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Defected Ground Structure (DGS) based microstrip patch Antenna for C-Band Applications

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ABSTRACT: Microstrip patch antenna with defects in the ground plane is proposed for C-Band applications. The defects or slots in ground plane are referred to as Defected Ground Structure (DGS) with shapes of L, U, I, E, Square has been presented. The antenna designs proposed here has shown good enhancement in Bandwidth (BW) and Return loss (S_{11}). High Frequency Structure Simulator (HFSS) is used to found the optimized performance parameters of the proposed antenna. The proposed antennas resonate in C-band at a frequency of about 5GHzwith bandwidth of nearly 400 MHz. A very good return loss of about -41.37dB was obtained for E-shaped slot in ground. Also, improvement in return loss can be observed for U- shaped slot and Square shaped slot.

KEYWORDS:

Bandwidth (BW), Defected Ground Structure (DGS), Directivity (D), Gain (G).

I. INTRODUCTION

Over past few decades, Microstrip Patch Antennas (MPAs) [1] are expansively used in the fields of communication for example ground to air communication, spacecraft's and satellite communication. The rapid demand of RF microwave and wireless communication systems in multiple applications led to the need of improving antenna performance in its characteristics. MPAs are mainly preferred over other antennas because of their attractive properties like lighter weight, enhanced performance, ease of installation, low cost and moreover because of its low profile structure[2]. Hence, the selection of Microstrip antenna is important for applications in various fields such as military, telecommunications, medical field and satellite system. However, there are few demerits with MPA's such slow efficiency, narrow bandwidth, less gain because of their compact size and high return loss. Many kinds of techniques, such as stacking, using of high permittivity dielectric substrate [3], photonic band gap, electromagnetic band gap, and defects in ground (DGS) or a combination of them have been reported and applied to patch antennas for overcoming the above drawbacks.

Out of all the reported techniques, DGS has gained more popularity for its simple structural design. DGS means integrating a slot or defect on the ground plane of microwave circuit. It emerged as a widely adopted technique for enhancing various performance parameters like low gain, cross-polarization, narrow bandwidth and so on.DGS structure disturbs the shield current distribution of the ground plane as reported in [4] and [5] which in turn changes the input impedance and current flow of the antenna. The geometry of DGS is simpler and does not need a larger area to implement it [6]. Many shapes of DGS slot have been reported in [7,9] on planar microstrip antenna designs which provides improvement in features such as size reduction, impedance, bandwidth and gain enhancement. Wong et.al embedded several slots in the ground of annular ring Microstrip antenna at TM/Sub 21/mode, so that the size is reduced, the impedance band and gain is enhanced in [8]. The compact broad band antennas with defected structures have been reported in [10]. The proposed design's impedance bandwidth could reach 60.3% that of the conventional Microstrip antenna.

In the present paper, five types of DGS structures are integrated in basic planar microstrip antenna and their performance characteristics are measured individually using HFSS tool. The design equations and the simulated outputs are discussed in next section.

II. METHODOLOGY:

The simple MPA and proposed antennas are designed using High Frequency Structure Simulator. The substrate has thickness (t) of 1.6mm and relative permittivity (Ɛ r) of 2.2. The patch of circular shape has the radius(r) of 7.2mm with height(hp) of 1.6mm and ground dimensions are 30mmX35mm with height same as patch. Here the antenna is excited with line feed having characteristic impedance of 50 Ω. The feed line has length of 12mm, width of 1mm and height of 1.6mm. The geometry of simple MPA is shown in Fig 1. In order to bandwidth and return loss ground plane is defected with a slot. However, defects in ground reduce the overall weight and size of proposed antennas. Design specifications for all kinds of antennas are shown in the Table1.

