Improved Performance of Patch Antenna based on Comparative Analysis between Fractal Geometry and Defected Ground Structure

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Abstract— In recent years, the demand for compact handheld communication devices has grown significantly. Devices having internal antennas have appeared to fill this need. The aim of this paper is to increase the performance of the gain. The proposed antenna has a size of 16.44×23.3×1.35mm³ including the ground plane and it is designed on FR4Epoxy substrate with dielectric constant of 4.4. The proposed antenna is characterized by a compact size and it is Inset feed and also the proposed work includes modifications of antenna ground plane called Defected Ground Structure (DGS). In this project we are going to implement the Design and Comparative analysis on the performance characteristics of Inset feed patch antenna with fractal geometry and Inset feed patch antenna with defected ground structure. The proposed antenna's simulation is carried out using finite element method based Ansoft High Frequency Structural simulator (HFSS). After simulation the antenna performance characteristics such as return loss, gain, VSWR, and Directivity are analysed.

Index Terms— Multi Band, Fractal Geometry, Microstrip Patch, Defected Ground.

I. INTRODUCTION

In telecommunication, a microstrip antenna (also known as a printed antenna) usually means an antenna fabricated using microstrip techniques on a printed circuit board (PCB). An individual microstrip antenna consists of a patch of metal foil of various shapes (a patch antenna) on the surface of a PCB, with a metal foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array [2]-[3].

Microstrip patch antennas are more popularly used now a days due to its various advantages such as light weight, less volume, compatibility with integrated circuits ,easy to install on the rigid surface and low cost. Microstrip patch antennas are design to operate in dual-band and multi-band application either dual or circular polarization. These antennas are used in different handheld communicating devices. The most commonly employed microstrip antenna is a rectangular patch which looks like a truncated microstrip transmission line [4].

Modern telecommunication systems require the antenna with wider bandwidth and smaller dimension than conventionally possible Fractal antenna's shape depends on the properties of the self-similarities and space filing. There are many fractal geometries that have been found to be useful in developing new and innovative a 2-dimensional. However, microstrip patch antennas are having narrow bandwidth and bandwidth enhancement is necessary for most of the practical applications, so for increasing the bandwidth different approaches have been utilized. Defected Ground Structure is one of them. In addition most of the applications which uses microstrip antenna in communication systems like mobile handheld communicating devices require smaller antenna size. Different advance tools to the design of very compact microstrip patch antennas have been introduced over the last few years [5]-[11].

II. INSET FEED ANTENNA

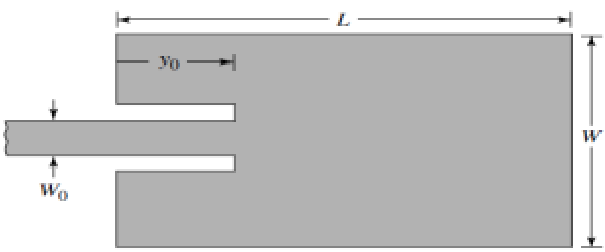

Fig 1: micro strip patch antenna

2.1 Design procedure:

The fundamental rectangular Inset feed printed antenna design is shown in figure. The substrate has been designed on FR4 epoxy of relative permittivity =4.4 and thickness h =1.35mm. As shown in Fig. 1, the dimension of substrate is 46.44 mm x 53.3 mm. The ground plane is also chosen to be rectangle with the dimensions of 46.44 mm x 53.3 mm. For exciting the operating frequencies at around 3.9 GHz.

Design specifications:

The three essential parameters for the design of a rectangular Microstrip Patch Antenna:

Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. The Mobile Communication Systems uses the frequency range from 2 to 11GHz Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 3.9 GHz.

Dielectric constant of the substrate (ε_r): The dielectric material selected for our design is FR4epoxy which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

Height of dielectric substrate (h): For the micro strip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.35 mm.

