M.TECH PROJECT II

4^{th} semester

REPORT

On

"DESIGN OF FRACTAL ANTENNA FOR MULTIBAND APPLICATIONS IN WIRELESS COMMUNICATION AND HEALTHCARE "

In partial fulfilment of the requirements for the award of the degree of

Master of Technology

In

MICROWAVE AND OPTICAL COMMUNICATION ENGINEERING

OF

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

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CERTIFICATE

I hereby certify that the report titled "**DESIGN OF FRACTAL ANTENNA FOR MULTIBAND APPLICATIONS IN WIRELESS COMMUNICATION AND HEALTHCARE**" which is submitted by Pranjit Deka (2k19/MOC/02) in Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the award of Master of Technology, is a record of project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date: 30/7/2021

for

Prof. Asok De

(SUPERVISIOR)

Professor,

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CANDIDATE'S DECLARATION

I, Pranjit Deka (2k19/MOC/02) students of M. Tech(Microwave and Optical Communication Engineering), hereby declare that the Report titled "**DESIGN OF FRACTAL ANTENNA FOR MULTIBAND APPLICATIONS IN WIRELESS COMMUNICATION AND HEALTHCARE**" which is submitted by me to the Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in the partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi

Date: 30/7/2021

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ABSTRACT

A fractal geometry-based technique has been incorporated to design a microstrip patch antenna and the simulated results are verified to be used in multiband operation for its application in wireless communication and healthcare domain. Initially, a Wireless Power Transmission (WPT) System having profile features like light weight and miniature design have been comprehended using a fractal antenna. Further, similar approach is carried out to achieve an antenna to be used in Wireless communication (namely- WIMAX, S-band, C-band, and satellite communication) and in healthcare such as Non-invasive glucose level monitoring system. But as there goes a surge in compactness of the devices for it to be more convenient, there is a need for miniaturization of its components without compromising its performance, which is achieved by the use of a fractal antenna where an elementary geometry of rectangle is made into a patch and is iterated to the 3rd level of the iteration process. The obtained rectangular patch antenna is excited using a microstrip feed excitation technique and the antenna is subjected to operate in the frequency range of 1 to 5 GHz and correspondingly the designed fractal antenna should resonate in the ISM band range for the desired applications mentioned above. Evidently, the proposed antenna achieved resonance at four different frequencies of 1.9/2.4/3.2/4.6 GHz in the range of 2 to 8 GHz frequency, with their respective return loss values as -13.20/-22.5/-11.8 dB. The simulation and corresponding results of the outlined antenna is done using Ansoft HFSS simulator.

Keywords: Wireless Power Transmission (WPT),
Solar Power Satellites (SPS), High Frequency
Structure Simulator (HFSS), Multiband antenna, Fractals,
Non-invasive glucose monitoring system

Tools/ software used: ANSYS HFSS

ACKNOWLEDGEMENT

With immense pleasure I, Mr. Pranjit Deka, Presenting **"DESIGN OF FRACTAL ANTENNA FOR MULTIBAND APPLICATIONS IN WIRELESS COMMUNICATION AND HEALTHCARE"** Major Project II Report as a part of the Curriculum of 'Master of Technology'.

I express my profound thanks to **Prof. Asok De** my project guide for his valuable support and guidance throughout the journey for making it possible to implement this project with all the necessary material and knowledge, without whom it won't have been possible. I would like to thank everyone who have indirectly guided and helped me in successfully completing this project work.

…………………………….

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Chapter 1

1.1 INTRODUCTION:

Today as the world sees a magnificent demand in wireless systems, starting from communication systems (namely-broadcasting antennas, satellites, health monitoring systems) to various wearable, all these areas of communication demand for more compact and scale downed profile for its overall system as we dive into the future needs. Hence, there has been an urgent need for the miniaturization of its components. For example, today's wireless communication system has brought attention to the development of a more miniaturized antenna, with larger bandwidth and smaller dimensions of its components as crucial features. With the advancement in technologies such as fractal antenna, this can be made possible and this project work displays a simulated microstrip fractal antenna, which is specifically designed for WPT (Wireless power transfer) system, for C-band, S-band and satellite communication and most importantly to be used in wearable such as a non-invasive glucose level health monitoring system. As fabricating such a small structured antenna is primarily required to be used in wearable or compact devices, doing so is quite critical and sensitive too, therefore a fractal significantly optimizes the shape and effective length of the antenna which uses its self-similarity and space-filling property to achieve it. By doing so it provides specialized edge in its usage such as low profile and economical fabrication cost, along with multiband operations capabilities with wide bandwidth to deal with increasing demand in data, significantly with reduced antenna size for a given resonant frequency without hampering the antenna characteristics like gain, return loss and radiation pattern. Therefore, a similar technique is being implemented in this project to design and simulate an antenna to be used in a WPT system in place of a conventional large antenna, which can also be used in WiMAX, S-band and C-band applications, and another vital application that is in portable wearable health monitoring systems is discussed.

Recent innovation in this domain and studies done by numerous researchers all over the world to associate and link fractal geometry theory with electromagnetic theory gave birth to distinguished and plenty of new yet innovative advanced antenna techniques as well as designs. In this report, we tried to give a glimpse of the recent innovations and developments in the surging domain of fractal antenna engineering.

The Fractal antenna engineering research and development is practised in two folds of stages where primarily the optimisation of the antenna design and thereby analysis of the resultant antenna is carried out and secondarily, with the implemented designing or optimisation technique such as fractal geometry to bring out showcasing the advancement in antenna engineering. Fractals does not have a specific characteristic size or shape, and usually have numerous copies of themselves at different scales, justifying their property of self-similarity. Distinctive properties and features of fractals like these are being exploited so as to attain the optimisation of the existing or innovation of a new antenna-element designs that have advantages like compact in size and multiband property. Contrarily, fractal arrays are one such subgroup of thinned antenna arrays, that is believed to several prominent properties such as multiband operation with rapid development of beamforming algorithms based on the recursive nature of fractals and low sidelobe levels. Fractal elements and arrays are also ideal successor for use in reconfigurable systems such as reconfigurable antenna and MIMO. Finally, a summary of few applications of incorporating such antenna in various field like communication and healthcare is studied and verified.