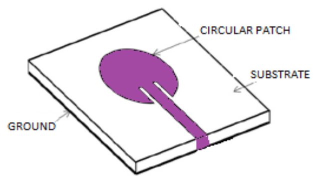


Fig 1. INSET FEED MICROSTRIP PATCH ANTENNA

Sr.	Specifications	Dimensions
1.	Ground (Lg×Wg)	30×35
2.	Substrate (Ls×Ws×hs)	30×35×1.6
3.	Patch (r_p×hp)	7.2×1.6
4.	Feedline (Lf×Wf×hf)	12×1×1.6
5	Permittivity of substrate	2.2

Table1. Common design specifications for all antennas

The considered patch antenna resonates at a frequency of 5GHz.The proposed patch with DGS consisting of L, U, I, E, square-shapes are shown in the figure 2 (a),(b),(c),(d) and (e) respectively.

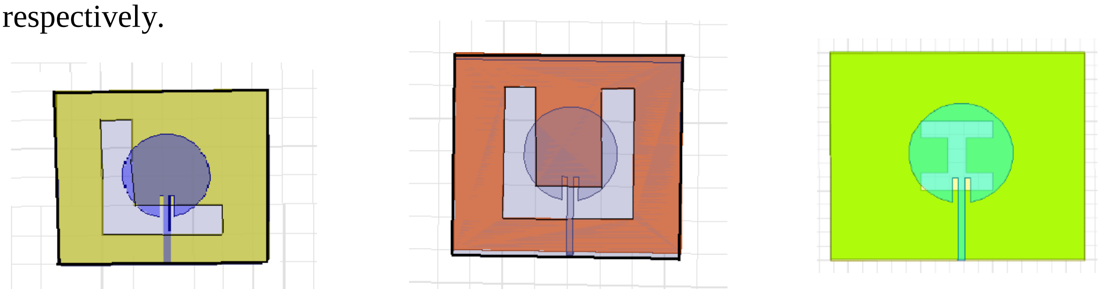


Fig 2 (a) L-Shaped DGS Antenna 2(b) U-Shaped DGS Antenna 2(c) I-Shaped DGS Antenna

2(d) E-Shaped DGS Antenna 2(e) Square-Shaped DGS Antenna

'L' Shaped DGS antenna resonating frequency is 5.18 GHz, 'U' Shaped defect/slot antenna resonating frequency is 4.71 GHz, 'U' Shaped defect/slot antenna resonating frequency is 4.71 GHz,‘I’ Shaped DGS antenna resonating frequency is 4.58 GHz, ‘E’ Shaped antenna resonates at a frequency of 4.68 GHz and finally square shaped DGS resonating at a frequency of 4.42 GHz.

The resonance frequency can be selected such that at which return loss is minimum. For a particular resonant frequency ‘fr’ and dielectric constant of ‘Ɛ r’, the width (W), length(L) of patch of MPA are expressed as follows.

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}} \quad (1) \qquad L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (2)$$

Where, ΔL is the extended Length of patch and it is expressed as:

$$\Delta L = 0.412h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \quad (3)$$

where, ‘Ɛ $_{eff}$’ is the effective dielectric constant of the substrate and is expressed as

$$\varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right] \quad (4)$$

The dimensions of ground plane given as $Lg = 6hg + L$ (5)

$$Wg = 6hg + W \quad (6)$$

where, ‘h_g’ is the height of the ground. L_g and W_g are length and width dimensions in the ground plane respectively. However, bandwidth and return loss can be improved with defected ground with slots. Also, the slot made on ground reduces the overall weight and its size of proposed antennas. The comparison table of the results is shown in the table 2.

III. RESULTS

The simulated results are discussed in this section. Fig 3(a), (b) shows the S11, VSWR of simple MPA.