Hence, the essential parameters for the design are: [1]-[2]

- f_o= 3.9 GHz
- ε_r = 4.4
- h=1.35mm

Step1: Calculation of the Width (W):

The width of the Microstrip patch antenna is given as:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

Where, c is the free space velocity of light.

Substituting C=3×10^11mm, f=3.9 GHz and εr=4.4

We get W=23.3mm

Step 2: Calculation of Effective dielectric constant (*εreff*):

The effective dielectric constant is:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+\frac{12h}{W}}} \quad (2)$$

Substituting εr =4.4, h=1.35 mm,

W=23.3mm

We get εreff =4.9

Step 3: Calculation of the Effective length (Leff):

The effective length is:

$$`L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

Substituting C=3×10^11mm, f=3.9 GHz and εreff =4.9

We get L_{eff} =17.64mm

Step 4: Calculation of the length extension (Δ*L*):

The length extension is:

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Substituting W=23.3mm, h=1.35mm, εreff =4.9

We get ΔL=0.6mm

Step 5: Calculation of actual length of patch (*L*):

The actual length is obtained by:

$$L = L_{eff} - 2\Delta L \quad (5)$$

Substituting εreff =4.9, C=3×10^11mm, f=3.9 GHz, ΔL=0.6mm

We get L=16.44mm

Step 6: Calculation of the ground plane dimensions ($L_g$andW_g):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by those similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L \quad (6)$$

Substituting h=1.35mm, L=16.44mm

We get L_g =46.44mm

$$W_g = 6h + W \quad (7)$$

Substituting h=1.35mm, L=16.44mm we get $W_g = 53.3mm$

The design of the inset feed patch antenna was shown below.