1.2 FRACTAL ANTENNA FOR WPT SYSTEM

A wireless power transfer system (WPT) works in such a way that it facilitates the transfer of power from one end to another through a medium without the use of wires. It first transforms the electrical power into microwave energy, then transfer it through one end into the free space and is received by the receiver end which then converts the EM energy collected into a DC signal using a rectenna. A rectenna is nothing but a system that consists of a Schottky diode followed by pre-rectification and post-rectification filtering circuits. As the wireless market has grown with more compact and portable/wearable devices, here fractal antenna can play a huge role by reducing the size of such conventional antenna without hampering its parameters, for-instance VSWR, return loss, directivity, radiation pattern, and gain.

1.3 FRACTAL ANTENNA FOR HEALTH MONITORING SYSTEM

Here, The implemented fractal antenna is incorporated to be used in a health monitoring system, where a non-invasive glucose level monitoring biosensor is complemented to tackle the everyday hurdle of diabetic patients. It works in such a way that a wearable consists of a biosensor that radiates EM wave into the human body part that the wearable is in contact with and using the understanding of, EM wave travels differently in different di-electric medium, a similar concept is applied where a diabetic person has more glucose saturation in its blood than a normal person, thereby it changes the dielectric constant of the medium having high glucose level in blood [2]. Hence, studying the return loss parameter, S21 gives a definite signature for a type of medium. Therefore, the reflected EM wave is studied using various post-processing algorithms to differentiate their signatures for diabetic patients and a normal human being. This is where the fractal antenna can play a major role in the transmitting and receiving section, minimizing the antenna size, as it facilitates more compactness of the whole wearable device for more portable and convenient use.

1.4 FRACTAL ANTENNA FOR COMMUNICATION SYSTEMS

Conventionally, the size or type of an antenna of any communication system can vary with required mode of communication Technology and the communication system itself, therefore proposing a fractal antenna can primarily reduce the size of the antenna as well as provide multiband operations such that a single antenna can be used for different bands of frequencies thereby making it possible for a single antenna to work for different mode of communication technology. Therefore, here such a fractal antenna is designed which operates and can support in WiMAX, S-band, c-band and satellite communication frequency bands.

The latest enthusiasm shown by numerous researchers worldwide to insert the fractal geometry theory to the world of electromagnetic theory has evolved a plethora of opportunities in the field of antenna and communication systems.[6] Therefore, in this report a series of latest innovation and development in the field of microstrip fractal antenna have been discussed, justifying its performance with conventionally used alternative. Fractal geometries are such that it doesn't have a definite shape or size, and usually comprised of different copies of shapes and structures, self-similar structural geometry within themselves at different scales and length which basically justify their property of Sab similarity. Thereby, doing so these creates different current Path which develops there another crucial property of multiband operations. Due to which they have modern applications in MIMO, antenna array and reconfigurable antennas.

By applying these fractals to antenna elements:

- We can fabricate smaller antenna size.
- Can opted for multiband operation with resonance frequencies.
- Can optimize gain of the system.

Therefore, fractal antenna engineering basically works as an optimising technique for antennas to provide a low profile and better performing system. With the inclusion of which it can provide wide bandwidth, multi band characterisation, and reduced antenna size, among others

CHAPTER 2 LITERATURE REVIEW

To start with the thesis work on the topic discussed above, firstly a brief research was carried out on the related topic with various study material and various research papers already published by researchers were studied. With the help of this literature review, I explored earlier findings and got the motivation and objective of pursuing my thesis work of design of fractal antenna for multiband application in wireless communication and healthcare.

Yogamathi, R., Banu, S., & Vishwapriya, A. (2013, July), proposed a clear understanding of how a fractal antenna can replace a conventional antenna of large size used in satellite communication. And, also provided work on further use of multiband operation in different communication technologies using the concept of fractal geometry.

Omer, A. E., Shaker, G., Safavi-Naeini, S., Kokabi, H., Alquié, G., Deshours, F., & Shubair, R. M. (2020). Unlike readily available invasive glucose level monitoring instrument an alternative way of low-cost portable microwave sensor for non-invasive monitoring of blood glucose level is detailed using a novel design utilizing of four-cell CSRR hexagonal configuration.

HFSS users manual,2005, version 10, Ansoft Corporation, The manual provided the softskills required for successfully simulate and design a proposed antenna in a given condition and thereby analysing further performance with the conventionally available components.

Balanis.C, 2009,"Antenna Theory and Design" 3rd Edition, McGraw, This book is believed to provide the best basics and fundamental knowledge that is required to be gathered for carrying out this thesis work successfully.

Sheik Mohammed.S,K. Ramasamy, T. Shanmuganantham Sheik,2010 "Wireless Power Transmission – A Next Generation Power Transmission System", proposes the idea of how wireless transmission system works and how the modern day generation of devices can use it explicitly in almost everywhere possible starting from smart devices to home appliances.

Vinoy.K.J, 2002, "Fractal Shaped Antenna Elements for Wide- And Multi- Band Wireless Applications" is a proposed thesis work at Pennsylvania State University which gives a clear knowledge about the use of wide-band and multiband capabilities of fractal antenna in communication systems.

Body Matched Antennas for Microwave Medical Applications by Xuyang Li, this work by xuyang li discusses about how antennas can be used in medical devices and how EM waves can interact or get affected with human tissues, with the study of which various medical devices can be used to monitor the health status of a person.

Werfelli, H., Tayari, K., Chaoui, M., Lahiani, M., & Ghariani, H. (2016, March). Provides the working of rectangular microstrip patch antenna and how it can be designed for the proposed thesis work.

Zhang, K., Li, D., Chang, K., Zhang, K., & Li, D. (1998), provided the study of how *Electromagnetic wave or radiation gets affected or behave through different types of media. Here, the effect of glucose concentration in blood with that of EM wave is explained.*

Reynolds, T. (2004, February). Advanced wireless technologies and spectrum management in ***ITU seminar,*** proposes can extensively wonderfully work on bands of spectrum and uses in communication systems which had been in use since the early era of civilisation till the modern-day communication technologies.

Sharma, Manish, Prateek Jindal, and Sushila Chahar. Showcases the use of fractal antenna for multiband applications such as in modern day communication techniques and how microstrip patch fractal antenna can work interestingly in most of the cases.