Table 2. Comparison Table

Parameter	MPA	L Slot	U Slot	I Slot	E Slot	quareSlot
$_{11}$ (dB)	-23.49	-39.84	-40.37	-37.23	-41.37	-40.5
'SWR	1.16	1.020	1.035	1.04	1.06	1.14
W (GHz)	0.32	0.79	0.82	0.44	0.34	0.34
ain (dB)	5.74	5.09	3.67	5.14	5.40	4.96
irectivity(dB)	6.88	6.39	5.07	6.20	6.43	6.00

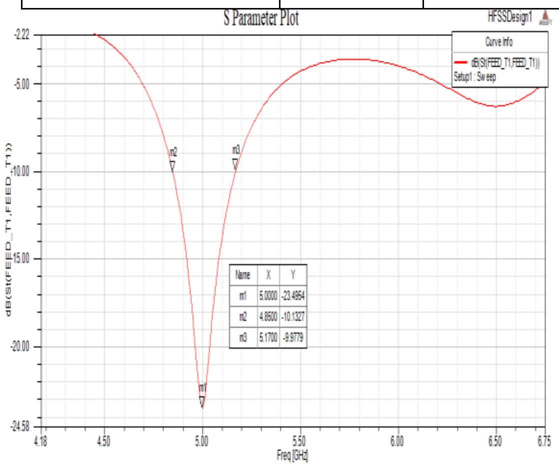


Fig 3(a) Return loss plot of MPA antenna

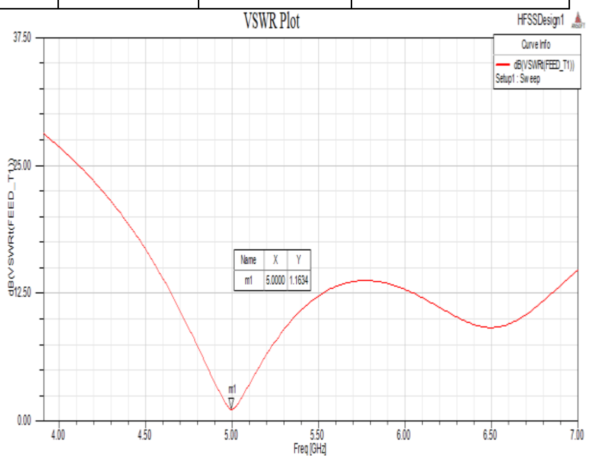


Fig 3(b) VSWR plot of MPA antenna

The Fig 4(a) shows return loss of L-Slot DGS Antenna. An enhanced return loss of -39.84 dB and an increased bandwidth of 790MHz are achieved for L-Shape DGS which was 320MHz for simple MPA.VSWR shown in Fig 4(b) The3-Dimensionalgain and directivity plots are shown in Fig 4(c) and 4(d) respectively.