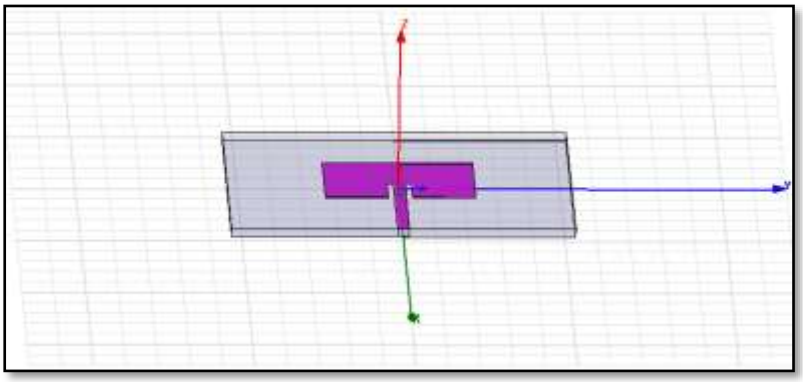

Fig 2: Designed micro strip patch antenna

2.2 Simulation results :

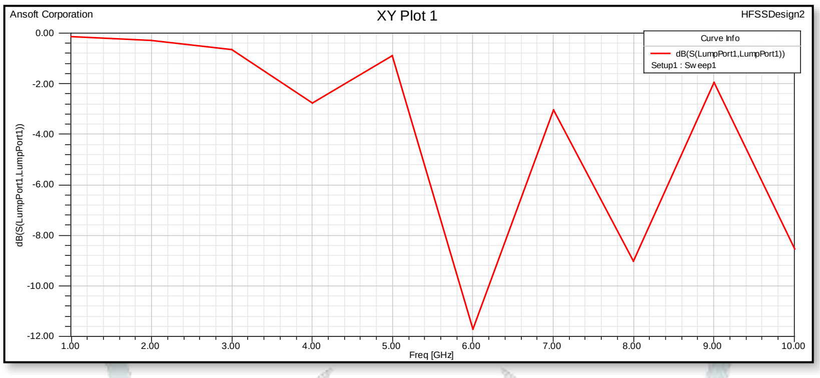

Fig 3: 2D Rectangular plot for Return loss

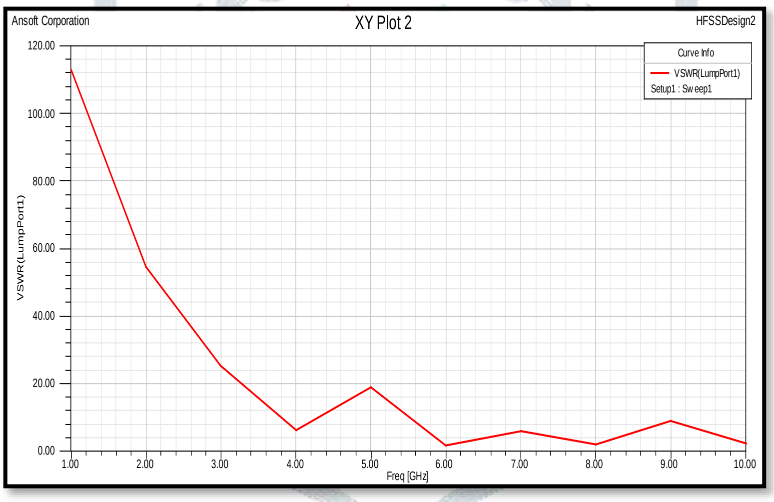

Fig4:2D rectangular plot for VSWR (dB)