CHAPTER 3

3.1 INTRODUCTIONING THE NEED FOR FRACTAL ANTENNA

An antenna can be defined as a radiating element, usually a conducting material like a wire or set of wires, which works as a transducer, sending out or receiving electromagnetic radiation. A given antenna can be either transmitting type, where AC current is radiated out in the form EM wave into the space or it can be a receiving type of antenna where it receives the radiated EM wave and convert it into AC. As antenna is the most vital component in a communication system, the size of an antenna is determined by the required compactness of the communication system. Therefore, several techniques have been developed to reduce the size of an antenna to be fitted into more compact devices without deteriorating its performance. As the world sees a rapid and magnificent bloom in wireless devices, with particular requirement of compact devices as new gadgets like wearables, smartphone and various systems launching every day, there have been an urgent requirement for smaller yet smart antenna than conventionally available antenna.

This is where the concept of fractal antenna can a play a major role in communication systems with its revolutionary properties.

Figure1- Antenna

The present day modern wireless communication systems, whether in the field of military applications or commercial purposes requires such an antenna which can provide multiband operations using a single antenna with reduced or more compact antenna size to be incorporated in a different communication device. Therefore, this has ignited the research and development of such smart antennas in various verticals of which fractal antenna is one of a kind which promises to deliver better capabilities than a conventional antenna with desired properties like miniaturized antenna and multiband operations, where a single antenna can operate at single as well as dual frequency bands for its application in different domains.

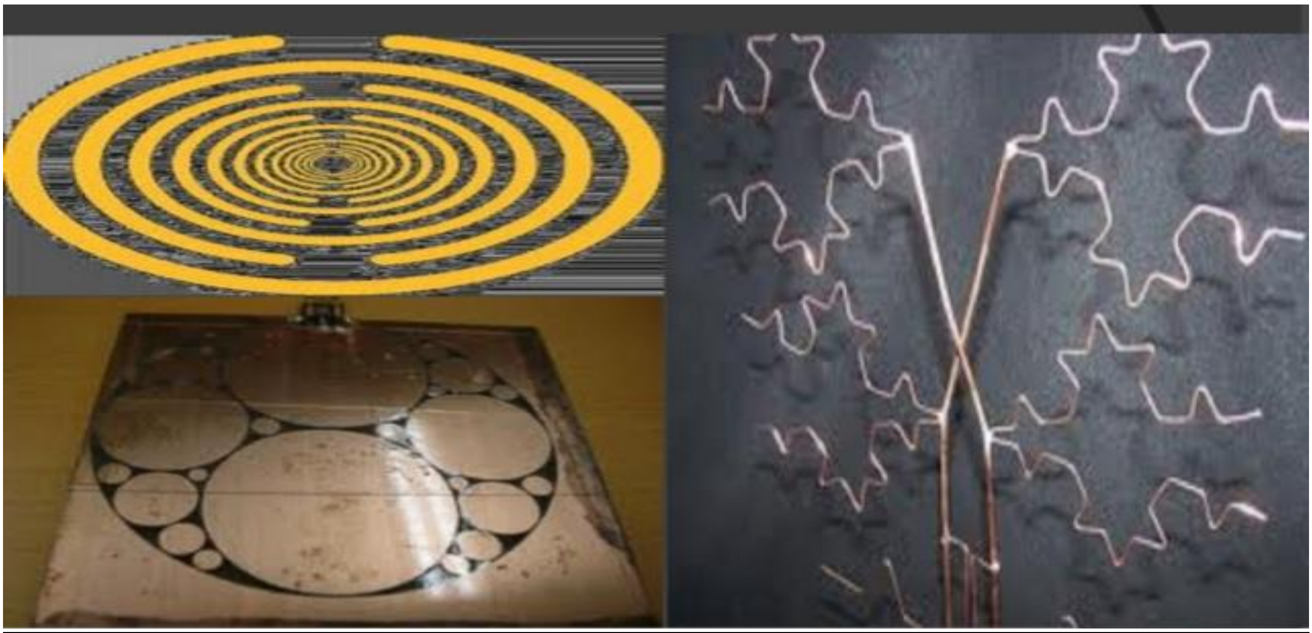


Figure 2- Fractal Antenna

Chapter 4

4.1 DEFINING FRACTAL ANTENNA

Mankind have understood and taken many qualities from nature and tried to mimic it for implementing on various technologies for betterment. Incorporating the concept of fractal geometry is one such insight which has significantly impacted various verticals of modern-day science and engineering; one of which is in the field of antennas. Antennas implemented on some of these geometries for various telecommunications applications are already available commercially worldwide, significantly caused the use of fractal geometries has been shown to improve several antennas features to varying extents. This research work is intended as a first step to fill this gap.

With regard to antenna performance, it is assumed that fractal-shaped geometries lead to multi-band properties and a reduction in antenna size. Although the usefulness of different fractal geometries varies in this regard, they are still the primary reasons for fractal antenna design. For example, monopole and dipole antennas using Sierpinski fractal connections have been widely reported and their multiband properties have been associated with the self-similarity of geometry. However, this qualitative explanation is not always possible, especially with other fractal geometries. The mathematically expressible property of fractal geometry is necessary for design optimization. To investigate this, a Koch curve is chosen as the candidate geometry, mainly because its similarity dimension can be varied from 1 to 2 by changing a geometric parameter (bleed angle). The numerical simulations presented here show that this variation has a direct influence on the primary resonance frequency of the antenna, its input resistance at this frequency and the ratio of the first two resonance frequencies. In other words, these antenna properties can now be linked quantitatively with the fractal dimension. This knowledge can lead to greater flexibility in antenna design using these geometries. These results have been validated experimentally. This observation now can lead to increased flexibility in designing the required antennas using these fractal geometries.

At the very beginning, renowned Mathematician, Polish-born French-American mathematician Benoit Mandelbrot was the first to introduce the concept of fractals back in 1975 where he talked about characterising structures whose dimension were not defined by whole numbers in general. With valuable imagination that such unique geometrical features can be extracted from usual occurrences in nature, such as tree plants, snow structures, galaxy, sand formation in coastlines and along beaches and many more natural examples to take from. Using the concept of which many field of studies have been incorporated with fractals due to its geometric advantage which can be mimics and learned from the nature in various forms to develop new technologies and one such field is antenna theory. [7]

Even though fractals are known for its geometry which can be implemented in many technologies it also comes within the disadvantage that it has infinite complexity due to its structures and detailed geometry. Having said that it is due to its self-similarity property which plays a crucial role in achieving multi-band property application, which is a resultant of increased effective area of the antenna thereby it reduces the overall profile of the antenna hence, with the combination of both infinite complexity and self-similarity property of the fractal geometry various wide band antenna can be designed with optimal performance parameters.