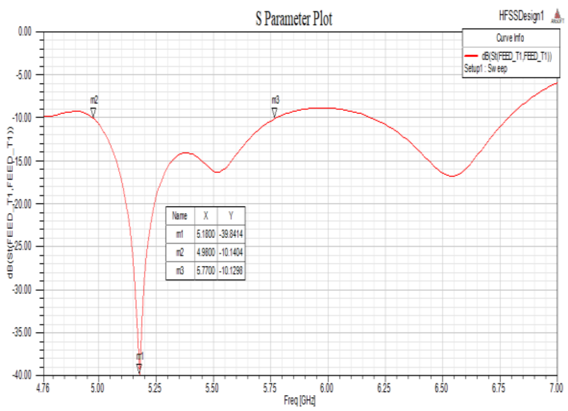


Fig 4(a) Return loss plot of L-Slot DGS

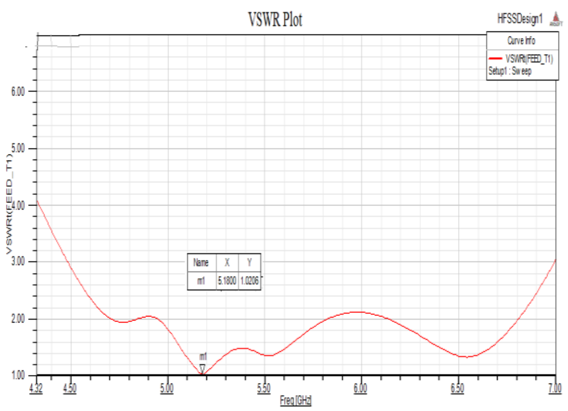
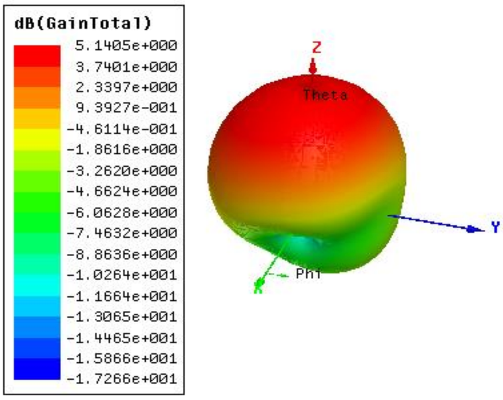


Fig 4(b) VSWR plot of L-Slot DGS Antenna



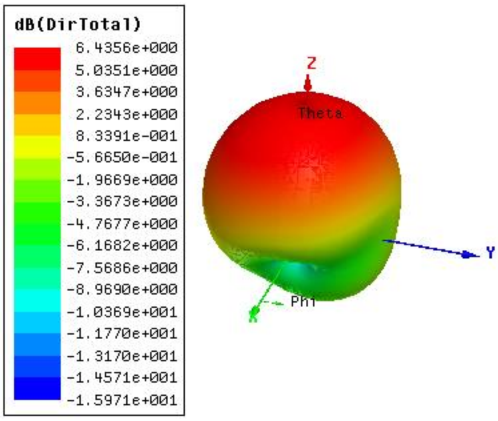
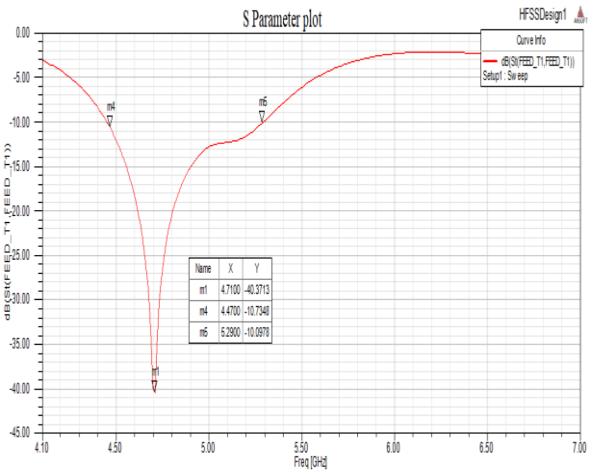


Fig 4(c) 3D Polar plot of gain of L-Shape Fig 4(d) 3D polar plot of Directivity of L-Shape

Fig 5(a) shows Return loss plot of U-Slot DGS Antenna. An enhanced return loss of -40.37 dB and an increased bandwidth of 820MHz are achieved for U-Shape DGS which was 320MHz for simple MPA.VSWR shown in Fig 5(b).The 3-Dimemnsional gain and directivity plots are shown in Fig 5(c) and 5(d) respectively.