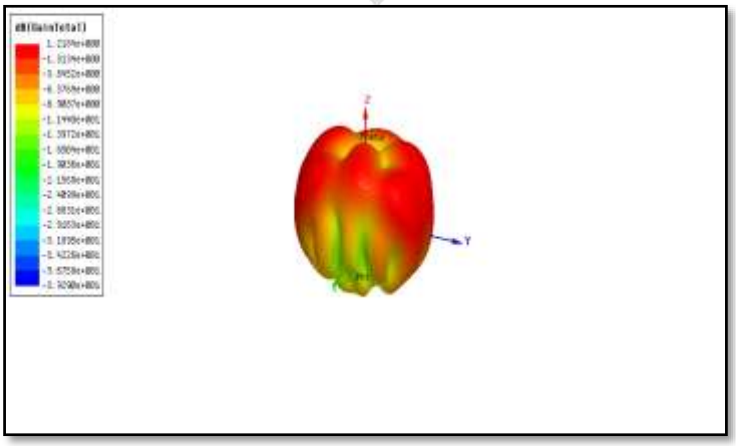

Fig 5: 3D Gain plot

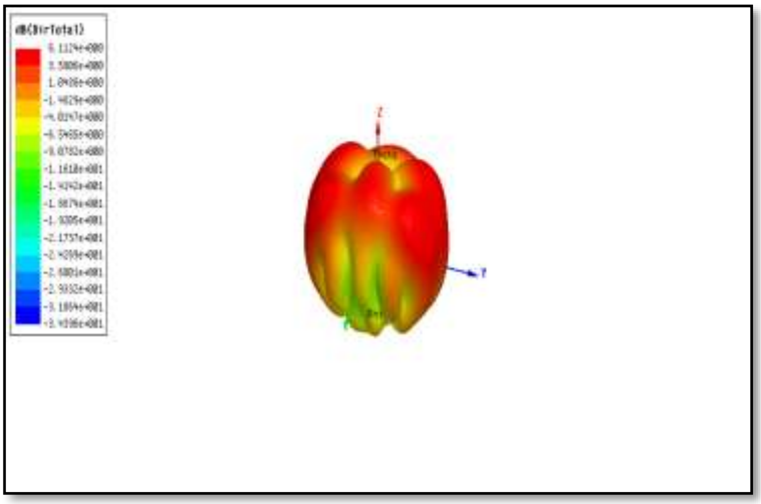

Fig 6: 3D Directivity plot

III. INSET FEED PATCH ANTENNA WITH FRACTAL GEOMETRY

In modern wireless communication systems wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications [5]. This has initiated antenna research in various directions; one of them is using fractal shaped antenna elements. Traditionally, each antenna operates at a single or dual frequency bands, where different antennas are needed for different applications. Fractal shaped antennas have already been proved to have some unique characteristics that are linked to the various geometry and properties of fractals. Fractal geometry has unique geometrical features occurring in nature. It can be used to describe the branching of tree leaves and plants, rough terrain, jaggedness of coastline, and many more examples in nature. Fractals have been applied in various field like image compression, analysis of high altitude lightning phenomena, and rapid studies are apply to creating new type of antennas. Fractals are geometric forms that can be found in nature, being obtained after millions of years of evolution, selection and optimization. There are many benefits when we applied these fractals to develop various antenna elements. By application of fractals to antenna elements: [6]-[8]

- We can create smaller antenna size.
- We achieve resonating frequencies that are multiband.
- Optimize for gain.
- Achieve wideband frequency band or multiband frequencies.

The design of the inset feed patch antenna with fractal geometry and the simulated results are shown.

