FRACTAL ANTENNAS FOR WIRELESS APPLICATIONS

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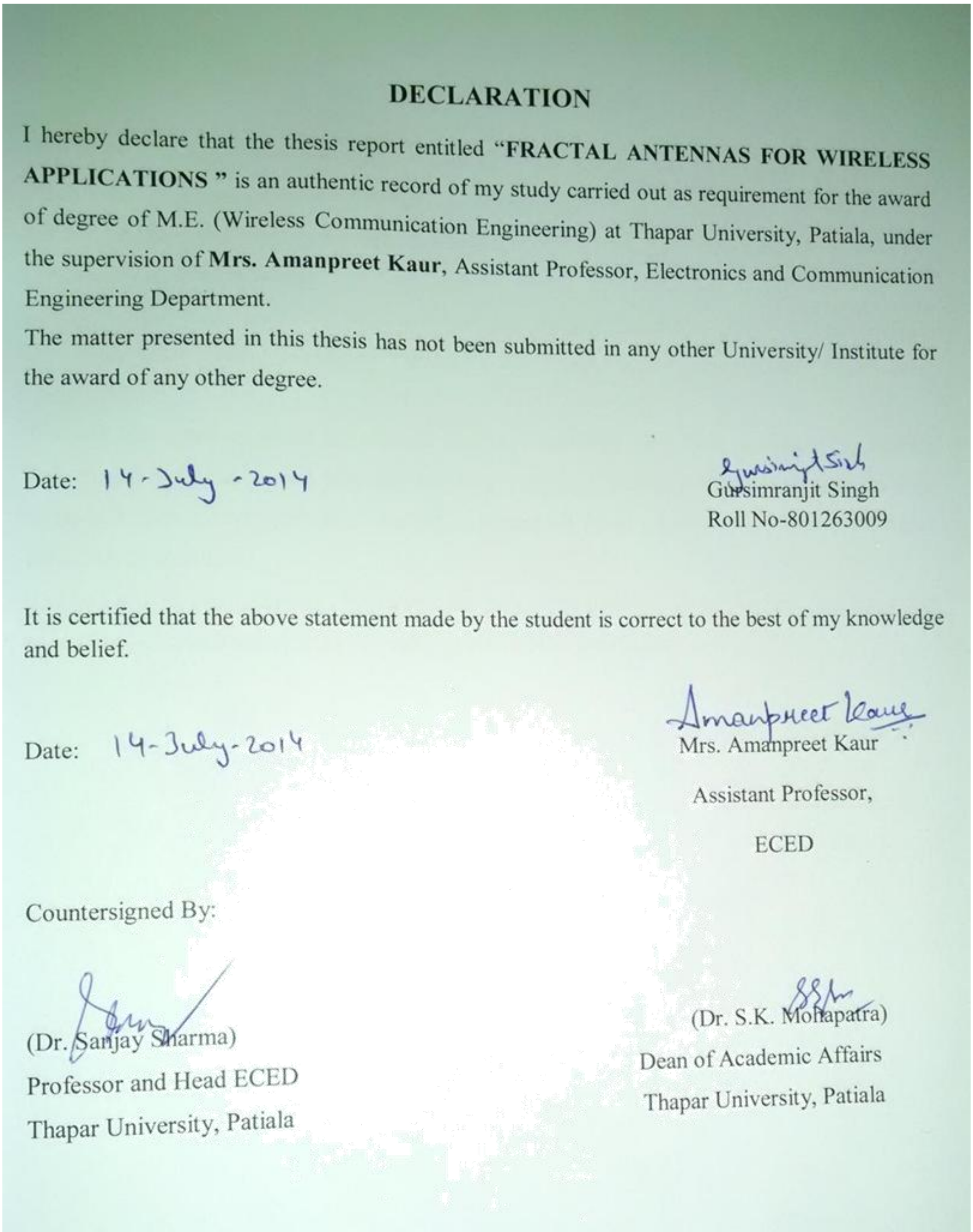

DECLARATION

I hereby declare that the thesis report entitled "**FRACTAL ANTENNAS FOR WIRELESS APPLICATIONS** " is an authentic record of my study carried out as requirement for the award of degree of M.E. (Wireless Communication Engineering) at Thapar University, Patiala, under the supervision of **Mrs. Amanpreet Kaur**, Assistant Professor, Electronics and Communication Engineering Department.

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ABSTRACT

The wireless revolution is transforming the existing global telecommunications networks into an integrated system that will provide a broad class of ubiquitous communications services to customers anywhere, anytime, in motion or fixed. Antenna is an important device in WLAN communication system because its performance will directly impact on the quality of wireless communications. The continuous shrinking size of electronic equipments demands similar size antenna elements in order to fit properly in wireless devices without compromising the other radiation properties of the antenna. In this respect microstrip patch antennas are quite an obvious choice. This project started by identifying two main disadvantages of the typical microstrip antenna that are the low gain and narrow bandwidth. These two major drawbacks have limited its application despite of other advantages as compared to the conventional antenna. With the purpose of designing a wideband microstrip antenna, the two already proven bandwidth enhancement techniques; the patch stack configuration and coplanar parasitic patch was studied. Several antenna configurations were proposed and from the simulation result, the antenna bandwidth was improved from the typical 8 ~ 9 % up to 36 % by using these two techniques using a simple coaxial probe feeding without any matching network. A microstrip patch antenna consists of radiating patch placed on the dielectric material. The feed line is sandwiched between the two substrates in proximity feeding technique. The different types of slots on the patch and the stacking help in increasing the bandwidth and give the efficient results.

In this thesis report various antenna designs are given and then study the various effects of different parameters like patch length, patch width, substrate height, and dielectric constant for WLAN applications. The antennas are designed using CST 2010 microwave studio. The antenna parameters like return loss, bandwidth, resonating frequency, directivity, gain and VSWR are calculated for each antenna design in order to get the best antenna.

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List of Abbreviations

BW	Band Width
CDMA	Code Division Multiple Access
CST	Computer Simulation Technology
DMS	Defected Micro-strip Structures
EDGE	Enhanced Data Rates for Global Evolution
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HPLAN	High Performance Local Area Network
MPA	Micro-strip Patch Antenna
PC	Proximity Coupled
Q factor	Quality Factor
RF	Radio Frequency
RL	Return Loss
UHF	Ultra High Frequency
UWB	Ultra Wideband
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

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Chapter 1

INTRODUCTION

1.1 Introduction

Wireless technology has undergone different phases of development ever since its inception [1]. Over the years there have been different standards of this technology that evolved out of the demands [2]. Presently, in strategic as well as public domain the wireless devices and systems need to cater to different frequencies, should be small in size, broadband and should be of low cost. Antenna is a component in a modern wireless device/system that has over a hundred and fifty years of history. Over this span of time it has assumed different forms for specialized applications. There have been numerous design changes of antenna with thousands of published documents relating to its design, analysis and optimization. Over the period new design concepts have been introduced for miniaturized design with broad band behavior. The present study is based on a new trend known as “Fractal Antenna”. It is now more than a decade in which geometrical characteristics of fractals are being applied in the design of passive components in the RF and Microwave domain. This geometry came in to its existence due to B.B. Mandelbrot in the year 1975 [3]. The word fractal means an object, which is indefinitely divided. Its Latin name is “fractus” that descends from the verb “frangere”, which means to break. This branch of geometry saw intensive study in 1970s. Later in mid 1990s it was seen that the properties of such geometry could be used to design frequency selective surface and multiband antenna as well as new configurations of antenna array [4].

1.2 Fractal Geometry

Fractal geometry was first discovered by Benoit Mandelbrot as a way to mathematically define structures whose dimension cannot be limited to whole numbers. According to Webster's Dictionary a fractal is defined as being "derived from the Latin fractus meaning broken, uneven: any of various extremely irregular curves or shape that repeat themselves at any scale on which they are examined [2]."

It is that branch of mathematics which studies properties and behavior of fractals. These geometries have been used to characterize objects in nature that are difficult to define with Euclidean geometries including length of coastlines, branches of trees etc. These geometries have been used to characterize structures in nature that were difficult to define with Euclidean geometries [4].

Fractal antennas are extension of classical antennas which employ fractal geometry. Thus, the fractal geometry and the antenna theory form the background of fractal antennas. These are discussed briefly as under:

1.2.1 Measurement of Fractals

The usual way of measuring a fractal is usually done by some form of dimension which is a fraction or non integer. Dimension form an important part of the fractal measurement because most of the fractal aspects of an object are reflected by its dimension.

1.2.2 Dimension of Fractals

Another definition of Fractals is "A fractal is by definition a set for which the Hausdorff-Besicovitch dimension strictly exceeds the topological dimension. Dimension of geometry can be defined in several ways. Some examples are topological dimension, Euclidean dimension, self-similarity dimension and Hausdorff dimension some of these are special forms of Mandelbrot's definition of the fractal dimension like self-similar dimension [5].

If there are n such copies of the original geometry scaled down by a fraction f, the similarity dimension D is defined as:

$$D = \frac{\quad}{-}$$

1.2.3 Specification

This involves an efficient way of defining a fractal, for example an Iterated Function Systems (IFS) can be used to specify a fractal of certain classes.

In mathematics, iterated function systems or IFSs are a method of constructing fractals; the resulting constructions are always self-similar. IFS fractals, as they are normally called, can be of any number of dimensions, but are commonly computed and drawn in 2D. The fractal is made up of the union of several copies of itself, each copy being transformed by a function (hence "functions system"). The canonical example is the Sierpinski gasket also called the Sierpinski triangle. The functions are normally contractive which means they bring points closer together and make shapes smaller. Hence the shape of an IFS fractal is made up of several possibly-overlapping smaller copies of itself, each of which is also made up of copies of itself, ad infinitum. This is the source of its self-similar fractal nature [4].

1.2.4 Properties of fractal

Fractals represent a class of geometry with very unique properties including:

(i) Self-similarity

(ii) Fractional dimension

(iii) Formation by iteration

(iv) Space-filling

These properties can further be exploited to design antennas which are miniaturized, have improved input matching ability and are multi band/wideband.

1.3 Engineering Applications of Fractals

Ever since they were mathematically re-invented by Mandelbrot, fractals have found widespread applications in several branches of science and engineering. Disciplines such as geology, atmospheric sciences, forest sciences, physiology and wireless communication have benefited significantly by fractal modeling of naturally occurring phenomena [7]. Several books and monographs are available on the use of fractals in physical sciences. Fracture mechanics is one of the areas of engineering that has benefited significantly from the application of fractals. The space filling nature of fractal geometries has invited several innovative applications. Fractal mesh generation has been shown to reduce memory requirements and CPU time for finite element analysis of vibration problems. In electromagnetic, scattering and diffraction from fractal screens have been studied extensively. The self-similarity of the fractal geometry has been attributed to the dual band nature of their frequency response. Fractal antenna arrays and fractal shaped antenna elements have evolved in 1990's [5].

1.4 Antenna Engineering

The antenna (aerial, EM radiator) is a device, which radiates or receives Electromagnetic waves. The antenna is the transition between a guiding device (transmission line, waveguide) and free space (or another usually unbounded medium). Its main purpose is to convert the energy of a guided wave into the energy of a free space wave (or vice versa) as efficiently as possible, while in the same time the radiated power has a certain desired pattern of distribution in space [2]. Many different structures can act as antennas. Generally, antennas are constructed out of conducting material of some nature and can be constructed in many shapes and sizes. The size is related to the wavelength of operation of the antenna. An antenna designed for operation at 10 kHz is almost always much larger than an antenna designed for operation at 10 GHz, for example. Transmission lines are used to guide the power from the transmitter to the antenna and should be impedance matched to both the transmitter and the antenna. The antenna forms a critical component in a wireless communication system. A good design of the antenna can relax system requirements and improve its overall performance. There are many different parameters that are used to characterize antennas [2].

1.5 Parameters for Measuring Antenna’s Performance

1.5.1 Effective Height

The effective height of an antenna represents the effectiveness of an antenna as radiator or collector of Electromagnetic wave energy. It indicates how far an antenna is the effective in transmitting and receiving the electromagnetic energy.

1.5.2 Gain and Directivity

- Gain is used to describe an antenna's ability to make the apparent power greater than the actual transmitted power in a given direction.
- Directivity is used to characterize an antenna. Directivity is defined as the ratio of the maximum radiation intensity to the average radiation intensity.
- Gain is equal to directivity if the efficiency of the antenna is 100 percent.
- Gain is a directional function; it changes with position around the antenna and is defined as

$$\frac{\quad}{\quad} \qquad (1.2)$$

Where U (θ, φ) is the radiation intensity and in P is the input power to the antenna.

Gain is usually measured in decibels with reference to another antenna either an isotropic radiator .or to a simple dipole. An isotropic radiator is an antenna that radiates equally in all directions and is just a theoretical model.

1.5.3 Front to-Back Ratio (FBR)

Front to Back isolation ratio is defined as the difference in gain from the front of the antenna and the gain from the back of the antenna. FBR is of concern to Communication Engineers when the antenna is to be used in a crowded frequency band. Amateur radio operators frequently use Front-to-Back isolation as a parameter when comparing Yagi-Uda antennas.

1.5.4 Input Impedance

The input impedance of the antenna should be matched to the impedance of the transmission line for maximum power transfer because when the impedance is purely resistive, the antenna dissipates the power presented to it. It is also important that the input impedance of the antenna is mostly resistive, so that most of the power introduced to the antenna is radiated. Input impedance has real and complex parts and its general form is:

$$Z_{in}=R_{in} + jX_{in} \tag{1.3}$$

Where in R represents the resistance or power radiating portion of the impedance, in X represents the reactive portion or power storage component of the impedance. Power can be dissipated from an antenna in two of the following ways:

- Ohmic or heating losses from the antenna structure.
- Power that leaves the antenna as electromagnetic waves at the desired frequency is another form of dissipation.