We need fractal antenna for following qualities possess by them:

- They qualify broadband and multiband operation characteristics.
- Facilitates compact size compared to conventionally available antennas.
- Mechanical simplicity and robustness.
- Characteristics of the fractal antennas are due to its geometry and not because of the addition of discrete components.
- Design to suit particular multi-frequency characteristics containing specified stop bands as well as specific multiple pass bands as required.

4.2 <u>WHAT IS FRACTAL-</u>

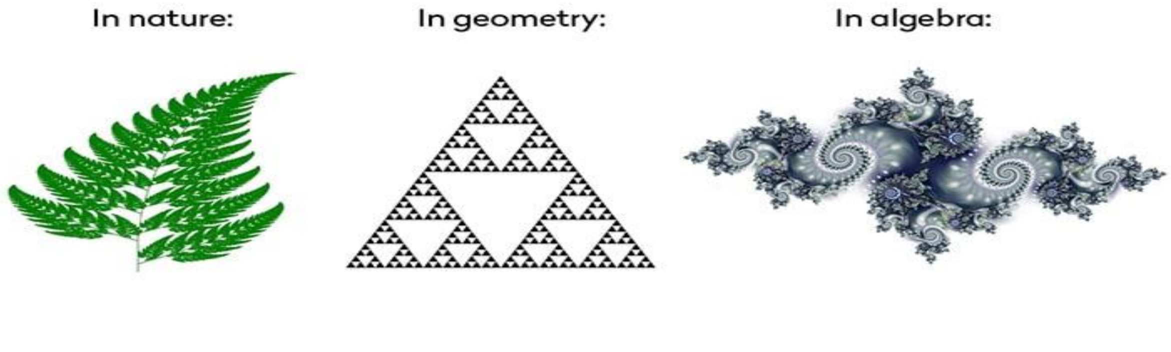


Figure 3- Fractal geometry

The word fractal is derived from a *LATIN* word which signifies the meaning of broken or irregular fragments, that quantifies the family of complex shapes that possess the quality of an inherent self-similarity or self- affinity property in their geometrical structure. Such geometry is widely seen in nature in the form of fern in plants and snowflake.

Figure 4- Fractals in nature, Fern and snowflake

CHAPTER 5

5.1 WHY ARE FRACTALS IMPORTANT?

Fractals help us study and understand important scientific concepts, such as the way bacteria grow, patterns in freezing water (snowflakes) and brain waves, for example. Their formulas have made possible many scientific breakthroughs. Wireless cell phone antennas use a fractal pattern to pick up the signals better, and pick up a wider range of signals, rather than a simple antenna. Anything with a rhythm or pattern has a chance of being very fractal-like.

