

**DESIGN AND DEVELOPMENT OF MULTIBAND FRACTAL
ANTENNA FOR WIRELESS APPLICATIONS**

*Thesis submitted in partial fulfilment of the requirement for the
award of the degree of*

MASTER OF ENGINEERING
In
WIRELESS COMMUNICATION

Submitted by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION
ENGINEERING**

THAPAR UNIVERSITY, PATIALA

(Established under the section 3 of UGC Act, 1956)

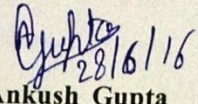
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June 2016

DECLARATION

I Ankush Gupta, hereby, declare that the work presented in the thesis entitled "Design And Development Of Multiband Fractal Antenna For Wireless Applications" by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Wireless Communication from Thapar University, Patiala, is an authentic record of my own work under the supervision of Dr. Hem Dutt Joshi, Assistant Professor, Electronics and Communication Engineering Department. The matter presented in this thesis has not been submitted in any other University/Institute for the award of any other degree.

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This is to certify that the above statement made by the student is correct to the best of my knowledge and belief.

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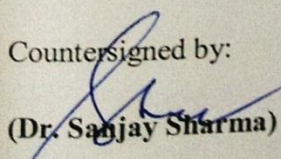


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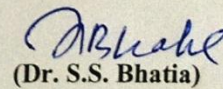
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ACKNOWLEDGEMENT

The real spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy supervisor and the Program Coordinator of Wireless Communication, **Dr. Hem Dutt Joshi**, Assistant Professor, Department of Electronics and Communication Engineering, Thapar University, Patiala for his valuable guidance in carrying out work under his effective supervision, encouragement, enlightenment and cooperation. Most of the novel ideas and solutions found in this thesis are the result of our numerous stimulating discussions. His feedback and editorial comments were also invaluable for writing of this thesis.

I shall be failing in my duties if I do not express my deep sense of gratitude towards **Dr. Sanjay Sharma**, Professor and Head of the Department of Electronics and Communication Engineering, Thapar University, Patiala, and **Dr. Rajesh Khanna**, Professor, Department of Electronics and Communication Engineering, Thapar University, Patiala, who have been a constant source of inspiration for me throughout this work, and for providing us with adequate infrastructure in carrying the work.

I would like to thank all friends who supported me throughout the course of this work. I would like to pay my gratitude towards my parents, who have always supported me in doing the things my way and whose everlasting desires, encouragement, affectionate blessings and help made it possible for me to complete my degree. I would also like to render my gratitude to the Almighty God who bestowed self-confidence, ability and strength in time to complete this task and for not letting me down at the time of crisis and showing me the silver lining in the dark clouds.

At last but not the least I would like to thank all those who have provided their help in a direct or indirect manner to achieve this goal.

Ankush Gupta

ABSTRACT

In today's world, the antenna designing plays the major role in design and development of any wireless communication system. In the current scenario, there is a huge demand of both wideband and multiband microstrip patch antennas for various wireless applications. There are number of techniques that can be useful for reducing size and making antenna multiband and wideband which include making use of fractal geometry, use of slot and DGS.

In this report, An X shaped patch antenna has been designed and fractal geometry has been applied in order to obtain self-similar characteristics. Different iterations have been carried out to achieve required bands. X shape is simpler in design as compared to traditional fractal shapes of Koch curve, Sierpinski carpet etc. Initially an X shaped fractal patch with a dimension 108 mm X 88 mm having ground plane of width 20 mm has been designed. FR4 is used as the substrate material having thickness of 1.6 mm. This antenna can operate over the frequency range of 5.2 GHz to 7 GHz. Thus, showing the wideband characteristics. Further in the thesis, use of Defected Ground Structure (DGS) in reducing the total size of antenna is shown by cutting two vertical I shaped slots in the ground plane and varying the width of ground plane. Parametric analysis of various parameters like no of slots, slots length, width of ground plane, substrate material and feed line length has been carried out in order to optimize the results. From parametric analysis we finally obtained two antennas.

First is reduced version of initially proposed antenna having same wide band characteristics with percentage bandwidth of roughly 28.8 percent and dimensions of 94mm X 88 mm. Thus, there is net 13 percent reduction in size. Antenna resonates at four bands of 3.6 GHz, 5.5 GHz, 5.95 GHz and 6.5 GHz. This antenna has good directivity of 4.36dBi, 7.13 dBi, 5.52 dBi and 5.55dBi. This antenna covers various applications like WiFi bands (IEEE802.11a), Fixed satellite radio transmission, vehicular communication systems (IEEE802.11P), licensed band (IEEE802.11y), cordless telephony.

Second is having multiband characteristics and it resonates at four bands of 2GHz, 3.5GHz, 4.9GHz, 6GHz. This antenna has good directivity of 3.23dBi, 4.3dBi, 5.95dBi, 6.5dBi respectively. This antenna covers various applications like Public safety WLAN, WiMAX applications, Earth to space communication and future 5G telecommunication.

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LIST OF ACRONYMS

CDMA	Code Division Multiple Access
CP	Circular Polarization
FDMA	Frequency Division Multiple Access
FDTD	Finite-Difference Time-Domain
GPS	Global Positioning System
GSM	Global System for Mobile
GPRS	General Packet Radio Service
HFSS	High Frequency Structure Simulator
IFS	Iterative Function System
ISM	Industrial Scientific and Medical
LAN	Local Area Network
MIMO	Multiple Input Multiple Output
RF	Radio Frequency
RFID	Radio Frequency Identification
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wide Band
VSWR	Voltage Standing Wave Ratio
WLAN	Wireless Local Area Network
WiMAX	Worldwide Interoperability for Microwave Access
WPT	Wireless Power Transmission

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INTRODUCTION

This chapter discusses about basics of antenna, advantage of micro strip patch antenna and fractal antenna. For low profile wireless communication either in form of voice (telecommunication), data (Wi-Fi) antenna plays the major role. Over a period of time, techniques have been developed for optimizing the antenna characteristics. For increasing the bandwidth and for making antenna multiband various techniques like CPW feeding or proximity couple feeding, use of parasitic element, use of L probe with slots and fractal techniques etc. have been used[1]. For Wideband characteristics different kind of antenna Biconical, Monopole Antenna, Slot type UWB Antennas or Fractal UWB Antennas are used [2]. For reducing the size of antenna various size reduction techniques like using parasitic elements [3], shorted pins, shaped slots [4,5] or post-gap [6] ,Coplanar Waveguide(CPW) feed[7] etc. came over a period of time. But all these techniques have some drawbacks such as poor efficiency, high Cross polarization, low gains and low bandwidth higher complexity etc. In the current scenario small, simple in design, compatible and affordable micro strip patch antennas are being the important area of research

Fractal geometries have two basic properties that make them different from others: space-filling and self-similarity [8].Use of fractal geometry makes the structures self-repeating in themselves which makes them multiband band; increases there electrical length for the same physical area which helps in reducing antenna size for lower resonant frequencies; makes the sharp corners in geometry which helps in increasing directivity and efficiency. Fractal geometry that is used in this thesis report is Simple X shaped fractal patch. Due to use of fractal geometry in antenna formation we increased electrical length due to which more number of frequency bands is obtained with net reduction in size. Defected Ground Structure (DGS) has been used in the presented antenna to enhance wideband and multiband feature of proposed antenna with net reduction in size. Proposed antenna is then fabricated to validate the results. Fabrication is done by etching the negative of designed antenna element and ground structure on Printed Circuit Board.

1.1 Description and Working of Antenna

The antenna act like transitional structure which converts one form of energy into other, by acting like a medium between guiding devices and free- space [9]. It is a device which converts electrical signal energy given to it into Electromagnetic waves which can travel through free space without the help of any medium and vice -versa. With reference from IEEE, “Antenna can be viewed as a device used to radiate or receive e.m. waves within a transmitting or receiving system”. These are 3-D structures and can be measured in terms of beam area, square degree, Ste radians, and solid angle. It has three polarizations: linear, circular and elliptical. Figure 1.1 shows the working of antenna where transition from a guided wave to a free-space wave is taking place at transmitter side and transition from a space wave to a guided wave is taking place at receiver end and. Thus, Antenna acts like a transducer or a wireless link or a between the transmitting and receiving antennas.

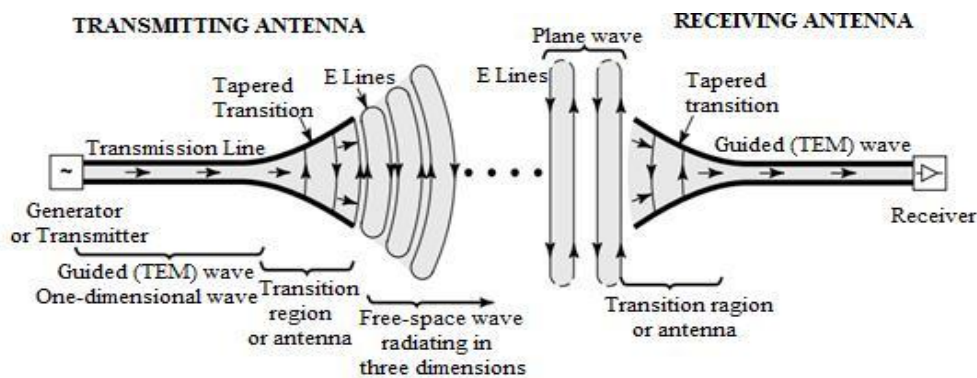


Figure 1.1 Wireless Connection showing Transmitting and Receiving Antenna [10].

1.2 Parameters To Measure Antenna’s Performance

Various parameters of antennas play major role for designing an efficiently radiating antenna .The few antenna parameters are [9]:

Return Loss: The return loss (RL) can be defines as logarithmic ratio (in dB) between the reflected power and the power which is given to the antenna by the help of transmission line. It is measured in db. It is the best way to find the resonating frequency of antenna, as at resonating frequency maximum power will be transferred hence we will get minimum return loss for those values. The RL is defined as equation 1.1

$$Return Loss = -10 \log_{10} \left| \frac{P_{ref}}{P_{inc}} \right| \quad (1.1)$$

Where, P_{ref} = Amount of power reflected

P_{inc} = Amount of power incident

Practically, return loss value should be less than minus ten dB [8].

Gain: The gain of antenna plays a major role in measuring antenna performance thus our main concern is to increase the gain of antenna. Gain can be defined as “The ratio between the radiation intensity in a particular direction with the radiation intensity if isotropic antenna is used.” It can be calculated by equation 1.2. Gain can also be defined as simply the product of efficiency and directivity.

$$Gain = 4 \times \pi \times \frac{U(\alpha, \beta)}{P_{inc}} \quad (1.2)$$

Where, $U(\alpha, \beta)$ = Radiation intensity.

Directivity: Directivity shows how much antenna can focus the radiated energy. It is the ratio of the radiation intensity in a particular direction with that if it is averaged over all direction”. If antenna is ideal without having losses then both Gain and Directivity are having same value. Directivity can be defined by the equation 1.3

$$Directivity = \frac{U_a}{U_{iso}} = \frac{4\pi U_a}{P_{rad}} \quad (1.3)$$

Where U_a = Radiation Intensity by the antenna;

U_{iso} = R.I. due to an isotropic source

P_{rad} = Overall power radiated by antenna. Directivity is calculated in terms of dBi.

Voltage Standing Wave Ratio: It shows impedance matching of transmission line with the antenna. It can be expressed in terms of reflection coefficient. It tells the amount of power which will get reflected from the antenna due to improper matching of transmission lines with receiving antenna. VSWR in term of return loss is shown by equation 1.4

$$VSWR = \frac{(1 + |S|)}{(1 - |S|)} \quad (1.4)$$

Here S is the reflection coefficient. For fully matched circuit VSWR is having unit value and VSLR is always a real number for any type of circuit.

Bandwidth: Bandwidth of an antenna can be viewed as a range of frequencies over which antenna work and have certain set of specification performance criteria. Graphically it is measured as range of frequency where return loss plot is having value less than minus ten db.

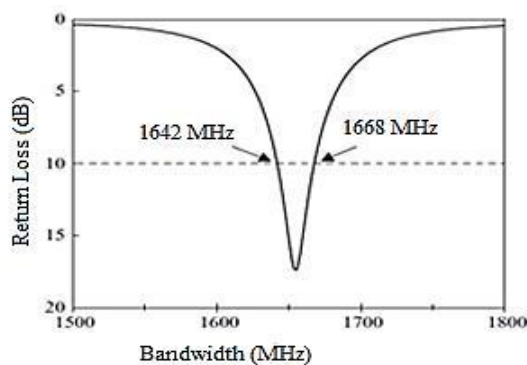


Figure 1.2 Bandwidth of Antenna

In Fig 1.2 Bandwidth is $1668\text{MHz} - 1642\text{MHz} = 26\text{ MHz}$

Radiation Pattern: Radiation pattern can be expressed as way to Graphical represent antenna radiation pattern in the form of a function of space coordinates. Pencil beam, fan beam pattern, Isotropic Pattern and Principal Plane Patterns are some common examples of radiation pattern. Fig 1.3 shows the radiation pattern with major lobe, minor lobe, side lobe and back lobe of the antenna.

