WIDEBAND FRACTAL MICROSTRIP ANTENNA FOR WIRELESS APPLICATIONS

A Thesis submitted towards the partial fulfillment of requirement

For the award of degree of

Master of Engineering

In

Wireless Communication Engineering

Submitted by

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PATIALA-147004 (PUNJAB)

JULY 2015

DECLARATION

I, Ashish Dhankhar hereby certify that work which is being presented in this thesis entitled "Wideband Fractal Microstrip Antenna for Wireless Application" by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Wireless Communication Engineering from Thapar University, Patiala is an authentic record of my own work carried under the supervision of Dr. Jaswinder Kaur and referred other researcher's work which are duly listed in the reference section.

The matter presented in this report has not submitted in any University/ Institute for the Award of Master of Engineering.

Ashish

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

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ACKNOWLEDGEMENT

This thesis is completed with prayers of many and love of my family and friends. However there are few people that I would like to specially acknowledge and extend my heartfelt gratitude who have made the competition of this thesis is possible. With the biggest contribution to thesis , I would like to thank **Dr. Jaswinder Kaur** had given me full support in guiding me stimulating suggestion and encouragement to go ahead in all the time of thesis.

I am also thankful to **Dr. Sanjay Sharma**, (Professor), Head, Electronics and Communication Engineering Department, for providing us the adequate infrastructure in carrying the work.

I am also thankful to **Dr. Amit Kumar Kohli**, (Assistant Professor) PG Coordinator of Electronics and Communication Engineering Department, for motivation and inspiration that triggered me for the thesis.

I am also thankful to **Dr. Hem Dutt Joshi**, (Assistant Professor) Program Coordinator of Wireless Communication engineering for motivation me for the thesis.

At last but not the least my gratitude towards my parents, I would also like to thank God for not letting me down at the time of crisis and showing me silver lining in the dark clouds.

ABSTRACT

The necessity for wireless communication and its estoric nature is enlarge during the two decades. In future, it is deduced to be more challenging and elaborate with evolution of different types of fractal antennas. Nowadays, smaller size of electronic equipment demand same size antenna element in order to place properly in the wireless devices without changing the radiation properties of antenna. Antenna plays an important role in WLAN communication system because it performance depend upon the quality of wireless communication. There are different types of fractal antennas like Sierpinski Gasket, Sierpinski Carpet and Minkowski fractal antenna for wireless communication. In Sierpinski Gasket, an equilateral triangle patch antenna is designed by the iterative procedure. Two or more copies of this triangle are generated attached to the original triangle. Sierpinski Carpet fractal antenna consists of square patch antenna which is also obtained by iterative procedure. Maximum iteration is applied to designed antenna is3.The behavior of designed antennas are enquired into such as return loss, gain and ultrawidebandwidth. The various types of slot on the patch helps in increasing the ultrawideband and give well planned result.

In this thesis report, different antennas design are given and then study the various effects of different parameter like patch length, patch width, substrate height and dielectric constant for WLAN and WIMAX applications. These antennas are designed using CST 2014 microwave studio. The antennas parameter like return loss, resonating frequency, gain and bandwidth are allocated for each antenna design in order to get the desired antenna.

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List of Abbreviation

CDMA	**Code Division Multiple Access**
CST	**Computer Simulation Technology**
WLAN	**Wireless Local Area Network**
GSM	**Global System for mobile communication**
MPA	**Microstrip patch antenna**
Q Factor	**Quality factor**
WiMAX	**Worldwide Interoperability for microwave access**
UWB	**Ultrawideband**
RL	**Return Loss**
PC	**Proximity Coupled**
IMT	**International mobile Telecommunications**
VNA	**Vector network Analyzer**

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Chapter 1

INTRODUCTION

1.1 INTRODUCTION

Over the past few decades, wireless communication systems kept enthralling the engineers, receiving a lot of advantage because of their built in advantage such as low cost and convenience. Wireless local area network (WLAN) are being universally identify as flexible, compact and high speed data connectivity solution. This guide to an growing out of microstrip patch antennas [2].The concept of microstrip antenna was given by Deschamps in 1953.a copyright was issued in 1955 in France in the name of Gutton and Baissinor. After 20 years, a practical antenna was designed. The first practical antenna was developed by Howell [27] and Munson [28]. Microstrip antenna are low profile, compact , simple and inexpensive which are in the great demand for both commercial and military application [22].Microstrip antenna have some disadvantage like narrow bandwidth and low gain. The main problem in microstrip antenna is broad banding. Conventionally each antenna is operating at single or dual frequency bands, where various antennas are needed for different application. It will lead limited place and space problem [29].

The present study is based upon new trends known as “fractal antenna”. Fractal geometry was developed by Benoit Mandelbort in 1975.FRACTAL means broken or irregular shapes, which have same shape as whole object but at a different scale. It means it exhibit the self similar property. Fractal geometry is widely used in model complex shapes found in nature such as trees, star and mountains. The complexity of nature was taken by fractal than Euclidian geometry whose interpretation of mountains and cloud as cone and triangular respectively would not be same as fractal geometry [25].Its Latin name is “fractus” that found from the verb “frangere” means break. This type of geometry became more popular in 1990. With the help of this geometry we can designed the multiband antennas as well as new dimension of antenna array. Recently, Fractal antenna has been become more popular because of its attractive features such as better input impedance matching, reduced mutual coupling in fractal array antenna, miniaturization and frequency independent [24]. There are two important properties in fractal geometry self similarity and space filling which are not present in the Euclidian geometry. Self similarity provides flexibility in antenna by reducing the antenna size in horizontal and vertical direction. Space filling property leads to increasing the electrical size of antenna so reduced the size of antenna [23].Fractal antenna have different structure like Sierpinski Gasket, Sierpinski Carpet and Minkowski Island.

1.2 WIRELESS STANDARD

1.2.1 GSM:- GSM stands for global system for mobile communication. It is an open source system and access to code. It operated on the different frequencies like 900 MHz, 1800MHz and 1900 MHz.GSM based upon on the time division multiple accesses (TDMA).and uses voice coding and decoders. Inspite of frequency selected by operator, it is divided in to timeslot for individual phone to operate. It allows eight full rate or sixteen half rate speech channels per radio frequency. These eight radio timeslot are grouped into the TDMA frame. The transmission power in handset is limited to 1watt in GSM 1800/1900.

1.2.2 IEEE standard for WLAN:- The IEEE , accepted the WLAN standard in 1997.IEEE evolved the 802.11 and 802.11X for wireless local area network (WLAN) technology. 802.11 refers to air interface between a wireless client and base station.802.11 family consist of a series of half duplex over the air modulation techniques.802.11b and 802.11 uses the 2.4 GHz ISM band. They suffered interference from cordless phone and Bluetooth. They controlled their interference by using direct sequence spread spectrum (DSSS). 802.11a uses 5GHz frequency band so that dual band antenna was designed for WLAN applications which increased the high speed data rate [31].

1.2.3 IMT (International mobile Telecommunication):- In 1980, The ITU worked on next generation of mobile radio standard to move prevail mobile network from regional standard. This will help in finding the new frequency band as well as to increase the confluence with in prevail second generation wireless mobile technology. In 1990, growth of 2G mobile increases rapidly, now ITU started to move from 2G to3G technology. Mobile radio technologies become easy to approach for the telecom service accessible to undeserved region in developing countries. ITU announced the IMT (2000) to support transmission data rate up to 2Mbps for fixed station and 384 Kbps for mobile stations. It consist of various standard include the following: CDMA2000, WCDMA and UMTS etc. In 2007, world radio conference finds spectrum for IMT, below 1GHz and above 2GHz.

1.2.4 IEEE STANDARD FOR WiMAX:- WiMAX refers " Worldwide Interoperability for microwave access" and also known as IEEE 802.16 wireless metropolitan area network. WIMAX become hot spot for global telecom operator across the development of broadband technology. In 1998, IEEE developed the WiMAX to transfer the internet service throughout the world [31]. WiMAX is based on various technology such as MIMO, OFDM and OFDMA. It supports the two types of standard: IEEE 802.16d supporting the air interface of fixed and mobile broadband wireless access system. It supports the data rate up to 80Mbps over 60 km.

TABLE 1.1: Different wireless standard and their frequency band [31]

Wireless Applications		Frequency Band (MHz)	Bandwidth (MHz)
GSM	GSM 900	890-960	70
	GSM 1800	1710-1805	95
	GSM 1900	1850-1990	140
IMT		2300-2400	100
		2700-2900	200
		3400-4200	800
		4400-4900	500
WLAN		2400-2484	84
		5150-5350	200
		5725-5825	100
BLUETOOTH		2400-2500	100
WiMAX		2500-2690	190
		3400-3690	290

1.3. NEED OF ANTENNA IN WIRELESS COMMUNICAION SYSTEM

In any wireless communication system, the antenna plays a vital role in the reliability and performance of the system. An antenna is a “a metallic (usually) device used for radiating or receiving electromagnetic waves which acts as the transition region between free space and guiding structure like a transmission line in order to communicate even in a longer distance”. It acts as a transducer which converts one form of energy in to other. An antenna consists of two parts; Transmitter and Receiver. A transmitting antenna takes waves that are generated by electrical signals inside a device such as a radio and converts them to waves that can travel in an open space. Antennas are required by any radio receiver or transmitter to combine its electrical connection to the electromagnetically field. Radio waves are electromagnetically waves which carry signal through the air or space [2]. Radio transmitters and receivers express information in the system including Wi-Fi and point to point communication. The receiving antenna takes free-space waves and translate them into guided waves (electrical signals) that are compatible for cables or wires. In can be used in the satellite communication, radar, missiles and rocket. [1]. The amount of escaped energy is so small due to mismatched between transmission line and surrounding space. As two wires are closed so to each other, radiation from one tip will cancel radiation from other tip (as they are opposite polarities and distance between is too small as compared to wavelength).

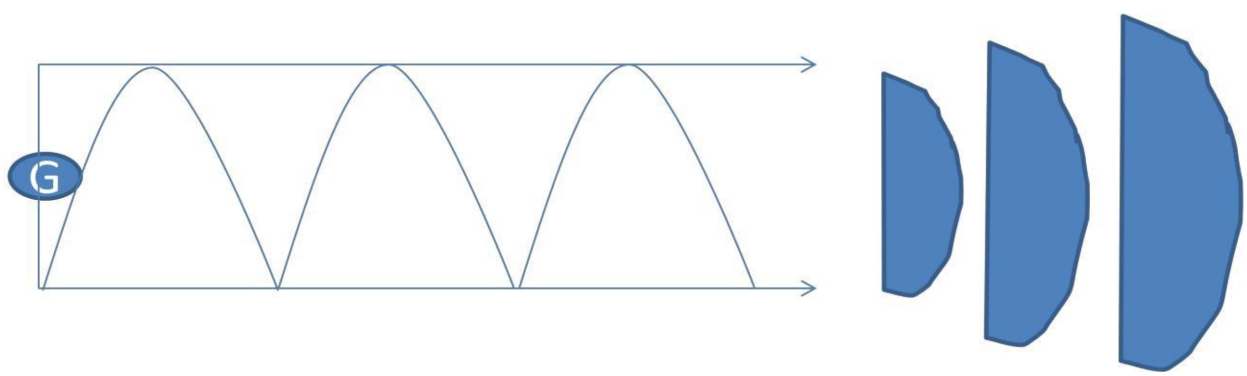


Figure 1: Radiation mechanism [2]

1.4 TYPES OF ANENNAS

Here, are some brief details about different types of antennas are [1]:-

Wire Antennas

Wire antennas are seen virtually every-where—on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are a variety of shapes of wire antennas such as a straight wire (dipole), loop, and helix. Loop antennas may take the form of a rectangle, square, ellipse, or any other configuration.

Aperture Antennas

Antennas of this type are very useful for aircraft and spacecraft applications, because they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. In addition, they are covered with a dielectric material to guard them from hazardous conditions of the environment.

Fractal Microstrip Antennas

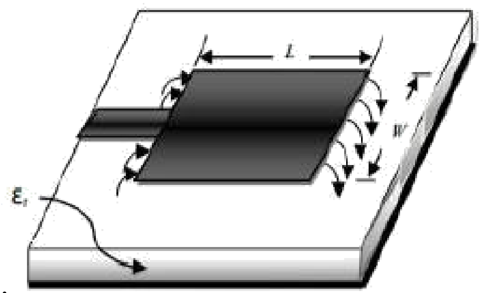
Fractal microstrip antennas became very popular in the 1970s. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations. However, the rectangular and circular patches are the most popular because of ease of analysis, fabrication, and low cross-polarization radiation. The fractal microstrip antennas are low profile, conformable to planar and non-planar surfaces, simple and inexpensive to fabricate, mechanically robust when mounted on rigid surfaces and very flexible in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mount on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

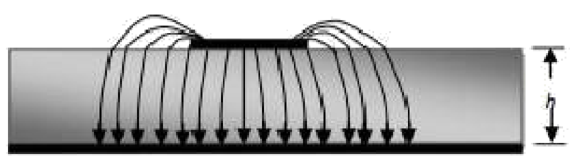
Reflector Antennas

In order to transmit and receive signals that had to travel millions of miles, a very ordinary antenna form for such an application is a parabolic reflector. Antennas of this type have been built with diameters as large as 305 m. Such Large dimensions are wanted to get the high gain essential to transmit or receive signals after millions of miles of travel.