In some antennas, the Ohmic losses are very small compared to the radiation losses. Non-zero capacitive or inductive reactance presents non-radiating and energy storing fields that reduce the total radiated power of the antenna.

1.5.5 Voltage Wave Standing Ratio (VSWR)

The voltage standing wave ratio (VSWR) is a measure of impedance match or mismatch between the transmission line and antenna. A VSWR of 1:1 indicates a perfect match, while a VSWR of ∞:1 indicates the worst case.

1.5.6 Frequency Bandwidth (FBW)

The bandwidth of an antenna is important in determining the frequency range and the application it can be used for. For example, a commercial radio transmission antenna can have a very narrow bandwidth because it will probably be used on only one frequency. A receiver antenna, however, must have a fairly large bandwidth to allow it to operate across many different frequencies.

- Antennas form three classes in terms of frequency coverage:
- Narrowband - These antennas cover a small range of the order of few percent around the designed operating frequency.

$$FBW = \frac{\quad}{\quad} *100\ \% \tag{1.4}$$

Where f_{max}, f_{min} are the maximum and minimum frequencies f_o is the centre frequency

- Wideband or broadband – these antennas cover an octave or two range of frequencies.

$$\text{FBW} = \frac{}{} \tag{1.5}$$

- Frequency Independent- These antennas cover a ten to one or greater range of frequencies.

1.5.7 Radiation Pattern

The radiation pattern or antenna pattern is the representation of the radiation properties of the antenna as a function of space coordinates. RP is measured in the far-field region, where the spatial (angular) distribution of the radiated power does not depend on the distance. The radiation pattern plot is useful for quickly evaluating the usefulness of an antenna for a certain application [2].

These parameters form a language and an important tool used to describe and compare antennas against one another. These parameters also allow a system designer to choose an antenna that is most suitable for their situation. For example, Gain, directivity are parameters that a radio systems engineer would use to choose an antenna for a specific job, i.e. an Omni-directional antenna would be used for wide area coverage, like for a television transmitter, while an antenna with a narrow beam width would probably be used as a television receiver antenna because of its large gain in one direction and its ability to screen out interference from the sides and back [4].

1.6 Fractals Antenna in Wireless Communication

The primary motivation of Fractal Antenna Engineering is to extend antenna design and synthesis concepts beyond Euclidean geometry. In this context, the use of fractals in antenna array synthesis and fractal shaped antenna elements have been studied. Obtaining special antenna characteristics by using a fractal distribution of elements is the main objective of the study on fractal antenna arrays. Fractals can be used in a set of antenna called antenna arrays [4]. Fractal and random fractal arrays have been found to have several novel features. Variation in fractal dimension of the array distribution has been found to have effects on radiation characteristics of such antenna arrays. The use of random fractals reduces the fractal dimension, which leads to a better control of side lobes. It has been seen that fractal properties such as self-similarity and dimension play a key role in the design of such arrays. Fractal antennas are one of the latest antennas used nowadays for multiband and wideband antennas are discussed below:

1.6.1 Fractal Shaped Antenna Elements

As with several other fields, the nature of fractal geometries has caught the attention of antenna designers, primarily as a past-time. However with the deepening of understanding of antennas using them several geometrical and antenna features have been inter-linked. This has led to the evolution of a new class of antennas, called fractal shaped antennas. Cohen has tried the usefulness several fractal geometries experimentally. Koch curves, Murkowski curves, Sierpinski gasket are among them. The first fractal that will he considered is the popular Sierpinski gasket [14].The first few stages in the construction of the Sierpinski gasket are shown in Figure 1.1 Another popular fractal is known as the Koch snowflake [14]. This fractal also starts out as a solid equilateral triangle in the plane, as illustrated in of Figure 1.1 number of structures based on purely deterministic or random fractal trees has also proven to be extremely useful in developing new design methodologies for antennas and frequency selective surfaces. An example of a deterministic tenary (three branches) fractal tree is shown in Figure 1.4.The space-filling properties of the Hilbert curve and related curves make them attractive candidates for use in the design of fractal antennas. The first four steps in the construction of the Hilbert curve are shown in Figure 1.3. The Koch snowflakes and islands have been primarily used to develop new designs for miniaturized-loop as well as Micro-strip Patch Antennas. New designs for miniaturized dipole antennas have also been developed based on a variety of Koch curves and fractal trees. Finally, the self-similar structure of Sierpinski gaskets and carpets has been exploited to develop multi-band antenna elements as can be seen below in the figures [4].

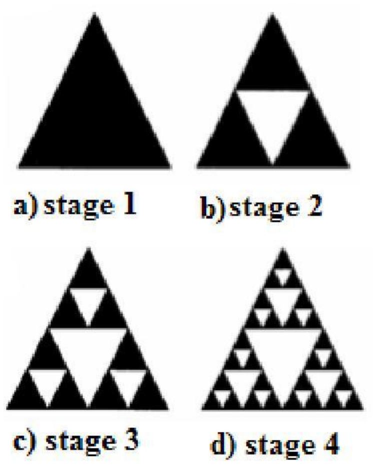

a) stage 1 b) stage 2 c) stage 3 d) stage 4

Figure 1.1 Several Stages

Of Sierpinski Gasket Fractal

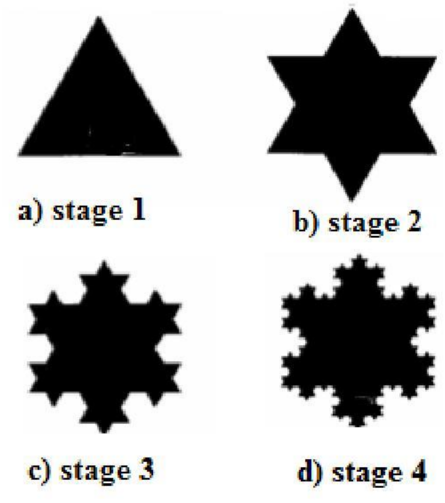

a) stage 1 b) stage 2 c) stage 3 d) stage 4

Figure 1.2 First few stages of

of a Koch, Snowflake Fractal

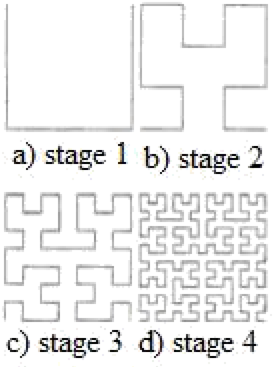


Figure 1.3 First few stages

of a Hilbert curve

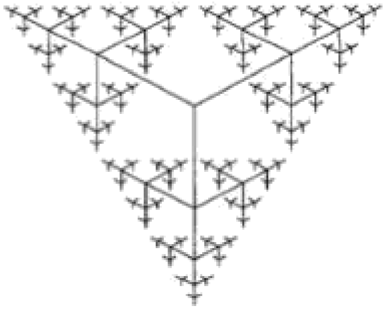


Figure 1.4 A stage Ternary

Fractal Tree

These geometries have a large number of tips and corners, a fact that would help improve antenna efficiency.

Fractal trees were explored for the same reason, and were found to have multiband characteristics. Self-similarity of the geometry is qualitatively associated with the multiband characteristics of these antennas.

1.7 Features of Fractal Antennas

As already mentioned the fractal antennas employ the fractal geometry for their design as compared to classical antennas which employ Euclidean Geometry. The two basic properties of fractals provide distinguished features to these fractal designed antennas, these are discussed with appropriate application areas below:

1.7.1 Multiband/ Wideband performance

Any good antenna system requires antenna scaling which means that the different parameters (impedance, gain, pattern etc.) remain same if all the dimensions and the wavelength are scaled by same factor. Since due to self-similarity possessed by fractals, the fractal structure appear to be same independent of size scaling and thus it can be interpreted that the fractal structures can be used to realize antenna designs over a large band of frequencies [8]. The antenna can be operated similarly at various frequencies which mean that the antenna keeps the similar radiation parameters through several bands.

Application: In modern wireless communications more and more systems are introduced which integrate many technologies and are often required to operate at multiple frequency bands. Thus demands antenna systems which can accommodate this integration. Examples of systems using a multi-band antenna are varieties of common wireless networking cards used in laptop computers. These can communicate on 802.11b networks at 2.4 GHz and 802.11g networks at 5 GHz. Use of fractal self-similar patterns offers solution.

1.7.2 Compact Size

Another requirement for antenna design in wireless systems is the compact size. The fractional dimension and space filling property of fractal shapes allow the fractal shaped antennas to utilize the small surrounding space effectively [9]. This also overcomes the limitation of performance of small classical antennas and helps in maintaining compact size in antenna which allows its application in cellular handsets. Because fractal antennas are more compact, they fit more easily in the receiver package. Currently, many cellular handsets use quarter wavelength monopoles which are essentially sections of radiating wires cut to a determined length. Although simple, they have excellent radiation properties. However, for systems operating at high frequencies such as GSM, the length of these monopoles is often longer than the handset itself. It would be highly beneficial to design an antenna based on fractal design with similar radiation properties as the quarter wavelength monopole while retaining its radiation properties. This designed antenna will fit in a more compact manner [5].

1.8 Advantages and Disadvantages

The various advantages of fractal antennas can be listed as:

- Smaller cross sectional area
- No impedance matching network required
- Multiple resonances
- Higher gain in some cases

Although in the early stage of their development, these antenna designs suffer from two main disadvantages. These are:

- Fabrication and design is little complicated
- Lower gain in some cases

Further investigations and new developments in this field may be helpful in overcoming these disadvantages.

1.9 Antenna Parameters

There are various parameters of antenna which are used to calculate in order to check the efficient working of antenna. The following are the few antenna parameters:

1.9.1 Return Loss

The return loss (RL) is the parameter which indicates the amount of power that is lost to the load and does not return as a reflection. Waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match [9]. Hence the RL is the parameter similar to VSWR to indicate how well the matching between the transmitter and the antenna has taken place. The RL is defined as

$$RL = -20 \log_{10}|\acute{\Gamma}| \qquad (1.6)$$

where $\acute{\Gamma}$ is the reflection coefficient. In practical applications, the applicable VSWR of 2 is acceptable corresponds to an RL of -9.5 dB or 11% power reflection.

1.9.2 Smith Chart

The Smith Chart, invented by Phillip H. Smith (1905-1987), is a graphical aid or monogram specializing in radio frequency (RF) engineering to assist in solving problems with transmission lines and matching circuits. The Smith Chart is plotted on the complex reflection coefficient plane in two dimensions and is scaled in normalized impedance (the most common), normalized admittance or both, using different colours to distinguish between them. These are often known as the Z, Y and YZ Smith Charts respectively. Normalized scaling allows the Smith Chart to be used for problems involving any characteristic impedance or system impedance, although by far the most commonly used is 50 ohms.

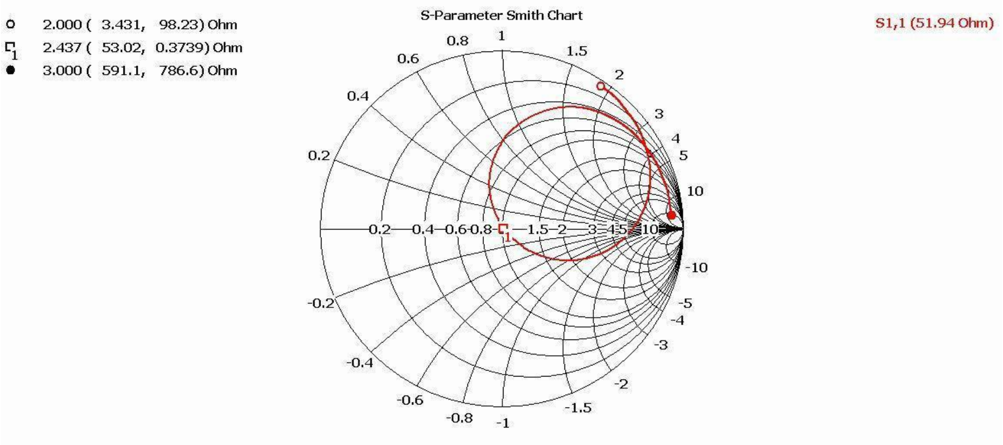


Figure 1.5 Smith Chart

1.9.3 Voltage Standing Wave Ratio (VSWR)

The most common case for measuring and examining VSWR is when installing and tuning the transmitting antennas. When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum energy transfer from the feed line to the antenna to be possible. When an antenna and feed line do not have matching impedances, some of the electrical energy cannot be transferred from the feed line to the antenna. Energy not transferred to the antenna is reflected back towards the transmitter. It is the interaction of these reflected waves with forward waves which causes standing wave patterns. Matching the impedance of the antenna to the impedance of the feed line is typically done using an antenna tuner. The tuner can be installed between the transmitter and the feed line, or between the feed line and the antenna. Both installation methods will allow the transmitter to operate at a low VSWR. Ideally, VSWR must lie in the range of 1-2.

1.9.4 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as “a mathematical function or graphical representation properties of the antenna as a function of space coordinates. The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization, and one plane cut. The patterns are usually presented in polar or rectilinear form with a dB strength scale. Since a Micro-strip patch antenna radiates normal to its patch surface, the elevation pattern for φ = 0 and φ = 90 degrees would be important. Figure 1.6 below shows the gain of the antenna at 2.438 GHz for φ = 0 and φ = 90 degrees. The maximum gain is obtained in the broadside direction and this is measured to be 6.8dBi for both, φ = 0 and φ = 90 degrees.