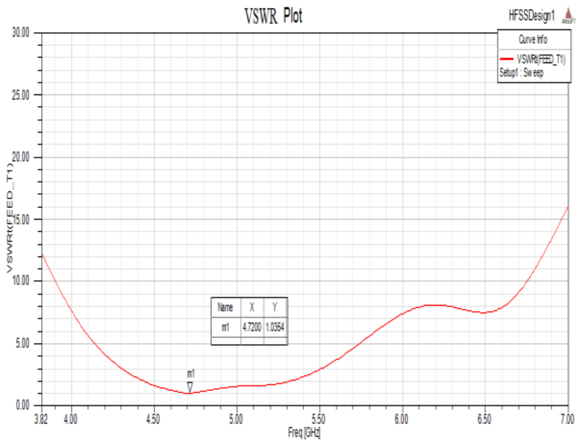
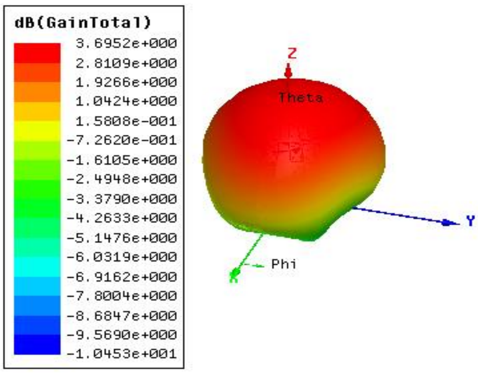


Fig 5(a) Return loss plot U-Slot DGS Antenna Fig 5(b) VSWR plot of U-Slot DGSAntenna



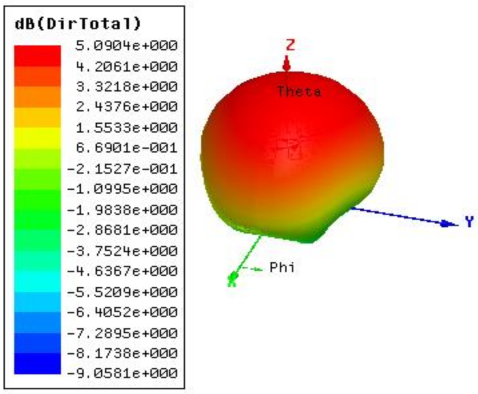


Fig 5(c) 3D Polar plot of gain of U-Shape **Fig 5(d)**3D polar plot of Directivity of U-Shape

Fig 6 (a),(b) shows Return loss, VSWR plot I-Slot DGS Antenna. A return loss of -37.23dB and an increased bandwidth of 440MHz are achieved for I-Shape DGS which was 320MHz for simple MPA. The 3-Dimemnsional gain plot and directivity plot of I shape slot are shown in Fig 6(c) and Fig 6(d) respectively.