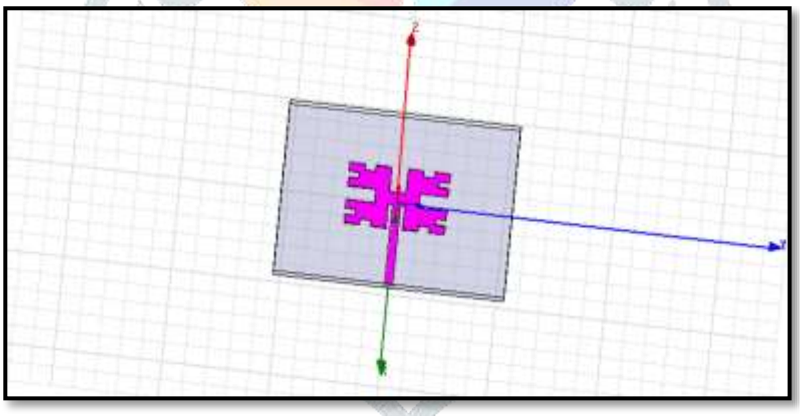

Fig 7: Designed fractal antenna

3.1 Simulation results:

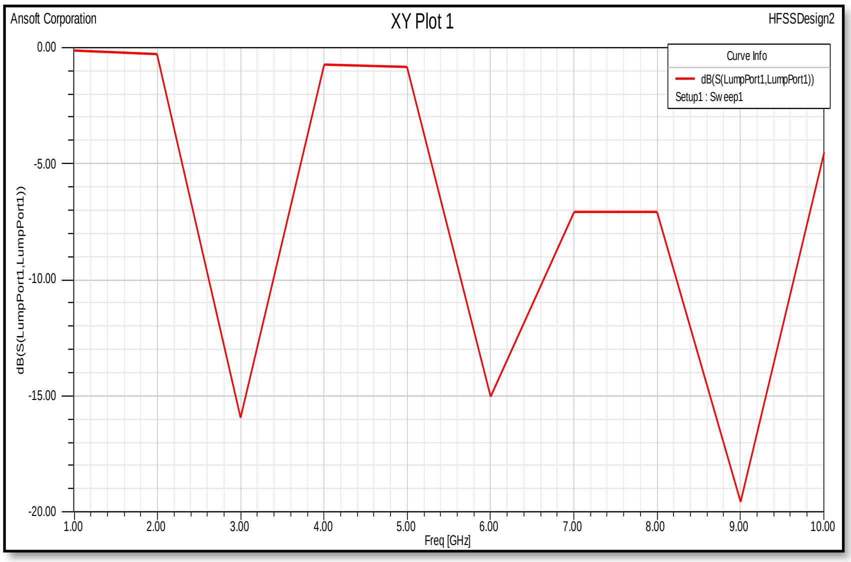

Fig 8: 2D rectangular plot for return loss

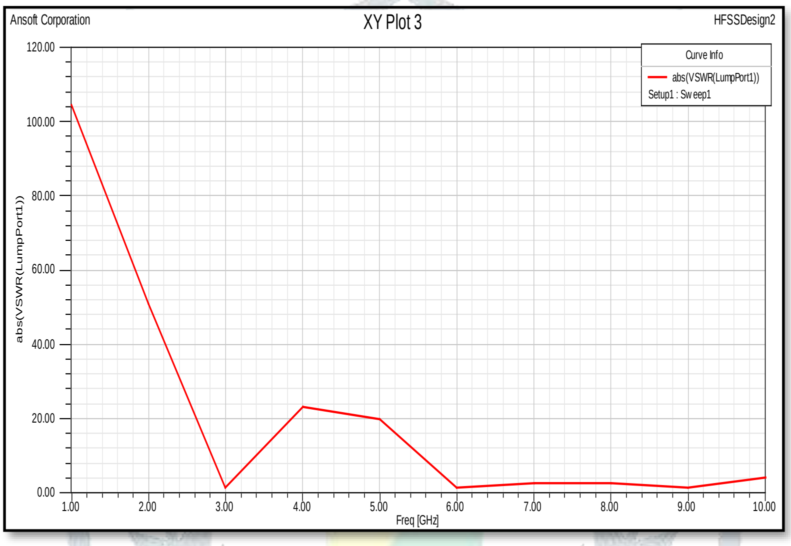

Fig 9: 2D rectangular plot for VSWR (dB)