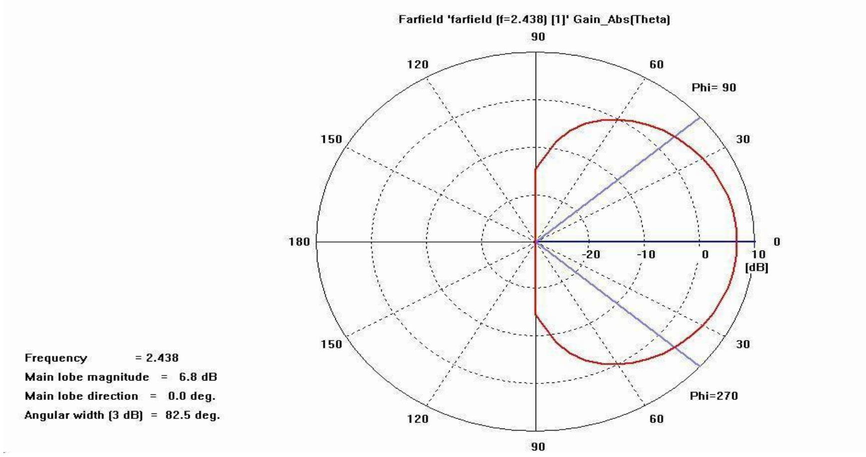


Figure 1.6 Radiation pattern for φ = 90 degree (E plane)

Out of all the antennas the most suited ones for the wireless applications is MSA because of its small size, comfort ability and inexpensive.

1.10 Work Covered in thesis

Nowadays there is a demand for systems that can perform over several frequency bands or are reconfigurable as the demands on the system changes. Fractal geometry, which has been used to model complex objects found in nature such as clouds and coastlines, has space filling properties that can be utilized to miniaturize antennas [11] and obtain a multi frequency behavior.

Fractals have non-integral dimensions and their space filling capability could be used for miniaturizing antenna size and their property of being self-similarity in the geometry leads to have antennas which have a large number of resonant frequencies. Fractal antennas also have multiband performance is at non-harmonic frequencies. Fractal antennas have improved Impedance, improved SWR (standing wave ratio) performance on a reduced physical area when compared to non fractal Euclidean geometries. Fractal antennas show Compressed Resonant behavior. At higher frequencies the Fractal antennas are naturally broadband. In many cases, the use of fractal element antennas can simplify circuit design. Often fractal antenna does not require any matching components to achieve multiband or broadband performance. Perturbation could be applied to shape of fractal antenna to make it to resonate at different frequency [12].

In this thesis work the above mentioned qualities are utilized to design three fractal antennas one is wide band Bowtie antenna second is I shaped fractal antenna and third is plus shaped fractal antenna for 8.2 GHz, 1.8 GHz and 3.2 GHz frequency bands for IMT-200 & WLAN applications. The design and simulation is done using the basic transmission line mode and its simulation is done using CST microwave studio 2010.

1.11 Organization of Thesis

Chapter 1 Covers the Introduction about Fractal Antenna and explained its application. It also covers different types of fractal antenna available. Their parameters used to judge antenna performance and an overview of work is done in thesis.

Chapter 2 Presents Literature Review and Thesis Objective in context to the fractal antenna for IMT-200 application.

Chapter 3 Covers the Design, Simulation and Analysis of bowtie shaped fractal antenna. Its discussion of design parameters are presented in this chapter.

Chapter 4 Covers the Design Procedure for single band I-shaped fractal antenna. Simulated results of antenna including resonant frequencies, bandwidth, fractional bandwidth, radiation efficiencies and gain are measured and compared.

Chapter 5 Covers the Design, Simulation and Results of plus shaped fractal antenna for IMT-200 application.

Chapter 6 Includes Fabrication and Testing of plus shaped fractal antenna using PCB technology and VNA respectively and comparison of simulated and measured results is done.

Chapter 7 Concludes the Work done in this dissertation and provides a brief discussion on the future scope of the work on the present thesis.

Chapter 2
LITERATURE REVIEW

2.1 Objective

In this chapter [14] advances in fractal antenna are revisited. Over a decade has passed since incorporation of fractal geometry in design of antenna to make it multiband and smaller in size. A number of designs reported by various researchers are summarized in this chapter. Applications to wireless communication systems have been reviewed. An account of some research in optimizing such antenna is also presented.

2.2 Fractal Antenna Elements

Early Work on Fractal Loop, Dipole, and Monopole Antennas

In **November, 1993**, the terminology fractal radiators and fractal antennas had been introduced publicly during an invited IEEE seminar held at Bucknell University [14].

In **May, 1994**, apparently the earliest published reference to use the terms fractal radiators and fractal antennas to denote fractal-shaped antenna elements appeared [15].

In **November 1993**, **Cohen** first reported in a series of articles the application of fractal geometry to the design of wire antenna elements [16].These articles introduced the notion of fractalizing the geometry of a standard dipole or loop antenna. This is accomplished by systematically bending the wire in a fractal way, so that the overall arc length remains the same, but the size is correspondingly reduced with the addition of successive iteration. It has been demonstrated that this approach, if implemented properly, can lead to efficient miniaturized antenna designs.

For instance, the radiation characteristics of Minkowski dipoles and Minkowski loops were originally investigated in [16]. Properties of the Koch fractal monopole were later considered in [17]. It was shown that the electrical performance of Koch fractal monopoles is superior to that of conventional straight-wire monopoles, especially when operated in the small-antenna frequency regime.

A fast approximation technique for evaluating the radiation characteristics of the Koch fractal dipole was presented in [18]. Monopole configurations with fractal top loads have also been considered in [19] as an alternative technique for achieving size miniaturization.

In **March 1999**, **Cohen** finally studied the effects of various types of symmetries on the performance of Koch dipole antennas [20].

2.3 Research on Sierpinski Gasket Antennas

In **January 1996**, **Puente et al.** first introduced a multi-band fractal monopole antenna, based on the Sierpinski gasket [21]. The original Sierpinski monopole antenna is illustrated in the Figure (2.1) In this case, the antenna geometry is in the form of a classical Sierpinski gasket, with a flare angle of α = 600 and a self similarity scale factor of δ = 2. The dimensions for a prototype

Sierpinski gasket monopole are given in the Figure (2.1). Figure (2.1) also contains plots of simulated and measured values of the input reflection coefficient versus frequency for the antenna, along with the associated curves for input resistance and reactance figure (2.2).

It was demonstrated in [22] that the positions of the multiple hands may be controlled by proper adjustment of the scale factor used to generate the Sierpinski antenna. The transient response of the multi-band Sierpinski monopole was investigated in [23]. This was accomplished by using a Method of Moments technique to solve the time-domain electric-field integral equation via a marching-on-in-time procedure. Linear parametric modeling techniques were also applied, in order to considerably reduce computation time. The dependence of the radiation characteristics of the Sierpinski monopole on flare angle was documented in [24].

Further investigations concerning enhancing the performance of Sierpinski-gasket monopoles through perturbations in their geometry were reported in [25]. It was found that a variation in the flare angle of the antenna translated into a shift of the operating hands, as well as into a change in the input impedance and radiation patterns. Fast iterative network models that are useful for predicting the performance of Sierpinski fractal antennas were developed in [26]. The predicted self-similar surface-cunent distribution on a Sierpinski monopole antenna was verified in [27] by using infra-red thermo grams.

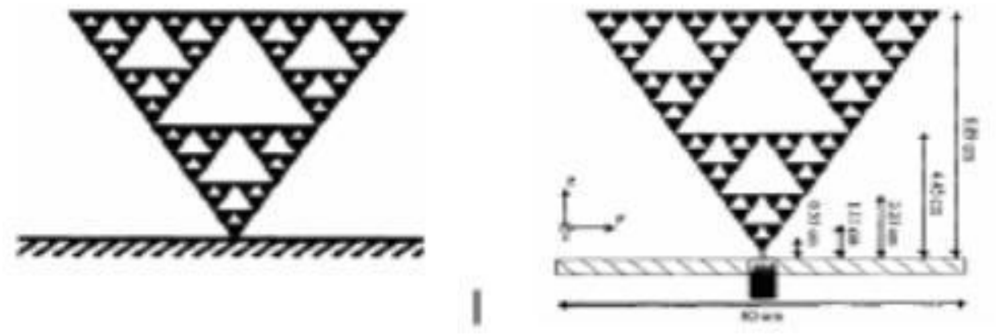


Figure 2.1 Sierpinski monopole[21].

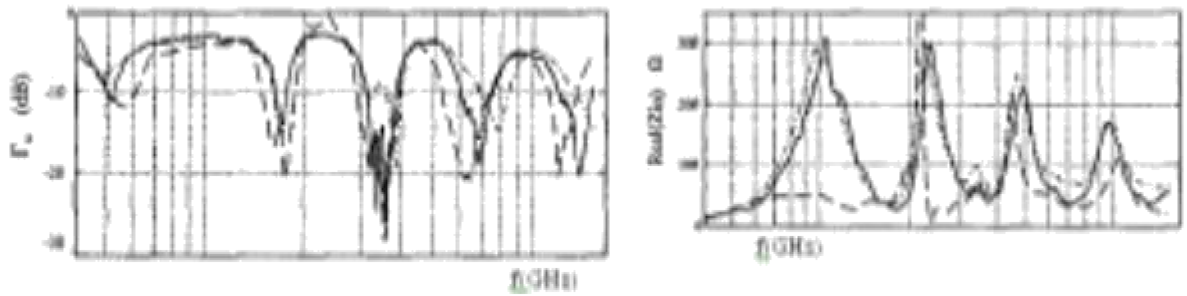


Figure 2.2(a); the input resistance, R (b); and the input reactance [21]

In **August 1999**, **Breden and Langley** presented measurements of input impedance and radiation patterns for several printed fractal antennas, including Koch and Sierpinski monopoles [28].

2.3 Research on Fractal Tree Antennas

The multi-hand characteristics of a deterministic fractal tree structure were considered in [29].

In **Nov. 1999**, **Puente et al.** investigated the multiband properties of random fractal tree-like antennas, created by an electrochemical deposition process [30]. It was found that these fractal tree antennas have a multiband behavior with a denser band distribution than the Sierpinski antenna. The multi-hand and wideband properties of printed fractal branched antennas were studied in [31].

In **Feb. 1999**, **Werner et al.** [32] considered the multi-band electromagnetic properties of thin-wire structures based on ateary-tree fractal geometry. In particular, the impedance behavior of a tri-band ternary fractal tree was studied by carrying out a numerically rigorous Method of Moments analysis of the structure. The unique multi-band properties of the antenna were confirmed by comparing the results of the numerical simulations with actual measurements.

In **July 2000**, **Gianvittorio and Rahmat-Samii** suggested the space-filling properties of two-dimensional and three-dimensional fractal trees as good candidates for application to the design of miniaturized antennas. It was shown that a reduction in the resonant frequency of a standard dipole can be achieved by end-loading it with two-dimensional or three-dimensional tree-like fractal structures. This decrease in resonant frequency was shown to asymptotically approach a limit as the number of iterations is increased.

Ways to improve antenna-miniaturization techniques were discussed in [33], employing fractal tree geometries as end-loads by increasing the density of branches (i.e., by using trees with a higher fractal dimensions).

2.4 Sierpinski Gasket Antennas and the Hilbert Curve Antenna

Dual-band designs, based on a variation of the Sierpinski fractal monopole, were presented in [34]. Specific applications of these designs to emerging GSM and DECT technologies were discussed.

In **April 2000**, **Castany et al.** investigated the multi-hand properties of fractal monopoles based on the generalized family of mod-p Sierpinski gaskets [35]. The advantage of this approach is that it provides a high degree of flexibility in choosing the number of bands and the associated hand spacing for a candidate antenna design. Examples of a mod-3 Sierpinski monopole are shown in Figure (2.3).

A novel configuration of a shorted fractal Sierpinski gasket antenna was presented and discussed in [36].The space filling properties of the Hilbert curve were investigated in [4] as an effective method for designing compact resonant antennas. The effect of the feed point location on the input impedance of a Hilbert curve antenna was studied in [37]. It was shown that while a center-fed Hilbert curve antenna may result in a very small radiation resistance: a properly chosen off center feed point can always provide a 50Ω match, regardless of the stage of growth.

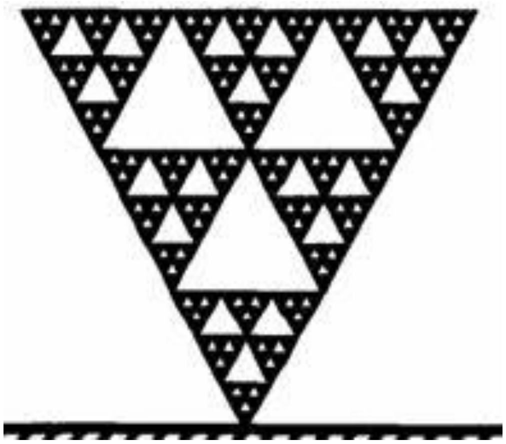


Figure 2.3 Variations of the Sierpinski gasket and related multi-band monopole antennas: a mod-3 Sierpinski monopole [35]

2.5 Research on Fractal Patch Antennas

In **July 2000**, **Borja and Romeu** proposed a design methodology for a multi-band Sierpinski microstrip patch antenna [38]. A technique was introduced to improve the multi-band behavior of the radiation patterns by suppressing the effects of high-order modes. Finally, high-directivity modes in a Koch-island fractal patch antenna were studied in [39]. It was shown that a patch antenna with a Koch fractal boundary exhibits localized modes at a certain frequency above the fundamental mode, which can lead to broadside directive patterns. Localized modes were also observed in a waveguide having Koch fractal boundaries.

Some additional applications of fractal concepts to the (design of microstrip-patch antennas were considered in [40]. For instance, [40] introduced a modified Sierpinski-gasket patch antenna for multi-band applications. A design technique for bowtie microstrip-patch antennas, based on the Sierpinski-gasket fractal, was presented in [41]. A computationally efficient Method of Moments formulation was developed in [42], specifically for the analysis of Sierpinski fractal patch antennas. The radiation characteristics of Koch-island fractal microstrip-patch antennas were investigated in [43].

In **1986**, **Gianvittorio and Rahmat-Samii** reported other configurations for miniaturized fractal patch antennas [44].