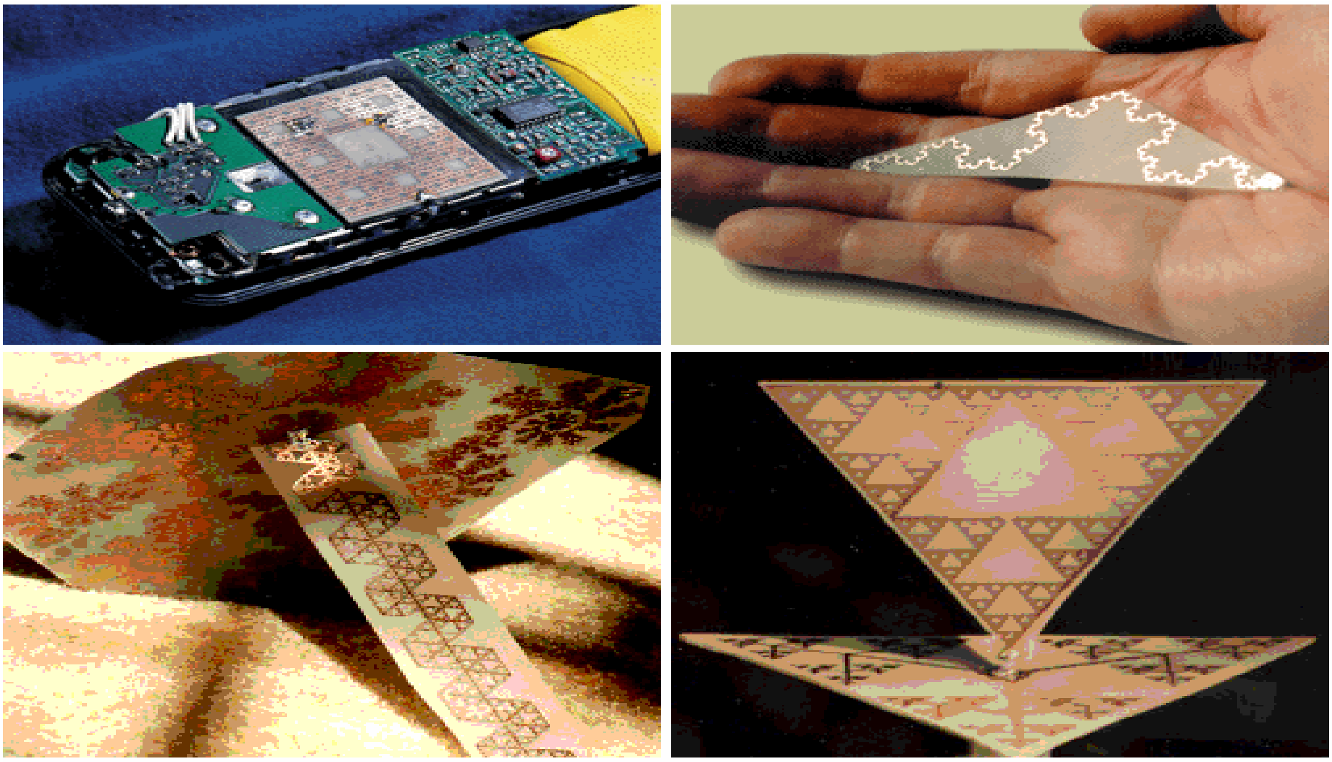


Figure 5- Fractal Antenna in modern communication devices

CHAPTER 6

FRACTAL GEOMETRIES

6.1 FRACTAL GEOMETRIES

After pioneering study on various naturally occurring irregular and fractured geometries not confined within the domains of standard Euclidian geometry, renowned Mathematician, Polish-born French-American mathematician Benoit Mandelbrot was the first to introduce the concept of fractals back in 1975 where he talked about characterising structures whose dimension were not defined by whole numbers in general. The term comes from the Latin word fractus, which is related to the verb fangere, which means "to eat" (meaning: to break). Previously, these profound geometries were dismissed as formless, but Mandelbrot discovered that they can give rise to certain unique properties. Many of these curves had been known for a long time and were frequently connected with mathematicians of the past. Mandelbrot's research, on the other hand, was ground-breaking: he uncovered a common ingredient in many of these seemingly irregular geometries and developed theories based on his discoveries. Snowflakes and the geographical of boundaries continents are two examples of naturally occurring fractal geometries. Like that, Fractals are abundant in nature, and some naturally occurring phenomena, such as lightning, can be better understood using fractals. The irregular nature of all of these fractals is an important feature. Some examples of fractals are given in Fig. (a). The majority of these geometries are infinitely subdivided, with each division being a duplicate of the parent. The unique character of these geometries has resulted in a number of intriguing phenomena rarely found in Euclidean geometry.

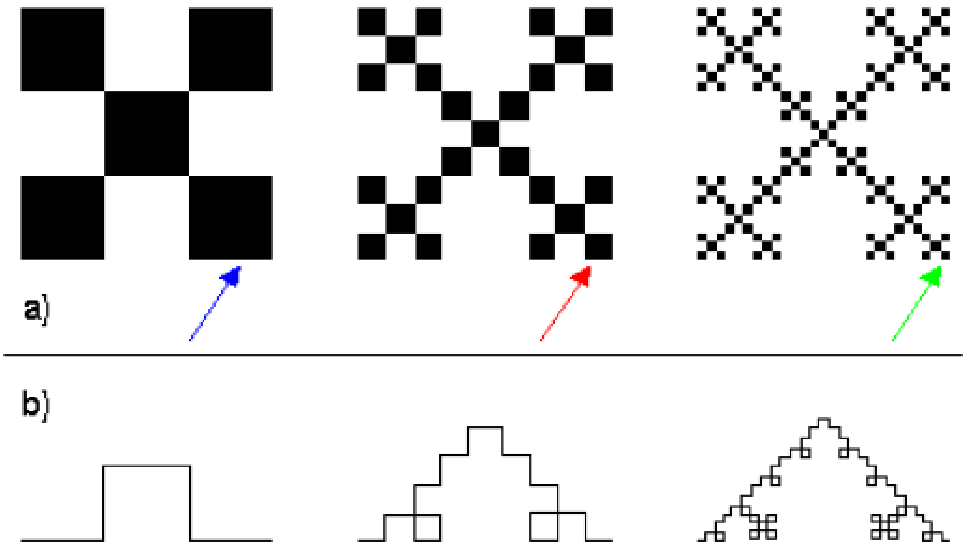


Figure 6- Formation of fractal geometry after iteration stages

Mandelbrot includes various definitions of the term fractal, each of which is based on the notion of their dimension. A fractal is a set whose Hausdorff-Besicovich dimension is strictly greater than its topological dimension. A fractal is any set with non-integer dimensions. Fractals, on the other hand, can have integer dimensions.

Fractal is defined as a set F such that:

- F has a fine structure with details on arbitrarily tiny scales,
- F is too irregular to be explained by classical geometry, and has a fine structure with details on arbitrarily small scales.
- F that is self-similar in some way (not necessarily geometric, can be statistical also)
- F can be represented in a recursive manner, and the Fractal dimension of F larger than the topological dimension of a geometry can be classified in a variety of approaches, the majority of which lead to the same number, but not always. Topological dimension, Euclidean dimension, self-similarity dimension, and Hausdorff dimension are some examples. Some of these are variants of Mandelbrot's fractal dimension definition. The self-similarity dimension, on the other hand, has the most straightforward definition. The geometry is divided into scaled-down to obtain this value, but identical clones of itself.

6.2 <u>HOW FRACTALGEOMETRY CAN BE FORMED-</u>

- Iterative mathematical procedure called Iterative function system (IFS), can be used to build the shape.
- It is based on a sequence of affine transformations.

$$W(x,y) =(ax+by+e, cx+dy+f) \tag{6.1}$$

❖a,b,c,d control rotation and scaling;
❖e,f control linear transformation;

- Fractal geometry is formed by repeatedly applying W to the prior geometry. A1 = W(A0); A2 = W(A1);...

6.3 SIERPINSKI GASKET GEOMETRY

The Sierpinski gasket geometry is known to be one of the most extensively used fractal geometry which finds application in variety of antenna applications. The process of constructing such a fractal geometry happens to be in steps or iterative process such that, a random yet simple geometry like triangle is taken in a plane surface, which is centralise with its vertices placed to other two triangle sides at the midpoints of each side and finally forms a shape like shown in figure 7, (Black triangular areas represent a metallic conductor and the white triangular areas represent the region from where metals are removed). the process is further repeated until the complexity permits. Here, one thing to be noticed is that the translation and rotating factor also plays a significant role in defining the final geometry of the fractal, as a variation in once factor results in a different geometry all together. This can be understood using the following relations-

The Sierpinski triangle is created by applying the following transformation to the equilateral triangular sub-set A:

$$V[A] = v_1[A] \cup v_2[A] \cup v_3[A] = \bigcup_{n=1}^{3} v_n(A) \tag{6.2}$$

- **where magnification factor (is taken greater than 1) and reduction factors are r and s respectively. x0 and y0 are translations parameters, while φ and ψ are rotation angles parameters.**

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} r\cos\phi & -s\sin\psi \\ r\sin\phi & s\cos\psi \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} \tag{6.3}$$

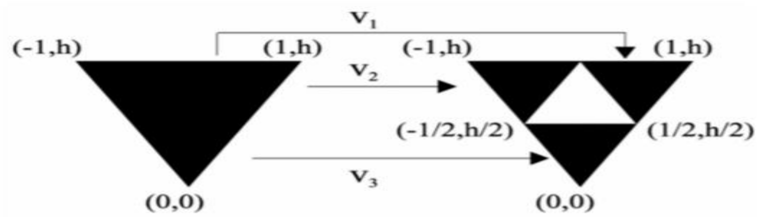


Figure 7: The first stage of the traditional Sierpinski gasket is generated using an iteration function.