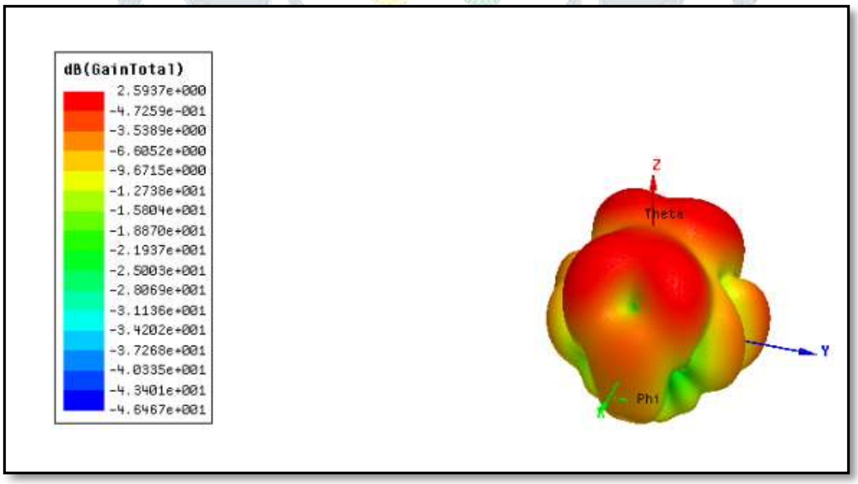

Fig 10: 3D gain plot

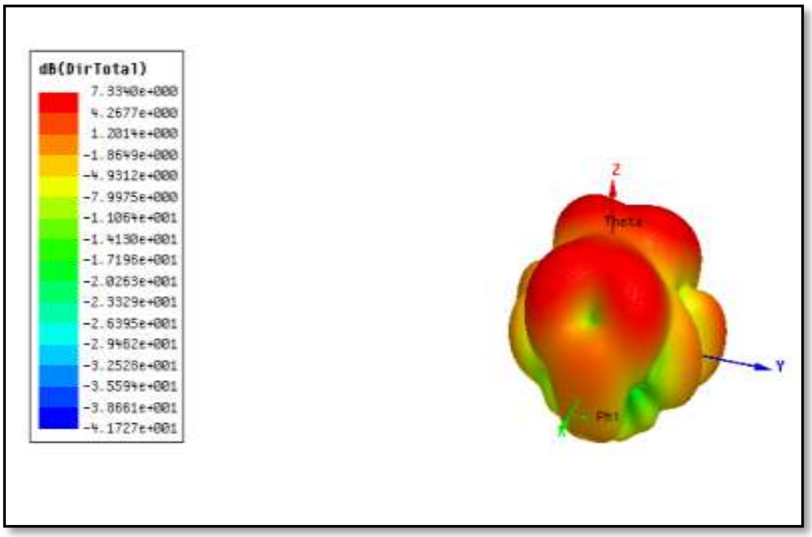

Fig 11: 3D Directivity plot

IV. INSET FEED PATCH ANTENNA WITH DEFECTED GROUND STRUCTURE

Microstrip patch antennas inherently have narrow bandwidth and bandwidth enhancement is usually demanded for practical applications, so for extending the bandwidth many approaches have been utilized. In addition some applications of the microstrip antenna in communication systems required smaller antenna size in order to meet the miniaturization requirements. So significant advances in the design of compact microstrip antennas have been presented over the last years [9]-[11]. Defected Ground Structure is one of the methods which is used for this purpose. The defect in a ground is one of the unique techniques to reduce the antenna size. So design the antenna with the defected ground structure, the antenna size is reduced for a particular frequency as compared to the antenna size without the defect in the ground. DGS is realized by introducing a shape defected on a ground plane thus will disturb the shielded current distribution depending on the shape and dimension of the defect. Many shapes of DGS slot have been studied in planar microstrip antenna designs, which provide many good performances such as size reduction (resonant frequency lower), impedance bandwidth enhancement (quality factor lower) and gain increasing. The compact, broadband microstrip antenna with defective ground plane has been realized in the impedance bandwidth of the proposed antenna could reach about 4.3 times that of the conventional microstrip antenna [12]-[13].

The etched design of the defected ground structure on the inset feed patch antenna was the [E+T] shape. The design and analysis of the shape was shown below.