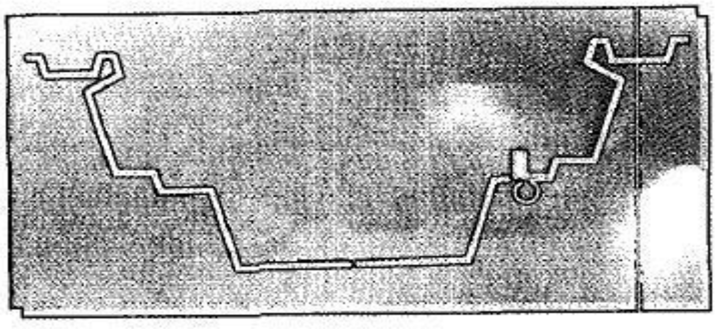


Figure 2.4 a dual-hand direct-write fractal dipole antenna with a direct-write passive LC load on Kapton [43]

2.6 Fractal Arrays Deterministic and Random Fractal Arrays

In **1986**, **Kim and Jaggard** originally coined the term fractal antenna array [45] to denote a geometrical arrangement of antenna elements that is fractal. Properties of random fractals were first used in [45] to develop a design methodology for quasi random arrays. In other words, random fractals were used to generate array configurations that were somewhere between completely ordered (i.e., periodic) and completely disordered (i.e., random). The main advantage of this technique is that it yields sparse arrays that possess relatively low side lobes (a feature typically associated with periodic arrays, but not random arrays), and which are also robust (a feature typically associated with random arrays, but not periodic arrays).

In **July 2000**, **Lakhtakia et al.** first studied the time-harmonic and time-dependent radiation produced by deterministic fractal arrays in the form of Paskal-Sierpinski gaskets [46]. In particular, the radiation characteristics were examined for Paskal-Sierpinski arrays, comprised of

Hertzian dipole sources located at each of the gasket nodes. A family of non uniform arrays, known as Weierstrass arrays, was first introduced in [47]. These arrays have the property that their element spacing and current distributions are self-scalable and can be generated in a recursive fashion. Synthesis techniques for fractal radiation patterns were developed in [48], based on the self-scalability property characteristic of discrete linear Weierstrass arrays, and the more general class of discrete linear Fourier-Weierstrass arrays. A fractal radiation pattern synthesis technique for continuous line sources was also presented in [48].

Liang et al. later extended the synthesis techniques developed for linear Weierstrass arrays to include concentric ring arrays as well [49].

2.7 Multi-Band Fractal Arrays

A design methodology for multi-band Weierstrass fractal arrays was introduced in [50]. The application of fractal concepts to the design of multi-band Koch arrays, as well as multiband and low-side lobe Cantor arrays, were discussed in [51]. A simplified Koch multi-band array, using windowing and quantization techniques, was presented in [52]. Finally, it was recently shown, in [53], that the Weierstrass-type and the Koch-type of multi-band arrays, previously considered independently in [50] and [51], respectively, are actually special cases of a more general unified family of self-scalable multi-band arrays.

2.8 IFS Arrays and Compact Arrays

In **Feb. 1991**, **Baharav** proposed an iterated function system (IFS) approach for the design of fractal arrays [52]. The use of IFS provides a very flexible design tool, which enables a wide variety of fractal array configurations, with many degrees of freedom, to be easily generated. A method for array side lobe reduction by small position offsets of fractal elements was investigated in 1961. It was shown that because of their compact size and reduced coupling, the use of fractal antenna elements allows more freedom to accommodate position adjustments in phased arrays, which can lead to a suppression of undesirable side lobes or grating lobes.

In **July 1999**, **Gianvittorio and Rahmat-Samii** have investigated the advantages of reduced mutual coupling and tighter packing, which can be achieved by using fractal elements in otherwise conventional arrays, [53]. A genetic-algorithm approach for optimizing fractal dipole antenna arrays for compact size and improved driving-point: impedance performance over scan angle was presented in [54]. The technique introduces fractal dipoles as array elements, and uses a genetic algorithm to optimize the shape of each individual fractal element (for self-impedance control), as well as the spacing between these elements (for mutual-impedance control).

A useful method for interpolating the input impedance of fractal dipole antennas via a genetic-algorithm-trained neural network (called IFS-GA-NN) was presented in [55]. One of the main advantages of this IFS-GA-NN approach is that it is more computationally efficient than a direct Method of Moments analysis technique.

2.9 Fractal Frequency-Selective Surfaces

In **July 2000**, **Parker and Sheikh** originally proposed Fractals for use in the design of frequency-selective surfaces (FSSes) [56]. This application makes use of the space-filling properties of certain fractals, such as the Minkowski loop and the Hilbert curve, in order to reduce the overall size of the unit cells that constitute an FSS. A dual-band fractal FSS design, based on a two-iteration Sierpinski gasket dipole, was first demonstrated in [58].

In **March 2000**, **Werner and Lee** showed that the fractal FSS reported in [57] exhibits two stop-bands with attenuation in excess of 30 dB. Another possible approach that uses fractal tree configurations for realizing multiband FSS designs was first suggested in [32].

A particular example was considered in [59], where a tri-band FSS was designed using Stage 3 crossbar fractal tree elements. The first three stages in the construction of a crossbar fractal tree are illustrated in Figure 2.5. Figure 2.6 shows four adjacent cells of a tri-band FSS. In this case, the individual elements or cells of this FSS are made up of Stage 3 crossbar fractal trees, which provide the required tri-band behavior. The transmission coefficient as a function of frequency is plotted in Figure 2.6 for a Stage I, Stage 2, and Stage 3 crossbar fractal FSS. The stop-band attenuations of this fractal FSS were found to be in the neighborhood of 30 dB.

This particular fractal FSS design approach also has the advantage of yielding the same response to either TE- or TM-mode excitation. Another noteworthy feature of this design technique is that the separation of bands can be controlled by choosing the appropriate scaling used in the fractal crossbar screen elements. More recently, various other self-similar geometries have been explored for their potential use in the design of dual-band and dual polarized FSSes [60].

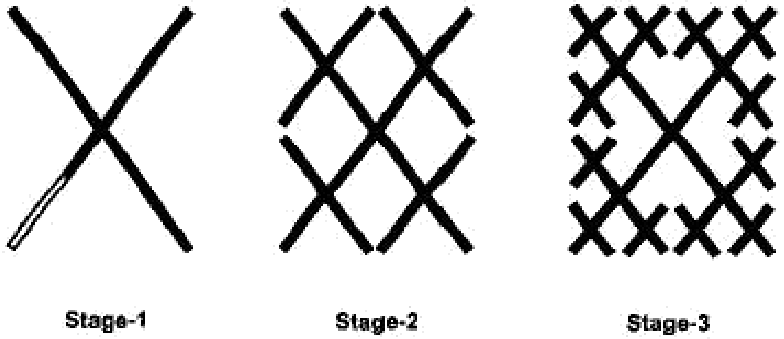


Figure 2.5 the design of tri-band FSS using fractal elements: The first three stages in the construction of a crossbar fractal tree. [59]

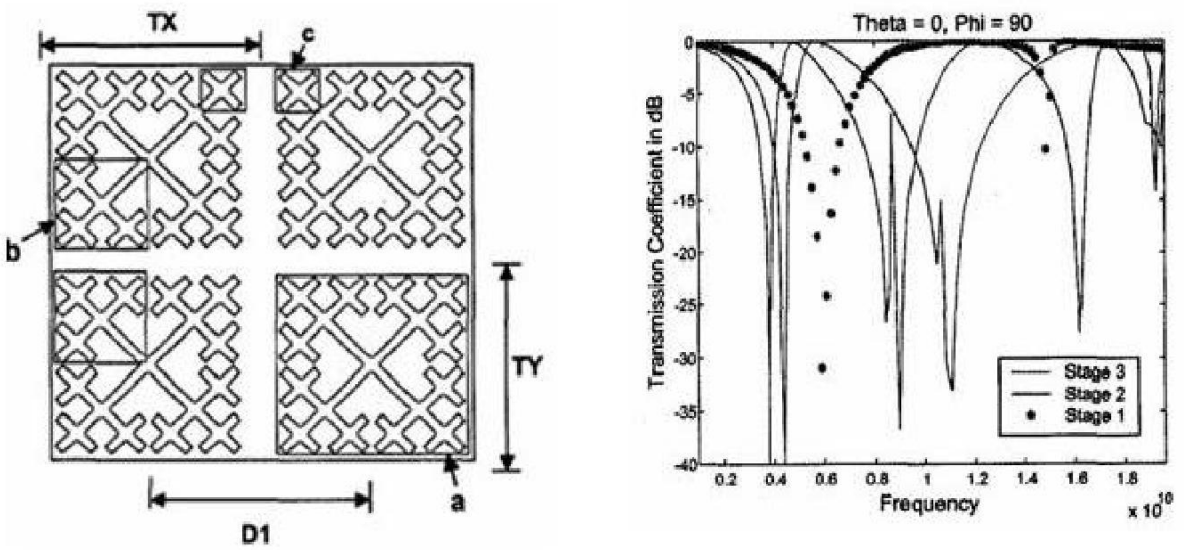


Figure 2.6 (a) A tri-band FSS design based on the crossbar fractal tree structure b) The transmission coefficient for the FSS [59]

2.10 Optimization of Fractal Antenna

Genetic algorithm with IFS and MoM are used to optimize a Koch dipole fractal element antenna [61] with 30 to 55 % reduction in size. Further studies on optimization of Koch like fractal antenna elements are reported in [62] where multi-objective GA is used along with numerical electromagnetic code (NEC) for improvement in bandwidth, efficiency and electrical size. It is seen that Koch like antenna elements are the candidates for optimization for miniaturization using Particle Swarm Optimization (PSO) [63]. The optimized antenna and its characteristics are shown in Figure (2.7). Their goal was to optimize the fractal shape and input impedance by making thickness of segments of the fractal antenna as one of the parameter such that matching network is not required.

In [64] Genetic algorithms are used for optimizing the layout of fractal random arrays resulting in poly-fractal arrays to obtain small beam width, low side lobe levels and wider bandwidth. An extension to such fractal antenna optimization using PSO for miniaturization of the device is reported in [65] for specific application to 3.4 3.6 GHz WI-MAX. Some electrically small thin wire antenna evolved using GA that had better performance than that of some variations of Sierpinski monopoles so far as resonance frequency, efficiency and Q factor [66]. They also explored closed loop shapes in addition to zigzag patterns and meander designs to expand the search space for optimization of antenna.

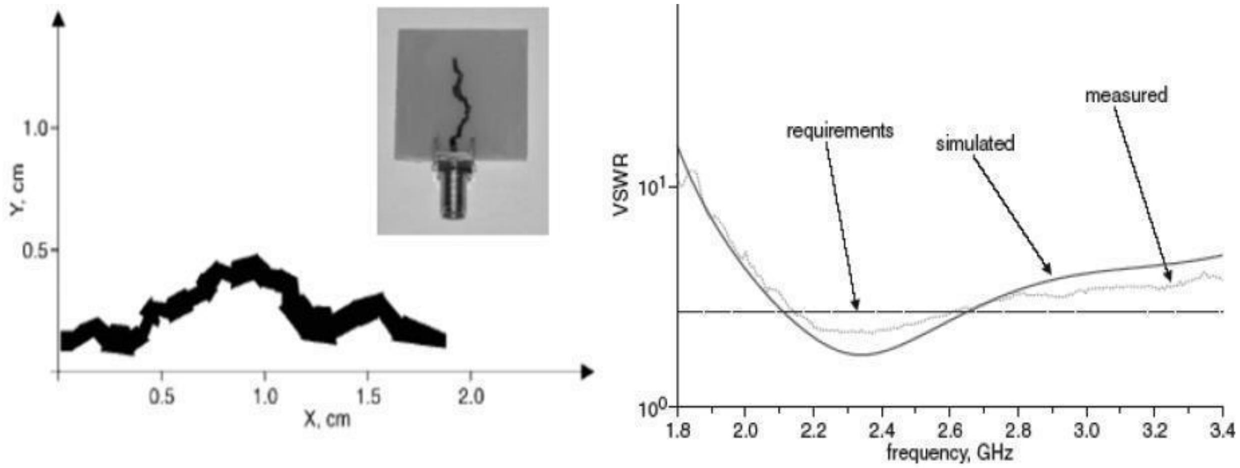


Figure 2.7 (a) Particle swarm optimization of Koch like antenna elements.
(b) VSWR characteristics of optimized antenna [63].

2.11 Research Gaps

- The major drawback in a straight-forward application of fractal geometry in antenna design is the lack of flexibility in the control of the operational frequencies.
- Return losses are more with higher operating frequency. So work can be done to design antennas with more return loss at higher operating frequency with greater bandwidth.
- It is seen that multiband behaviour is observed with higher frequencies with different fractals. The same behaviour can be worked upon for lower frequencies too.
- The use of parasitic elements, stacked patches, using thick substrates of low permittivity etc. have proved to improve the bandwidth of the antenna. However, the broad banding design in micro-strip antenna results in high volume in spite of its efficient results. With the fractal, reduction of the profile can be done.

- The hexagonal fractal antenna is observed to possess multiband behaviour similar to the Sierpinski gasket antenna. However, the hexagonal fractal antenna resonant frequencies repeat with a factor of three whereas the Sierpinski gasket antenna resonant frequencies repeat with a factor of two in frequency.
- The fractal tree antenna is extended involving three-dimensional structures. Not much work is seen in this area.

2.12 Thesis Objective

- The main objective of this thesis is to design, fabrication and testing of the rectangular micro-strip patch antenna using proximity feeding technique covering all the bands of WLAN.
- The other job is to improve the bandwidth of the micro-strip antenna up to the wide band level by using stacking phenomenon and improve the gain of the antenna using fractal shaped antenna.
- To design Micro-strip patch antennas for a specific resonating frequency, accurate dimensions of patch, the substrate with efficient dielectric constant and height is required.
- Therefore, it becomes necessary to use simulation programs to test the performance of the antenna before fabrication.

For the modelling and simulation of patch antennas, here we are using Computer Simulation Technology (CST) Microwave Studio version 2010.