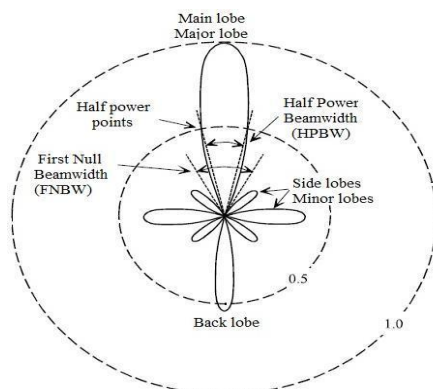


Figure 1.3 Radiation Pattern of Antenna [9]

Front to Back Ratio: It can be defined as the ratio between the front and back direction of

power gain in any directional antenna. In other words we can measure it by ratio of directivity in the forward direction with that in the backward or reverse direction. If we plot the principle plane on relative dB scale, it can be calculated as a difference in dB level in the direction of maximum radiation and in direction of 180 degrees to it.

1.3 Fractal Geometry

Fractals mean broken or irregular pieces having self-similarity in design. These are created using iterated function system (IFS) which is simply a feedback process, in which a generator shape is taken, as a input for the mapping function, and its output will act as input for the next iteration [11]. Therefore, a fractal antenna may be iterated many times to satisfy the space-filling properties and self-similarity property of the fractals. It can be mathematically expressed as

$$\xi = \frac{h_n}{h_n + 1} \tag{1.5}$$

Where, ξ is the scale factor ratio, h_n is the height of iterated antenna where n represents the iteration number [12].

Using this, many antenna configurations have been developed over a period of time like Koch, Sierpinski Carpet, Minkowski, Hilbert, Sierpinski Gasket and Fractal trees.

1.4 Development of Fractal Geometries

Fractal geometries started to get its mathematic explanations in early 17th century, when recursive self-similarity properties are being considered by philosopher and mathematician, Leibniz. However by 1872 Karl Weierstrass gave a function having non-intuitive property of being continuous everywhere but nowhere differentiable. However, in 1904 a better geometric definition known as Koch snowflake for a similar function is given by Helge von Koch. By 1915, Waclaw Sierpinski gave his first triangle based fractal geometry and within a year one more carpet shaped fractal geometry. Further, by 1938, Paul described space curves and surfaces named as the Levy C curve, which consist of part similar to the whole new fractal curves.

By the 1960s, Benoit Mandelbrot based on earlier work of Lewis Fry Richardson, started finding the self-similarity in papers, statistical self-similarity and fractional dimensions. Finally in 1975, Mandelbrot named all objects whose Hausdorff-Besicovitch dimensions are greater than its topological dimensions by the word ‘fractalo’, which were illustrated by striking computer-construct visualizations. This leads to the term fractal with its popular meaning [28-33].

1.5 Fractal as antenna and its Characteristics

A fractal antenna is the type of antenna that utilizes fractal geometry or design to increase the electrical length that transmit/receive electromagnetic signals. It has two most important characteristics of space filling and self-similarity. Because of this, the fractal antennas are compact in size and have wide applications in various modern communication devices such for GPS, Bluetooth, Wi-Fi, cellular telephony etc. [8]

The fractal geometries have two important characteristics that make them so much practically usable.

a) Self-similarity

The basic property which fractal shows is due to its geometrical behaviour of showing self-similarity. Self-similarity means a structure is made up of sub-units which will match the structure of the whole object. If the fractal pattern is enlarged or shrieked with equal ratio, then its appearance will remain unchanged. However these properties do not hold indefinitely in practical world. There are some lower and higher bounds limits over which this self-similar behaviour can be applied. Therefore, Self-similarity can be applied on objects that remain unchanged in their appearance over different scales thus can be associated with fractals easily [19].

b) Space Filling with a Fractal Dimension

Space filling is the other important property of fractal with a fractional dimension D . D is a statistical quantity that tells how a fractal will appear to fill space, as one zooms down to the finer and finer scales. The fractional dimension D can be mathematically defined as:

$$D = \frac{\log(T)}{\log(1/s)}$$

Where, T is the total no. of discrete copies which are similar to C , and C is scaled down by a ratio of s [13].

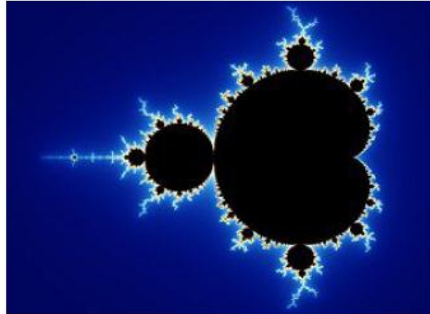
These characteristics of fractals can be exploited to design antennas with following advantages [16-18]:

- a) **Miniaturization:** An antenna can radiate only when it is having size corresponding to the fraction of the wavelength of the transmitting radiation. Therefore, for low frequency operation we have very large antenna. By using the fractional dimensions in any fractals it electrically increases its length but not physically.
- b) **Multiband and wideband antenna:** For any antenna to operate over many frequencies or to be independent of frequency it must have no particular characteristics size or it must have so many characteristics sizes. Due to their self-similarity property, multiple copies of fractal objects are present in a typical fractal antenna, that's why fractal antennas can be used for multiband operations.
- c) **Better efficiency:** Fractal has sharp edges and corners due to which abrupt changes in direction of current occur which enhances the net radiations from antenna. Therefore, they are better and efficient radiators of electromagnetic energy.
- d) **Input impedance matching:** Generally, small antennas have less input impedance and have significant negative input reactance with poor radiation properties, resulting in high expenses and difficulty in matching the input impedance of antenna with their matching network. However, fractal antennas have comparatively smaller input reactance and greater input resistance. Even with dimensions smaller than other common antennas fractal antennas can resonate at same frequencies. Thus, the net cost associated for the matching of input impedance can be reduced.
- e) **Directivity:** Fractals are self-similar structures. Due to sharp cuts, the direction of current changes, due to which there is acceleration of charge hence greater directivity of an antenna is achieved by modelling the antenna in the form of fractal geometry.

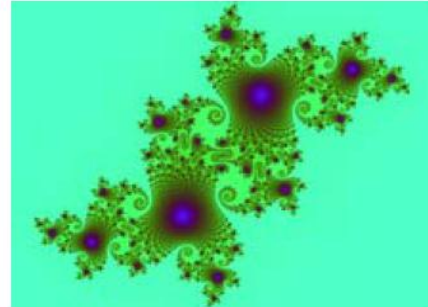
1.6 Key Fractal Geometries

Fractals can be deterministic or random. Most fractal objects that are founded are random in nature. These fractals are created randomly from a set of non-determined steps. Fractals which are

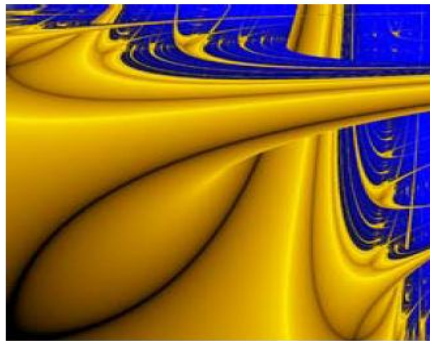
produced artificially by the result of anti-algorithm that are created by successive expansions and translations of the original set are deterministic [13]. Some of the basic fractal geometric structures are shown in Figure 1.4.



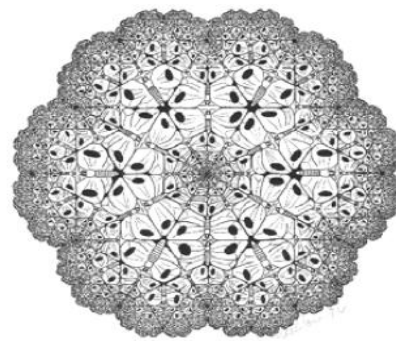
a) Mandelbrot Set



b) Julia Set



c) Lyapunov fractal



d) Escheresque

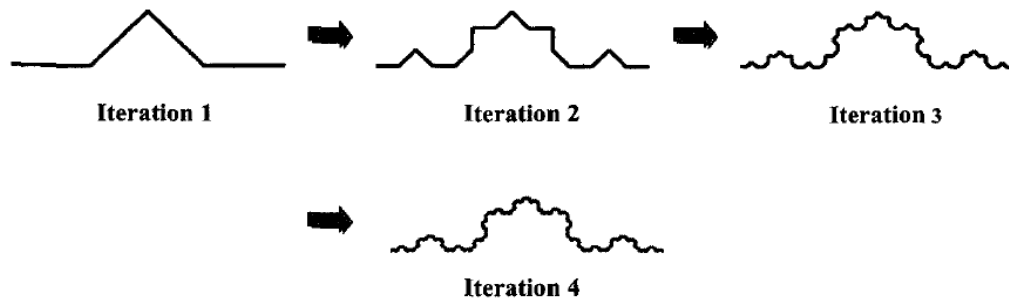
Figure 1.4 Different types of fractal geometries [19].

There are various types of fractal antennas that can be made using different fractal geometries. It is discussed in next section.

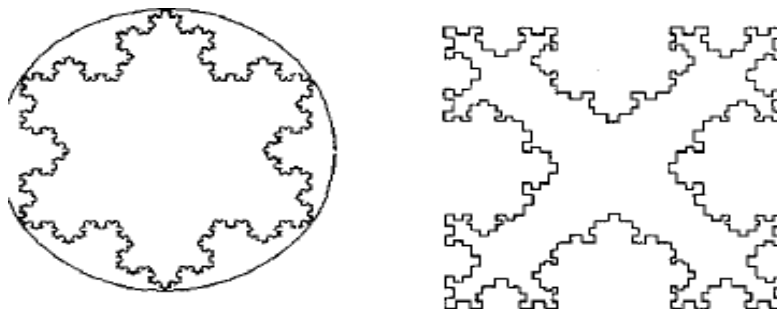
1.7 Types of deterministic Fractal Geometry

1. Koch curve
2. Sierpinski fractal curve
3. Hilbert Curve

1.7.1 Koch Curve



(a)



(b)

Figure 1.5 (a) Basic Koch (b) Koch snowflakes/islands [8]

These are used for the miniaturization of patch antennas, loop antennas and Dipole antennas. Initially process begins from the segment of single length also called the zero generation of the Koch curve. Generator is then divided in three equal lengths. In next step centre part is then divided into two equilateral lines having same length as that of other two partitions. This process goes on and on for an infinite number of times.

1.7.2 Sierpinski gaskets and carpets

A) Sierpinski carpet

The Sierpinski Carpet is also known as a deterministic fractal which is a result of generalization into two dimensions of Cantor set. Initially, for the construction of this fractal, the procedure started by taking a square in a plane, further it is subdivided into nine smaller congruent squares. From these nine squares, the central one (opened) is carried out. Similarly, same process is repeated for each of the remaining eight squares. The process can be continued but it also has limitation from the generalization of the cantor set [14].

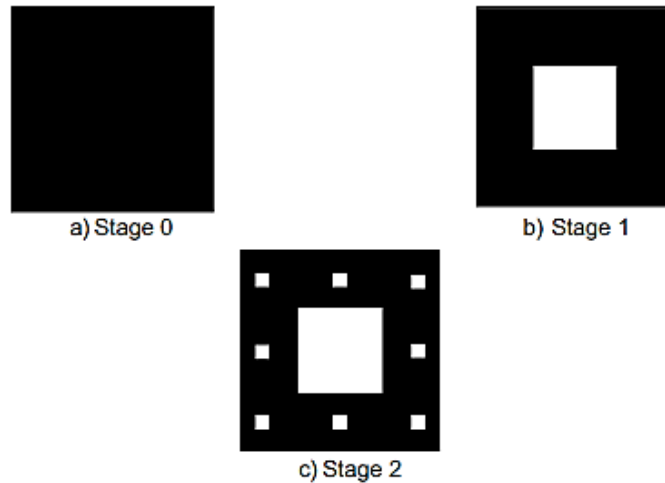


Figure 1.6 Sierpinski Carpet fractal antennas [14]

B) Sierpinski Gasket (Triangle)

In this an equilateral triangle with area A is taken as a generator. Initially a triangle of area $A/4$ is removed which is made by connecting the midpoint of each side of initial triangle. In second step a total of $3A/16$ area is removed by three triangles that are formed by joining the midpoint of triangle of previous step. This similar process goes on and we keep on removing more and more number of Triangles. Thus increasing the perimeter at each stage [14-15].

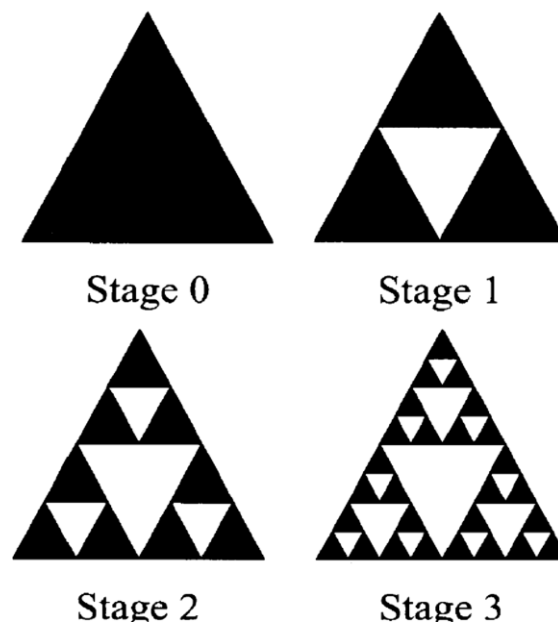


Figure 1.7 Sierpinski Gasket [13]

1.7.3 Hilbert curve:

Hilbert curve have self-similar properties and have simpler structure with an important characteristic that these curves are plane filling curves. The geometries of first few fractal iteration of Hilbert curve are shown in figure 1.8

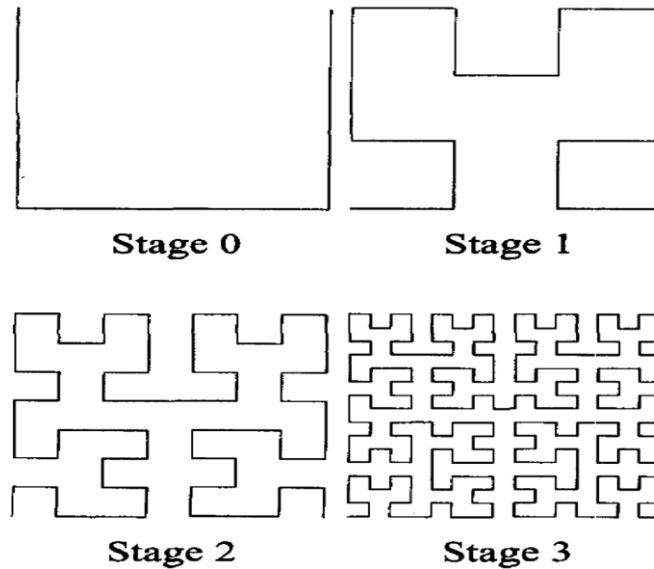


Figure 1.8 Hilbert Curve [8]

This shows that by keeping the area same as we increase the iteration number, the total size of the line segment will increase roughly in the form of geometric progression. This is the main factor that results in relatively lower resonant frequency of Hilbert curves. Thus within a small area we can accommodate a large line length resonant antenna.