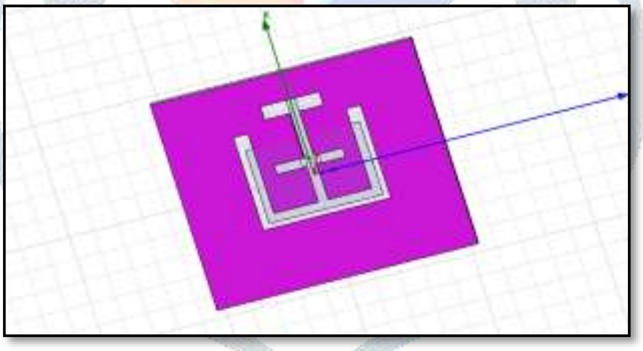

Fig 12: Designed antenna with DGS

4.1 Simulation results:

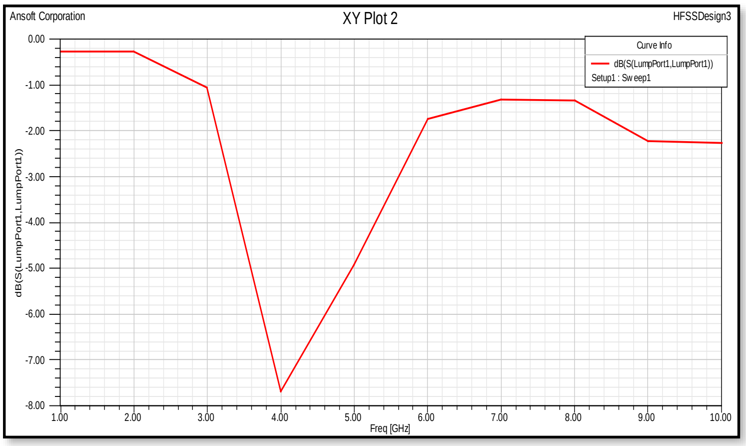

Fig 13: 2D Rectangular plot for return loss

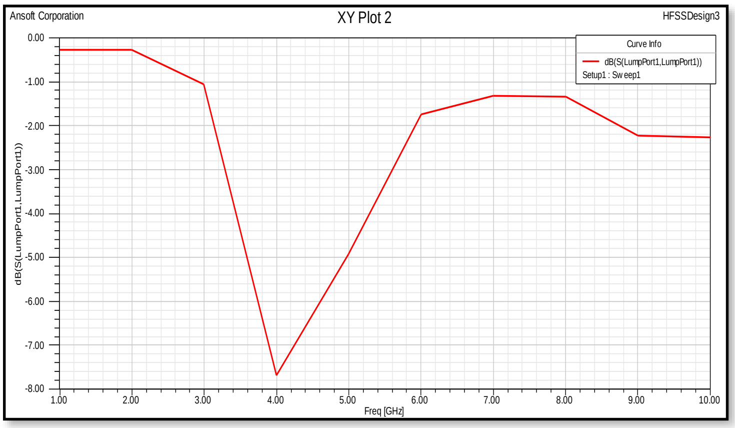

Fig 14: 2D Rectangular plot for VSWR

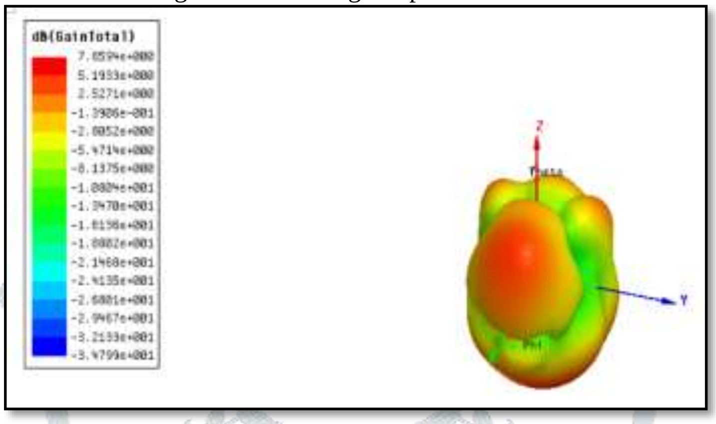

Fig 15: 3D Gain plot

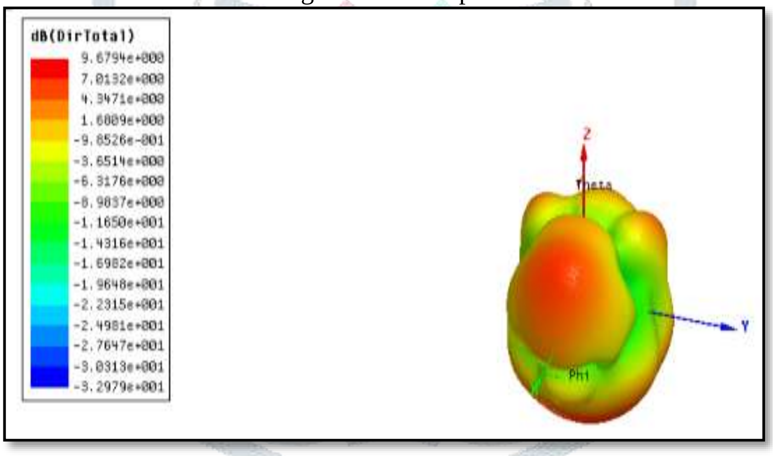

Fig 16: 3D Directivity plot

V. COMPARATIVE ANALYSIS OF THE INSET FEED PATCH ANTENNA

The analysis of the inset feed antenna with the fractal geometry and the inset feed antenna with the defected ground structure was shown in the tabular format.