Chapter 3

DESIGN OF BOWTIE SHAPED FRACTAL ANTENNA FOR WIRELESS COMMUNICATION

3.1 Introduction

In this chapter, the general procedure for designing a Bowtie shaped fractal antenna has been presented. The antenna is designed to operate in both IEEE 802.11a/b bands respectively. The design of the antenna has been undertaken in four major steps. In the first phase the fractal Antenna is designed using CST studio 2010. Antenna is simulated using CST to verify the design parameters. The best result obtained from the second step is used such that fractal geometry could be incorporated into the design. The final phase involved studying the characteristics of Rectangular Microstrip antenna.

3.2 General Design of Bowtie shaped fractal Antennas

The basic design procedure for designing Bowtie shaped fractal antenna is illustrated in steps in the following box diagram

Step 1:- Choose desired the resonant frequencies

↓

Step 2:- Choose appropriate substrate height and dielectric constant based on transmission line model equations mentioned in section 3.6

↓

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

As shown in the Figure 3.1, the feed line is sandwiched between two dielectric substrates and the radiating patch is on top of the upper substrate. The advantages of this kind of feeding technique called proximity coupled feeding are elimination of spurious feed radiation and high bandwidth due to overall increase in the thickness of the Microstrip Patch Antenna. Impedance matching is achieved by controlling the length of the feed line and the width-to-line ratio of the patch. Difficulty in fabrication due to the need of proper alignment between the two substrates is the main disadvantage of this technique [3].

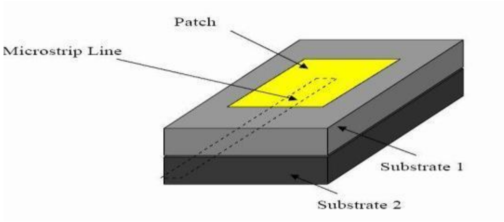


Figure 3.1 Proximity Coupled Feeding

3.4 Selection of Proximity Coupled Feeding Technique for Research Work

The following few advantages of proximity feeding technique over the other feeding techniques results in the selection of this particular technique for the research work.

1. Higher bandwidth as compared to other feeding techniques
2. Proximity feeding technique has less spurious radiations
3. There is no direct contact between the feed line and the radiating patch
4. Highly reliable feeding technique
5. It has good suppression of higher order modes
6. Impedance matching is easy

3.5 Design Considerations for Fractal Antennas

Based on the formulation of length, width of fractal for a given dielectric constant and resonant frequency of the antenna, the patch size is designed. A microstrip antenna element can be used alone or in combination with other like elements as part of an array. In either case, the designer should have a step-by-step element design procedure. Usually, the overall goal of a design is to achieve specific performance characteristics at a stipulated operating frequency. If a microstrip antenna configuration can achieve these overall goals, then the first decision is to select suitable antenna geometry. A fractal antenna can be designed using the procedure described in the next subsection.

3.5.1 Substrate Selection

The first design step is to choose a suitable dielectric substrate of appropriate thickness h and loss tangent. A thicker substrate, besides being mechanically strong, will increase the radiated power, reduce conductor loss, and improve impedance bandwidth. However, it will also increase the weight, dielectric loss, surface wave loss, and extraneous radiations from the probe feed. The substrate dielectric constant ε_r plays a role similar to that of substrate thickness. 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 $\varepsilon_r = 4.4$ are preferred. Here substrate thickness h=1.6 mm and dielectric constant $\varepsilon_r = 4.4$ are considered (FR4) for the desired antenna.

3.5.2 Element Width and Length

Based on the simplified formulation, a design procedure is outlined which leads to practical designs of fractal antennas. The procedure assumes that the specified information 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 selecting the patch dimensions L and W for a given substrate, the next task is to determine the feed point so as to obtain a good impedance match between the generator impedance and the input impedance of the patch element. It is observed that the change in feed location gives rise to a change return loss and hence provides a simple method for impedance matching. The feed line in proximity feeding technique should end at the center below the patch.

3.6 Design Procedure of Bowtie Shaped Fractal Antenna Using Proximity Feeding.

Step 1: Calculation of Width (W)

For an efficient radiator, practical width that leads to good radiation efficiencies is calculated by transmission line model equation:

$$f_o = c / 2 \sqrt{\{\varepsilon_{eff} [(m/L)2 + (n/W)2]^{1/2}\}} \qquad (3.1)$$

where m and n are modes along L and W respectively, f_o is the resonance frequency and W is the width of patch.

Step 2: Calculation of Effective Dielectric Coefficient (ε_{reff})

The effective dielectric constant is obtained by referring to equation:

$$\varepsilon_{reff} = (\varepsilon_r + 1) / 2 + (\varepsilon_r - 1) / 2 \, [1 + 12 \, W / h]^{1/2} \qquad (3.2)$$

Where $\mathcal{E}_{\text{reff}}$ is effective dielectric constant, $\mathcal{E}_r$ is dielectric constant of substrate, h is height of dielectric substrate, W is width of the patch.

Step 3: Calculation of Effective Length (L_{eff})

The effective length is calculated using equation

$$L_{eff} = L + 2\Delta L \tag{3.3}$$

Step 4: Calculation of Length Extension (ΔL)

The value of L can be obtained by using equation

$$\Delta L = 0.412h\,(\mathcal{E}_{\text{reff}} + 0.3)\,[W/h + 0.264]\;/\;(\mathcal{E}_{\text{reff}} - 0.258)\,[W/h + 0.8] \tag{3.4}$$

Step 5: Calculation of Actual Length of Patch (L)

The actual length of radiating patch is obtained by the expression

$$L = L_{eff} - 2\quad L \tag{3.5}$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

The Transmission Line Model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane.

It has been shown that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L \tag{3.6}$$

$$W_g = 6h + W \tag{3.7}$$

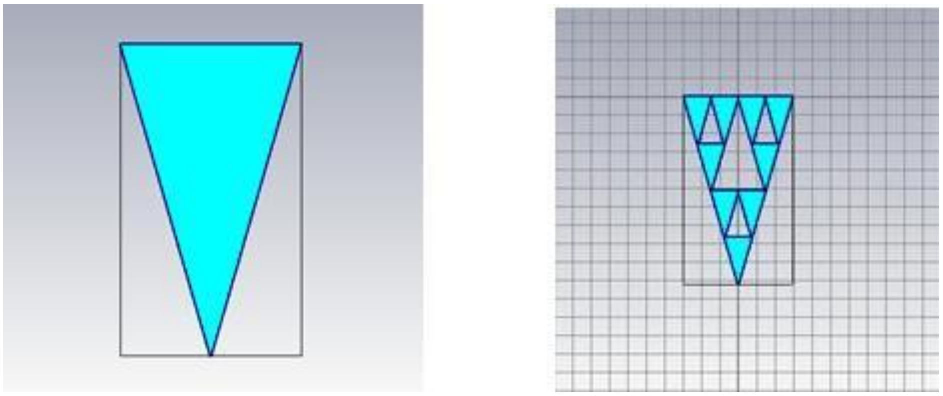
3.6.1 Antenna Design

We have calculated the parameters required for designing the triangle from equations described in Section 3.5. The radiating patch is printed on the upper side of the first substrate. The length of equilateral triangle is 40.08mm. The two substrates used are of same material and have same height. The substrate is made up of material having dielectric constant 4.4 and height of the substrate is 1.6mm. The feed line is sandwiched between the two substrates. The feed line is from the center of the microstrip towards the patch axis along the positive y direction having gap of 0.08544085053.

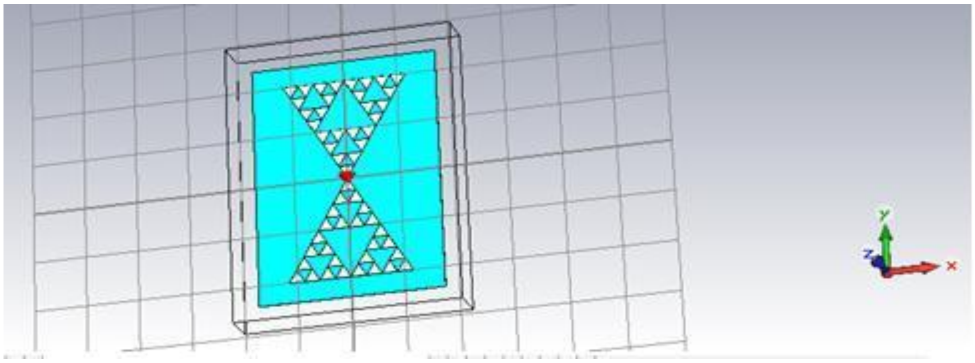
Variable	Value
Total Length of substrate	96.298701397463
Total Width of substrate	69.435939845479
Height of substrate	1.6
Width of feed line	0.08544085053
Flare angle	60^0

Table 3.1 Dimensions of the Patch Antenna Design

The simulated antenna design using CST 2010 studio is given in the Figures below:



a) Iteration 1 b) Iteration 2



c) Iteration 3

Figure 3.2 Designed Structure of Bowtie Fractal Antenna on CST 2010

3.6.2 Simulation

Results a) Return loss

The simulation results of the above designed antenna for various parameters like return loss, impedance, gain, time signal and VSWR are given by using CST studio 2010.

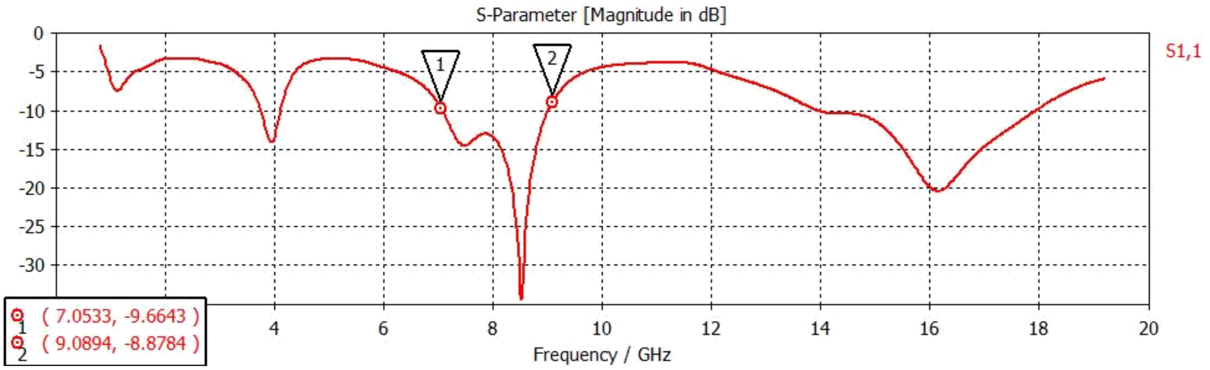


Figure 3.3 Simulated Return Loss

The above designed antenna shows good return loss approximately -35dB at a frequency of 8.4 GHz which is a good result. This antenna resonates at 8.2 GHz frequencies and gives a bandwidth of approximately 2.3GHz. The bandwidth is calculated by subtracting lower frequency from the upper frequency at -10dB and it comes out be 8.2 GHz in this specific case.

The proposed antenna design gives good impedance of approximately 100 ohms which shows that the antenna is perfectly matched and the power loss is minimal. The results obtained for the designed antenna is given below.

b) Smith Chart

Markers 1 and 2 show the bandwidth at resonant frequency 8.2 GHz.

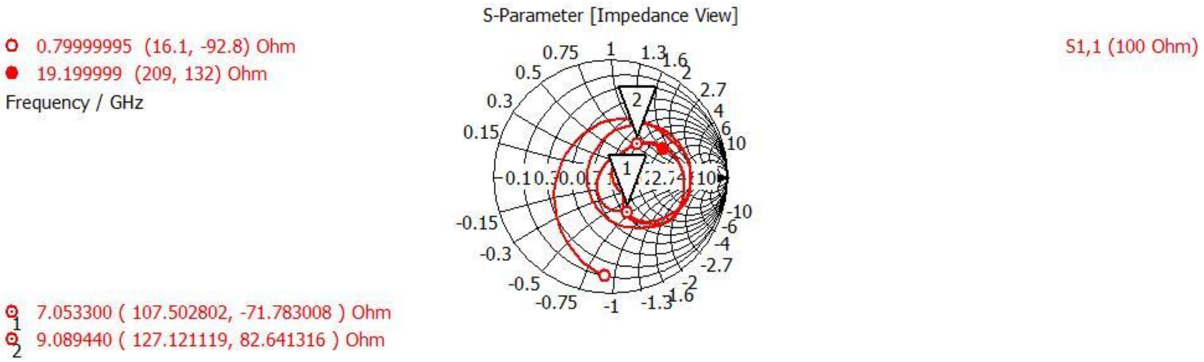


Figure 3.4 Smith Chart

c) Directivity

The simulation results of Directivity in 2D are given below, the value of Directivity is 6.4 dBi at 8.2 GHz frequency.