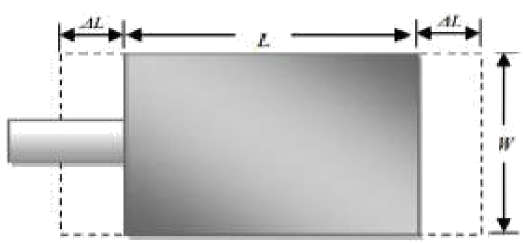
1.5 BASIC OF MICROSTRIP ANTENNA

Microstrip is also known as patch antenna. Nowadays, Microstrip antenna used in various applications such as aircraft, spacecraft, satellite and missile due to several advantages. These antennas have advantage of being low profile, simple, inexpensive and suitable for planar and non planar structure. Microstrip antenna was a simple antenna consists of radiating patch, dielectric substrate and ground plane. There are different types of dielectric substrate used which have their own dielectric permittivity value. Ground layer is thin layer of copper which is also good conductor. The thickness of dielectric substrate 'h' is usually $0.003<h<0.05$.and the thickness of patch 'L' above substrate is much less than λ (λ is free space wavelength). For a rectangular patch, the length of element is usually $\lambda/3<L<\lambda/2$ and dielectric constant of substrate [2].





(a) (b)



(c)

Figure 2: Microstrip antenna (a) Top view (b) Electrical field lines (c) Equivalent length [1]

Microstrip antenna can be designed with any shape. The mostly used shape are square, trapezoidal, rectangular, circular and triangular. Various shapes are given in figure 2.2.Mostly we used the square and rectangular shape as radiating element because they can be easily investigated by the theoretical model and symmetric structure. They can be applied to easily on various bandwidth improvement techniques on it. Antenna can be radiated in two ways: Broadside and end fire radiation. In Broadside, radiation pattern is normal to the axis of antenna and in End fire, radiation pattern is along the axis of antenna. Microstrip antenna can be designed by various substrates. As low dielectric constant material substrate is chosen to achieve high bandwidth and return loss. For reducing size of microstrip patch antenna, higher dielectric constant material is chosen. But it shows the poor radiation efficiency [15].

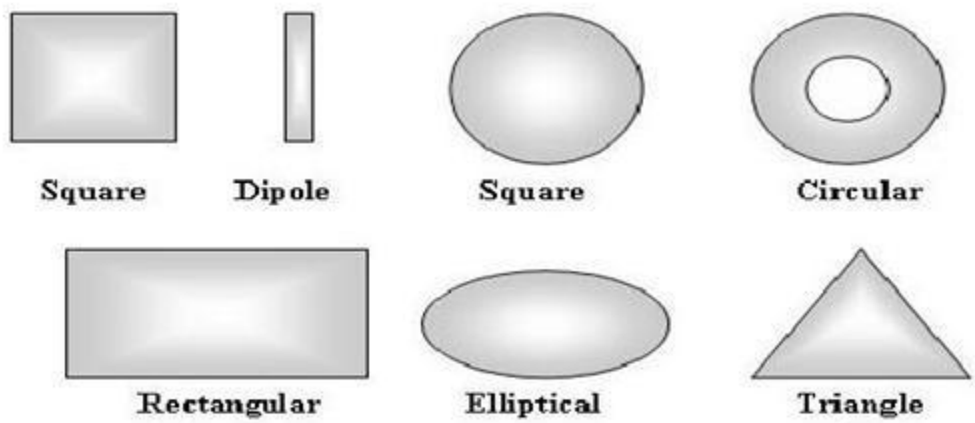


Figure 3**:** Different types of Microstrip patch antenna [1]

Quality factor is an important antenna parameter that represents the antenna loss like dielectric, surface wave and conduction losses. The total quality factor Q_t contributes the loss due to radiation, conduction, dielectric and surface waves which can be given as:-

$$\frac{1}{Q_t} = \frac{1}{Q_c} \quad \frac{1}{Q_d} \quad \frac{1}{Q_{SW}} \quad \frac{1}{Q_{rad}} \qquad (1.1)$$

Where,

Qt = Total Quality factor

Qc = Quality factor affected due to the conduction losses

Qd = Quality factor affected due to the dielectric losses

Qsw = Quality factor affected due to the surface wave losses

Qrad = Quality factor affected due to the radiation losses

Radiation mechanism of microstrip patch antenna

As dimension of patch are finite along length and width, field at the edge of patch undergoes fringing. As the patch antenna can be seen as open circuit transmission line, voltage reflection coefficient would be -1. When this happens, voltage and current are out of phase. So, at the end of patch antenna voltage is maximum (+V volt). At the start of patch antenna voltage is minimum (-V volt).An effective dielectric constant is introduced to account for fringing and wave propagation. Because of fringing effect, electrically patch of microstrip antenna look greater than physical dimension. Amount of fringing is function of dimension of patch and height of substrate So, field below the patch shown in figure 3, which shows the fringes of field around the edges [1].

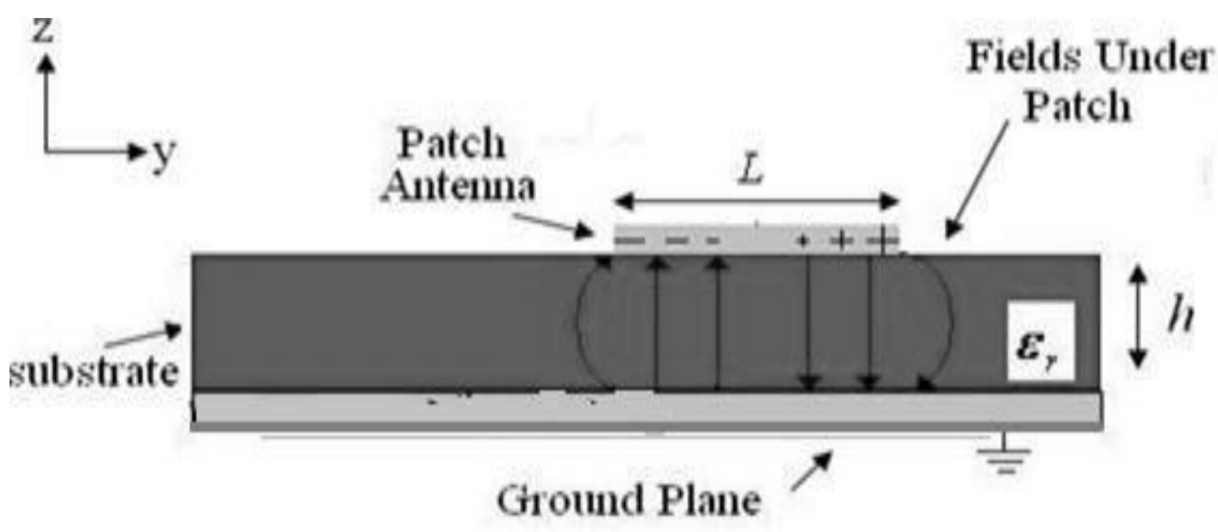


Figure 4: Side view of patch antenna with E field [1]

1.6 FRACTAL GEOMETRY

Benoit Mandelbrot described the term 'FRACTAL' and he has described the relationship between fractal and nature using discovery made by Gaston Julia and Pierre Fatuous [11]. Its Latin name is fractus means 'broken': some of parts have same shape as whole object but on a different scale. Fractals concept have been applied to many branches of science and engineering including fractal electrodynamics for radiation and propagation. Fractal geometries have been used to determine the objects in nature that is tough to define with Euclidian geometry [12]. Fractal geometry formed using an iterative process that leads to self similarity and self affinity structure.

Fractal; can be classified in to two categories: Deterministic and Random. *Deterministic* are those that are generated several scale down and rotated copies of themselves. *Random* fractal contain element of randomness that allow that allow simulation of natural phenomenon. Fractal antennas are addition of classical antenna which utilizes fractal geometry and antenna theory plays an important role in the fractal antennas [13]. They are described as below:

1.6.1 Measurement of Fractal

Fractal dimension allows us to determine the degree of complication by assessing how fast our measurements increase or decrease as our scale become larger or smaller. Dimension of any object plays an important role in fractal measurement because many of fractal design are shown by its dimension.

1.6.2 Dimension of fractal

The dimension of many ideal fractal shapes is usually carried out by applying an infinite number of times an iterative algorithm such as multiple reduction copy machine (MRCM) algorithm [14].In such process, an initial structure called generator replaced by many times at different position and scale. Hausdorff and Box counting dimension are two types of fractal dimension. Box counting states that how does the number of boxes it takes to cover the fractal scale with size of boxes and *Hausdorff* dimension states that how does the number of ball it takes to cover the fractal with the shape and size of ball. Benoit Mandelbrot also described the Euclidian dimension and Topological dimension [15].

1.6.3 Specification

For antenna to work at all resonating frequencies it meets two things: it must be symmetrical about point and it should be self similar.IFS also plays an important role in the specification of fractal. Iterated mathematical process formed the shape of fractal. This process can be narrated by IFS algorithm, which is based on series of affine transformation [Weiner and Ganguly 2003].

So, the shape of fractal is made up of overlapping smaller copies of itself, each copy is changed by IFS system. Such Fractal can be obtained by using computer graphics require particular mapping that is replicate over and over recursive algorithm. The best example is Sierpinski Gasket which is also known as Sierpinski triangle.

1.6.4 Properties of fractal

Fractals have some special property to make the antenna design attractive [14]:

Gain: Fractal antenna displays a gain which depends slowly on frequency over large frequency range.

Space filling properties: Fractal antennas place long electrical length into small volume only.

Self similar pattern: Because of this property, Fractal antenna operates in similar way at several wavelengths and antenna should keep radiation pattern through several bands.

Mechanical simplicity and robustness: The feature of fractal antenna is obtained due to its geometry and not by the addition of discrete component.

Spatial structure: Fractal antenna display a spatial structure which is resemble to the antenna gain so that antenna concentrate more power in fixed position or not anywhere.

Broadband operation: Fractal antenna detects and radiate easily within the wide range frequencies. Frequency range is determined by the smallest and largest size in the antenna. So, detection efficiency does not change as a function of frequency.

These properties can be more helpful in designing antennas which are miniaturized and have improved multiband and compact behavior.

1.7 Fractal Antenna

Overview

The term **FRACTAL,** which mean wrecked or asymmetrical fragments. The original inspiration for the development of fractal geometry came largely from an in-depth study of the patterns of nature. For instance, fractals have been successfully used to model such complex natural objects as galaxies, cloud boundaries, mountain ranges, coastlines, and snowflakes, continue to be found in many branches of science and engineering. One such area is fractal electrodynamics, in which fractal geometry is mutual with electromagnetic theory for the use of analysis a new class of radiation, propagation, and scattering problems. One of the most capable areas of fractal-electrodynamics research is in its application to antenna theory and design. Usually, approaches to the analysis and design of antenna systems have their foundation in Euclidean geometry. There has been a significant amount of recent interest, however, in the possibility of developing new types of antennas that employ fractal rather than Euclidean geometric concepts in their design. We refer to this new and quickly growing field of research as fractal antenna engineering, because fractal geometry is an extension of classical geometry [8]. There is some valuable geometry for fractal antennas and they are demonstrated as follows:

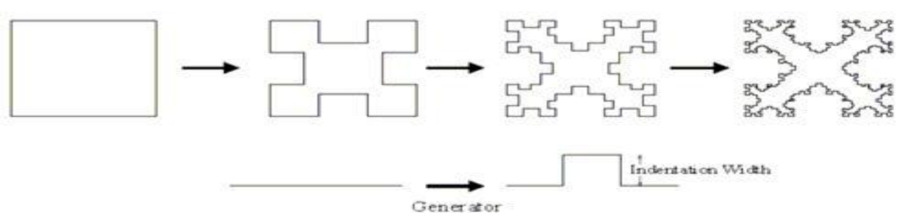


Figure 5: Minkowski Fractal Island [12]

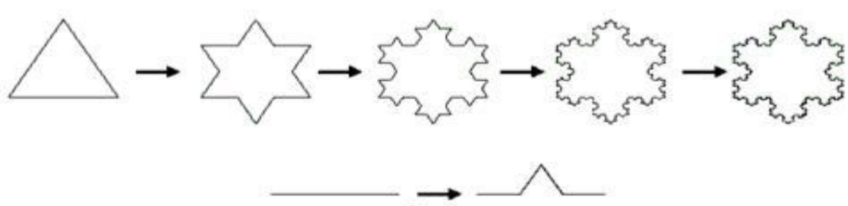


Figure 6: Koch Fractal [10]

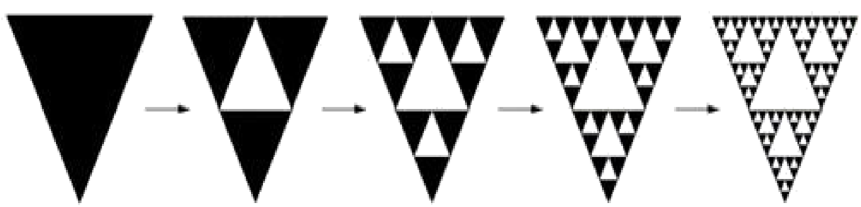


Figure 7: Sierpinski Fractal [10]

Advantages of Fractal antenna

Minituratization

Better impedance matching

Reduced mutual coupling in fractal array antenna

Frequency independent (depend over large frequency range).