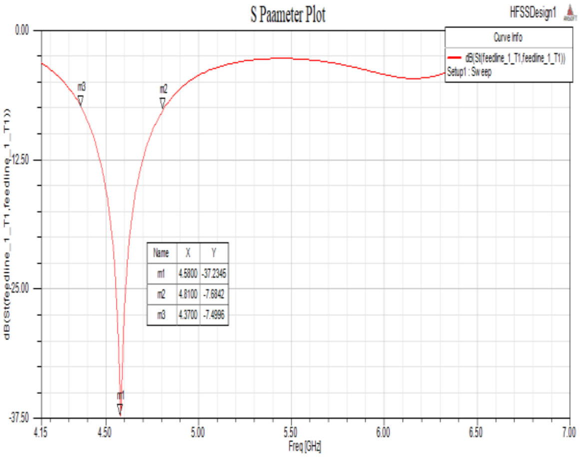


Fig 6(a) Return loss plot of I-Slot DGS Antenna

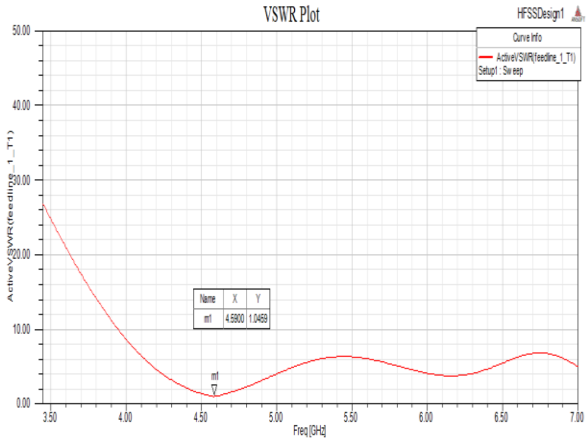


Fig 6(b)VSWR plot of I-Slot DGS Antenna

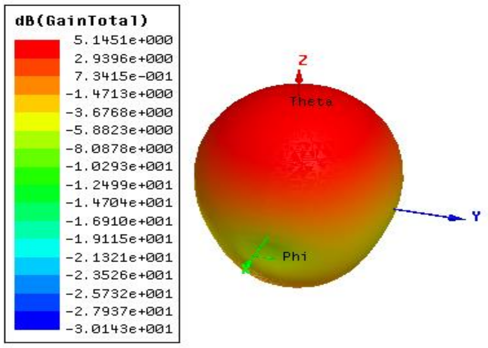


Fig 6(c) 3-Dimensional gain plot

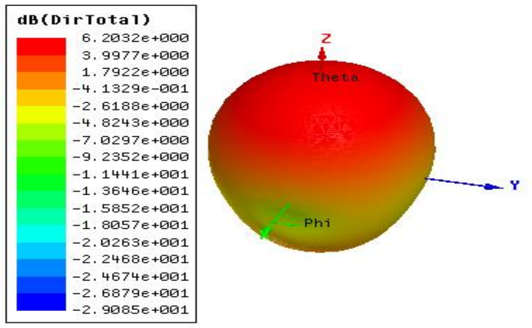


Fig 6(d) 3-Dimensional directivity plot of I-Shape

Fig 7(a),(b) shows Return loss, VSWR plots of E -Slot DGS Antenna. An improved return loss of -41.37 dB and an increased bandwidth of 340MHz are achieved for E -Shape DGS which was 320MHz for simple MPA.The 3-Dimemnsional gain plot and directivity plot of E shape slot are shown in Fig 7(c) and Fig 7(d) respectively.

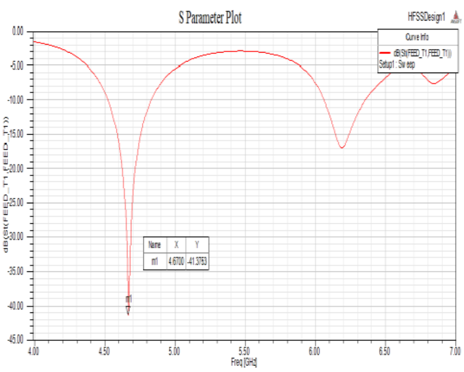


Fig7(a) Return loss plot of E-Slot DGS Antenna

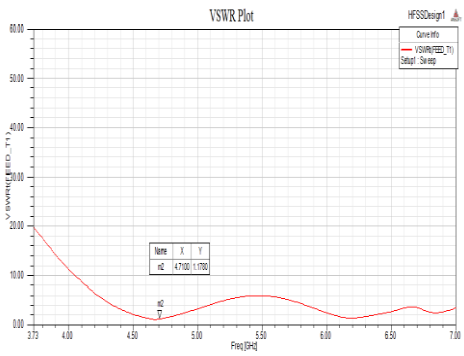
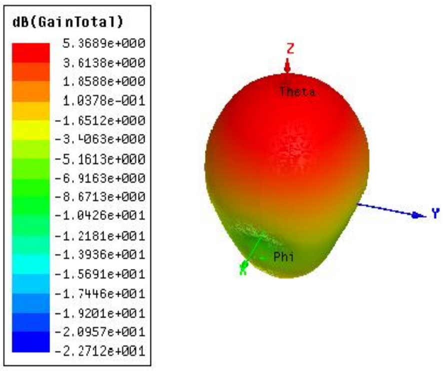