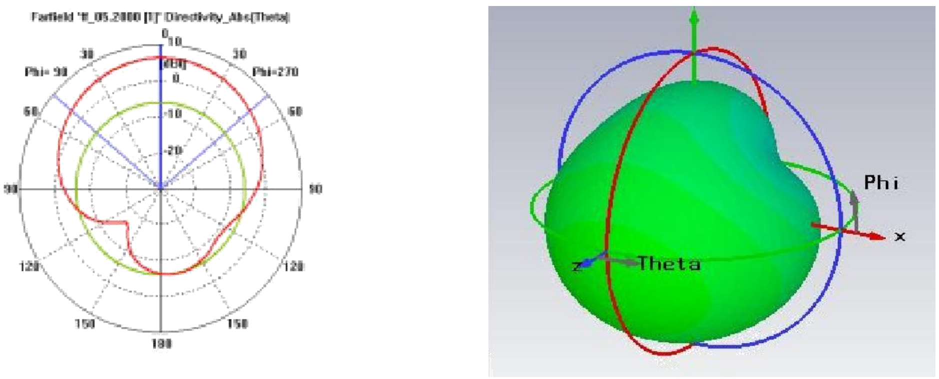


Figure 3.5 a) Simulated 2D Directivity b) Simulated 3D Directivity

d) Gain

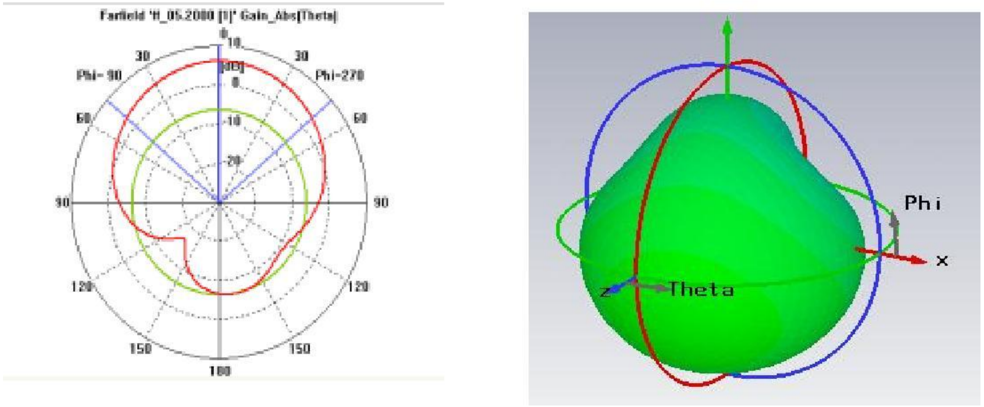


Figure 3.6 a) Simulated 2D Gain b) Simulated 3D Gain

3.7 Conclusion

In this chapter we wanted to design wideband antenna for applications at 8.2 GHz and we achieved wideband antenna which resonates at 8.2 GHz and having bandwidth approximately 2.3 GHz. The Designed Antenna gave good impedance.

Parameters	Value
Operating frequency	8.2 GHz
Return loss	-35 dB
Impendence	100 ohms
Bandwidth	2.3 GHz
Directivity	6.4 dB
Gain	6.17 dB

Table 3.2 Simulated Results of antenna at 8.2 GHz

Chapter 4

DESIGN OF I-SHAPED FRACTAL ANTENNA FOR GSM APPLICATION

4.1 Introduction

The aim of this chapter is to design a Fractal Antenna. In this chapter, I-Shaped Patch is taken as a base shape. I-shaped geometry has been applied to micro-strip patch antenna to reduce its overall size. It is found that as the iteration number and iteration factor increases, the resonant frequency becomes lower which provides the GSM application.

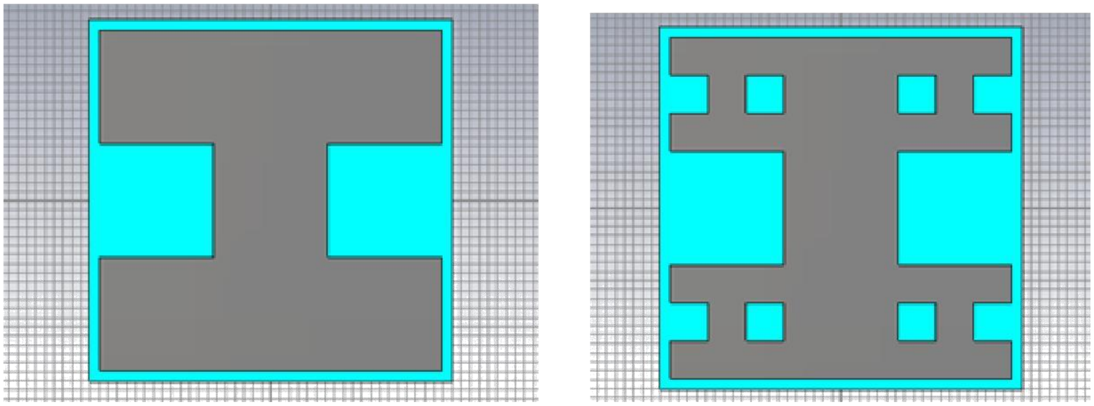
4.2 Antenna Design

The dimensions of the I-shaped patch are width Wp is 37.6218 mm and length Lp is 37.6218 mm. The radiating I-shaped patch is printed on the upper side of the upper substrate. The two substrates used are of same material and have same height. The substrate is made up of material having dielectric constant 4.4 and height of the substrate is 1.6 mm. Feed line is sandwiched between the two substrates. The width of the feed line is 2 mm and the length from the center of the microstrip towards the patch axis along the positive Y direction to end. In this design the dimensions of the upper and the lower substrates are same. The following parameters for antenna design are calculated:

Variables	Values
Width of patch	37.6218 mm
Length of patch	37.6218 mm
Width and length of substrate	37.6218 mm
Height of substrate	1.6 mm
Width of slot	2 mm
Length of slot	18.8109 mm

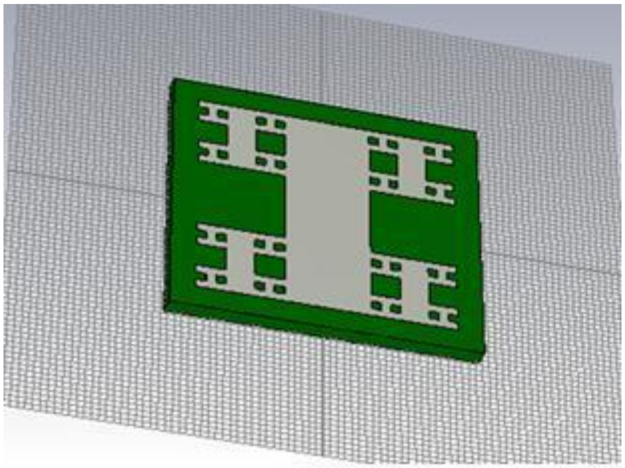
Table 4.1 Dimensions of Single Band Antenna Design for 1.8 GHz frequency

The Figures below shows the simulated antenna design using CST 2010 studio and represent three different iterations.



a) First Iteration

b) Second Iteration



c) Third Iteration

Figure 4.1 Antenna Design of an antenna using CST 2010 at 1.8 GHz

4.2 Simulation
Results a) Return loss

The simulation results of antenna parameters like return loss, impedance, bandwidth and gain are obtained using CST 2010 studio and given in the next section. The designed antenna gives a return loss of -15dB which shows that matching of antenna is good and the losses are minimal. The bandwidth obtained is acceptable for GSM applications. The simulated result of the antenna is given as follows:

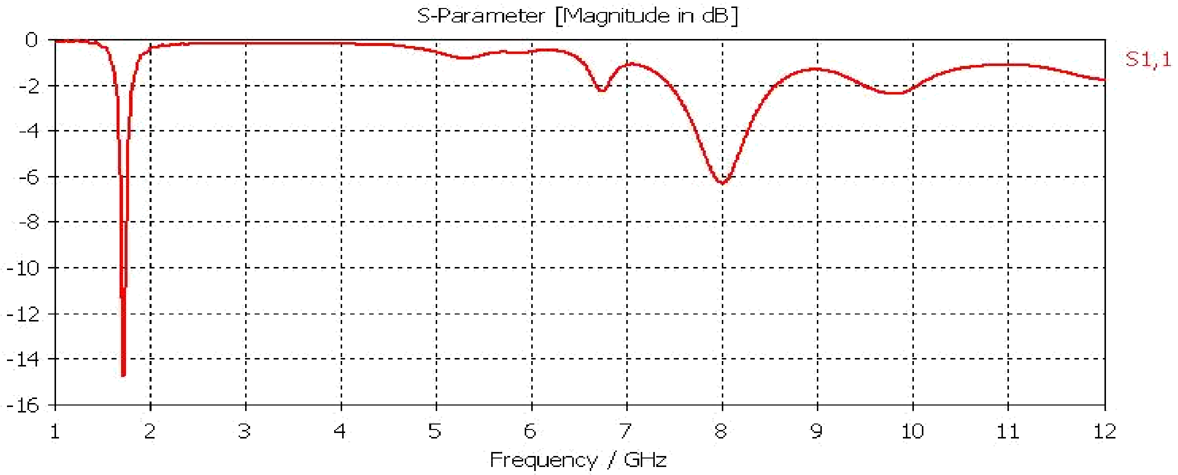


Figure 4.2 Simulated Return Loss

b) Smith Chart

The designed antenna gives an impedance of 50.76 ohms where as for practical applications impedance of 50 ohms is acceptable. The results show the best impedance thus antenna is perfectly matched.

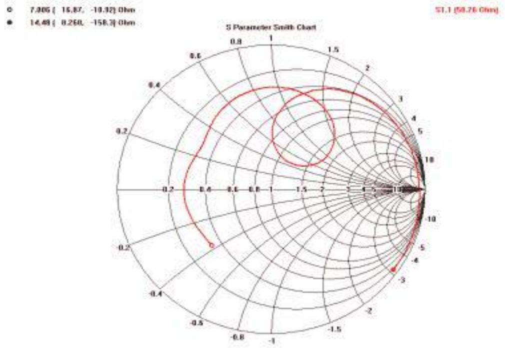


Figure 4.3 Smith Chart

c) Directivity

The above designed antenna gives a directivity of 5.96dBi at 1.8 GHz frequency

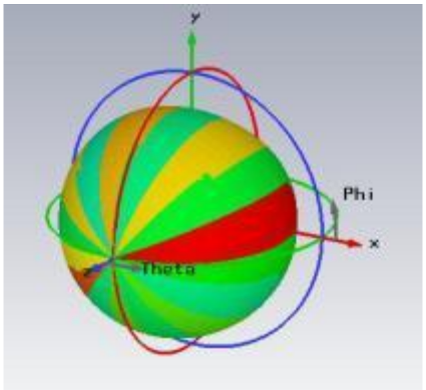


Figure 4.5 Simulated Directivity at 2.4 GHz

d) Gain

The designed antenna gives a gain of 5.57 dB at 1.8 GHz frequency. The simulated results are given as follows:

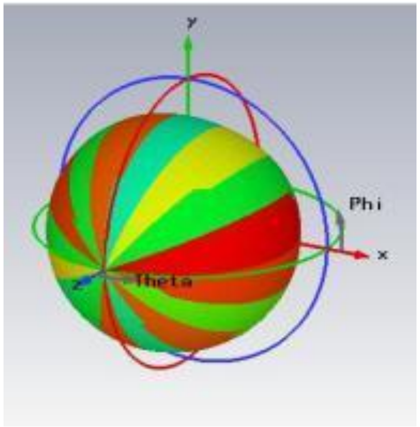


Figure 4.6 Simulated Gains at 2.4 GHz

4.3 Conclusion

The aim of this chapter was to design and simulate a compact antenna for WLAN applications. The simulated results of various parameters of the above designed antenna have been discussed above. It is seen that a Bandwidth of 92 MHz, Gain of 5.57 dBi and Directivity of 5.96 dB is obtained for this antenna which proves that it is good for WLAN applications. The simulated values of parameters show that antenna results are good for practical WLAN applications.

Parameters	Value
Operating frequency	1.8 GHz
Return loss	-15 dB
Impendence	50 ohms
Bandwidth	92 MHz
Directivity	5.96 dB
Gain	5.57 dB

Table 4.2 Summary of the Antenna Parameters of Designed Antenna at 1.8 GHz frequency

Chapter 5

DESIGN OF PLUS SHAPED FRACTAL ANTENNA

5.1 Introduction

The aim of this chapter is to design and simulate patch shaped fractal antenna. In this chapter, plus shape patch is taken as a base shape is placed touching the base shape. In the present simulated results a Plus shape patch is taken as a base shape and in first iteration four other plus shape patches of the order of 1/3 of base shape are placed. Plus shaped geometry has been applied to microstrip patch antennas to reduce their overall size. It is found that as the iteration number and iteration factors increases, the resonance frequencies become lower than those of the zero iteration, which represents a conventional plus shape patch.

5.2 Antenna Design

In this section a multi band antenna is designed which resonates efficiently at two frequencies

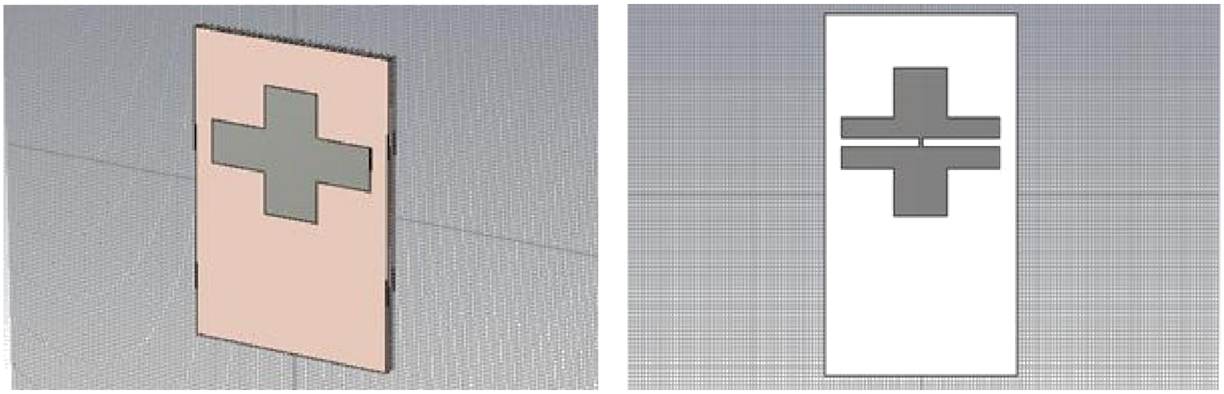
3.2GHz and 3.65GHz. The design of the antenna has patch width "a" of 45.3 mm and the length of patch "c" is 35.4 mm. The substrates used are of same material having dielectric constant of 4.4 and the height of the substrate is 1.6 mm.