1.8 Applications of Fractal Antennas

Fractal patch antennas reduce antenna size and make them multiband and wideband for practical applications. So, a rapid growth in the field of wireless communications in the form of data, voice etc. can be seen in this field. Cell phones, laptops etc. are some of the common examples where we can see the use of fractal antennas. Following are the some applications of fractal antennas.

- Mobile Applications-As For mobile communication there is need of such kind of antenna that can resonate /work for GPS, Wi-Max, GSM, WLAN and UMTS applications single headedly. Thus fractal antennas are completely suitable for mobile applications [20].
- Radio Frequency Identification- RFID applications uses the fractal antennas. RFID reader and tag antenna have fractal antennas in them for traffic toll collection, logistics management and tagometry [9].

- Wideband Applications- Self Similarity and number of iterations make the fractal antenna to show wideband behaviour. So, Fractal antennas suits best for the super and ultra-wideband applications [2].

1.9 Work done in thesis

- Literature survey of various papers on Microstrip patches antenna and Fractal antenna and the research gaps in them.
- Design and Simulation of an X fractal antenna with different Iterations for required bands.
- Parametric study of various parameters like ground width, number of slots, slots length etc. to optimize the results.
- Designing and Fabrication of antenna using Defected Ground Structure to reduce the net size of antenna with wideband characteristics.
- Designing and Fabrication of antenna using DGS and reduced feed line with different parametric variation for multiband applications.

1.10 Organization of Report

Chapter 1 Covers the introduction about antennas and their working. Further, it covers an overview of fractal antenna and their development over a period of time. A detailed discussion on types of fractal geometry and their unique characteristics with reasons is also presented.

Chapter 2 Presents Literature review and Thesis Objective in context to the fractal antenna for multiband and wideband applications.

Chapter 3 Covers the designing and simulation of new simple shape X fractal antenna with different iteration number and ground width of proposed antenna.

Chapter 4 Covers the designing and simulation of antenna using Defected Ground Structure to reduce the net size of antenna (as proposed in chapter 3rd) with wideband characteristics. Parametric study of various parameters like ground width, number of slots, slots length etc. has been presented to optimize the results. Further, Chapter covers the designing and simulation of a new multiband antenna with DGS and different length of feed

line.

Chapter 5 Covers the fabrication process of both proposed antennas given in chapter 4th; there testing and finally the measured and simulated results are presented to show the agreement between them.

Chapter 6 Concludes the work done and provides a brief discussion on the future scope of the work.

LITERATURE REVIEW

This chapter provides a literature survey on the designing of microstrip patch antenna, advancement in the field of fractal patch antenna and their various applications are revisited.

2.1 Related work

S.H Liu (1992)[36]: The paper discusses the basic mathematical concept and explain the concept of fractal by providing examples of different kind of fractals present in nature, like trees ,sea shore etc. They are drawn from condensed matter physics. It further explains how fractals are formed in nature with the help of computer simulation. Paper uses diffusion as an example for illustrating some anomalous physical properties of fractal systems.

Carles Puente-Baliarda et al. (1998)[21]: This paper proposes a Sierpinski fractal antenna having multiband behaviour. Proposed antenna is triangular in shape. Further it provides comparison between proposed antenna and a single-band bow-tie antenna. Experimental and mathematical results are provided to prove self-similarity in design for the fractal shape by studding their equivalent electromagnetic behaviour.

D.H.Werner et al.(1999)[22]:This paper discusses the overview about the recent advancement in the field of fractal antenna engineering which emphasises on the principle and design of fractal arrays. Few important and basic properties of the fractal arrays has been proposed in this paper like methods for having low-side lobe designs ,the frequency-independent multi-band characteristics and the methods to develop rapid beam-forming algorithms from fractals that are recursive in nature.

Baliarda, C.P. et al. (2000)[23]: This paper proposes that due to fractal nature, Sierpinski fractal antenna shows the multiband behaviour. Variation of Flare angle of proposed model is carried out to predict the behaviour of proposed Sierpinski fractal antenna. It gives a good prediction about the nature of the antenna including some second order effects too. Finally it shows that fractal geometry inherited by the log periodic nature of the antenna.

K.J. Vinoy et al.(2001)[24]: This paper proposes new Hilbert curve fractal geometry. The proposed fractal geometry has lower resonant frequency as compared to other geometries. Some changes in the proposed geometry have been done by adding few interconnecting segments to the Hilbert geometry which results in the significant changes in radiation pattern. There is significant reduction in the antenna size by using Hilbert fractal curve geometry. Proposed antenna has various applications of the modern telecommunication systems, as the space availability is the main concern for them. Further paper shows that by incorporating RF switches the input characteristics of the antenna can be made frequency agile along its length.

Douglas H.Werner et al.(2003) [8]: This paper proposed two ideas about Fractal antenna engineering, First deals with the design and investigation of fractal antenna elements, and the another with the application of fractal theories in designing of antenna arrays. To have multiband and wideband characteristics with compact size of antenna, different properties of fractals have been exploited and have been presented in paper. It also provides a brief summary on recent work in the field of fractal frequency-selective surfaces.

Reza Dehbashi et al. (2006) [5]: This paper proposed an antenna having U slot, This antenna is compared with the common inset fed square patch antenna. The new antenna has an area of 27.6 mm X 35 mm whereas that of the square patch has occupied the area of is 40 mm X 40 mm. Thus, the new antenna is having size reduction of about 40 percent as compared to that with the square patch. This U slot antenna has harmonic rejection property. Thus antenna helps to eliminate the Band Pass Filter used in rectenna systems; hence, increases the net efficiency of the system.

T.Mustafa Khalid (2007) [25]: This paper presents a minor size fractal dipole antenna known as combined fractal antenna with multiband characteristic for 2D and 3D formations. It presents a design where main antenna body is the combination of different fractal geometries. The antenna combines the geometry of Hilbert curve and Koch curves and results show that final antenna has combined or hybrid properties of both the antenna geometries that create the final geometry.

Rowdra Ghatak et al. (2008)[7]: This paper proposed a CPW feed, perturbed Sierpinski carpet fractal antenna used for IEEE 802.11a and 802.11b lower and mid bands, plus for HiperLAN2 system. Various steps for designing the antenna for achieving the desired

resonance characteristics have been discussed. Initially, a Sierpinski carpet fractal antenna having no perturbation is presented. Then intermediate design geometry of proposed antenna is simulated to obtain its return loss characteristics. Finally, perturbed Sierpinski carpet fractal monopole antenna is presented and return loss plot shows that proposed antenna covers the required bands.

Bayatmaku et al.(2011) [26]:This paper proposes a probe fed E-shaped fractal patch antenna for LTE/WWAN operation . Various iterations are carried out for patch and best optimized design has been presented. Increasing iteration number gives better antenna performance in terms of resonating band and their bandwidth. Simulated results with its numerical counterpart has been presented to study various antenna properties like impedance bandwidth, radiation efficiency, radiation patterns, electric current distributions, and antenna gain in detail.

Suganthi, S et al.(2011)[27]: This paper proposed a newly shaped fractal geometry whose performance results have been carried by HFSS 3D simulation software. Proposed antenna is made up of FR4 substrate. Patch is made up of copper annealed. The proposed antenna resonates at many frequencies. It has low return loss values and VSWR values. Basic fractal properties have been used to have the desired bands in the C, J and X regions.

Behera et al.(2012)[28] :This paper proposed a new design of dual band fractal ring antenna. Key fractal geometry use for designing the antenna is Minkowski fractal geometry. Initially, in proposed design, one side of ring of patch is exchanged by fractal Minkowski curve. The shape of structure is varied and design parameters are chosen to control the ratio of resonance frequencies. Indentation factor is varied and results are presented with increased gain and bandwidth. Further, width of other two sides of ring is also varied and its resonance characteristics are shown in paper.

Kiran Raheel et al. (2012) [29]: This paper discusses and reviewed various techniques for designing of antenna for ultra-wideband applications. Due to increasing demand for larger bandwidth antennas for higher data rate in wireless communication systems different studies are carried out over a period of time. Paper discusses various feeding techniques to affect the response of antenna and making them wideband. Categories are made based on different

feeding techniques and their results of return loss and other basic parameters are concluded. Paper focuses on different ultra-wideband antennas, their design parameters and their design.

Khidre et al.(2013) [30] : This paper presents a U slot microstrip patch antenna for higher mode applications. It is dual band antenna with resonating frequency band having frequency range from 5.17 GHz to 5.81 GHz hence covering many applications. This dual radiation beams are directed at centre frequency. This antenna is having a radiation gain of 7.92 dBi. The proposed antenna has impedance bandwidth of 11 percent with VSWR less than 2. Proposed antenna is having dimensions of 64X 74 mm² with dielectric constant having permittivity of 2.2 and thick. of 3.1 mm. Design and Simulation results are carried out by HFSS shows dual band behaviour of antenna.

Janani.A et al.(2013) [20] : This paper presents a E-shaped fractal antenna for multiband applications. Firstly, entire length has been divided to make E shape patch by making two slots. Fractal geometry has been applied to each section. It has dimensions of 150 mm by 130 mm and is fabricated using two FR-4 substrate having thickness of 0.8 and 1.6 mm with an air gap of 4 mm between the two substrate. Various Parameters like return loss, gain, impedance bandwidth has been studied with the help of HFSS simulation software. Proposed antenna covers various applications of mobile communication.

Ghorpade et al.(2013) [31] : This paper presents a comparison in E-shaped fractal and E-shape microstrip patch antenna. The design and simulation has been done by the help of HFSS simulation software. Further from the analysis it shows that fractal antenna have large size of order of 150X130 mm² but shows multiband characteristics. Different antenna characteristics have been compared in terms of VSWR, gain and return loss. Due to E shaped fractal geometry antenna resonates at 1.93 GHz and 3.52 GHz, covering various GSM frequency bands, Bluetooth and Wi-Max applications.

Manish Sharma et al. (2014) [32]: This paper proposed the designing of a multiband rectangular fractal antenna whose analysis is carried out with multiband Koch fractal antenna. Micro strip line feeding technique is used to give power to proposed fractal antenna. Various parameters like dielectric constant, substrate height are varied to obtain desired resonant frequency. Various antenna properties like return loss, VSLR, gain, Directivity and Bandwidth are discussed and analysed.

B. Taoufik *et al.* (2014) [33]: This paper proposed the designing of a low cost Multi band fractal micro strip antenna. Proposed antenna has applications in the ISM band at 2.45 GHz and 5.8 GHz frequency range. Paper focuses on the development of an antenna which can be used in a rectenna system with a RF-DC rectifier, for wireless power transmission "WPT". Fractal geometry is used to have multiband characteristics. The dimensions of proposed antenna are 65 x 30mm. Simulation results show that antenna is a multiband antenna with ISM band applications.

Wei-Chung Weng *et al.*(2014)[34] :This paper proposed a H shaped fractal antenna for multiband applications of 2.45GHz and 5.5GHz WLAN band. New H shape is used as compared to conventional Serpinski Carpet, Hilbert Curve or Koch curve due to its simple design and is to implementation design.FR4 substrate is used for fabrication with 1.6mm thickness. Simulated and measured results have been provides to confirm the multiband feature of proposed antenna. Various parameters like scale factor, stage number and initial length have been varied and PSO method has been used for optimizing the antenna performance.

Dhananjay Karkhur (2016) [35]: This paper compared and presents different design techniques for designing multiband patch antenna. Due to their superior demand and usefulness multiband antenna are in great demand in today's world. Detailed literature review of past work of multiband fractal antenna is presented in this paper. Different design techniques and design issues along with comparison chart are also presents. Review of study results is presents to show which technique is better than other for designing multiband antenna.

2.2 Research Gap

- It is seen that generally both multiband and wideband behavior are not present in the same antennas. So work can be done for achieving multiband antennas having wide range of frequency band to work upon.
- Lack of flexibility in controlling the operational frequencies is the major problem in using the fractal geometry according to our applications required.

- Higher operating bands have more return loss as compared to lower bands. Thus, work can be done to increase gain and bandwidth at lower bands.
- More work is required in the field of fractal tree antennas involving three dimensional structures.
- It is seen that mostly slots are taken from the patch of antenna. So, more work can be done with Defected Ground Structures to increase bandwidth and gain.
- Major drawback is in the fabrication of fractals due to their complex designs. Thus, more focus should be on designing simple fractal shapes which are easy to implement.
- Multiband behavior is observed mostly with the higher frequency bands in different fractals. Therefore, work should be done to achieve this at lower frequency bands too.