Smaller cross sectional area

Multiple Resonance

High gain in few cases

Disadvantages of fractal antenna

Gain Loss

Numerical limitation

Fabrication and design is difficult

New development and more research in this area will be helpful in overcoming these advantages**.**

1.8 Feeding Techniques

There are many different feeding techniques that can be used to feed the fractal antennas. The most popular feeding techniques are Micro strip line, coaxial probe, Proximity feed, Aperture coupled feed and CPW feed. Feeding mechanism can be described in two parts: Contacting and non- Contacting. In contact feeding, feed line has direct contact with radiating patch. And in non contact feeding, energy is electromagnetically coupled from microstrip line to radiating patch [1].

1.8.1 Microstrip feed line

Microstrip feed line is a conducting strip, usually of much smaller width as compared to the patch. The microstrip line is easy to fabricate and easy to get impedance matching by using inset feed. However as the substrate thickness increases, surface waves and spurious feed radiation increases which for predicted design limit the bandwidth (2.5%). A microstrip patch antenna with electrical equivalent circuit and microstrip feed line as shown in figure:-

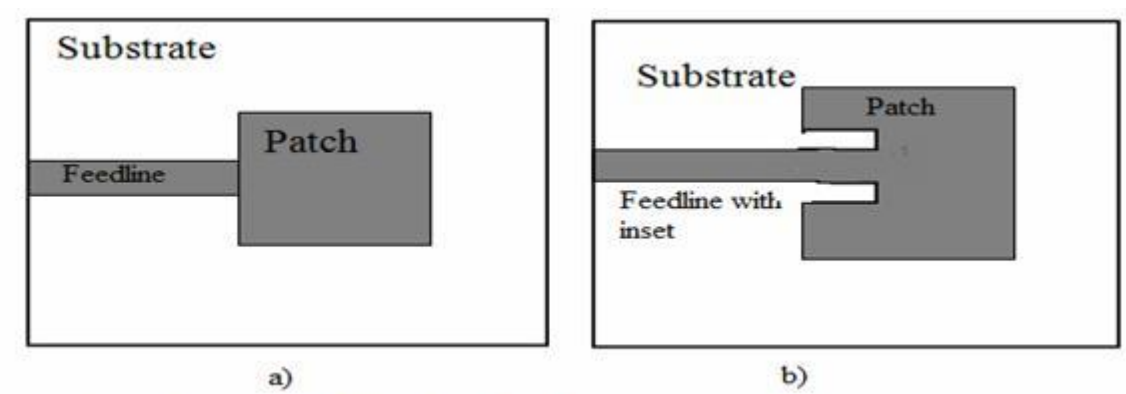


Fig.3:-Geometry of Micro-Strip Feed line (a) directly feed (b) Inset feed

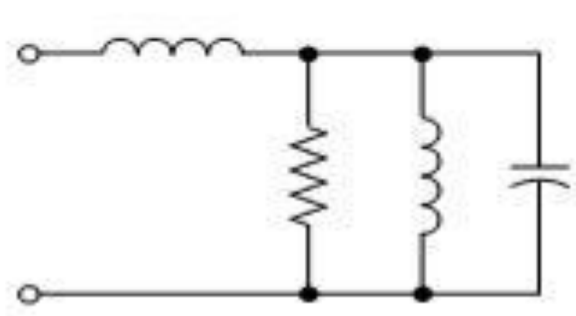


Figure 8: Equivalent Circuit [1]

1.8.2 Coaxial Probe feed

In this technique, inner conductor of coaxial attached to the radiation patch and outer conductor is made connected to the ground plane. This feed is easily to fabricate, match and it has low spurious radiation. However , it has narrow bandwidth and difficult to model for thick substrate. Its equivalent circuit is same as microstrip feed line. Primarily, Probe and microstrip line feed stimulate the dominant patch and these feeds generate some higher order modes which produces the cross polarized radiation.

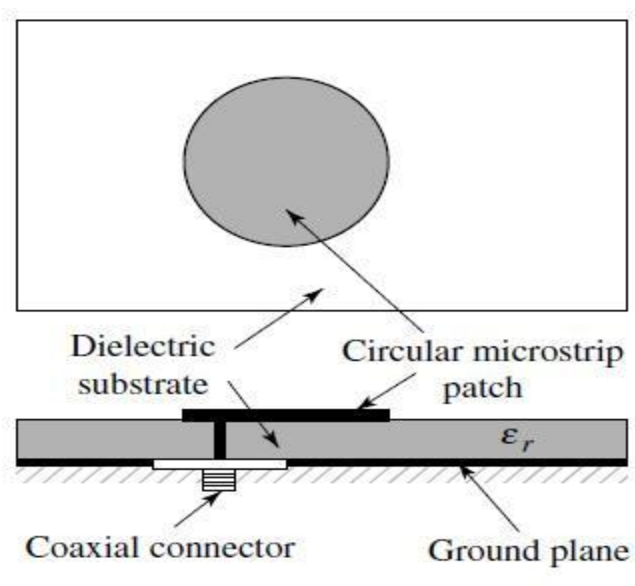


Figure 9: Coaxial Probe feed Line [1]

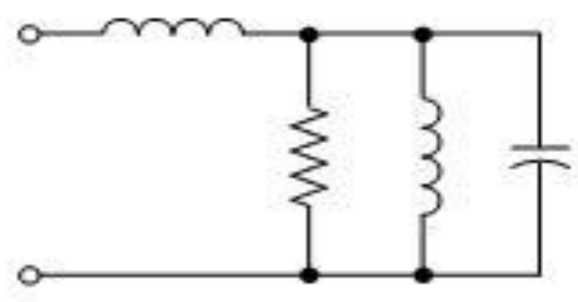


Figure 10: Equivalent Circuit [1]

1.8.3 Aperture Coupled feed

In this, two types of dielectric substrate are used. They are separated by metallic ground plane. The upper one is called superstrate. As, high dielectric material used for bottom substrate and thick low dielectric constant for upper substrate. The lower one can be used for energy coupling and upper one is responsible for radiation from patch. So, Microstrip line is used in this feeding which is placed below substrate and energy from feed line coupled electromagnetically through aperture made on ground plane. Rectangular and Circular are two most common aperture in this feeding. The disadvantage of this feeding is that it is difficult to fabricate due to multiple layer which also increase the antenna thickness. It provides narrow bandwidth. Antenna with aperture coupled feed and its electrical equivalent shown below:-

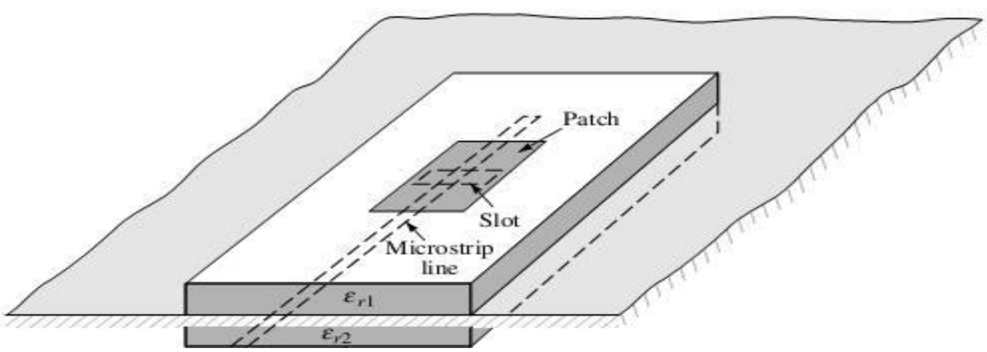


Figure 11: Aperture Coupled feed [1]

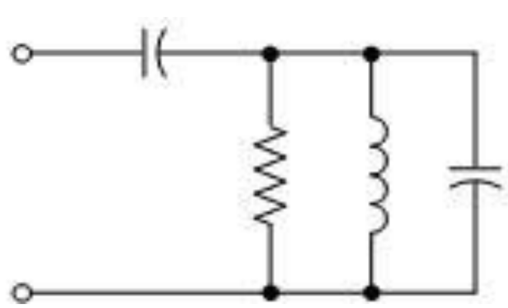


Figure 12: Equivalent Circuit [1]

1.8.4 Proximity Coupled feed

In this feeding technique, two substrate are used. It is a type of non-contacting feed. This feed line separate two substrate. As in case of aperture coupled feed, selection of substrate material are choosing same. The disadvantage of this technique is its fabrication because of multiple layers. The advantage of proximity coupled feed techniques is its maximum bandwidth and it also reduced the spurious radiation and coupling. The coupling to the proximity is of capacitive nature. Equivalent circuit has capacitor in series with parallel RLC resonator that represent patch. Antenna with proximity coupled feed with shown below:-

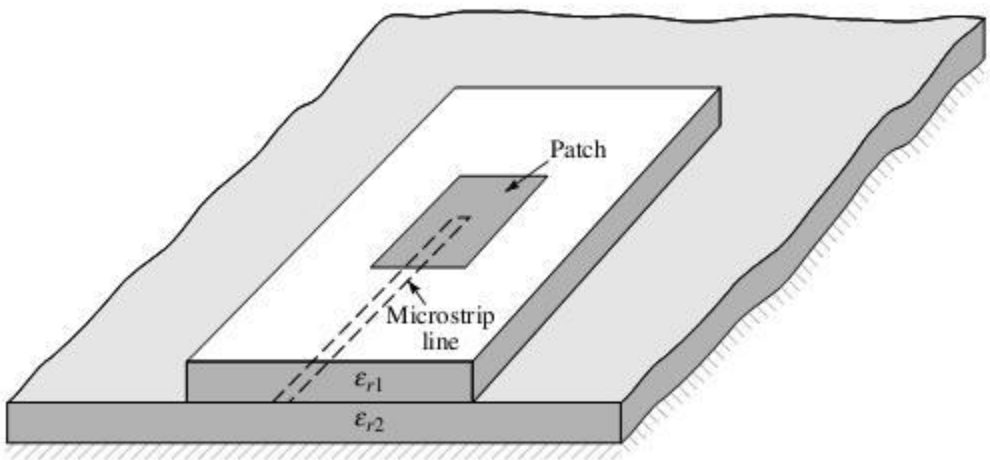


Figure 13: Proximity coupled microstrip patch [1]

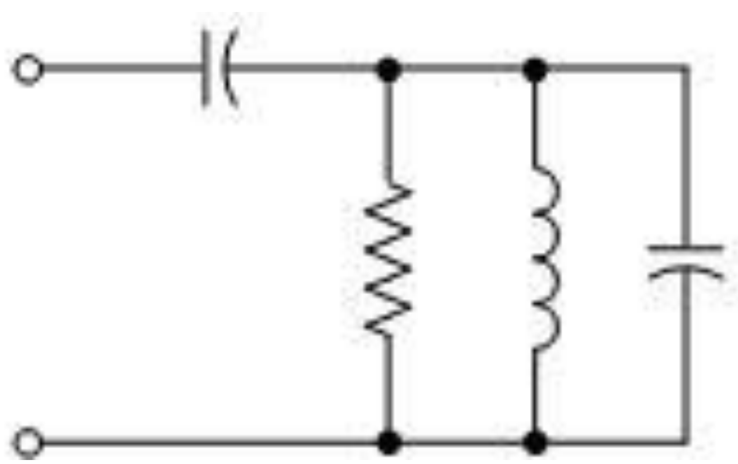


Figure 14: Equivalent Circuit [1]

1.8.5 CPW feed

This feed was introduced by C.P.WEN in 1969. It consist of median metallic strip deposited on the surface of dielectric substrate slab with two narrow slit on ground electrode running adjacent and parallel to the strip on same surface. The advantage of this feeding is low radiation loss ,less dispersion and easy integrated structure. These feeding techniques have attractive features such as wider bandwidth and better impedance matching. Antenna with Cpw feed as shown below:

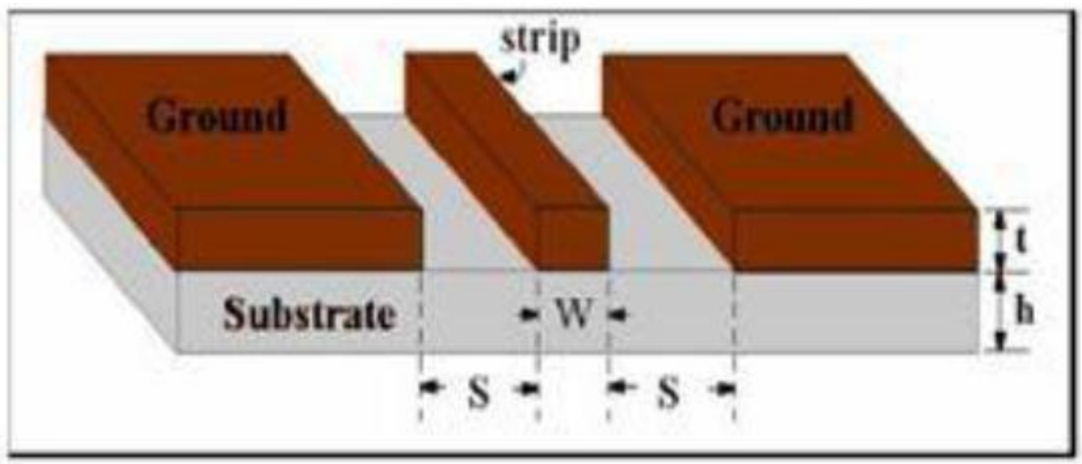


Figure 15: Geometry of Coplanar Waveguide feed [1]

Table 1.2: **Comparison for feeding method for MPA [1]**

Characteristic	**Microstrip feed line**	**Coaxial feed**	**Aperture coupling feed**	**Proximity feed**	**Coplanar waveguide**
Spurious feed radiation	More	More	More	More	More
Reliability	Better	Poor due to soldering	Good	Good	Good
Bandwidth	2-5%	2-5%	13%	21%	40%

For more reliability and easy impedance matching, Proximity coupled feeding technique is used. Because it provides better bandwidth as compared to the Microstrip feed line and coaxial probe**.**

1.9 Application of fractal

Fractal can be used in the electrical and electronics engineering field [10]. The various applications are shown below:

1.9.1 Lightning Model

Lightning model is accomplished with fractal. It is used in various application. Study of lightning stroke on full scale model of aircraft on ground require lightning stroke which is produced by fractal modeling.