The following parameters for designed antenna are given below:

Variables	Values
Length of patch	35.4 mm
Width of patch	45.3 mm
Length of substrates	55 mm
Width of substrates	85 mm
Width of feed	2 mm

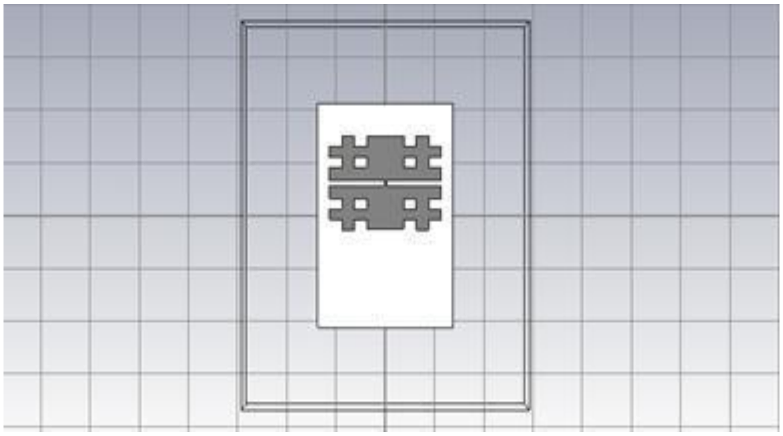
Table 5.1 Various Parameters of Plus Shaped Fractal Antenna

The simulated design of the antenna is given the Figures below which shows the different iterations of plus shaped antenna operating at 3.2 GHz. There are four iterations shown in figure. Iterations helps to lower operating frequency and increase gain.

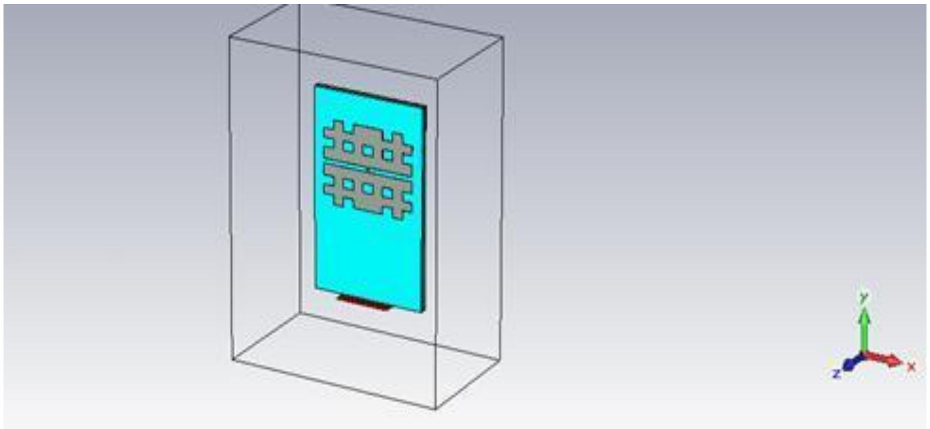


a) First iteration

b) Second iteration



c) Third iteration



d) Fourth iteration

Figure 5.1 Simulated Design of plus shaped fractal antenna

5.3 Simulation
Results a) Return loss

The return loss (RL) is the parameter which indicates the amount of power that is lost to the load and does not return as a reflection. As already known, waves are reflected leading to the formation of standing waves when the transmitter and antenna impedance do not match. Hence the RL is the parameter similar to VSWR to indicate how well the matching between the transmitter and the antenna has taken place. The simulated results of the return loss and given in the Figure below:

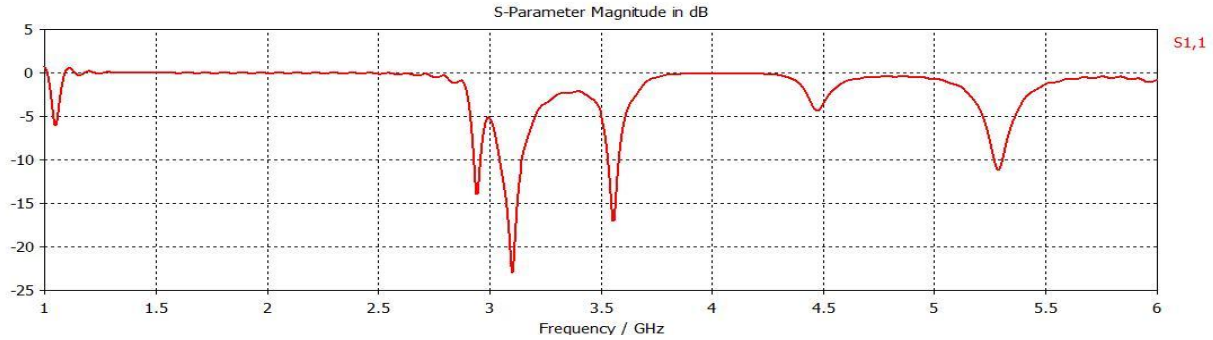


Figure 5.2 Simulated Return loss

According to results it included that at different operating frequencies it shows the applications of IMT-200, IMT-800.

1. At resonant frequency of 3.2 GHz it has bandwidth of 200 MHz for IMT Application.
2. At resonant frequency of 3.6 GHz it has bandwidth of 90 MHz for WiMaX & GSM Application.

b) Smith Chart

The smith chart below shows no. of circles for different resonating frequencies. The circles passes through resistance 1 circle which shows that the antenna is perfectly matched and thus losses are minimal.

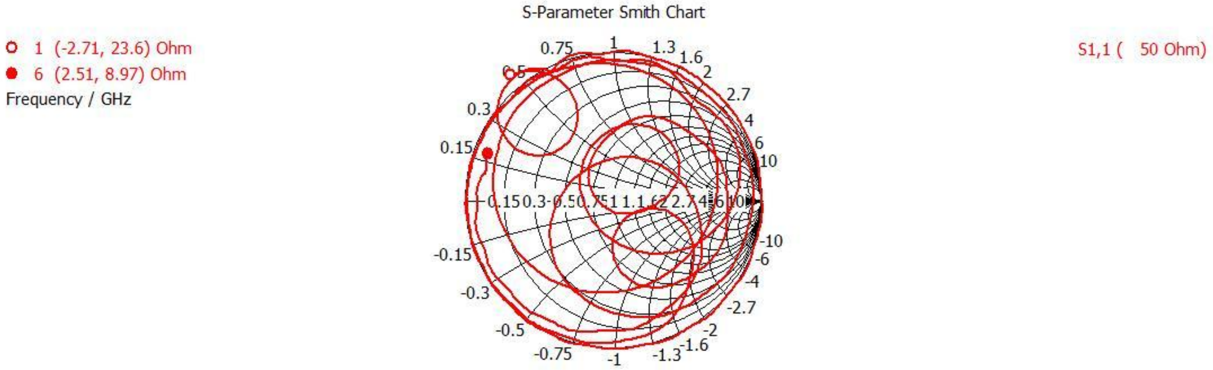


Figure 5.3 Smith Chart

c) Directivity

The designed antenna gives a directivity of 7.33 dB at frequency of 3.2 GHz.

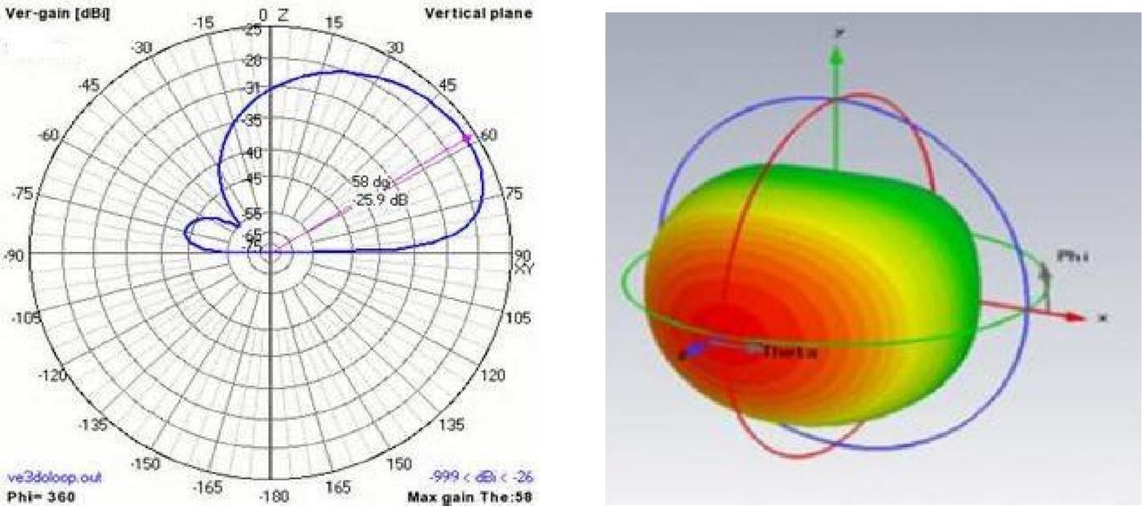
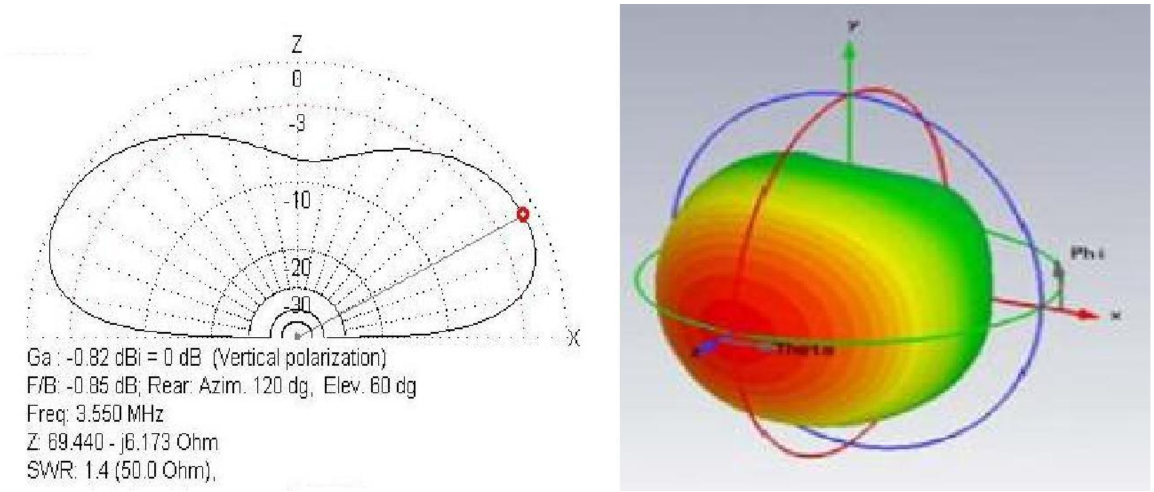


Figure 5.5 a) Simulated 2D Directivity b) Simulated 3D Directivity

e) Gain

The simulation results of gain are given in Figure 5.6 and gain obtained is 7.12 dB at 3.2 GHz.



Ga : -0.82 dBi = 0 dB (Vertical polarization)
F/B: -0.85 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 3.550 MHz
Z: 69.440 - j6.173 Ohm
SWR: 1.4 (50.0 Ohm),

Figure 5.6 a) Simulated 2D Gain b) Simulated 3D Gain

5.4 Conclusion

The aim of this chapter was to design and simulate a compact antenna for IMT-200 applications. The simulated results of various parameters of the above designed antenna have been discussed above. It is seen that a Bandwidth of 200 MHz, Gain of 7.12 dBi and Directivity of 7.33 dB is obtained for this antenna which proves that it is good for IMT-200 applications.

Parameters	Value
Operating frequency	3.2 GHz
Return loss	-22 dB
Impendence	50 ohms
Bandwidth	200 MHz
Directivity	7.33 dB
Gain	7.12 dB

Table 5.2 Summary of the Antenna Parameters of Designed Antenna at 3.2 GHz frequency

Chapter 6

FABRICATION, TESTING AND RESULT DISCUSSION OF FRACTAL ANTENNA

6.1 Introduction

In this chapter, the simulation and fabrication of single band antenna operating at IMT-200 frequency bands has been done. The simulation has been carried out using CST 2010 software and the fabrication is done using the PCB fabrication process. The results are measured on VNA and compared with the simulated ones.

6.2 Simulated Antennas Resonating At 3.2 GHz

By referring to the Section 5.2 and Section 5.3 for the Design of an Antenna resonating at 3.2 GHz, we obtain the following parameters for simulation using the Transmission Line Model. The simulated results of the return loss and the smith chart of the antenna designs resonating at 3.2 GHz for IMT-200 applications are given below:

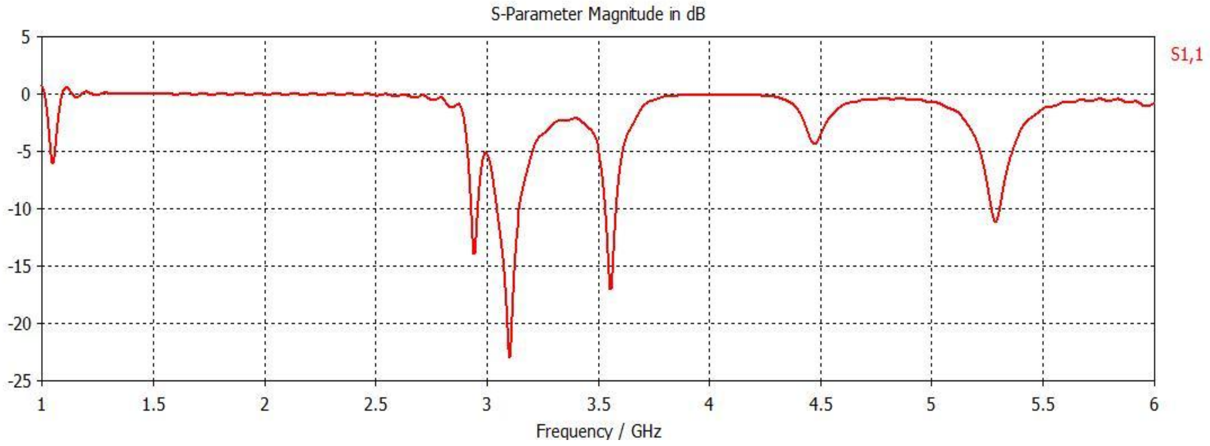


Figure 6.1 Simulated Return loss of Plus shaped Antenna at 3.2 GHz

6.3 Flow Chart of Antenna Fabrication Process

In this topic, the whole fabrication procedure of the Micro-Strip Patch Antenna using Proximity Feeding technique is covered. The fabrication of the antenna is done in certain steps which are given in the flow chart which makes it easier to understand the fabrication procedure.