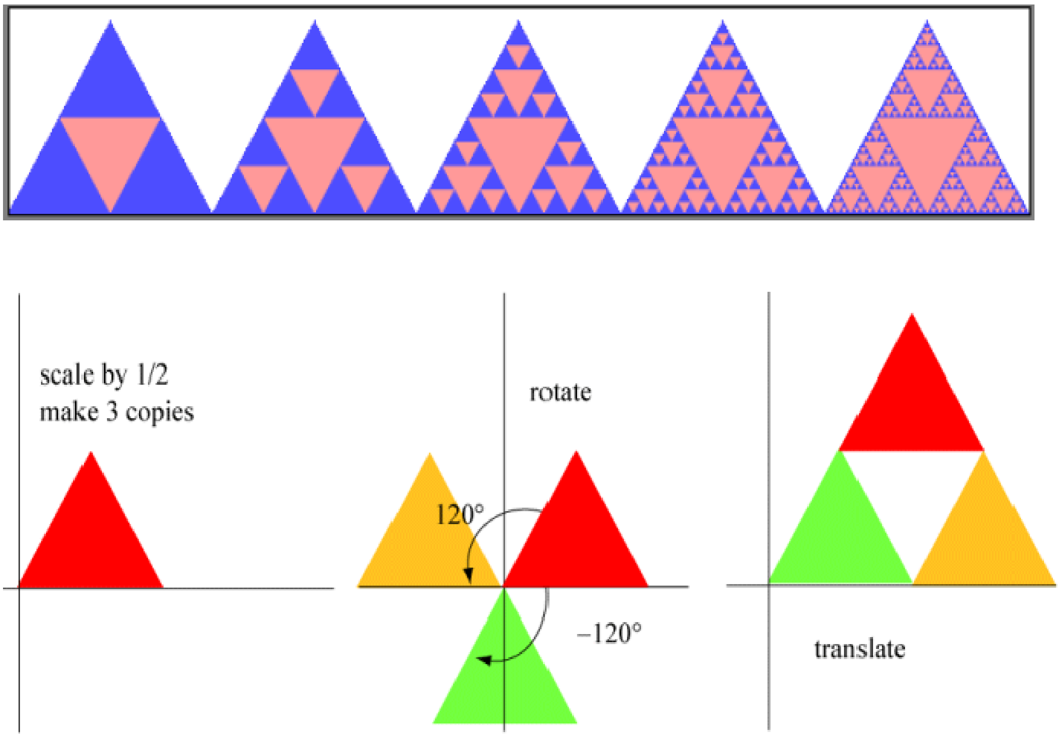


Figure 8- Steps of construction of sierpinski gasket geometry

6.4 SIERPINSKI CARPET GEOMETRY

The process of rebuilding Sierpinski carpet geometry is almost similar to Sierpinski gasket geometry, only difference being instead of using a triangular shape, it uses square shape as the initiator and further process consecutively uses the square generator, where the open central square being omitted. The remaining eight squares are subdivided into nine smaller squares that are all congruent.

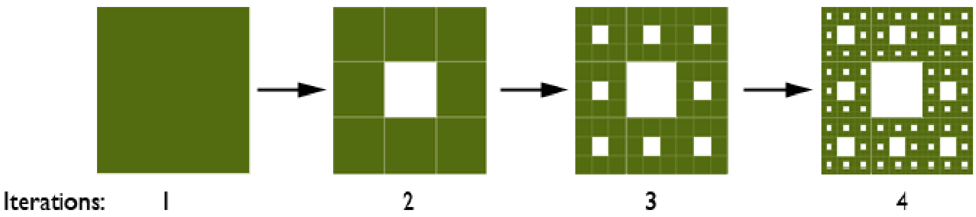


Figure 9: The sierpinski carpet geometry step-wise construction

6.5 KOCH CURVES

Koch Curve is another important yet most basic form of fractal geometry consideration which comprises of a straight line that acts as an in initiator. The process of iteration in Koch fractal is such that the line is divided into three equal with the centre segment being replaced with two additional segments of equal length, red portion as shown in the figure below. Doing so, the first initial version of the resultant geometry after iteration is known as generator. The process is further repeated to higher stages where the initial geometry repeatedly reused again.

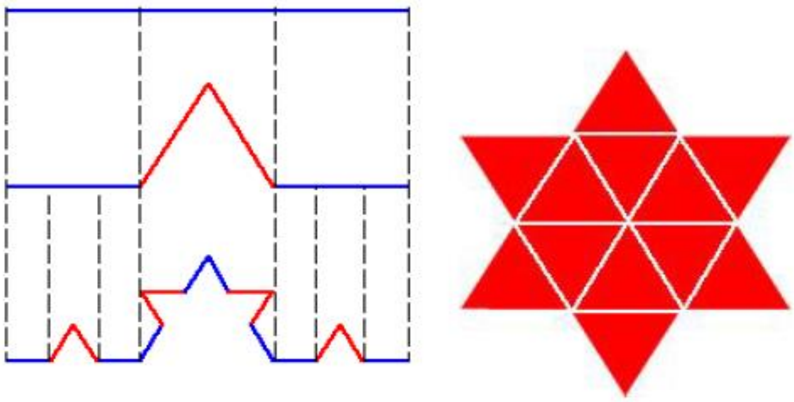


Figure 10- Formation of fractal geometry after iteration stages

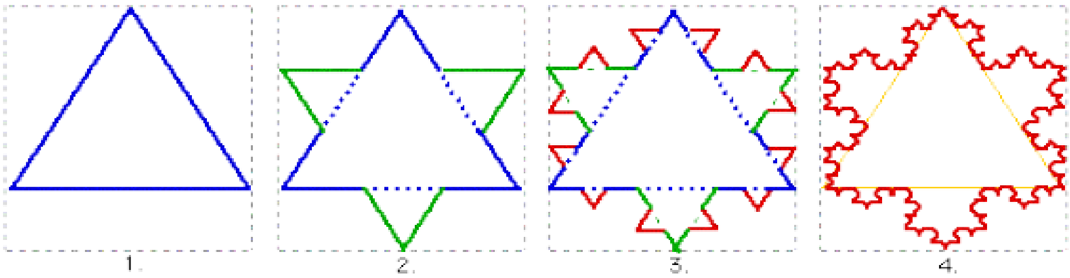


Figure 11- Steps for construction of the Koch curve geometry

6.6 FRACTAL DIMENSIONS

- The self-similarity feature of the fractal geometry is defined as

Ds = log(n)/ log(1/s)

where s is the scaling factor and N is the number of self-similar structure replicas.