1.9.2 High impedance fault detection

In electrical and power systems, high impedance faults are very unusual. These fault do not draw much current to operate protective relay. They also fail to initiate return path, as fault goes it melt the conductor, causes current very disorder. FD is measure of this fault as shown in figure 16.

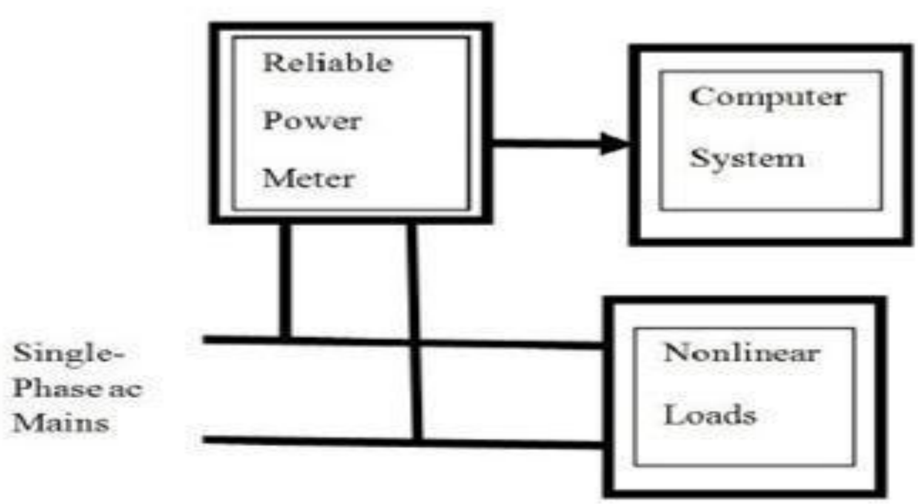


Figure 16: Block diagram of fault locator [10]

1.9.3 Fractal radar concept

Tone, Texture and structure features on radar are crucial bases of target recognition in fractal radar. FD can extract the texture and structural features of ground object.

1.10 Objective of thesis

a) To design and simulate the Sierpinski Gasket Fractal antenna for multiband application.

Parametric studies on the proposed antenna design.

b) To design and simulate the novel microstrip feed circular rectangular corner fractal antenna for ultrawideband application.

Parametric studies on the proposed antenna design.

Fabrication and testing of proposed antenna design.

1.11 Methodology

Detailed study of wideband fractal microstrip antenna structure.

Forconductingsimulationofproposedantennadesigns,FullWaveElectromagnetic Simulator will be used.

The return loss or S_{11} parameters of the proposed antennas would be measured using Vector Network Analyzer.

The field patterns and gain measurements would be analyzed using Anechoic Chamber.

For showing the comparative analysis of simulated and measured results for return loss and radiation pattern, the simulation software math works-Matrix Laboratory (MATLAB) would be used for making various types of plots.

1.12 Organization of thesis

The thesis is divided into Six Chapter.

Chapter 1 covers the introduction about fractal antenna, its application and overview of wireless communication. It also covers the basic of microstrip antenna and different types of fractal antenna available.

Chapter 2 presents the Literature review in context of wideband fractal microstrip antenna for wireless application.

Chapter 3 covers the design of Sierpinski Gasket fractal antenna for multiband applications. Simulated results of proposed antenna including return loss, directivity and resonant frequency are measured and compared.

Chapter 4 covers the novel microstrip feed circular rectangular corner fractal antenna for ultrawideband application. In this proposed antenna is fed with microstrip feed line which give desired frequency band, ultrawideband and better return loss. The antenna is fabricated and results are compared with simulated results.

Chapter 5 includes fabrication and testing of the novel microstrip feed circular rectangular corner fractal antenna for ultrawideband application using VNA and comparison of simulated and measured result is done.

Chapter 6 This chapter gives the conclusion to thesis and future scope of work on the present thesis.

Chapter 2

LITERATURE REVIEW

2.1 Objective

In order to start the thesis, the first step is to study the research papers that have been performed previously by other researchers. The papers that are related to this title are chosen and studied. With the help of this literature review, it gives more clear understanding to perform this thesis. This chapter gives idea about evolution of fractal microstrip antenna and various developments in the past.

Keith R. Carve ***et al. [1981]*** proposed that the choice of material is a very important task in antenna design. PTFE (Polytetrafluoroethylene) being electrically and mechanically robust and available in wide range of thicknesses and sheet sizes became the most used material type. Basically, by the proper selection of the material, it becomes easy to eliminate the temperature effects on the resonant frequency of a fractal microstrip patch antenna [4].

David M Pozar ***et al. [1992]*** proposed the emphasis on new antenna configuration for improved electrical performance and manufacturability and advance in the analytical modelling of microstrip antenna and array. Materials with electric and magnetic anisotropy find useful application in microstrip antenna and array. Electro optic technology with fibre optic line can be used to control signal to radiating modules in array, thus simplifying the layout and construction of large array antenna [5].

Hugo F.Pues ***et al. [1992]*** *et al* proposed the emphasis on new antenna configuration for improved electrical performance and manufacturability and advance in the analytical modelling of microstrip antenna and array. Materials with electric an magnetic anisotropy find useful application in microstrip antenna and array. Electro optic technology with fibre optic line can be used to control signal to radiating modules in array, thus simplifying the layout and construction of large array antennas [6].

M Jamshidifar ***et al. [2005]*** proposed reduced size and wide band fractal patch antenna is introduced because its likeness to butterfly it has named fractal butterfly patch antenna. By its comparison to conventional square patch antenna more than 65% size reduction and third iteration of fractal is achieved. By utilising T-probe feed method 13% method impedance band width is obtained as well 60% reduction in size [7].

K. Siakavara ***et al. [2007]*** proposed compact fractal microstrip antenna for global positioning system and terrestrial radio services presented. It is composed via the union of four inverse Koch fractal patches. The antenna operates in three frequency ranges (GPS, Digital Cellular System DCS1800 and 2.7 GHz). At GPS, the antenna is capable of generating a circularly polarized field and other two frequencies the field is linearly polarized [8].

M.S.R. Mohd. Shah, ***et al. [2009]*** Due to the current trend, one way of improving and making maximum use of wireless communication is by using array antennas. As the number of arrays in the antenna increases, there is an increase in gain, return loss, bandwidth [9].

Yogesh Kumar Choukiker ***et al.*** **[2011]** proposed a new size fractal microstrip antenna in wideband frequency range. It is designed with combination of two fractal geometry the length and width of koch and cantor fractal geometry is achieved to a wide band width. The propose antenna has Omni directional radiation and good gain at wide band frequency range [10].

J L Medeiros ***et al. [2012]*** proposed development of new substrates with high permittivity has allowed a considerable reduction of physical dimensions of microstrip antennas. The development of several types of dielectric substrates as the ceramics substrates widely used. In this paper we design and build titanium dioxide ceramic substrate for microstrip fractal antenna which has high index or refraction and chemical stability. Fractal antenna with dielectric ceramic layer using small device for wireless application [11].

B H Ahmed ***et al. [2013]*** proposed fractal in microstrip antenna with Minkowski island split ring resonator (MI-SRR). Four MI-SRR structures connect to the corner of Minkowski island fractal to improve bandwidth of antenna. Now it is found that MI-SRR creating the broad band antenna improved its return loss efficiency and bandwidth [12].

B Hephzibah Lincy ***et al. [2013]*** proposed design analysis of fractal antenna which uses self similarity property of fractal geometry. The present antenna is circle inscribe octagon shape. It is observed that number of side lobe reduced as number of iteration increased. Return loss of third iteration is less than second in both frequency range. Microstrip fractal antenna assured simplicity in design and fabrication [13].

Divya Dixit Saxena *et al. [2013]* proposed fractal based microstrip antenna in wireless communication which have multiband performance and non harmonic frequency. The fractal antenna has compressed resonant behavior. Fractal microstrip antenna and microstrip antenna have compared and conclude that fractal antenna have better in terms of VSWR and return loss than patch antenna. Far radiation pattern plot in far smoother far case of fractal antenna [14].

X Yang *et al. [2014]* proposed Minkowski fractal antenna for Bluetooth application has design. In this analysis we have compared antenna parameter such as gain impedance, antenna efficiency, gain efficiency, VSWR. Minkowski antenna up to first iteration with microstrip feed has designed. After making a fractal bandwidth has been enhanced to 18.9 MHz for same resonant frequency. Antenna efficiency to 69.7% from 60.7% which clearly indicates advantage the patch fractal [15].

Archana Singh *et al. [2014]* proposed a square antenna achieved shifting resonant frequency using Minkowski island pattern of fractal compared with initiator and Minkowski fractal microstrip antenna shows shifting in resonance frequency due to incrementing length of microstrip antenna. Fractal pattern of Minkowski Island introduced increase in electrical length and return loss [16].

Nadar Behdad *et al. [2004]* presents wideband multi resonant single element slot antenna with excellent radiation parameter over the entire bandwidth. Single element slot antenna achieved wideband operation from different radiation mechanism and field distribution at different frequencies. It also presented low cross polarization level at the different directions and frequencies [17].

Jianxin Liang *et al. [2005]* presents the study of novel antenna for ultrawideband applications. A planar circular disc monopole provides an ultrawidebandwidth -20dB return loss and bandwidth with satisfactory radiation properties. Performance of antenna in terms of frequency domain characteristics depend on feed gap, width of ground plane and dimension of disc. The impulse response of antenna has stagnant ringing effect due to the mismatch between antenna bandwidth and pulse bandwidth [18].

Mehmet Sezgin *et al. [2010]* represents the enhanced elliptical planar dipole antenna design for UWB communications and impulse radar. Elliptical slots are used on dipole arms to increased the gain and return loss bandwidth of antenna. Gain has been increased by elliptical slots in frequency range from 2.7 to 11GHz at standing wave ratio is less than 2 along 94.4% of operation bandwidth from 1.1 to 11GHz. When the time domain characteristics of proposed antenna analyzed narrow pulse can be transmitted and produce ringing effect for impulse radar system [19].

Kostas Dangakis *et al. [2006]* presents the lower circular and elliptical coplanar waveguide fed slot and microstrip antenna design targeting the 3.1-10.6 GHz band. It represent the good behavior throughout the 7.5GHz of allocated bandwidth in terms of impedance matching, radiation efficiency and radiation pattern characteristics. By transforming the Cpw feed to microstrip UWB characteristics are preserved along the radiation profile [20].

Joeri R. Verbiest *et al. [2006]* presents a novel antenna topology based on printed tapered monopole antenna is investigated in terms of ultrawideband wireless body area network applications. The bandwidth in presence of human arm is studied than pulse distortion of modulated Gaussian pulse studied based on measured S_{21} Parameter. This design also yields a larger bandwidth [21].

Kailas K. Sawant *et al. [2012]* presents the novel circular feed circular square corner fractal antenna with vary notch band frequency characteristics. The antenna exhibit UWB characteristics from 3.1GHZ to 15GHZ band. The main function of notch to reduced the interference with frequency band of WLAN. The proposed antenna having frequency band notch characteristics for fourth generation UWB wireless communication system and vehicular radar [22].

Min Ding *et al. [2007]* presents the pulse preserving capabilities of printed circular disc monopole antenna with different ground for specified for input signal forms respectively. The correlation factor of these monopole with different ground measured the correlation between the transmit antenna signal and electric field intensity signal in far field transmitting region of transmitting antenna. The improvement in the correlation factor in the x-y plane is introduced by curved and hexagonal ground is about 6.4% and 8.1 % respectively. This gives the significant improvement with printed monopole antennas [23].

