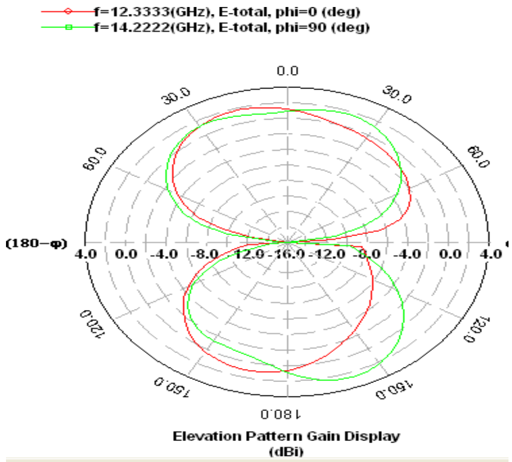

Fig .16 Elevation Pattern of Conventional Patch Antenna

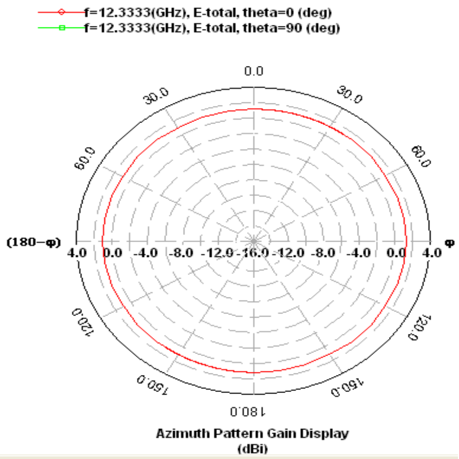

Fig .17 Azimuth Pattern of ConventionalPatch Antenna

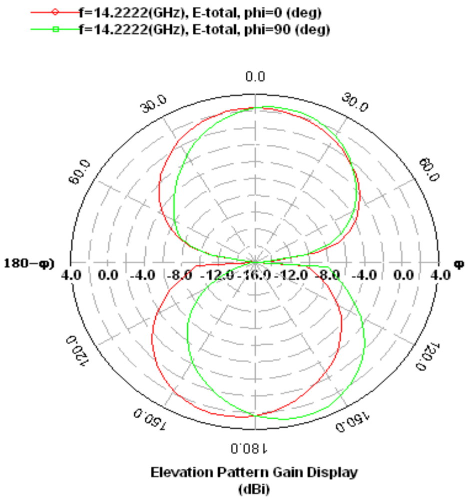

Fig .18 Elevation Pattern of antenna with DGS

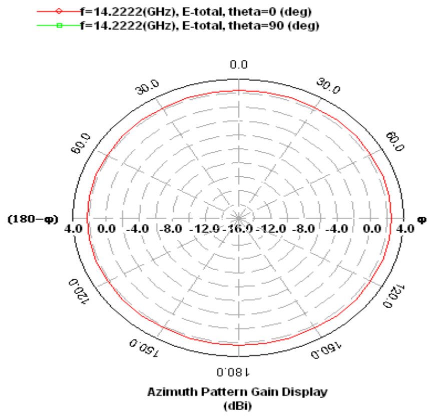

Fig 19. Azimuth Pattern of Patch antenna with DGS

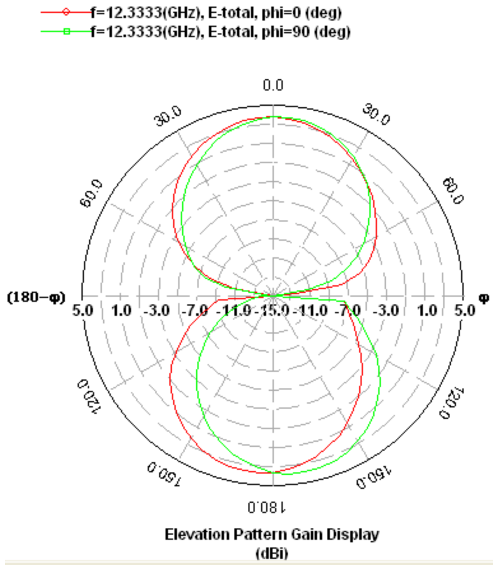

Fig. 20. Elevation Pattern of Patch Antenna with DGS and slotted Patch

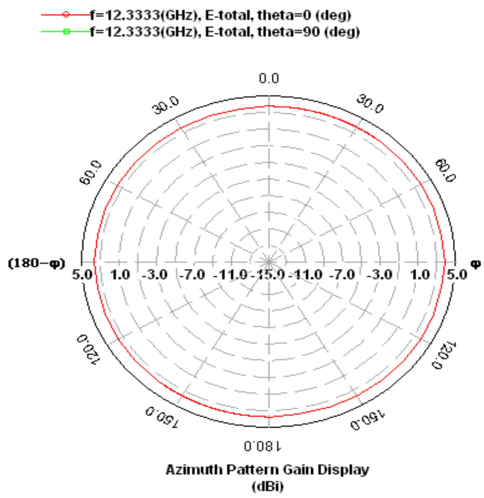

Fig. 21. Azimuth Pattern of Patch antenna with DGS and slotted Patch

Table 1. Comparison of Performance Characteristics

S.No.	Design	PARAMETERS			
		Resonant frequency	Return loss	Gain (dbi)	Directivity
1.	Simple Rectangular Patch Antenna	11.9 GHz	-16 db	3.72	5 dbi
2.	Proposed Rectangular Microstrip Patch antenna with Defected ground Structure	12.3GHz	-22.5db	3.23	6dbi
3.	Proposed Microstrip Patch antenna with Defected ground structure and slotted patch	12.3 GHz	-27db	4.04	6dbi

IV. CONCLUSION

In the presented work, Antenna designs have been compared with the help of DGS and slots in the patch. From the characterization of the gain, directivity, Return Loss, Axial Ratio and Radiation pattern, it is concluded that design with DGS and slotted Patch shows the best results over the conventional rectangular Microstrip patch antenna. Also there will be a reduction in the size of the antenna with the application of DGS and slotted patch and thus reducing the overall fabrication cost. The above design can be used for the X-band and Ku- band applications like Terrestrial communications and Networking, Motion detectors, Traffic light crossing detectors, Fixed Satellite service (11.7-12.2 GHz) and Broadcast satellite service (12.2-12.7 GHz), VSAT etc.

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