2.3 Objectives

Following objective has been proposed.

- Design and simulation of new Simple Fractal shape Antenna for S and C applications.
- Parametric study of various parameters for Optimization of antenna parameter for bandwidth, gain and return loss, size reduction by the use of fractal configurations, Defected Ground Structure (DGS) etc.
- Fabrication of proposed antenna to validate the experimental results with simulated results.

DESIGN OF X FRACTAL ANTENNA FOR C BAND APPLICATIONS.

In this chapter, designing and simulation of an X shaped fractal antenna with Microstrip line feed suitable for various C band applications has been discussed. Fractal geometry having simple design with multiple iterations is used in order to have multiband characteristics. Width of ground plane is varied to improve antenna characteristics like gain, return loss, bandwidth etc.

3.1 Fractal Geometries Used in Designing Antenna

An X-shaped simple fractal design is used in the proposed antenna. Various fractal shapes like Hilbert, Koch, Sierpinski and Minkowski etc. have been developed and in use for practical applications over a period of time but they lack simplicity in design. Proposed shape also shows multiband and wideband characteristics by simply varying some parameters of antenna like feed line width, ground plane width, substrate material etc. In the proposed shape, the construction of X fractal begins by taking two perpendicular strips in form of X, having Width W and length L_1 as shown in stage 1 of fig 3.1. Width of strips will remain constant for all the iterations. In stage 2 four pairs of the X shapes are then added to previous X of stage 1st, all are having length of L_2 , where L_2 is m times L_1 and m is the scale factor. Correspondingly stage 3 and stage 4 are designed by going in the same manner as in stage 1st and 2nd. Fig 3.1 shows the design procedure for X shaped fractal stage by stage.

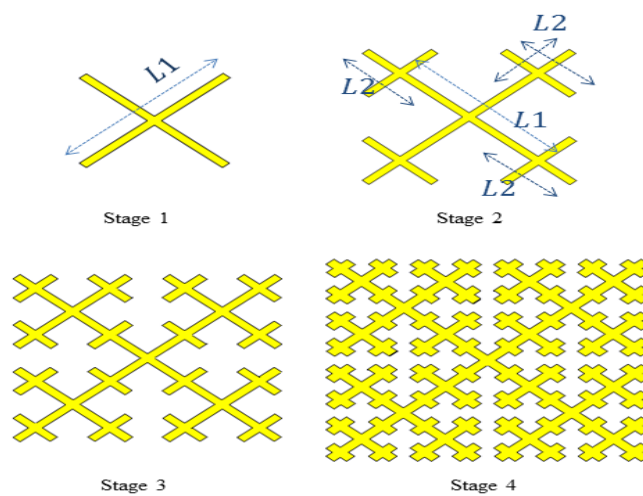


Figure 3.1 Intermediate Design Stages for X shaped Fractal

3.2 Design Considerations for Fractal Antenna

It is important to design the antenna in such a way that its required characteristics are attained. For an X shape fractal it is important to take into consideration that while giving power to antenna by Microstrip line feed, sides of X shape do not touch the feed line or they do not form any closed shape structure. For this following equation can be used to avoid overlapping in X shaped fractal after Nth iteration

$$1 - \left[\sum_{j=1}^{N-1} m^j \right] > \frac{W_0}{L1} \quad (3.1)$$

Where, N is the stage number (Iteration no), W_0 is the width of feed line and $L1$ is the initial length of strip lines in stage-1.

3.3 Design Procedure of X shaped Fractal Antenna

3.3.1 Calculation of Width (W)

Using transmission line model for efficient radiator practical width is calculated by

$$W = \frac{1}{2\pi f \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{1}{2 + \epsilon_{eff}}} \quad (3.2)$$

3.3.2 Calculation of Effective Dielectric Coefficient (ϵ_{eff})

The Effective dielectric constant can be calculated by following equation

$$\epsilon_{eff} = \frac{\epsilon_{rs} + 1}{2} + \frac{\epsilon_{rs} - 1}{2} \sqrt{\left[1 + 12 \left(\frac{Z}{T} \right) \right]} \quad (3.3)$$

Where ϵ_{eff} is the effective dielectric constant, ϵ_{rs} is dielectric constant of the substrate, T is the height of dielectric substrate and Z is the width of patch.

3.3.3 Calculation of Effective Length (L_{eff})

The effective length is calculated by

$$L_{eff} = L + 2\Delta L \quad (3.4)$$

3.3.4 Calculation of Length Extension (ΔL)

The value of ΔL can be calculated by

$$\Delta L = 0.412T \frac{(\epsilon_{\text{reff}} + 0.3) \left[\frac{Z}{T} + 0.264 \right]}{\epsilon_{\text{reff}} - 0.258 \left[\frac{Z}{T} + 0.8 \right]} \quad (3.5)$$

Where, Z is the width of patch and T is the height of dielectric substrate.

3.3.5 Calculation of Actual length of Patch (L)

The actual dimension of length of patch is calculated by expression

$$L_{\text{actual}} = L_{\text{eff}} - 2\Delta L \quad (3.6)$$

3.3.6 Calculation of Ground Dimensions: Practically ground plane can't be infinite; it must be finite with particular dimensions. So, the ground plane is selected in such a way that its dimensions is greater than patch dimensions by approx. 6 times the substrate thickness all around periphery.

$$L_{\text{gnd}} = 6t + L_{\text{actual}} \quad (3.7)$$

$$W_{\text{gnd}} = 6t + W \quad (3.8)$$

Here L_{actual} and W are the length and width of patch respectively, t is the thickness of substrate and L_{gnd} and W_{gnd} are the length and width of ground plane. Hence measurements of ground plane depend on the thickness of substrate and dimensions of patch.

3.3.7 Substrate Selection: It plays major role in deciding the dimensions of patch. It can be observed that as the value of dielectric constant increases, dimensions of antenna required to resonate at same frequency will decrease and efficiency and gain also decrease. Therefore for proposed design, substrate of dielectric constant 4.4 with loss tangent of 0.02, FR4 (lossy) is used.

3.3.8 Substrate Thickness (h): By increasing the thickness of substrate, efficiency and bandwidth of antenna increase but on the other hand it makes antenna more bulky. Thus proper thickness needs to be selected keeping in mind all the parameters. In our proposed design substrate thickness 1.6 mm has been used.

3.3.9 Feed Point Location: After selecting patch dimensions, the next task is to select feed

point location. It is observed that change in feed point location will change return loss and input impedance of antenna which is required for proper matching and maximum power transfer. There are mainly five feeding techniques but the more commonly used are microstrip and coaxial feeding technique. In proposed antenna microstrip line feed is used.

3.4 Antenna Design

Based on equations described in above section we have calculated the value of different parameters required for designing the X shaped fractal antenna of up to 4th Iteration as shown in table 3.1. We can further iterate the antenna for 5th stage but that will make antenna almost double in size which is practically difficult to use.

Table 3.1: Input Parameters

Parameter	T	Wg	W_o	W1-W4	Lg
Size(mm)	1.6	20	3	3	88
Parameter	L1	L2	L3	L4	m
Size(mm)	62	31	15.5	7.75	0.5

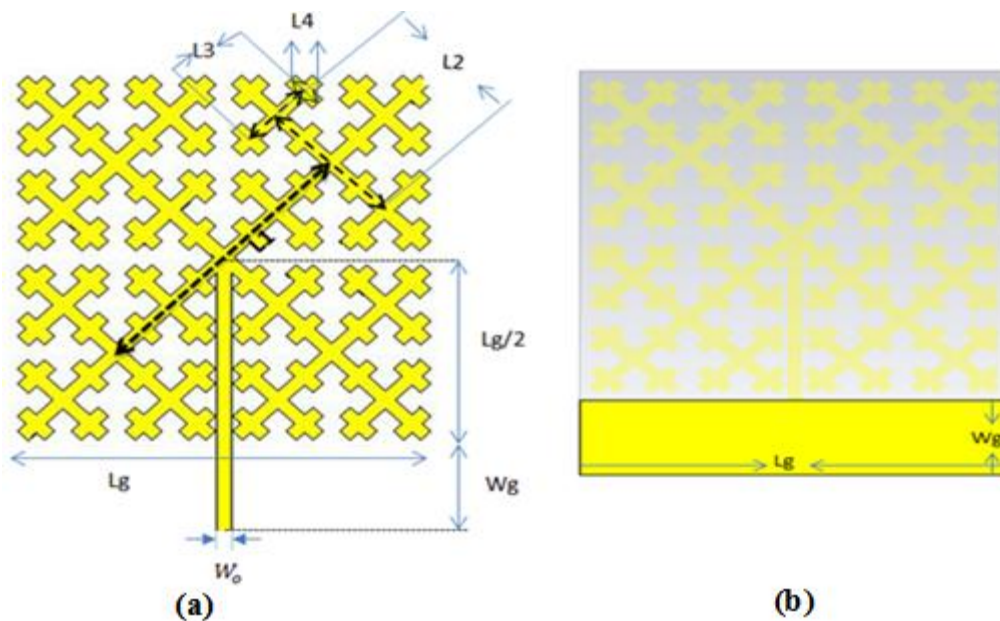
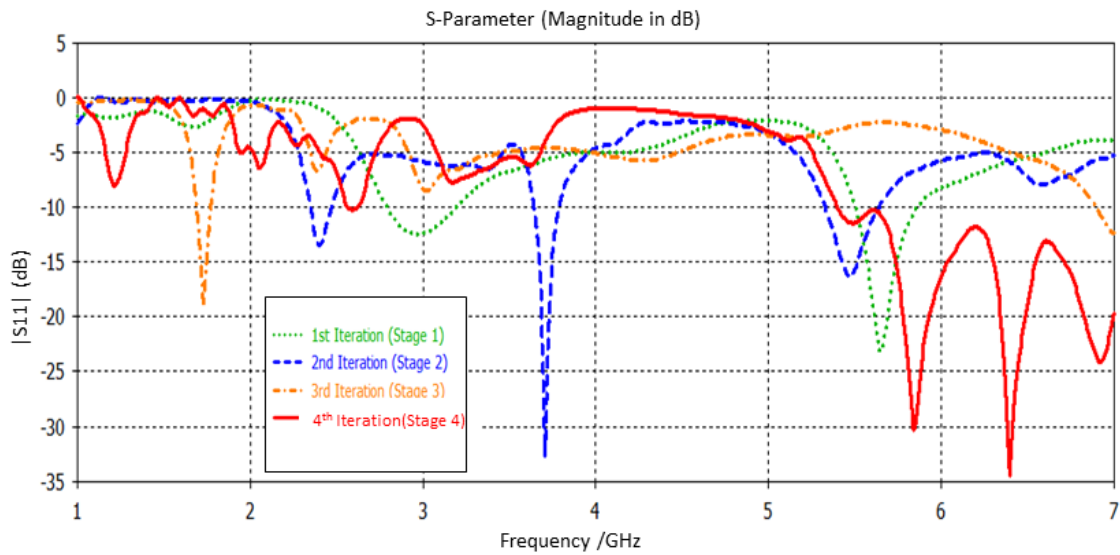


Figure 3.2 The dimensions of the proposed antenna at stage- 4. (a) Front view, (b) Back view

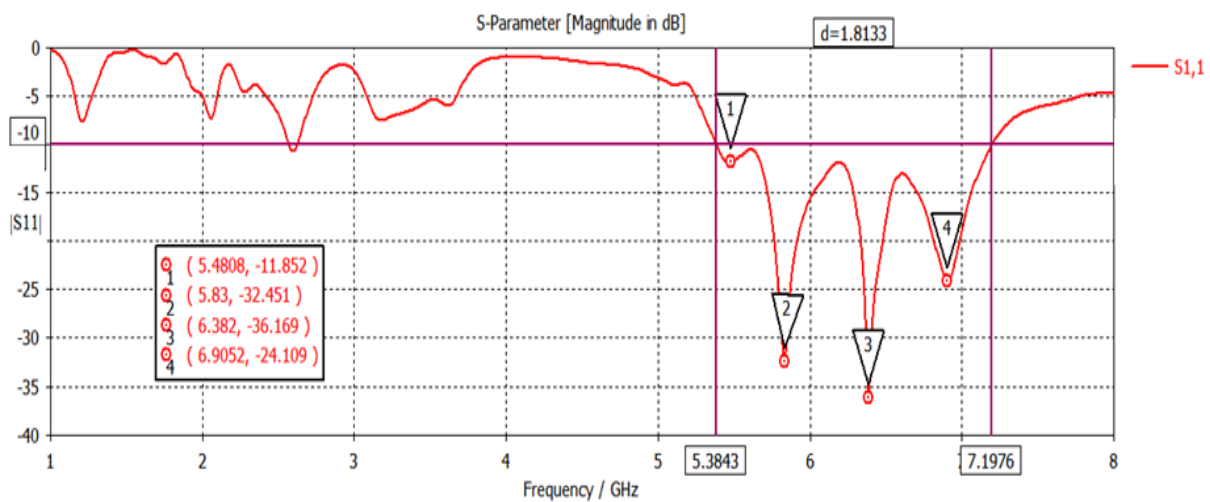
3.5 Simulation Results

The simulation result of antenna parameters like return loss, resonant frequency and gain are obtained using CST Microwave studio 2014 and given in next section.

A) Return loss



(a)



(b)

Figure 3.3 Return loss Plot (a) For different Stages (b) For stage 4th with value markers

The return loss plot shows that above designed antenna resonates at 5.4 GHz, 5.83GHz, 6.4 GHz and 6.9 GHz frequencies with a good return loss of approximately -11.85 dB, -32.45dB,-36.17 and -24.19dB respectively.