Rowdra Ghatak ***et al [2008]*** presents the printed antenna for WLAN application. It adopted the modified geometry of sierpinski gasket in planar monopole configuration. Return loss characteristics shows that antenna is suitable for hiperlan2 system. The measured peak realized antenna gain is around 3.21dBi at high frequency band. Overall size can be used integrated with other component in WLAN communication [24].

J. Malik ***et al [2011]*** presents the microstrip sierpinski modified and fractalized antenna using multilayer structure to achieve dual band behavior for WLAN application. The proposed antenna design is smaller than the conventional Euclidian type because of space filling property of fractal geometry. This antenna is suitable for dual band application. A significant size reduction of 22% and 36% for 2.4 and 5.6GHz band respectively [25].

R. Ghatak ***et al [2009]*** presents the novel technique for designing sierpinski gasket fractal microstrip antenna. It uses an evolutionary method based on real coded genetic algorithm in conjunctions with electromagnetic simulation. The side length and fractal iteration number of antenna for the operation at 4.56, 7.55 and 11.78GHz determined in this method. This design uses two differential RCGA implementation strategies. First one is Adewuya mating and second is heuristic crossover in conjunction with non uniform mutation. Simulation results shows that undulation in radiation pattern are observed with increasing frequency and pattern is consistent in any given band but changes as frequency band changes [26].

Zubair Ahmad ***et al [2009]*** presents the sierpinski gasket fractal monopole antenna. Sierpinski gasket fractal antenna constructed through iteration which display multiband behavior with 3 bands. And scale factor determines the geometrical self similarity of sierpinski fractal. Simulated return loss and radiation pattern display multiband behavior. Results shows that band position could be controlled by changing the scale factor but on account of poor input impedance matching. The poor matching is improved by the microstrip line and return loss to less than -15 dB. It also concluded that number of log periodic band is directly proportional to the fractal iteration [29].

Peter Z. Petkov ***et al [2014]*** presents the analysis of modified sierpinski gasket antenna for Wi-Fi applications. Modified antenna is smaller in size and exhibit larger gain. Performance of this antenna is coupled with the simple monopole and deterministic sierpinski gasket. It covers the frequency 2.4 and 5GHz band. This antenna design shows that typical antenna feature with performance enhanced by departure of strict deterministic fractal generated geometry allocated to industry allocated frequency band [30].

Rafael Pous ***et al [1998]*** presents the multiband behavior of sierpinski gasket fractal antenna. Antenna is compared to well known single bowtie antenna due to its triangular shape. It shows that as number of iteration increases, number of multiband frequency increases. Self similarity property of fractal structure is translated into the electromagnetic behavior and allows similar behavior of antenna through bands [32].

S. Ahmad ***et al [2012]*** presents the new fractal based printed slot antenna for dual band wireless communication application. Antenna slot structure in the form of Sierpinski gasket first iteration. Simulated results show that antenna exhibit dual frequency resonant behavior suitable for dual band communication system including dual band WLAN application. It has founded that adding a vertical stub at proper position on the feed will provide better matching and precise allocation of the second resonant frequency. It is useful for the dual band communications applications [33].

Jaume Anguera ***et al [2004]*** presents dual frequency antenna based on the sierpinski fractal with two parasitic patches to enhance the impedance bandwidth. To know about the antenna physical behavior, an electrical model was formed by RLC resonator to achieve the dual band operation minimizing a trial and error numerical proof. The antenna has been designed using a method of commercial code and obtain two band with broad bandwidth and radiation pattern. Numerical current distribution shows that only top parasitic patch is working for the first band while bottom is quite transparent. For second band only bottom parasitic is operated. The measured prototype shows bandwidth 4.7% for first band and 6.8% with same radiation pattern for whole bandwidth and similar for both band conforming the dual band configuration [34].

E. A. Abdallah *et al [2009]* presents the novel compact design UWB planar monopole antenna. The basis for achieving the UWB operation through using semicircular microstrip monopole antenna with circular modified ground plane. The shape produce bandwidth ranges from 3 to 35 GHz band with discontinuities in certain band from 7 to 10GHz. The antenna size is 27%of the conventional microstrip patch antenna. For further improvement of antenna performance EBG structures are used. Bandwidth of microstrip antenna is improved in the frequency band from 1 to 35 GHz when embedded square EBG structures are used [35].

2.2 Research Gaps

As operating frequency increases, the value of 10 dB down return loss increases to an unacceptable level [12].

For designing a Minkowski fractal antenna up to the first iteration, results obtained were fine while changing W2 from 1 to 8mm keeping W1 constant as 1mm, but starts deteriorating beyond that [16].

As the total number of iterations increase, the value of 10 dB down return loss increases with a shift in operating resonant frequency[14].

Work can be done with different shapes of fractals for increasing bandwidth [10].

At higher operating frequency return loss increases. So, antenna can be designed with more return loss at higher operating frequency with greater bandwidth[18].

The major disadvantage of fractal geometry in the antenna design lack of flexibility in control of operating frequencies [10].

Chapter 3

DESIGN OF SIERPINSKI GASKET FRACTAL ANTENNA USING PROXIMITY COUPLED FEED MECHANISM FOR MULTIBAND APPLICATIONS

3.1 Introduction

In this chapter, the general procedure for designing a Sierpinski Gasket Fractal antenna using proximity coupled feed mechanism for multiband application is presented. The antenna is designed to operate in the multiband frequency application. It has been found that as number of iteration increases, number of resonant frequencies increases to the Sierpinski Gasket structure. The proposed antenna is suitable for wireless application. This design is simulated using 3D electromagnetic simulator CST MWS 14.0. Finally the results are obtained from simulation are demonstrated.

3.2 General design of Sierpinski Gasket Fractal shaped antenna

The basic design of Sierpinski Gasket Fractal antenna is illustrated in steps in following Table1.3.

Table 1.3: Steps for designing Sierpinski Gasket Fractal antenna

Step 1:- Choose desired the resonant frequencies
Step 2:- Choose appropriate substrate height and dielectric constant
Step 3:- Select the calculated length and height
Step 4:- Proper feed point location is chosen
Step 5:- Simulation is done by using CST 2010 software
Step 6:- The best result is selected to design antenna to resonant at desired frequency

3.3 Proximity coupled feeding

In this feeding technique, two substrate are used. It is a type of non-contacting feed. This feed line separate two substrate. As in case of aperture coupled feed , selection of substrate material are chosing same. The disadvantage of this technique is its fabrication because of multiple layers. The advantage of proximity coupled feed techniques is its maximum bandwidth and it also reduced the spurious radiation and coupling.

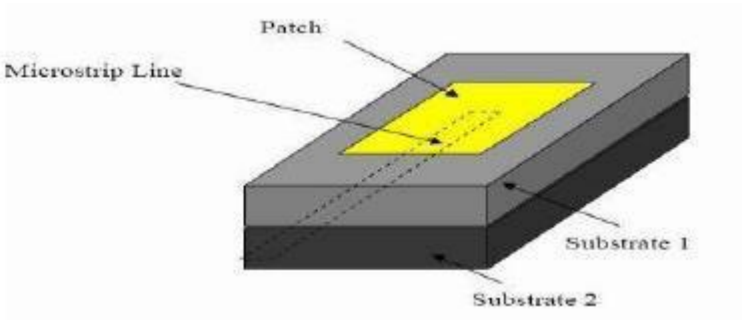


Figure 17: Proximity Coupled Feeding

3.4 Selection of Proximity Coupled Feeding Technique

There are few advantage of Proximity Coupled feeding technique over other feeding techniques.

Higher Bandwidth

Impedance matching is easy

No direct contact between feed line and radiating patch Higher reliable feeding technique

Less spurious radiation

3.5 Design consideration of fractal antenna

The patch size is designed based on width, Length of fractal for a given resonant frequency and dielectric constant of antenna. An array can be used as group of elements which can be used in designing antenna. The overall goal is to achieve specific performance characteristics at desired operating frequency. If antenna configuration achieves these goals, the first aim to select suitable antenna geometry. A fractal antenna can be designed using the procedure described in next section.

3.5.1 Substrate selection

The first step to choose good dielectric substrate with thickness h and loss tangent for designed antenna. A substrate with high dielectric constant reduced the dimension of antenna**.** A low value of ε_r for the substrate will increase the fringing field at the patch periphery, and thus the radiated power. Therefore, substrates with ε_r = 4.4 are preferred. Here substrate thickness h=1.6 mm and dielectric constant ε_r =4.4 are considered (FR4) for the desired antenna.

3.5.2 Element length and width

A design procedure is outlined which leads to practical designs of fractal antennas, based on the simplified formulation. The procedure includes the dielectric constant of the substrate (ε_r), the resonant frequency (f_0), and the height of the substrate h.

3.5.3 Feed point location

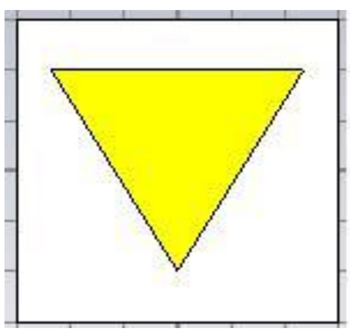
After choosing the patch dimension for a given substrate, the next thing is to determine the feed location to provide the good impedance between input impedance of patch element and generator impedance. It is shown that change in feed position give rise to change in return loss.

3.6 Antenna design

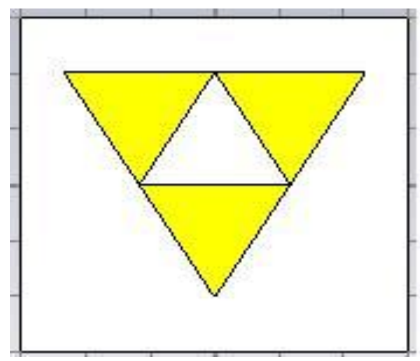
The procedure of how to make Sierpinski Gasket fractal antenna is shown in Figure 17(a), Figure 17(b) and Figure 17(c). The numerical design values of various antenna parameters are presented in Table 1.4. The final designed Sierpinski Gasket antenna shown in Figure 17(c) is designed on FR-4 Lossy Substrate (dielectric constant 4.4) with substrate thickness of 1.6 mm. There are three important parameters for the designing of designed antenna: height of substrate, dielectric material of substrate and resonant frequency. First a simple equilateral triangle is taken as shown in Figure 17(a). For first iteration, remove central inverted triangle from main triangle and process is repeated for further iteration [33]. This antenna is fed through proximity coupled feeding technique which provides maximum bandwidth with the benefit of minimizing spurious radiations.

Table 1.4: **Physical dimension of proposed antenna**

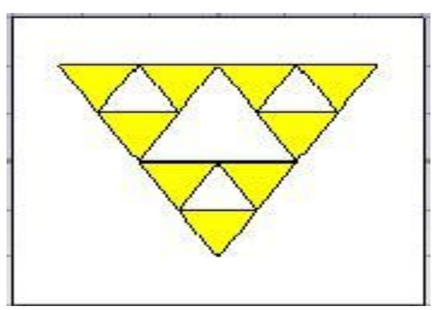
S.NO	**Antenna Parameter**	**Design Value**
1	Dielectrical Material	FR4_LOSSY
2	Substrate Height	1.6 mm
3	Flare Angle	60
4	Side Length	46.80 mm
5	Height	40.50 mm
6	Scale Factor	2
7	Dielectric Constant	4.4



(a) Zero Iteration



(b) First Iteration



(c) Third Iteration

Figure 18: Different iteration of Sierpinski Gasket Fractal Antenna

3.6.1 Simulation Results

The dimensions of designed antenna are optimized by hit and trial method using parameter sweep option available in transient solver window of CST MICROWAVE STUDIO Version 14.0. S_{11} parameter indicates Return Loss and it is defined as maximum reflection of power from the given antenna. The designed antenna structure is simulated starting from the initial iteration/generator to second iteration. The corresponding return loss curves are also shown side by side for all the three iterations thus illustrating the value of frequency of resonance and return loss. As the number of iterations increase, numbers of resonating frequencies also increase. The second iteration of the proposed antenna shows multiband behavior. Directivity is defined as maximum value of directive gain [1]. The simulated return loss curves of proposed antenna for initial, first and second iterations are shown in Figures 19(a), 20(a) and 21(a) respectively. 3D radiation patterns that represent directive gain are also analyzed for all the three iterations using the field monitors option in CST MWS V14.0 and are presented in Figures 19(b), 20(b), 20(c), 21(b), 21(c) and 21(d) correspondingly. The quick analysis of return loss and directivity for all the three resonating frequencies is tabulated in Table 1.4.