The flow chart of the antenna fabrication process is given:

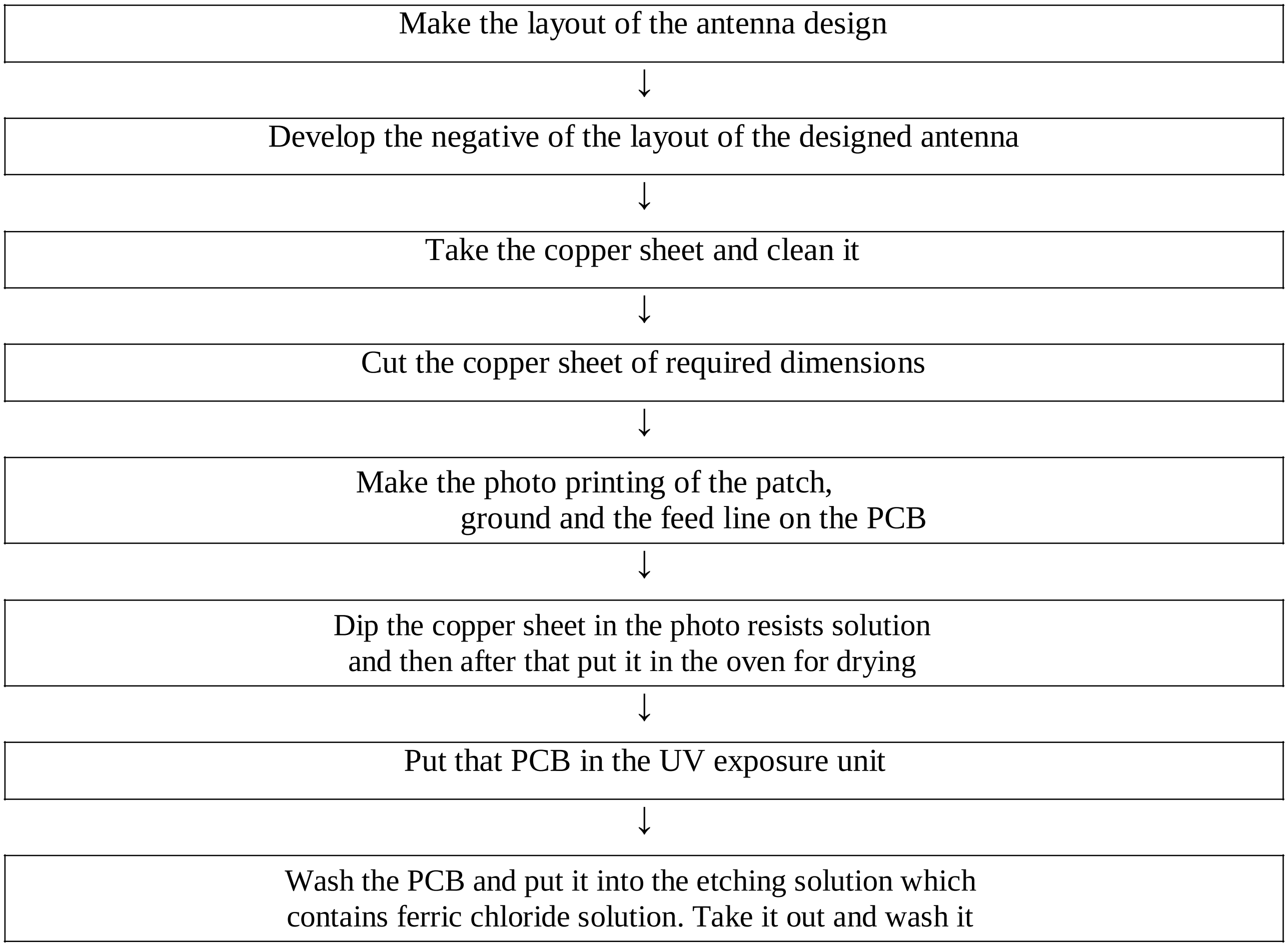


Figure 6.2 Flow Chart of Antenna Fabrication Process

6.4 Fabricated Antenna Design

The fabricated design of the fractal antenna is given in the Figures below:

Figure 6.3 Front view of Antenna

Figure 6.4 Back view of Antenna

Figure 6.5 Feed line of Antenna

6.5 Testing of Antenna

The testing of antenna can be done by using Network Analyser (E5071C-ENA Series) which analyses one port and two port networks. The Figure below shows the network analyser and measured result:

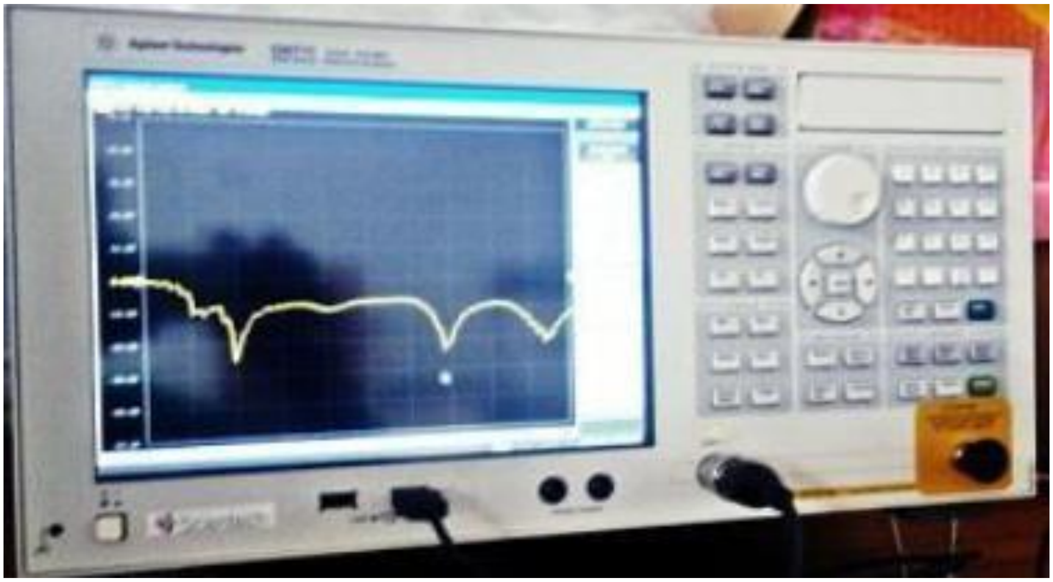


Figure 6.6 Network Analyser with antenna connectivity for Testing

The table below shows the comparison of the simulated and the tested results of the designed antenna and the results are 90% matched.

Parameters	Simulated Results	Tested Results
Return loss	-22dB	-25dB
Impedance	50 ohms	46.63 ohms
Resonating Frequency	3.2 GHz	3.4 GHz

Table 6.1 Tested Results of Antenna Design at 3.2 GHz Frequency

6.6 Conclusion

The simulated and tested results are 90% matched; the 10% losses are due to lose soldering connections, due to presence of air or due to lose SMA connector connections. After these small variations in the results due to some reasons the results are still acceptable.

Chapter 7

CONCLUSIONS AND FUTURE SCOPE

7.1 Conclusion

In this thesis report three configurations of Micro-Strip Patch Antenna using Proximity feeding technique is given for WLAN applications. The first is the typical design of wide band bowtie shaped fractal antenna, the second is the single band I-shaped fractal antenna and the third is the multi-band plus shaped fractal antenna using proximity feeding technique. The various antenna parameters like return loss, impedance, VSWR, directivity, gain, bandwidth and operating frequency are studied for antenna designing. The effect of physical parameters on the antenna parameters are also studied in this thesis report.

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

Chapter 3 presents the designing of the Wide Band Bowtie shaped Fractal Antenna operating at 8.2 GHz for WLAN applications. The designed Wide Band Antenna gives efficient results. The results gives return loss of -35 dB and band width of 2.3 GHz. The antenna has various applications in mobile phones, electronic devices like microwave ovens, satellite communication etc.

Chapter 4 represents a dual band micro-strip patch antenna is designed using proximity coupling that is using two substrates at a time. I-shaped slot on the patch helps in improving the results. The designed antenna gives efficient results resonating at 1.8 GHz. The proposed antenna can be used for various applications like RADAR, mobile, biomedical instruments etc.

Chapter 5 covers the multi band antenna covering two bands of WLAN using proximity coupling technique. The plus shaped slot in the patch helps in improving the results, bandwidth and gives the multiple bands. The slots length, width and the position of the slots are varied in order to obtain the desired results of the antenna. The designed antenna efficiently resonates at 2.9 GHz, 3.2 GHz and 3.6 GHz and gives the improved results.

It is also concluded that physical parameters like patch width, patch length, slot width, slot length, and feed line width etc. effects the results of the antenna. It can be observed that varying these parameters in the right manner gives optimized results for a desired resonant frequency operation of MSA.

The table below shows the variation of S parameters width respect to the patch width at a resonating frequency of 3.2 GHz for WLAN. By applying a sweep, as the patch width is increased from 40.5 mm to 45.1 mm the desired results obtained with patch width of 45.1 mm that is return loss of -25 dB and the resonating frequency of 3.2 GHz. Table 5.1 shows the variations.

Patch Width	45.1 mm	42.16 mm	40.5 mm
Return loss	-25 dB	-24.1 Db	-21.67 dB
Resonating frequency	3.2 GHz	3.1 GHz	3.05 GHz

Table 7.1 Variation of S Parameter with respect to the Patch Width

By applying a sweep on the feed line width, as the feed line width is increased from 1.286 mm to 3.05 mm for 3.2 GHz antenna design the optimized results obtained at 3.05 mm width with a return loss of -25 dB and a resonating frequency of 3.2 GHz.

Feed width	3.05 mm	2.14 mm	1.286 mm
Return loss	-25 dB	-24.1 dB	-21.67 dB
Resonating frequency	3.2 GHz	3.1 GHz	3.05 GHz

Table 7.2 Variation of S parameters with respect to Feed width

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

Parameters	**Bowtie antenna**	**I-shaped antenna**	**Plus-shaped antenna**
Operating frequency	8.2 GHz	1.8 GHz	3.2 GHz
Return loss	-35 dB	-15 dB	-25 Db
Impendence	100 ohms	50 ohms	50 ohms
Bandwidth	2.03 MHz	92 MHz	200 MHz
Directivity	6.4 dB	5.96 dB	7.33 dB
Gain	6.17 dB	5.57dB	7.12 dB
Feeding technique	Proximity coupling	Proximity coupling	Proximity coupling

Table 7.3 Comparison of all designed Antenna Parameters Values

7.2 Future Scope

Since the area of fractal antenna engineering research is still in its infancy, there are many possibilities for future work on this topic. However, many possible fractal structures exist which may undoubtedly have desirable radiation properties. Thus, a possible approach for future work is to investigate other types of fractals for antenna applications. A novel development is the use of fractal patterns for antenna arrays. Fractal antennas can be studied in several areas. One area of development is to implement fractal antennas into current technologies in practical situations such as expanding wireless market. For this application an analysis of the polarization of these antennas will need to be looked. Another benefit that can be explored is lower covered area of resonant loop antennas. This may lead to antenna with lower cross sections. Also, fractals can be used into micro strip antennas.

Still there is enough scope for improvement and further research. Some such works are briefly mentioned below.

- Antennas using other fractal geometries like V-Koch, Sierpinski gasket, and Multi-band fractal antenna can be designed.
- Some preliminary studies on Sierpinski fractal loop antenna have been undertaken. This can be further characterized and also antenna can be optimized using evolutionary techniques such as MOPSO, Genetic Algorithms.
- CPW feed can be optimized with changing the shape of ground plane rather than perturbing the geometry itself.
- Stacked fractal antenna Engineering is another field that can be worked upon future.
- We can also use meta-material to design antennas:-**Meta-materials:** A meta-material is a metallic or semiconductor substance whose properties depend on its inter-atomic structure rather than on the composition of the atoms themselves. Certain meta-materials bend visible light rays in the opposite sense from traditional refractive media. Some meta-materials also exhibit such behavior at infrared (IR) wavelengths. Possible applications of transparent meta-materials with negative indices of refraction include red and IR lasers, optical communications systems, spectrometry, monitoring systems to detect trace gases in the atmosphere, medical diagnostic equipment and optical cloaking devices. In meta-materials both ε_r and μ_r are negative.

The work on micro-strip antenna design using proximity coupling can be extended to:

- Using different structure configuration, the use of different dielectric substrate material as well as combination of different substrate in one structure.
- Using different slots on the patch and the ground, the use of different shape of patch with larger radiating area.
- Using impedance matching network to enhance the impedance bandwidth.

Other Feeding Techniques: The other feeding techniques of micro-strip patch antenna like micro-strip line, coaxial feeding, aperture coupling and CPW can also be used in future to design the same micro-strip patch antennas.

PUBLICATIONS

Published

Gursimranjit Singh and Amanpreet Kaur, “A Review Paper on Fractal Antenna Engineering”, vol. 3, issue 6, IJAREEIE, June 2014.

Communicated

“Design of Plus Shaped Fractal Antenna”, IJRITCC, vol. 2, issue 7, July 2014.

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