B) Bandwidth: From the return loss plot as shown in fig 3.3, impedance bandwidth can be calculated by the equation, $|S_{11}| < -10\text{dB}$, thus 7.19-5.58 i.e. 1.8133 GHz

$$\text{Percentage Bandwidth} = \frac{\text{Upper limit} - \text{Lower limit}}{(\text{Upper limit} + \text{Lower limit})/2} \times 100$$

(3.9)

Therefore, Percentage Bandwidth = $(1.8133/6.29) \times 100 = 28.8$ percent

Therefore proposed antenna is a Wideband antenna.

C) Smith Chart

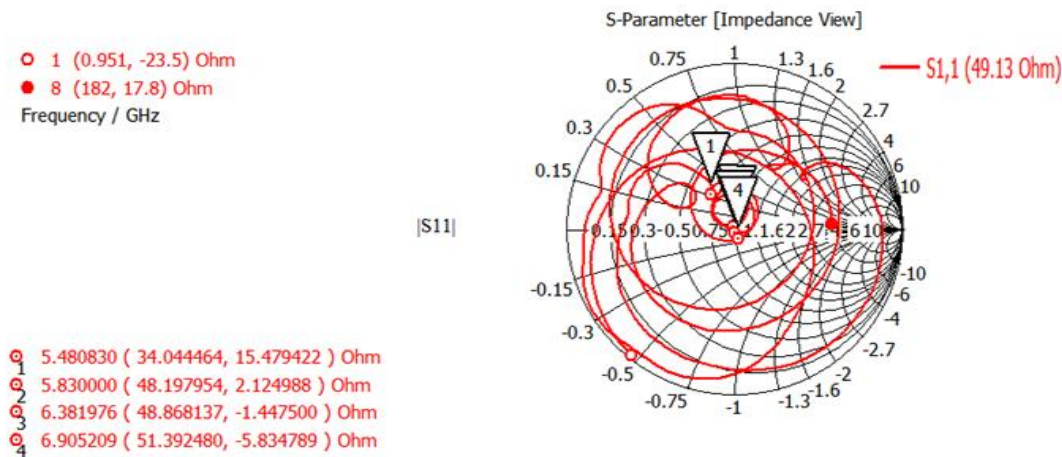


Figure 3.4 Smith Chart plot

As antenna is excited with the help of 50Ω Coaxial line therefore for maximum power to be transformed it is required that input impedance of antenna should match with impedance of Coaxial line. From Z smith chart plot it can be shown that our proposed antenna have input impedance of 49.13Ω, thus we can have minimum loss and maximum power transfer to take place.

D) Directivity

The measured peak realized antenna gain is shown in fig 3.5

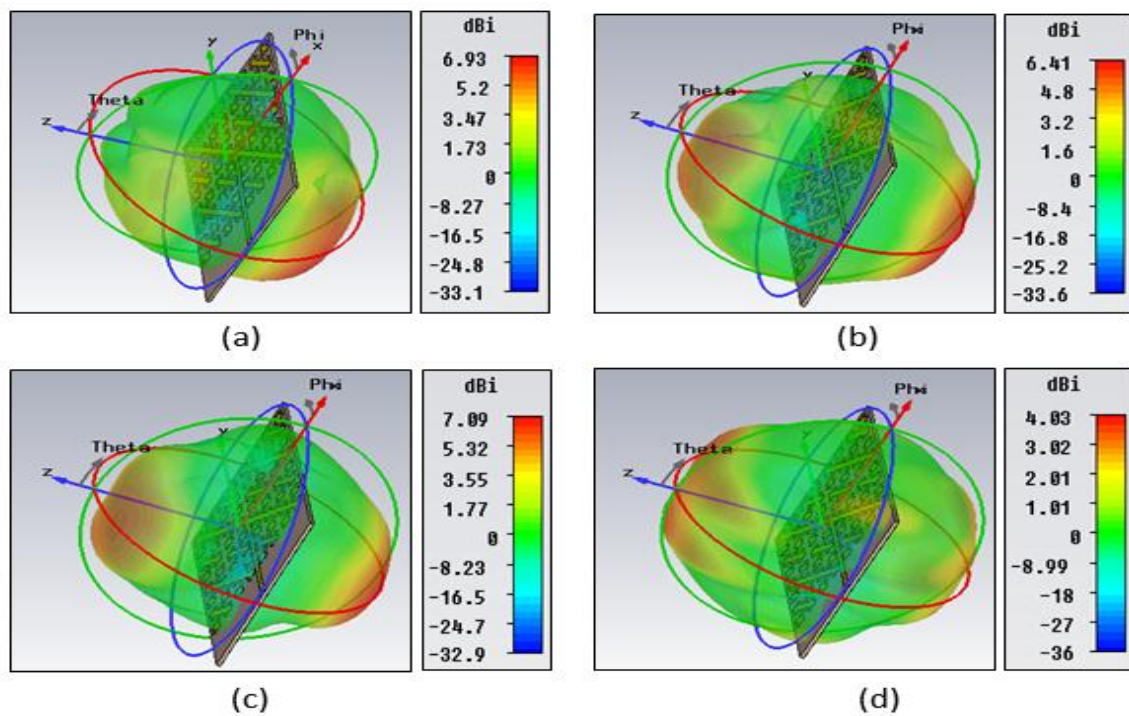


Figure 3.5 Directivity at lower band i.e. 2.4 GHz

Proposed antenna shows a good directivity and efficiency at required frequencies as shown in table 3.2

Table 3.2: Results of Radiation pattern

Frequency (Ghz)	5.5	5.83	6.4	6.9
Directivity (dBi)	6.93	6.41	7.09	4.03
Radiation Efficiency (%)	71.91	70.99	54.91	66.47
Total Efficiency (%)	67.06	70.93	54.86	66.22

3.6 Conclusion and Application

In this chapter we designed an X-shaped fractal patch antenna with Microstrip line feed suitable for various applications of C band given in table 3.3.

Table 3.3: Frequency bands and their applications.

Center Frequency	Frequency Range(MHz)	Application
5.4 GHz (IEEE802.11a)	5470-5725,5725-5875	For Wi-Fi application(Two out of total three bands depending on the region of the world)[54]
5.6 ,5.8 GHz	(5650-5670) for uplink and (5830-5850) for downlink.	5cm band by Amateurs and C band by AMSAT for uplink and downlink[54]
5.7 GHz	5729-5800	Fixed Satellite Radio Transmission [56]
5.8 GHz	5741-5828	Used for cordless telephony in United States[55]
5.9 GHz (IEEE802.11P)	5850-5925	Used in vehicular communication systems[53]
6 GHz	5800-7707	Used for military applications[54]
6.5GHz	6000-6800	Over 6 GHz band for future 5G telecommunication network[54]

Antenna resonates at desired bands with good directivity and total efficiency. Proposed antenna is a multiband and wideband antenna.

Table 3.4: Simulated Results of Antenna

Parameters	Value
Resonating Frequency	5.4 GHz, 5.83GHz, 6.4 GHz ,6.9 GHz
Return Loss	-11.85 dB, -32.45dB,-36.17 and -24.19dB
Impedance	49.13 ohm
Directivity	6.93dBi, 6.41dBi,7.09dBi,4.03dBi
Bandwidth	1813.3 MHz (28.8%)

DESIGN OF X FRACTAL ANTENNA WITH DEFECTED GROUND STRUCTURE (DGS)

This chapter covers the design and simulation of two different X fractal antennas, both having patch as X shaped fractal, proposed in previous chapter and ground with different slots i.e. Defected Ground Structure (DGS) to improve gain, bandwidth, no of bands and to reduce total size of antenna as compared to proposed antenna designed in previous chapter. Chapter also covers detailed parametric study of various parameters for optimizing the results.

4.1 Parametric Analysis of Proposed Antenna to reduce the size

It has been analysed from previous study that by applying four iterations, characteristics of antenna improves a lot. In this chapter other parameters are varied in order to improve gain, bandwidth and mainly to reduced net size of antenna. It is found that with help of parametric analysis, we can obtain best configuration which have better results.

Following parametric analysis is studied:

- ✓ Effect of changing width of Ground plane.
- ✓ Effect of cutting slots in ground plane with slot length.
- ✓ Effect of changing substrate material.

4.1.1 Effect of changing width of Ground plane.

In this section we will study the antenna properties with help of return loss plot by changing the width of ground plane. It can be analysed from the fig 6.1 that just by changing the width of ground plane one can have better impedance bandwidth and better return loss values i.e. $|S_{11}| < -10$ dB for same fractal patch and for same input impedance.

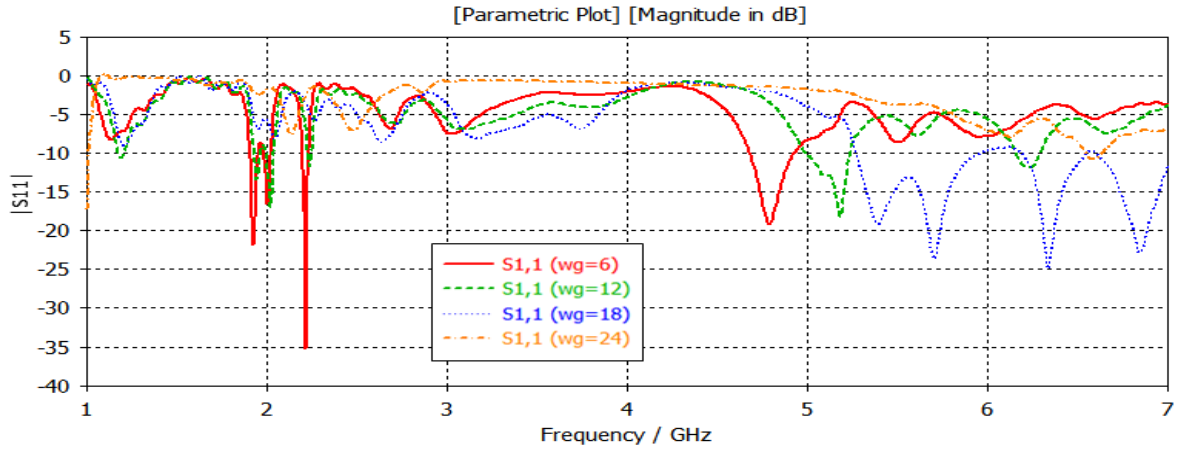


Figure 4.1 Simulated reflection coefficients for different width of ground plane

In our proposed antenna we choose Width of ground plane to be 6mm (fig 4.2) as antenna shows multiband behaviour with improved return loss at this value of ground width.

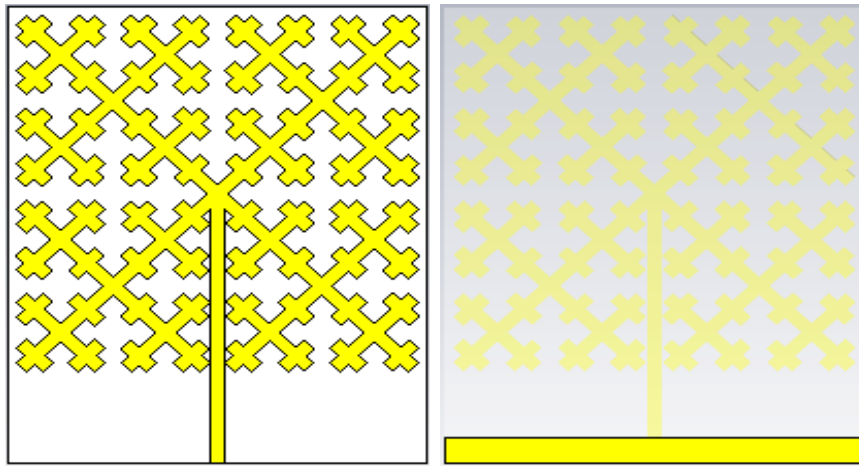


Figure 4.2 Front view and back view for X-fractal antenna while varying the ground plane width

4.1.2 Effect of cutting slots in ground plane with slot length

In this section, once we fix the ground width, we will cut the slots in ground plane and will vary their lengths as shown in Fig 4.3 to get optimized results. Due to increase in electrical length we get better return loss values with improved gain and reduced total size. Different no of slots have been cut down in ground plane with different shape. From the analysis it is found that by cutting three vertical “I” slots we get best optimized results. Now for further optimization we analyse return loss plot for different value of slots lengths. Fig 4.4 shows the return loss plot for different value of “I” slot length (a) in the ground plane.