The most popular dimension and component in fractal design is-

A) The Initiator (0th stage) which is also the basic structure of the fractal geometry.

B) The Generator which is the structure which is repeated in a sequential pattern on the initiator in the consequent stages with the different dimensions.

- The fundamental and basic equation for calculation of any dimension is n =1/s^D
- The dimension has an integer value. Then, few numerical analysis and calculations have to be performed withfew dissimilar values of n and s , where D is a partial or fractional dimension.
- Now by taking logarithm of above equation, we'll have
- Log n = Log (1/s^D)

$$D = \frac{\text{Log } n}{\text{Log } (\frac{1}{s})} \tag{6.4}$$

For Sierpinski,D =log4/log2

For Koch, D=log4/log3

6.7 WHY USE THE ANTENNA OF FRACTAL GEOMETRY?

Antennas are usually narrow-band devices, and their launching are heavily influenced by the size of the antenna in relation to the wavelength being measured. This implies that when the operating frequency varies, the characteristics of some fixed antenna sizes, such as power gain, input impedance, radiation patterns, side lobe level, and distribution or alignment of surface currents, will be challenged. To function successfully and efficiently, frequency dependence also means that the antenna should maintain a minimal size in proportion to the wavelength of the relevant operation. This means that, for a given frequency, the antenna cannot be made too small; it must be at least a quarter wavelength in size.

These are some well-established antenna engineering standards that have been routinely followed in the construction of antennas for various telecommunications systems for many years. However, in many systems where previously used antennas are not particularly helpful, the dependence of the wavelength on antenna size continues to be a challenge. In this way, using fractal geometry to build antennas and antenna arrays can help with challenges like creating antennas that satisfy the demands of modernization of communication systems that have yet to be realised. The fact that fractal antenna design appears to be an appealing approach to build it is supervening (Figure 12).

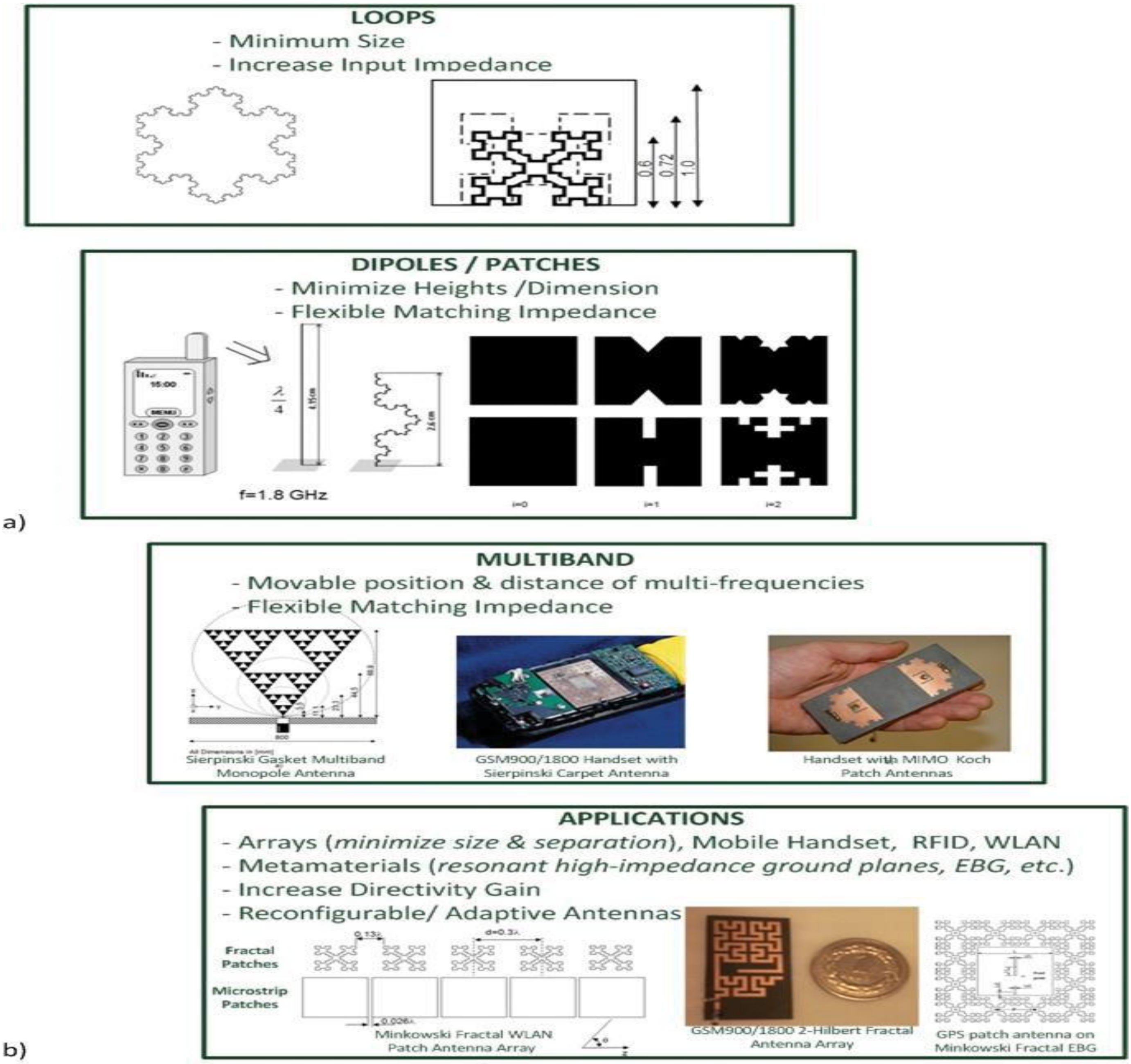


Figure 12- Fractal antennas (a) and the numerous fractal geometries, fit into few basic types: loops, dipoles, multiband fractal patches, antenna arrays, (b)metamaterials.