Fig.7(b)VSWR plot of E-Slot DGS Antenna



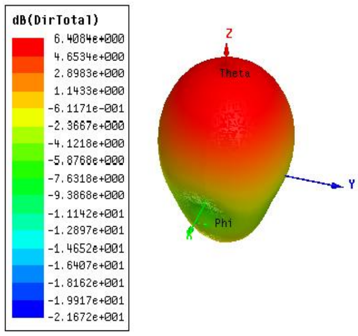
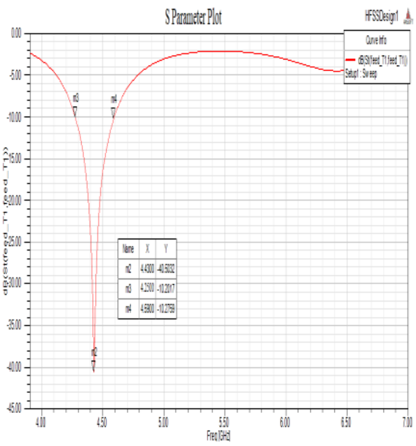


Fig 7(c) 3-Dimensional gain plot   Fig 7(d) 3-Dimensional directivity plot of E-Shape

Fig 8(a),(b) shows Return loss, VSWR plot of Square -Slot DGS Antenna. An improved return loss of -40.50 dB and an increased bandwidth of 340MHz are achieved forSquare -Shape DGS which was 320MHz for simple MPA.The 3-Dimemnsional gain plot and directivity plot of square shape are shown in Fig8(c) and Fig 8(d) respectively.



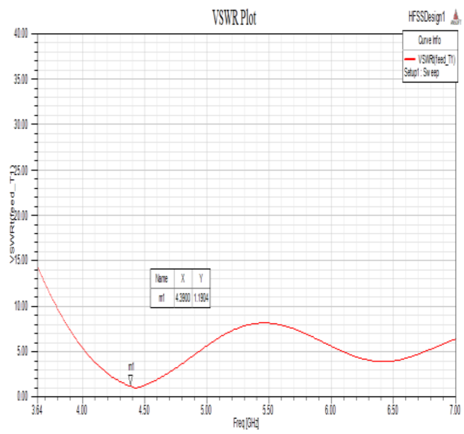
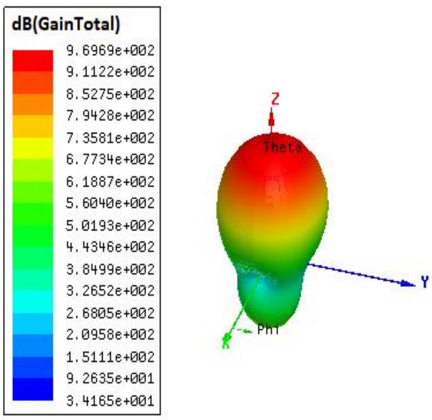


Fig8 (a) Return loss plot Square-slot DGS   Fig8(b)VSWR plot of Square-Slot DGS Antenna



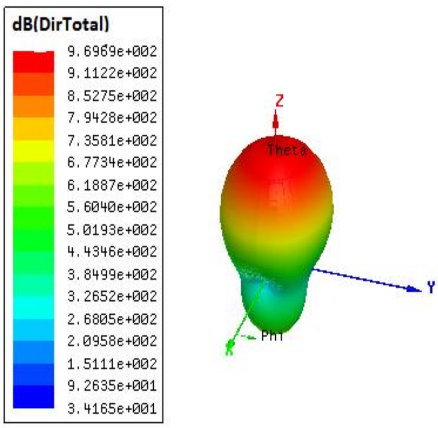


Fig 8(c) Dimensional gain plot   Fig 8(d) 3-Dimensional directivity plot of Square shape

IV. CONCLUSION

Five different shapes of defects or slots on ground plane of patch antenna working in C-Band have been successfully implemented in this paper. A simple MPA provides a Return loss (S_{11}) of -23.49dB but the results obtained in this paper showed that by adding slots in the ground plane of simple microstrip patch antenna, return loss can be enhanced upto -41.37dB. Hence the proposed DGS structures resulted in best performance parameters in terms of its return loss and bandwidth. All results are taken using HFSS simulator.

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