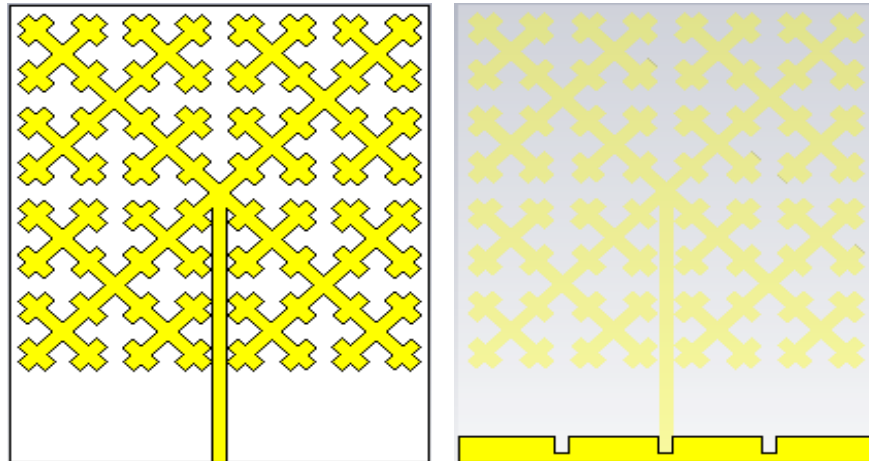


Figure 4.3 Front view and back view for X-fractal antenna with three slots in 6 mm ground plane

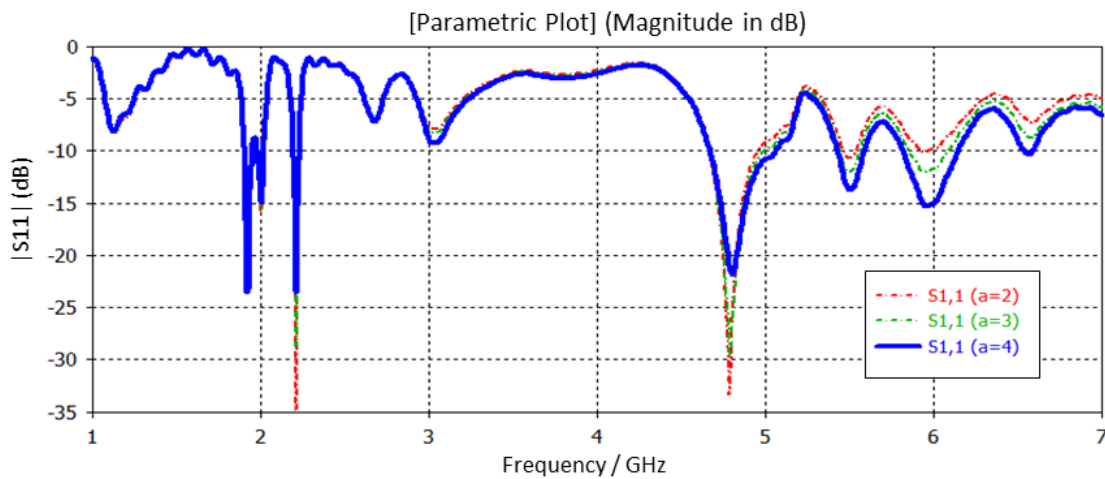


Figure 4.4 Reflection coefficients value of the proposed antenna for three slots in the ground plane of different length

From the return loss value it can be analysed that for slot length (a) of 4 mm we get best optimized results.

4.1.3 Effect of changing substrate material.

In our proposed antenna, substrate used is FR-4, but other substrates can also be used in order to analyse the results. FR-4 is mostly used as it is suitable for frequency range of 1 to 8 GHz with its easy availability and low cost as compared to other substrate materials available in the market. It has dielectric constant of 4.4 and loss tangent of 0.02. There are many other substrates available that can be used for analysing the results in place of FR4 can be Roger

RO4232 or Arlon Di 870. Roger RO 4232 has dielectric constant of 3.2 and loss tangent of 0.0012. Whereas Arlon Di 870 has dielectric constant of 2.33 and loss tangent of 0.0013. It has been found that when the dielectric constant of antenna has been changed then resonant frequency and input impedance of antenna also changes. So, we can choose the substrate material accordingly to our desired bands and impedance of Coaxial cable used to excite the antenna. Figure 6.5 shows the return loss plot for different substrate material and Fig 6.6 shows the input impedance corresponding to different substrate material as 51.02 Ohm for Arlon, 49.16 Ohm for FR4 and 55.95 Ohm for Roger. As we excite the antenna with the help of coaxial cable of characteristic impedance of 50 Ohm, therefore we choose FR4 with 49.16 Ohm input impedance as it will allow maximum power to be transferred for radiation.

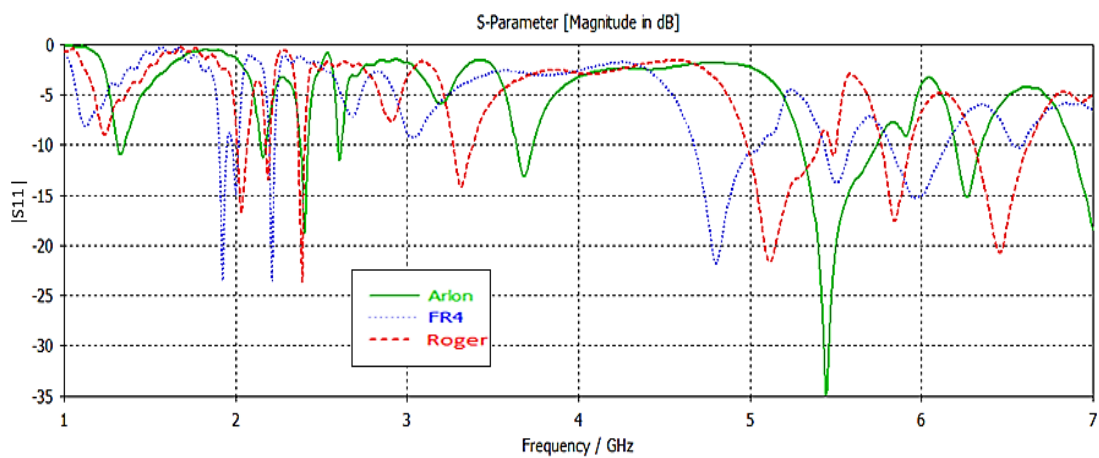


Figure 4.5 Return Loss plot for different substrate material

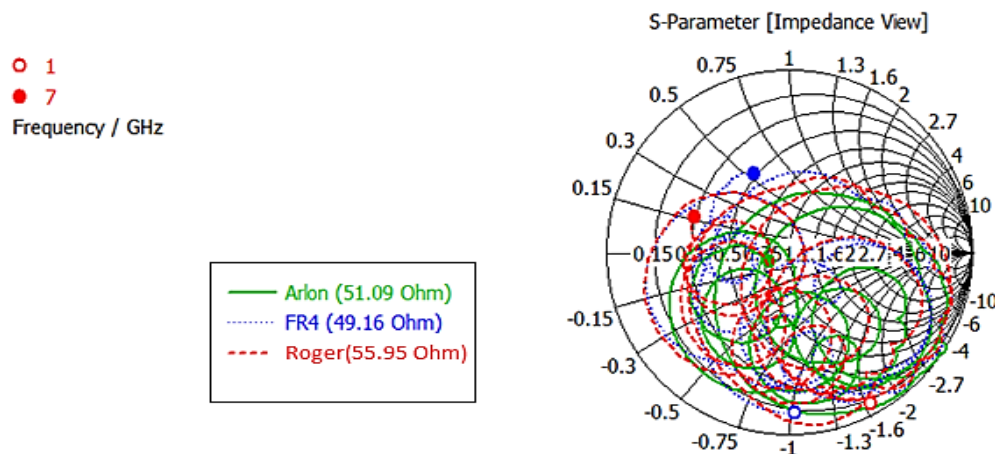


Figure 4.6 Smith Chart showing the impedance value for different substrate material

4.2 Designing of X shaped antenna:

From the parametric analysis in the above section, we design two different kinds of antennas which are discussed in next section

- A. An X shaped antenna with reduced size covering same bands as proposed antenna in previous chapter.
- B. A new X shaped multiband antenna covering various application of S and C band.

4.2.1 An X Shaped Wideband Fractal Antenna with Reduced Size

4.2.1.1. Designing of proposed antenna

From the analyses of parameter sweep new reduced size antenna is shown in figure 4.7 . New antenna is having the dimension of 94 X 88 mm as compared to previous antenna of 108 X 88 mm. In this new antenna, three slots are cut in the ground plane and ground plane width is reduced to 6 mm as compared to 20 mm width in actual antenna.

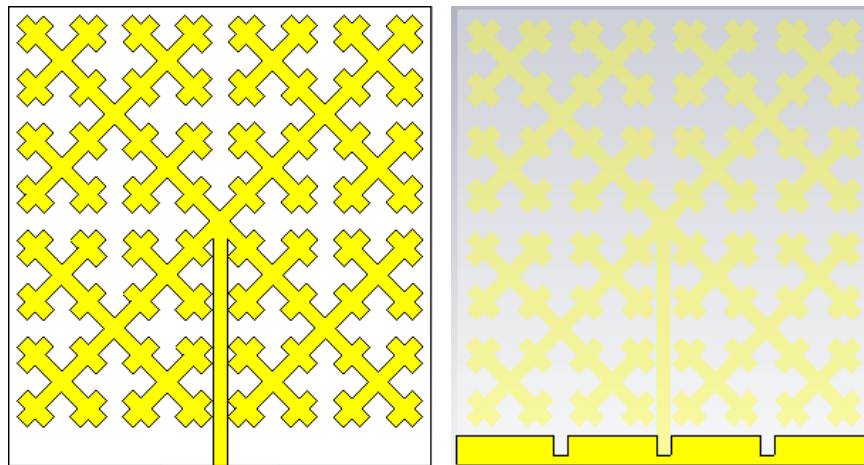


Figure 4.7 Front view and back view for X-fractal antenna with reduced total size

4.2.1.2. Simulated Results

The simulation result of antenna parameters like return loss, resonant frequency and gain are obtained using CST Microwave studio 2014.

A) Return loss

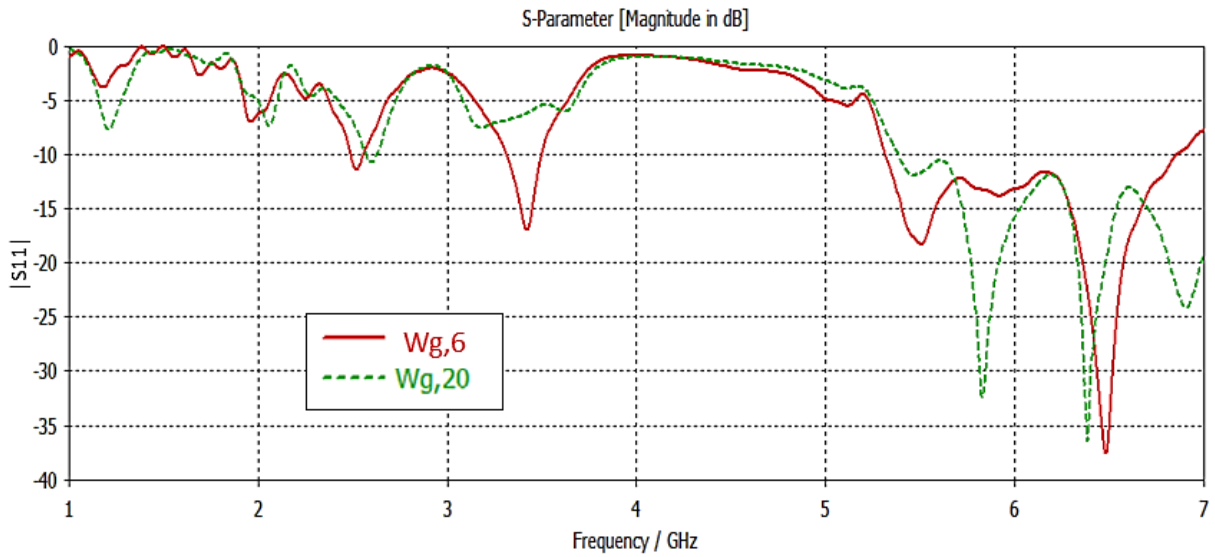


Figure 4.8 Return Loss Plot of proposed antenna with ground width 20 mm and our new reduced size antenna with a ground width of 6 mm having three slots into it.

B) Smith Chart

Figure 4.9 shows the value of input impedance for the proposed reduces size antenna as 49.11Ω

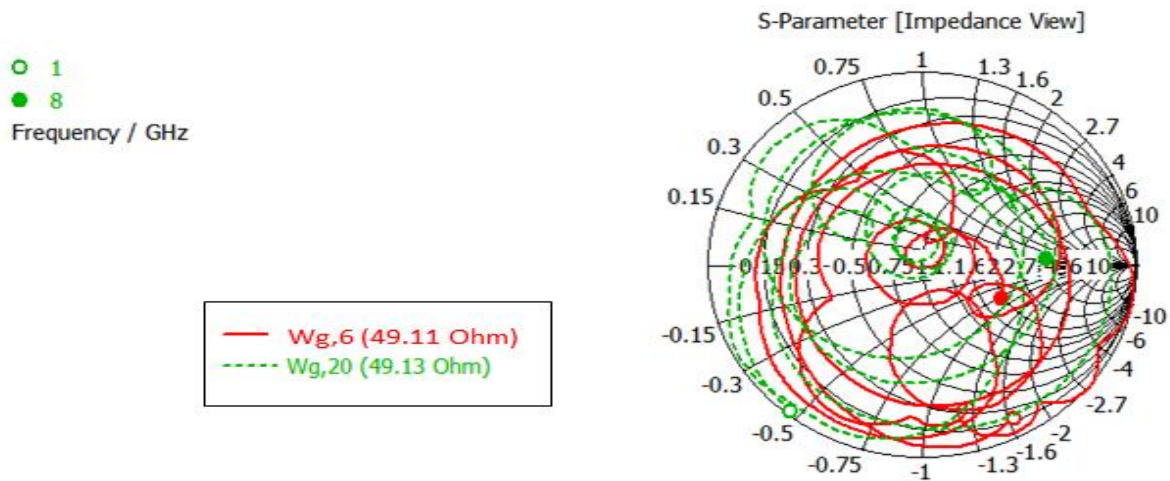


Figure 4.9 Smith Chart Plot

C) Directivity

Figure 4.10 shows the 3D radiation patterns of the proposed antenna with its value and efficiency given in table 4.1. Proposed antenna shows better directivity with good radiation efficiency