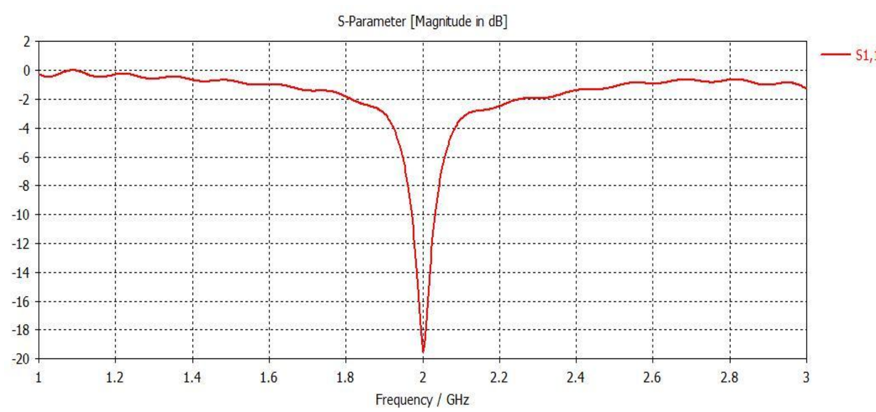


Figure 19(a): Return loss of initial iteration of designed antenna

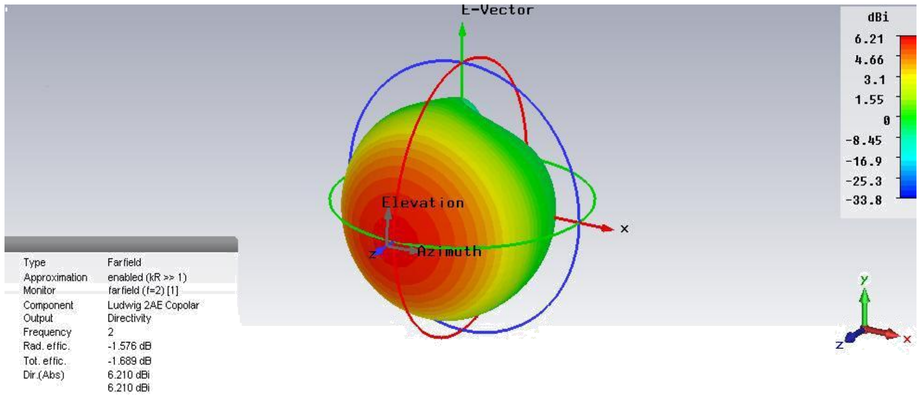


Figure 19(b): Directivity of initial iteration of designed antenna at 2 GHz

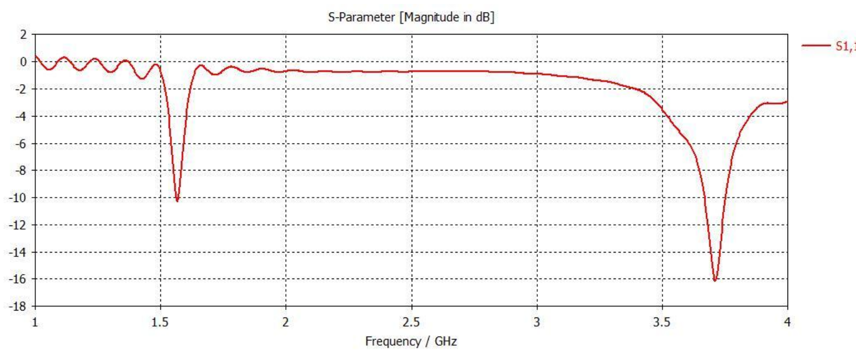


Figure 20(a): Return loss of first iteration of designed antenna

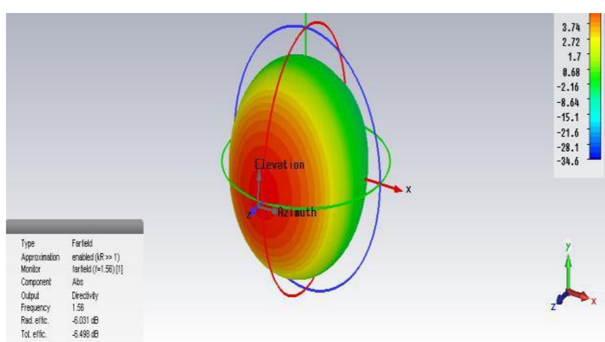


Figure 20(b): Directivity of first iteration of designed antenna at 1.56 GHz

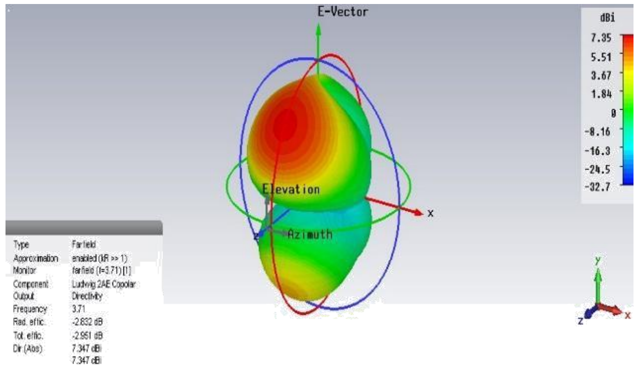


Figure 20(c): Directivity of first iteration of designed antenna at 3.71 GHz

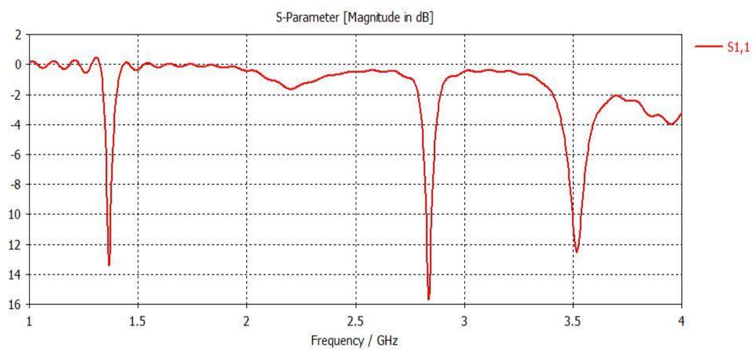


Figure 21(a): Return loss of second iteration of designed antenna

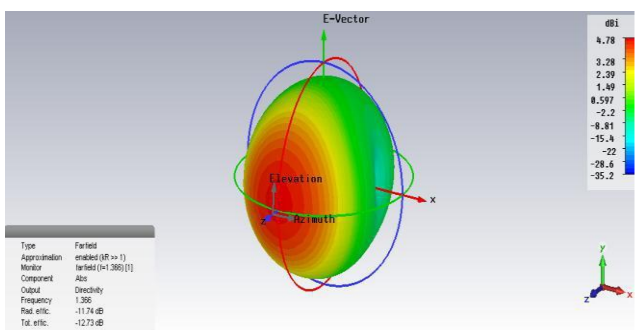


Figure 21(b): Directivity of second iteration of designed antenna at 1.36 GHz

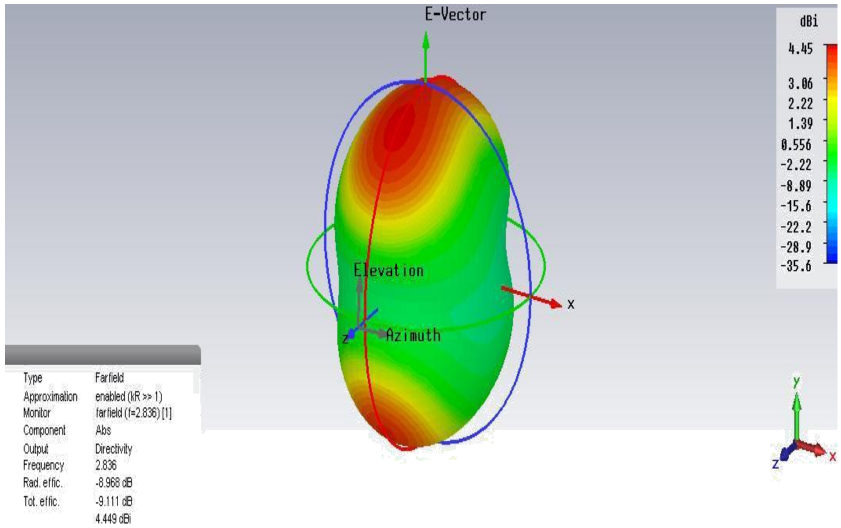


Figure 21(c): Directivity of second iteration of designed antenna at 2.83 GHz

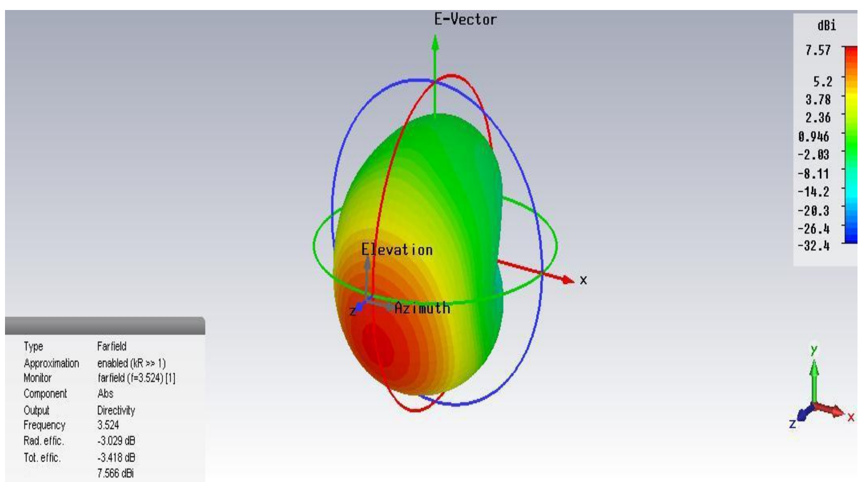


Figure 21(d): Directivity of second iteration of designed antenna at 3.52 GHz

TABLE 1.5: Comparison of return loss and directivity at various frequencies for zero, first and second iteration

ITERATION	RETURN LOSS	DIRECTIVITY (dBi)	FREQUENCY (GHz)
First	-19.5	6.21	2
Second	-10.3	3.70	1.66
Second	-16.1	7.34	3.71
Third	-13.4	4.77	1.36
Third	-15.8	4.44	2.83
Third	-12.5	7.56	3.52

The initial iteration starts with a triangular patch resonating at the frequency of 2 GHz with return loss -19.5 dB and directivity 6.21dBi. After this iteration, Sierpinski Gasket antenna resonates at two different frequencies viz. 1.66 GHz and 3.71 GHz with return loss values -10.3 dB and -16.1 dB and directivity 3.70 dBi and 7.34 dBi respectively. In the last iteration Sierpinski Gasket fractal antenna resonates at three different frequencies viz. 1.36 GHz, 2.83 GHz and 3.52 GHz with return loss values -13.4 dB, -15.8 dB, -12.5 dB having directivity 4.77 dBi, 4.44 dBi and 7.56 dBi respectively.

3.6.2 Conclusion

Sierpinski Gasket fractal antenna with proximity feeding technique has been presented in this paper. This fractal antenna has been analysed using CST Microwave Studio V14.0. It is observed that from second iteration onwards, it starts exhibiting multiband behaviour with an acceptable frequency response at multiple frequencies simultaneously. As number of iterations increase, number of resonant frequencies also increases which gives multiband performance to the Sierpinski Gasket antenna structure. The result shows that antenna gives appreciable return loss and directivity with miniaturization and is best suited for wireless applications.

Chapter 4

DESIGN OF A NOVEL MICROSTRIP FEED CIRCULAR RECTANGULAR CORNER FRACTAL ANTENNA FOR UWB APPLICATIONS

4.1 Introduction

In this chapter, The general procedure for designing of novel microstrip feed circular rectangular corner fractal antenna for ultrawideband application is presented. Partial ground Plane is chosen in order to improve the ultrawideband behaviour. . Simulated results of this antenna exhibit ultrawideband characteristics from frequency 3.8 GHz to 11.7 GHz. Consequently, this antenna covers the IMT, WLAN, C Band communication satellite and narrowband PCS Service application. It is found that as number of iteration increase, resonant frequency becomes lower which provide UWB application.

4.2 Antenna Design

The final antenna designed with microstrip feed is shown in Figure 22(d). As iteration wise, this antenna is build from simple normal monopole antenna shown in figure22 (a), 2(b), 22(c) and 22(d). There are three important parameters for the designing of designed antenna: height of substrate, dielectric material of substrate and resonant frequency. In this paper, the rectangular monopole antenna is printed on FR-4 Epoxy substrate (dielectric constant 4.4) with substrate thickness of 1.6 mm and diameter (d_1) of 13.90 mm. This is called initial iteration. The first iteration of this fractal antenna made by fitting the rectangular corner patch of dimension 14.30(L_1)*14.26(W_1) mm inside the circle and removed from circle known as first iteration shown in figure22(b).The 2nd iteration has been made by fitting the circle of diameter(d_2) 9.80 mm and inscribed rectangle of dimension 12.25(L_2)*12.21(W_2) mm has been removed from this inner one circle shown in figure 22(c).In the third iteration, a circle of diameter(d_3) 6.90 mm is made and inscribed rectangular of dimension of 10.80(L_3)*10.76(W_3) mm is removed as shown in figure 22(d). At the bottom of substrate, there is Partial ground plane is used in the designed antenna which gives the ultrawideband behavior. The following parameter for antenna designed is shown in below Table 1.6.