Table 5.1: comparative analysis

Parameters	Inset Feed	Inset Feed with Fractal Geometry	Inset Feed with Defected Ground (E + T shape)
VSWR	10	20	5
GAIN	1.2 dB	2.5 dB	7.8 dB
DIRECTIVITY	6.1 dB	7.2 dB	9.6 dB
RETURN LOSSES	-2.25 dB	-4.5 dB	-6.8 dB

As shown in the table the performance of the inset feed patch antenna with DGS was better compared with fractal. The VSWR, return loss, gain was improved.

VI. Conclusion

In this paper we have designed and compared the simulated results and performance characteristics of Inset feed patch antenna with and without fractal geometry and Defected ground structure. The analysis of the inset feed patch antenna with defected ground structure gives the better results than the inset feed patch antenna with and without fractal geometry. The gain improved from 1.2dB to 7.8dB and the return loss from -2.25dB to -6.8dB. There is a reduction in size of antenna. It is also observed that there is a drastical decrement of the VSWR from 10 to 5. VSWR and Gain are better for this design.

References

[1] Ch. Bindu madhavi, Sunanda, Praveen, Dr E. Kusuma Kumari, Smt. D. Rama Devi, "Design and Analysis of inset feed rectangular microstrip patch antenna with and without fractal geometry for wideband applications", International Journal of Engineering Technology Science and Research , ISSN 2394 – 3386. Volume 2 Issue 3. March 2015.

[2] Lee, Kai Fong, Luk, Kwai Man (2011). Microstrip Patch Antennas. World Scientific. pp. 8–12. ISBN 184816453X.

[3] Bancroft, R. Microstrip and Printed Antenna Design Noble Publishing 2004, chapter 2-3.

[4] M. Manohar, Rakhesh Singh Kshetrimayum, A. K. Gogoi, "Printed Monopole Antenna with Tapered Feed Line, Feed Region and Patch for Super Wideband Applications," IET Microwaves, Antennas and Propagation, vol. 8, no. 1, pp. 39-45, January 2014

[5] Hitesh H. Mathukiya, Vishal M. Chudasama , Mahendra G. Mathukiy , " Implementation and analysis of Microstrip patch antenna using Fractal geometry for multiband wireless applications", International Journal of Engineering Associates (2320 – 0804) / #21 / Volume 2 Issue 6 , pp.21-23.

[6] C. Puente, J. Romeu, R. Bartoleme, and R. Pous, "Fractal multiband antenna based on Sierpinski gasket," Electron. Lett, vol. 32, pp. 1-2, 1996.

[7] Douglas H.Werner and Suman Ganguly "An overview of Fractal Antenna Engineering Research Communications and Space sciences Laboratory", Department of Electrical Engineering. The Pennsylvania state University, University Park, PA16802 USA.pp38-57.

[8] Yao Na and Shi Xio-wei," Analysis of the Multiband behaviour on Sierpinski Carpet Fractal Antenna, "National Laboratory of antennas and Microwave Technology, Xiadian University, APMC Proc 2005.

[9] P.A. Nawale, and Prof. R.G. Zope, "Rectangular Microstrip Patch Antenna for 2.4 GHz Communication Using Defected Ground Structure", International Journal of Advance Foundation and Research in Computer (IJAFRC) Volume 2, Issue 1, January 2015. ISSN 2348 - 4853, pp.1-11.

[10] International Journal of Computer Applications (0975 – 8887) Volume 73– No.9, July 2013 Microstrip Patch Antenna with Defected Ground Structure for Bandwidth Enhancement Gurpreet Singh, Rajni, Ranjit Singh Momi.

[11] International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012 2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth Rajeshwar Lal Dua, Himanshu Singh, Neha Gambhir.

[12] RajeshwarLalDua, Himanshu Singh, "2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth", IJSCE, ISSN: 2231-2307, Volume-1, January 2012.

[13] Antenna with Defected Ground Structure (DGS) for WLAN Application", IOSR-JECE, ISSN: 2278-2834-, ISBN: 2278-8735.