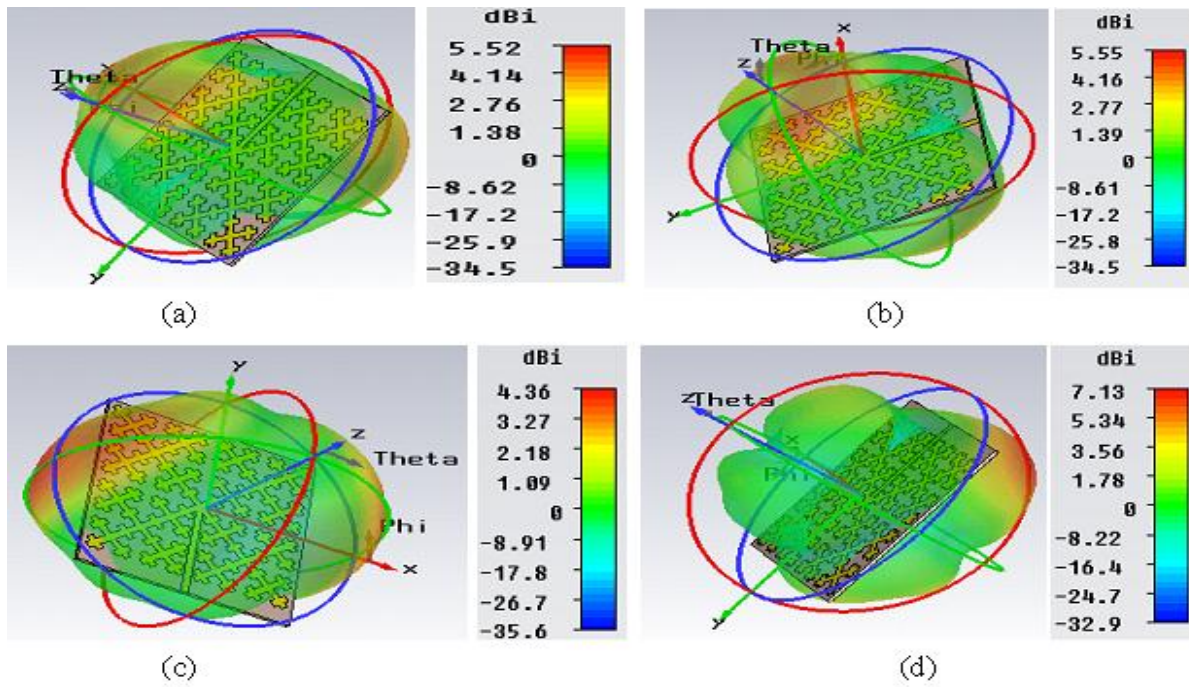


Figure 4.10 Simulated 3-D radiation patterns of the proposed X-fractal antenna with reduced size for frequency (a) 3.6 GHz (b) 5.5 GHz (c) 5.95 GHz (d) 6.5 GHz

Table 4.1: Results of Radiation patterns

Frequency (Ghz)	3.6	5.5	5.95	6.5
Directivity (dBi)	4.36	7.13	5.52	5.55
Radiation Efficiency (%)	61	70	70	64
Total Efficiency (%)	45	69	68	64

4.2.2 A New X Shaped Multiband Fractal Antenna with DGS

4.2.2.1 Designing of proposed antenna

From the analyses of parameter sweep new reduced size antenna is shown in figure 4.11

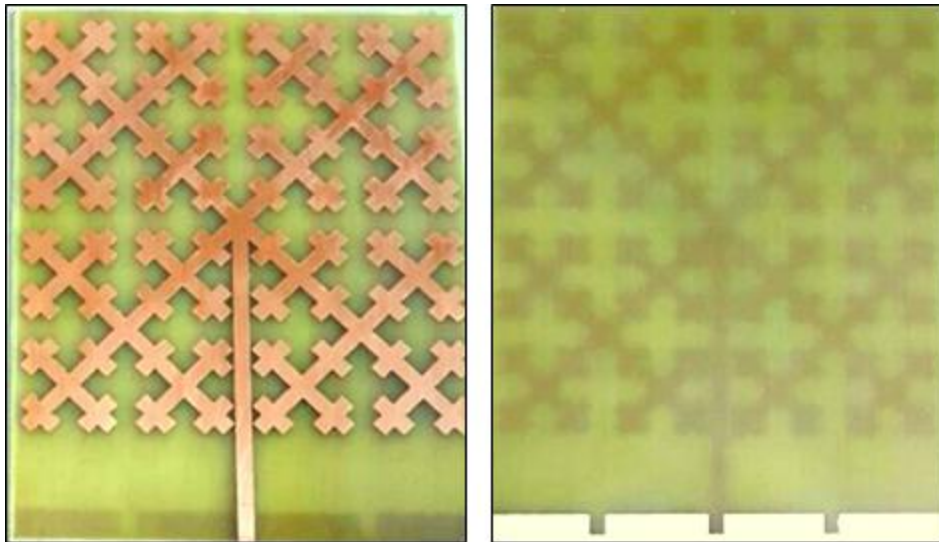


Figure 4.11 Front view and back view for multiband X-fractal antenna

4.2.2.2 Simulated Results

The simulation result of antenna parameters like return loss, resonant frequency and gain are obtained using CST Microwave studio 2014

A) Return loss

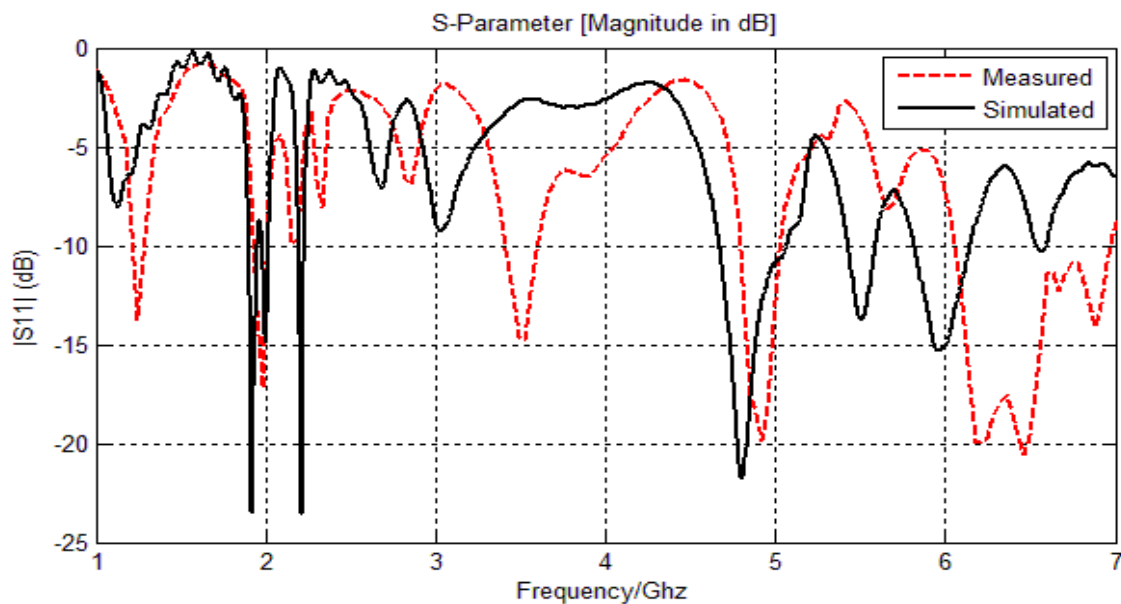


Figure 4.12 Measured and simulated reflection coefficients of the proposed multiband X-fractal antenna

B) Directivity

Figure 4.13 shows the 3D radiation patterns of the proposed antenna with its value and efficiency given in table 4.2. Proposed antenna shows better directivity with good radiation efficiency

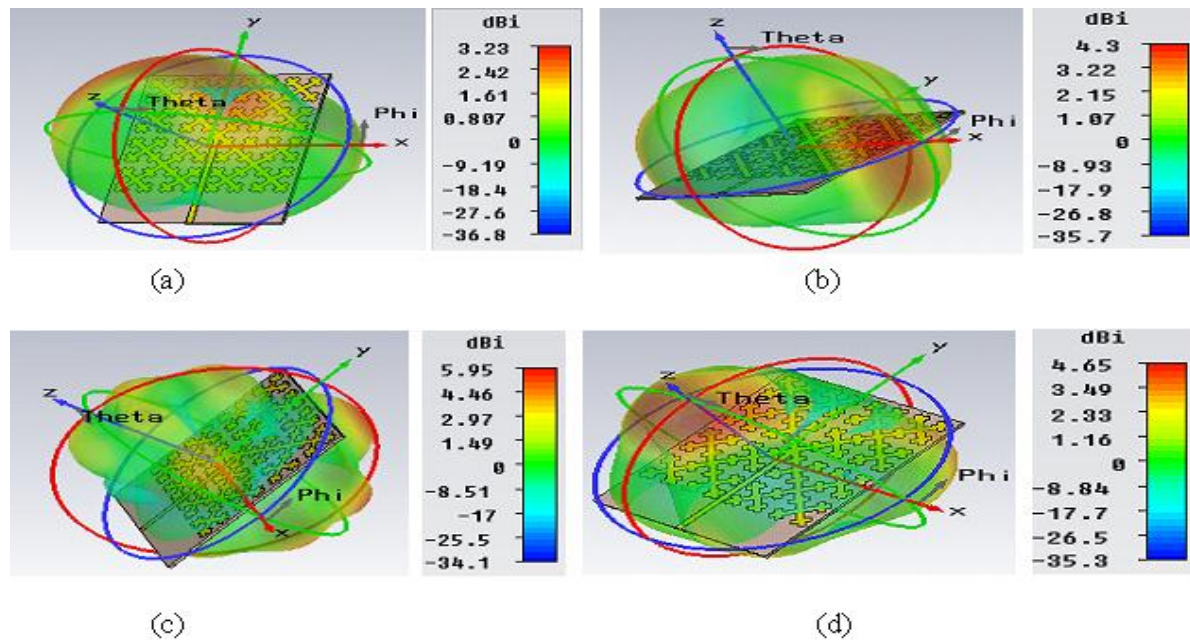


Figure 4.13 Simulated 3-D radiation patterns of the proposed X-fractal antenna with reduced size for frequency (a) 2 GHz (b) 3.5 GHz (c) 4.9 GHz (d) 6.5 GHz

Table 4.2 Results of Radiation patterns

Frequency (Ghz)	2	3.5	4.9	6.5
Directivity (dBi)	03.23	04.30	05.95	04.65
Radiation Efficiency (%)	46.00	79.00	73.00	58.00
Total Efficiency (%)	45.00	40.00	70.00	51.00

4.3 Conclusion and Application

First, new I slot antenna is compared with ordinary X fractal patch antenna. The new antenna has an occupied area of 94 mm X 88 mm while that of the Simple fractal patch is 108 mm x 88 mm. Therefore, the size of the new antenna comparing with the simple X fractal patch antenna is reduced about 13 percent. Due to Defecated Ground structure (DGS)

net electrical length of the antenna increases therefore it shows similar or better results for the net reduced physical size of antenna. Second, due to slotted ground plane there are sharp edges and corners due to which abrupt changes in direction of current occur which enhances the net radiations and makes it multiband.

Table 4.3 and table 4.4 cover various application of two proposed antenna with their frequency bands in detail.

Table 4.3: Frequency bands and their applications of wideband X fractal antenna with reduced size

Center Frequency	Frequency Range(MHz)	Application
3.65 GHz(IEEE802.11y)	3655-3695	Used as licensed band in United States[52]
5.4 GHz (IEEE802.11a)	5470-5725,5725-5875	For Wi-Fi application(Two out of total three bands depending on the region of the world)[54]
5.6 ,5.8 GHz	(5650-5670) for uplink and (5830-5850) for downlink.	5cm band by Amateurs and C band by AMSAT for uplink and downlink[54]
5.7 GHz	5729-5800	Fixed Satellite Radio Transmission [56]
5.8 GHz	5741-5828	Used for cordless telephony in United States[55]
5.9 GHz (IEEE802.11P)	5850-5925	Used in vehicular communication systems[52]
6 GHz	5800-7707	Used for military applications[53]
6.5GHz	6000-6800	Over 6 GHz band for future 5G telecommunication network[53]

Table 4.4: Frequency bands and their applications of new multiband X fractal antenna with DGS

Center Frequency	Frequency Range(MHz)	Application
2 GHz	1980-2010	Used for Earth to space communication in Europe[50]
3.5GHz(IEEE802.16)	3400-3500	WMAN band for WiMAX applications(one of the band depending on the region of world)[51]
4.9 GHz (IEEE802.11y)	4940-4990	Used for Public safety WLAN[52]
6.5GHz	6000-6800	Over 6 GHz band for future 5G telecommunication network[53]

FABRICATION, TESTING AND RESULT DISCUSSION OF X FRACTAL ANTENNA

5.1 Introduction

In this chapter various fabrication steps of two proposed antenna (of part A and B of chapter 4) with their testing results has been discussed. Fabrication is done with the help of PCB fabrication process. The results are then measured using E5071C network analyser and measured results are then compared with the simulated once.