TABLE 1.6: Physical dimension of designed antenna

S.NO	Antenna Parameter	Design Value
1	Dielectrical Material	FR4_EPOXY
2	Substrate Height	1.6 mm
3	Relative permitivity	4.40
4	Length of substrate(L)	30 mm
5	Width of substrate (W)	30 mm
6	Lengthof microstrip feed (L_f)	15.4 mm
7	Loss tangent	0.009
8	Lengthof rectangular patch(L_1)	14.30 mm
9	Widthof rectangular patch(W_1)	14.26 mm
10	Diameter(d_1)	13.90mm
11	Lengthof rectangular patch(L_2)	12.25 mm
12	Widthof rectangular patch(W_2)	12.21 mm
13	Diameter(d_2)	9.80 mm
14	Lengthof rectangular patch(L_3)	10.80 mm
15	Widthof rectangular patch(W_3)	10.76 mm
16	Diameter(d_3)	6.90 mm

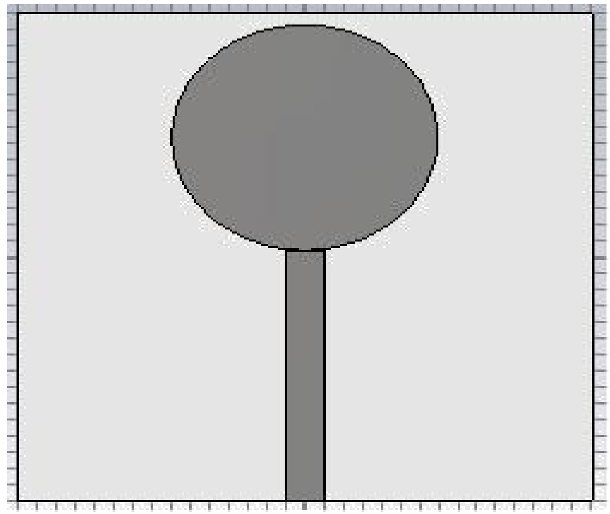


Figure 22(a): Initial Iteration

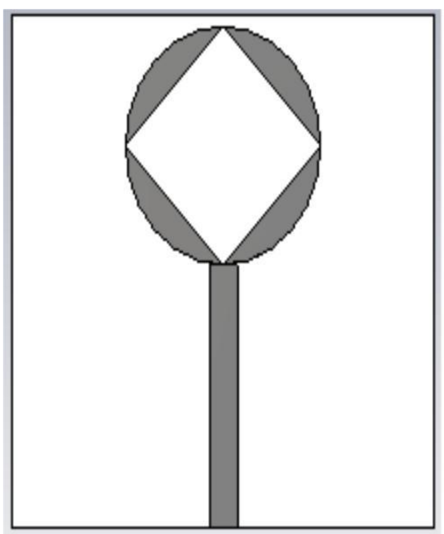


Figure 22(b): First Iteration

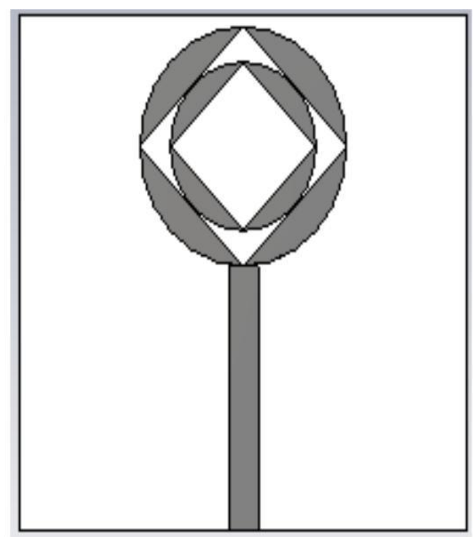


Figure 22(c): Second Iteration

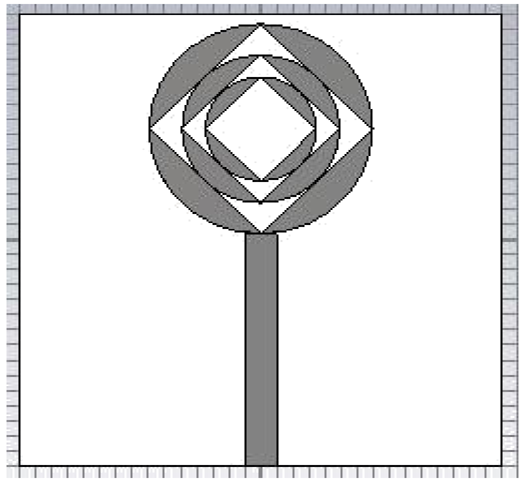


Figure 22(d): Geometry of final designed antenna

4.3 Simulation Results

The simulation results of fractal antenna parameter like Return loss and Gain are obtained using 3D electromagnetic simulator CST MWS 14.0. S_{11} parameter indicates Return Loss and it is defined as maximum reflection of power from the given antenna [1]. The designed antenna structure is simulated starting from the initial iteration/generator to third iteration. The designed antenna is simulated and shows the ultra wideband behavior. Return loss and Gain is shown in the figure 23(a), 23(b), 23(c), and 23(d). The final iteration of designed antenna shows excellent ultrawideband from 3.8 GHz to 11.7 GHz and shows multiband behavior. Gain is defined as ratio of maximum radiation intensity from subject antenna to the maximum radiation intensity from reference antenna with same power input [1]. 3D radiation patterns that represent gain are also analyzed for the final designed antenna iteration the field monitors option in CST MWS V14.0 and are presented in figures 23(b), 23(c), 23(d) correspondingly.

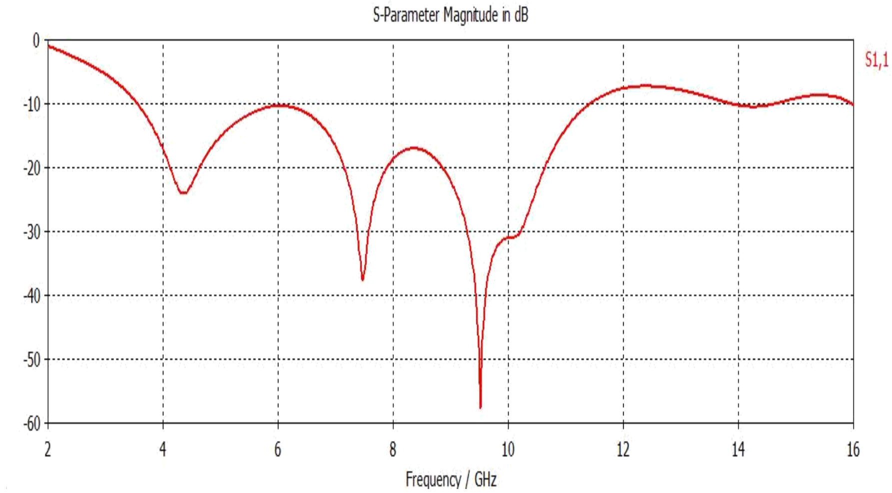


Figure 23(a): Return loss of designed antenna

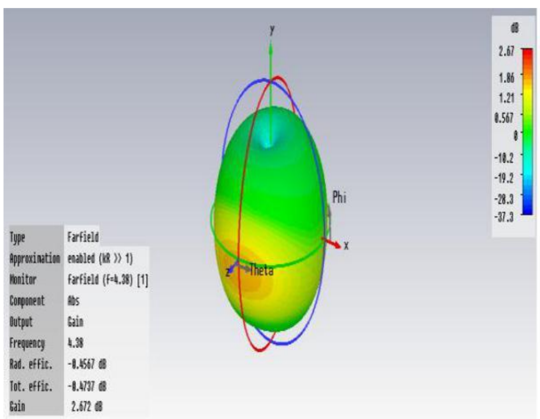


Figure 23(b): Gain of designed antenna at 4.38 GHz

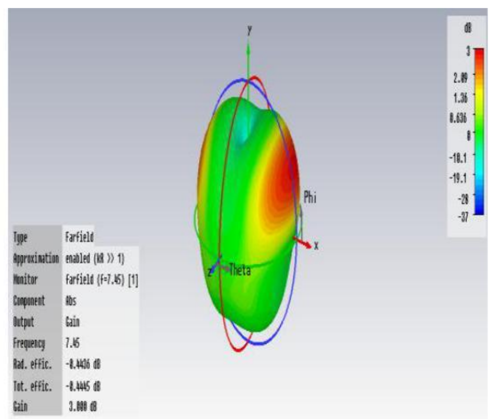


Figure 23(c): Gain ofdesigned antennaat7.45GHz

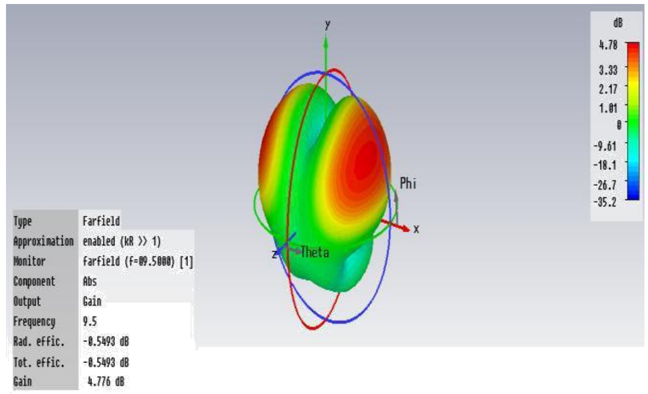
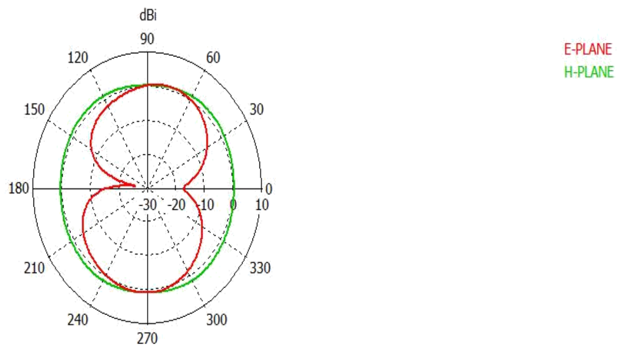


Figure 23(d) Gain of designed antenna at 9.5 GHz

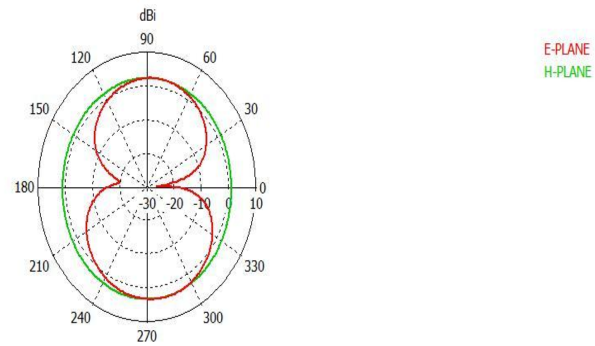
TABLE 1.7: Comparison of return loss and gain at various resonant frequencies for final designed antenna

ITERATION	RETURN LOSS	GAIN (dBi)	FREQUENCY (GHz)
Third	-24.15	2.47	4.38
Third	-37.5	3.0	7.45
Third	-57.6	4.77	9.5

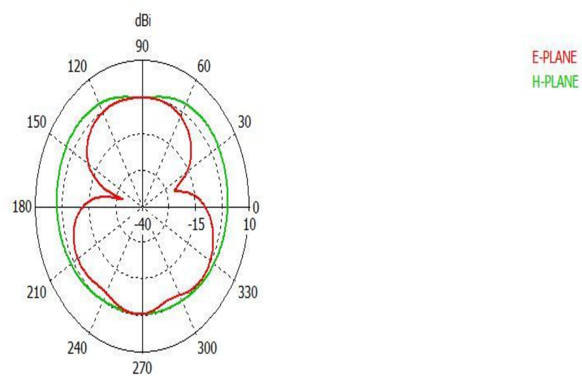
Simulatedresultsshowsthat designed antennaexhibitexcellentultrawidebandwidth behavior from 3.8GHz to 11.7GHz with return loss greater than -10dB at different resonant frequency 2GHz, 7.45GHz and 9.5GHz with increased gain 2.47dB,3.0dB and 4.77dB respectively in figures 19(b), 19(c), 19(d).



(a)



(b)



(c)

Figure 24: Simulated radiation patterns for the designed antenna at

(a) 4.38 GHz (b) 7.45 GHz (c) 9.5 GHz

The result of simulated radiation pattern of this designed antenna have been calculated using 3D electromagnetic simulator CST MWS 14.0 at frequency 4.38 GHz, 7.45 GHz and 9.5 GHz as shown in figure 24(a), 24(b) and 24(c). Omni directional radiation pattern represented in the H- Plane and dumble shape radiation pattern represented in the E- Plane. It shows that as frequency increase, radiation pattern also changes. The green line represents the H-Plane pattern and the red line represents the E-Plane pattern.

4.4 Conclusion

In this paper, a novel microstrip feed Circular rectangular corner fractal antenna for UWB applications was designed to provide the ultrawideband behavior and to increase the return loss and gain.This design was followed upto 3 iterations.This fractal antenna has been analysed using CST Microwave studio V14.0. As number of iteration increases, number of resonant frequency give multiband performance to the designed antenna structure. An improvement in the returm loss of -57.6 dB and gain of 4.77 dB was achieved.The designed fractal antenna is very simple, compact in size, low weight and less in volume and proper impedance matching attained by alter the microstrip feed structure..The simulated results indicates that multiband frequencies suitable for WLAN(5.1-5.825) GHz, C-Band communication satellie from (3.8-4.2) GHz for their downlink and band of frequencies from (5.92-6.42) GHz for their uplink and IMT(4.4-4.9) GHz,(9.0-9.45) GHz for narrowband PCS service wireless communication principle.