5.2 Flow chart of fabrication process

In this section, fabrication process of proposed antenna using Microstrip line feed is discussed. Fabrication is done in certain steps explained in flowchart given below:

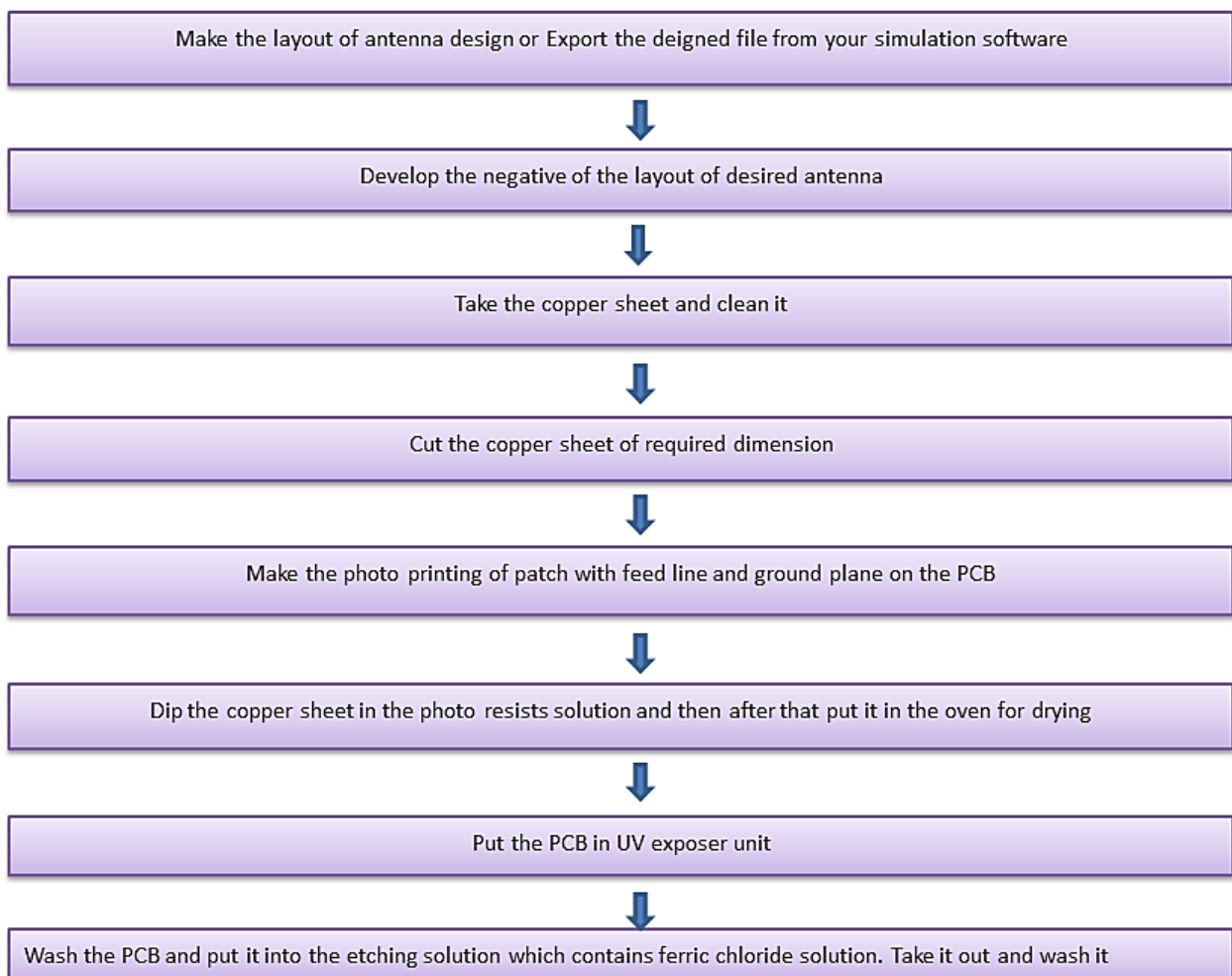


Figure 5.1 Flow Chart of Fabrication Process of Antenna

5.3 Designing and Testing Result

5.3.1 An X Shaped Wideband Fractal Antenna with Reduced Size

1. Fabricated Antenna Design

The photograph of fabricated design of the proposed fractal antenna is given in figure5.2



Figure5.2 Photograph of front and back view of the fabricated antenna with reduced size

2. Testing of Antenna

The testing of antenna is done with E5071C network analyser which analysis one port and two port networks. Figure below shows the return loss plot for the measured and simulated value.

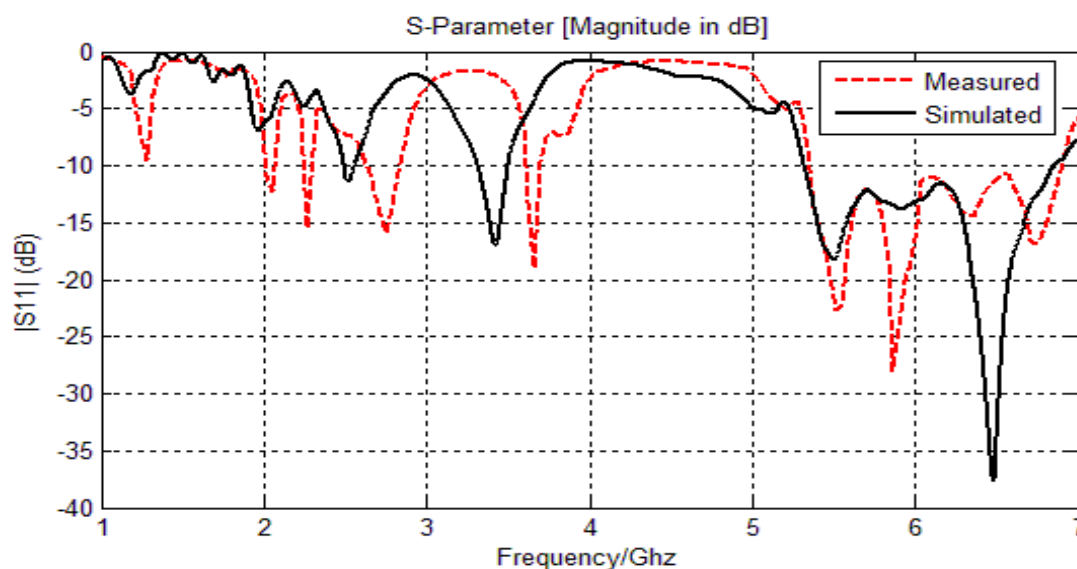


Figure 5.3 Measured and simulated reflection coefficients of the proposed X-fractal antenna with reduced size

5.3.2 A New X Shaped Multiband Fractal Antenna with DGS

1. Fabricated Antenna Design

Fig below shows the photograph of fabricated design of proposed antenna

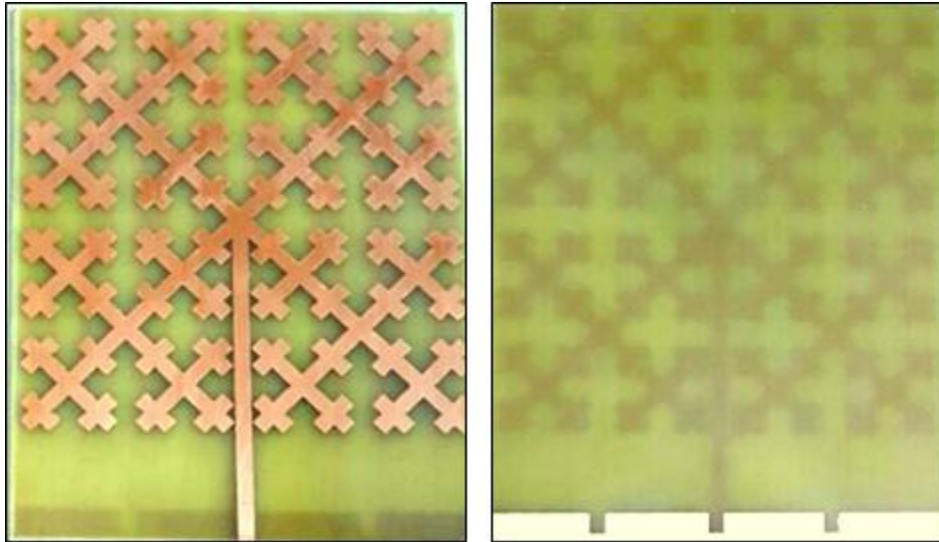


Figure 5.4 Photograph of front and back view of the fabricated antenna

2. Testing of Antenna

The testing of antenna is done with E5071C network analyser which analysis one port and two port networks. Figure below shows the return loss plot for the measured and simulated value.

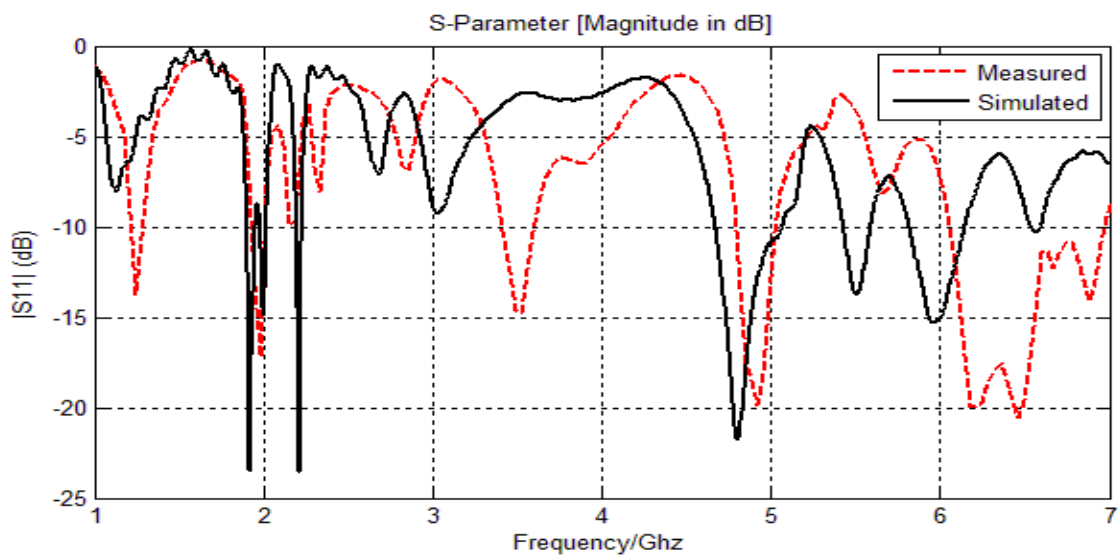


Figure 5.5 Measured and simulated reflection coefficients of the proposed new X-fractal antenna with DGS

5.4 Conclusion

Figure 5.3 and Figure 5.5 shows the good agreement of return loss between simulated results and measured results of fabricated antenna. The small difference is due to presence of air or due to lose soldering connection or due to lose SMA connector or due to transmission loss during feeding etc. After theses small variations in the result due to losses, the result is still acceptable. Fabricated antenna shows the wideband and multiband behaviour, covering the desired bands of S and C frequency range.

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

In this thesis report three configurations of X fractal microstrip patch antenna has been designed and simulated. Firstly a simple X fractal antenna for given resonating frequencies, dielectric constant and height of substrate is deigned. Different iterations are carried out to get desired results and to optimize various antenna characteristics. Second, An X fractal antenna with Defected Ground Structure is designed and compared with ordinary X fractal antenna of previous chapter. The new antenna has an occupied area of 94 mm X 88 mm while that of the old fractal is 108 mm x 88 mm. Therefore, the size of the new antenna comparing with the older one is reduced about 13 percent with roughly same input impedance of 49 Ohm for both the cases. Third, is a new X fractal antenna is deigned in which feed line length is varied and slots in ground plane are taken out to obtain multiband characteristics that covers many applications in the S and C band.

Chapter 1 covers the introduction of fractal geometry and there use as a antenna. It further describes various types of fractal geometries founded in nature and covers various antenna parameters to study the antenna performance.

Chapter 2 covers the literature survey of Microstrip patch antenna, fractal antenna engineering and advancement this field.

Chapter 3 presents a new simple shape X fractal antenna with different iteration number (1-4) and ground width is varied from 4 mm to 24 mm to obtain the optimized results of proposed antenna.

Chapter 4 Covers the designing and simulation of antenna using Defected Ground Structure to reduce the net size of antenna (as proposed in chapter 3rd) with wideband characteristics. Proposed antenna have percentage bandwidth of 28.8% and we know that antenna having percentage Bandwidth greater then 20percent is Wideband antennas, therefore current antenna is a wideband antenna. Parametric study of various parameters like ground width, number of slots, slots length etc. has been presented to optimize the results. Further, Chapter covers the designing and simulation of a new multiband antenna with DGS and different length of feed line.

Chapter 5 Covers the fabrication process of both proposed antennas given in chapter 4th; there testing and finally the measured and simulated results are presented to show the agreement between them.

It can be concluded that by using simpler geometry with different iterations, and by varying feed line length, ground width, number of slots and their lengths we can achieve multiband and wideband characteristics with good gain and efficiencies.

6.2 Future Scope

Since the fractal antenna engineering is the wide area for research work and still in its infancy, there are several ways we can use in future work.

- Antenna using other fractal geometries which are simpler in design can be designed like E shape, F shape, K shape etc.
- By Using Meta materials. A metamaterial is a metallic or semiconductor substrate whose properties depend upon interatomic structures rather than composition of atom themselves.
- CPW feed can be used to optimize along with changing the shape of ground plane rather than just cutting the slots.
- Other feeding techniques can be used like coaxial feeding, aperture coupling or proximity coupling etc.
- By using slots at the regular interval in the patch along with DGS Configuration.
- By using fractal algorithms to make hybrid fractal i.e. combination of more than one shapes.

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LIST OF PUBLICATIONS

1) Communicated:

“An X-shaped Fractal Antenna with DGS for Multiband Applications,” submitted in International Journal of Microwave and Wireless Technologies, published by Cambridge University Press and the European Microwave Association, an SCI indexed Journal.



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