Chapter 5

FABRICATION, TESTING AND RESULT DISCUSSION OF FRACTAL ANTENNA

5.1 Introduction

The simulation and fabrication of a novel microstrip feed corner rectangular fractal antenna for ultrawideband application is discussed in this chapter. The fabrication is done using the PCB fabrication process and simulation is carried out using 3D electromagnetic simulator CST MWS V14.0. Results are measured on VNA and compared with simulated results.

5.2 Simulated antenna results resonating at various frequency

The simulated results of gain and return loss of the antenna design resonating at the various frequencies which covers the ultrawideband and used in various application like narrowband PCS Service, C-Band communication satellite for uplink and downlink frequency, IMT and WLAN and WiMAX .

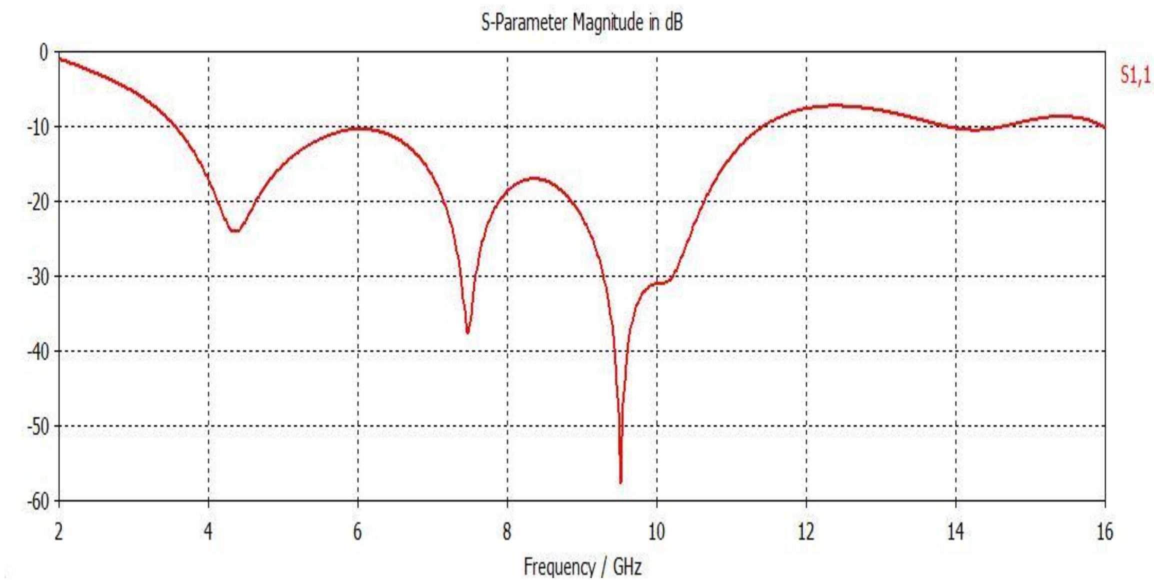


Figure 25: Simulated return loss of designed antenna

5.3 Antenna fabrication process

When we fabricate the antenna, there are various steps involved. This can be shown through flow chart.

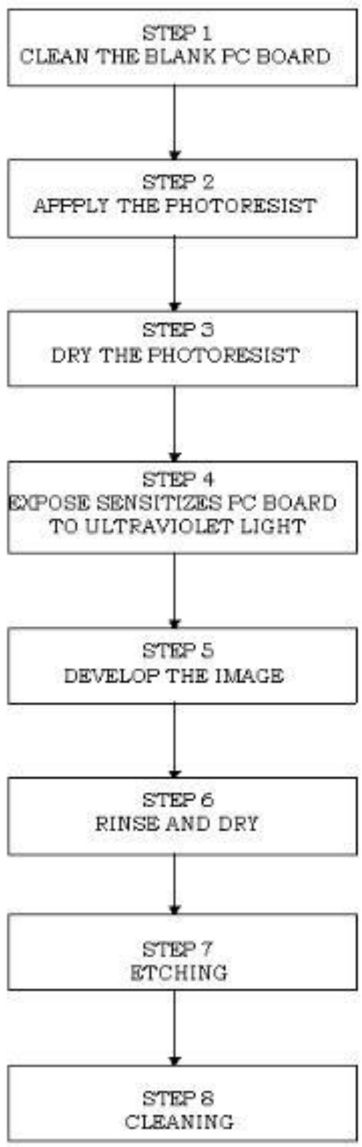


Figure 26: Flow chart of fabrication Process

5.4 Instrument used while fabricating Fractal Antenna

There are two Process that include the fabrication of designed antenna namely PCB (Printed circuit board) design and testing of the antenna. Different steps for PCB design are explained as:

Negative developing: The negative developing process is done by using software. Software designed the whole design and then print out of that design is taken.

As per desired size for PCB'S, PCB cutter is used. Substrate size of material, like FR4 substrate is used here. Figure 27 shows the PCB cutter.

Figure 27: PCB Cutter

Operation on PCB: Now PCB is dipped once in the Photo resist developer placed in yellow light. It dried in oven for 3-5 minutes. The oven unit is used to dry the final designed on antenna, which contain the paint on layer that protect the copper to clean up. Oven unit dries the PCB at 140-150 degree temperature properly.

Figure 28: Oven Unit

Figure 29: Etching unit

5.5 Fabricated Antenna design

(a) Top View

(b) Bottom View

Figure 30: Fabricated antenna with SMA Connector

5.6 Testing of Antenna

Testing of antenna has been done using VNA model no: Amritsu MS46322A, frequency range is 0 – 20 GHz which analyzed the one and two port network. The figure below shows the network analyzer.

Figure 31: Insrument used for testing

The antenna shows that results are 70% are matched with simulated results. The tested results of designed antenna using network analyzer shown in below figure.

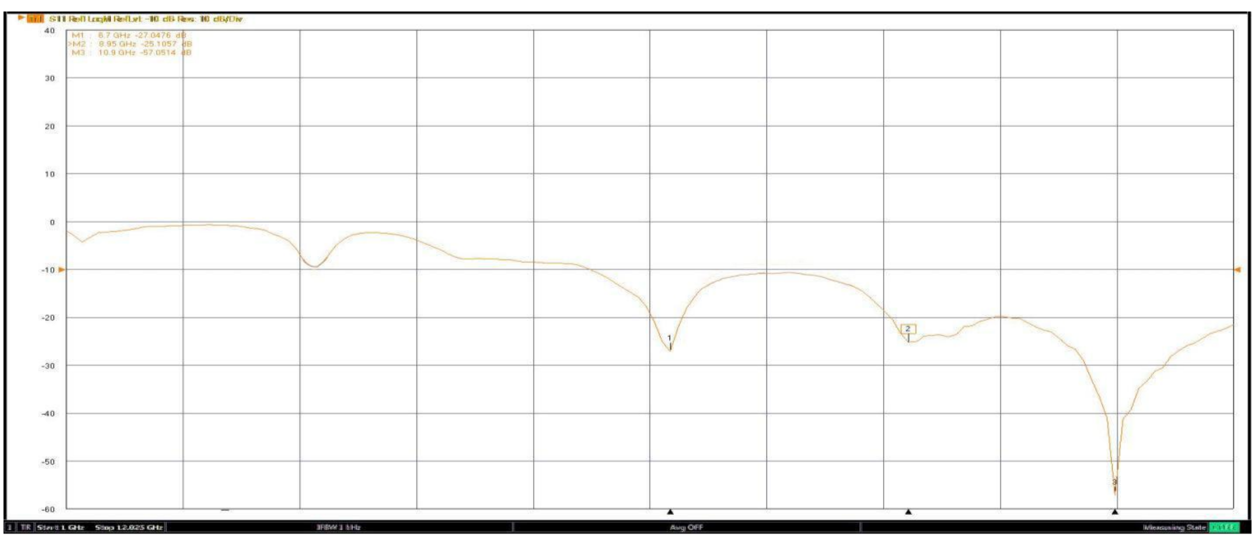


Figure 32: Measured results of Simulated Antenna

The comparison of measured and simulated results of designed antenna shown in the below Table1.8.

Table 1.8: Comparison of Measured and simulated Results of Antenna Design

Resonating Frequency	Simulated Results	Measured Results
First	4.38	6.7
Second	7.45	8.95
Third	9.5	10.95

5.7 Conclusion

The measured and simulated results are 70% matched and 30% loss are due to the lose soldering connection, due to presence of air and due to lose SMA Connnector Connection. After these small variation in the results due to some reason results are still acceptable.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

In this thesis report two design of fractal antenna using proximity coupled feed and microstrip feed for multiband and WLAN, IMT, Narrow band PCS Service and C- Band communication satellite is discussed. The first is the typical design of Sierpinski Gasket fractal antenna using Proximity coupled feed and second is the novel circular rectangular corner fractal antenna for ultrawideband applications. The various antenna parameters like Return loss, Gain, Directivity, and Radiation pattern are studied for antenna designing. The effect of physical parameter on antenna parameters also studied in this thesis report.

Initially, the works starts with the introduction of fractal and microstrip patch antenna and described various geometries of fractal antenna which proceeds with the survey of literature and work done until today. Hence, concluded the gaps in research of fractal antenna.

Chapter 3 presents the design of Sierpinski Gasket fractal antenna using proximity coupled feed for multiband applications. It is observed that from second iteration onwards, it starts exhibiting multiband behavior with an acceptable frequency response at multiple frequencies simultaneously. As number of iterations increase, number of resonant frequencies also increases which gives multiband performance to the Sierpinski Gasket antenna structure. The result shows that antenna gives appreciable return loss and directivity with miniaturization and is best suited for wireless applications.

Chapter 4 presents the design of novel microstrip feed circular rectangular corner fractal antenna for Ultrawideband application was designed to provide the excellent ultrawideband behavior.This design was followed upto 3 iterations.This fractal antenna has been analysed using CST Microwave studio V14.0. As number of iteration increases, number of resonant frequencies increases which give multiband performance to the designed antenna structure. The designed fractal antenna is very simple, compact in size, easy to fabricated and can be integrated with MMIC/MICs.The simulated results indicates that multiband frequencies suitable for WLAN(5.1-5.825) GHz, C-Band communication satellie from (3.8-4.2) GHz for their downlink and band of frequencies from (5.92-6.42) GHz for their uplink and IMT(4.4-4.9) GHz,(9.0-9.45) GHz for narrowband PCS service wireless communication principle.

The results of designed antenna are summarized in the following table:

Table 1.9: Comparison of all designed antenna parameter values

ITERATION	**RETURN LOSS**	**DIRECTIVITY (dBi)**	**FREQUENCY (GHz)**
First	-19.5	6.21	2
Second	-10.3	3.70	1.66
Second	-16.1	7.34	3.71
Third	-13.4	4.77	1.36
Third	-15.8	4.44	2.83
Third	-12.5	7.56	3.52

(a)

ITERATION	**RETURN LOSS**	**GAIN (dBi)**	**FREQUENCY (GHz)**
Third	-24.15	2.47	4.38
Third	-37.5	3.0	7.45
Third	-57.6	4.77	9.5

(b)

6.2 FUTURE SCOPE

The designed antennas in this thesis report are used for various applications such as IMT, WLAN, Narrowband PCS Service and C- Band communication satellite.

Still there is more scope for improvement and further research in the fractal area. Such works are briefly mentioned below:

Stacked fractal antenna is another field that can be worked upon future.

Antenna using other fractal geometry like Sierpinski Carpet, V Koch and multiband antenna can be designed.

Electromagnetic Band Gap Structure for fractal antenna significantly reduced the effect of surface waves as function of frequency and provides the broadband frequency performance.

Metamaterials can be used to design the antenna. A Metamaterial is a metallic or semiconductor substance whose properties depend upon interatomic structures rather than the composition of atom themselves.

Other feeding techniques: The other feeding technique of microstrip patch antenna like microstrip patch line, coaxial feeding, aperture coupling can be used in future to design same microstrip patch antenna**.**

The work on fractal microstrip antenna designed using proximity coupled feed and microstrip feed can be extensive to:

With different slot on the patch and ground, the use of different shape of patch with larger radiating area.

With impedance matching network to improve bandwidth.

With different structure configuration, the utilize of different dielectric substrate material as well as the grouping of different substrate in one structure.

PUBLICATIONS

1. Ashish Dhankhar, Dr. Jaswinder Kaur "Design of Sierpinski Gasket Fractal Antenna using proximity coupled feed mechanism for multiband applications”, International Journal of Advanced Research in Computer and communication Engineering, vol. 4, issue 4, pp.86-89, April 2015. (Impact factor = 2.117)
2. Ashish Dhankhar, Dr. Jaswinder Kaur “Design of a novel microstrip feed circular rectangular corner fractal antenna for UWB applications” **communicated** in Microwave and Optical Technology Letters, July 2015. (Impact factor = 0.623)

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