Firstly, each antenna is supposed to be comparable to the others, since they are built with many replicas of the same but in varied scales, ranges, and sizes to function in a similar manner throughout a few wavelengths. This means that for a few wavelengths, the antenna's radiation characteristics should remain constant.

Secondly, the features of some fractals' self-filling to an area (fractal size) may allow small objects in fractal shapes to make greater use of the limited surrounding space. Fractal antenna and antenna array designs are often a combination of two seemingly unrelated sciences, notably electromagnetic theory and geometry. From the first spiral and log-periodic antennas developed in the early 1960s by D.E. Isbell, R. DuHamelet, and variants by P. Mayes and from the works of Benoit Mandelbrot fractal geometry, The fractal antenna seems to be a natural way to resolve the issue of antennas that work on multiple frequencies and antennas of reduced size.

CHAPTER 7

ADVANTAGE AND DISADVANTAGE OF FRACTAL ANTENNA

7.1 ADVANTAGE OF FRACTAL ANTENNA TECHNOLOGIES ARE -

- Miniturization property (Fractal Antenna is small in size)
- Better input impedance matching capability.
- Wideband or multiband characteristics (uses only one antenna instead of many)
- It is now possible to attain frequency independence. (Performance that is consistent throughout a wide frequency range)
- In fractal array antennas, the mutual coupling time is reduced.

7.2 DISADVANTAGE OF FRACTAL ANTENNA TECHNOLOGY ARE -

- Gain loss incorporates
- Complexity in design and fabrication
- The benefits have numerical restrictions
- The benefits gradually fade after first iteration or few iterations.

CHAPTER 8

MICROSTRIP ANTENNA DESCRIPTION

8.1 MICROSTRIP ANTENNA DESCRIPTION

The microstrip patch antenna could be a comparatively recent invention that was initial fictional in 1955 however took over twenty years to achieve wider implementation. A dielectric substrate is sandwiched with a skinny diverging conductor component on one facet and a ground-plane conductor on the opposite side (Fig. 13), wherever the radiating element is rectangular conductor joined on to a microstrip feed line, is employed to form a microstrip

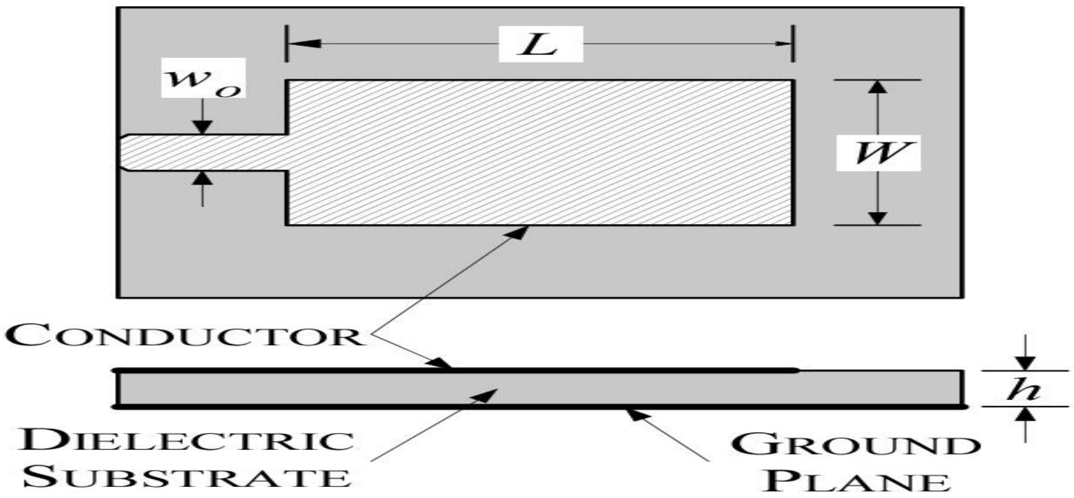


Figure 13 - ***Microstrip antenna construction*****.**

The attributes of microstrip antennas are given below in *Table* 1.

Table 1- Attributes of microstrip antenna

MICROSTRIP ANTENNA ATTRIBUTES	
POSITIVE ATTRIBUTE	**NEGATIVE ATTRIBUTE**
Low cost fabrication – printed circuit manufacturing methods	Narrow bandwidth – bandwidth increase generally requires increasing volume
Surface conformable – facilitated by flexible substrate materials	Sensitive to temperature and humidity – low-loss substrates utilize PTFE in composite
Mechanically stable – dielectric substrates may use composite ceramic filled construction	Limitation on maximum gain
Polarization diversity – readily achieved using alternate feed methods	Poor cross-polarization – limited element and feed isolation
Flexible gain and pattern options – readily achieved using alternate feed methods and array techniques	Spurious radiation – surface and other propagation modes
Ease of integration with other passive and active functions – achieved via compatibility with passive and active components	Low efficiency due to dielectric and conductor losses
Low profile – low profile planar construction	Modest power handling

The radiation intensity of an appropriately built microstrip antenna is normal to the radiating element (i.e., broadside). The length, L, of a rectangular microstrip antenna is usually taken as 1/3rd to 1/2 of operating wavelength, which is further based on the substrate relative dielectric constant, (typically 2 to 10), however lower dielectric constants result in better efficiency.

In terms of efficiency and bandwidth, the substrate height, h, is another important component. It's also crucial for minimising unwanted propagation modes at conductor edges and within the substrate.

The input of RF energy to the radiating microstrip via the feed-line structure can be accomplished using a variety of ways. Changes in the feed-line topology can affect the efficiency, gain, and bandwidth of the microstrip antenna in some circumstances. Connecting the radiating edge directly is the most usual kind of feeding technique for a rectangular microstrip antenna, as displayed in Fig. 13.

The most common antenna geometry is rectangular microstrip. Alternate shapes (such as circular and triangular) are useful in some cases. For improving operating bandwidth, thin strips for implementing half-wavelength dipoles are desirable.

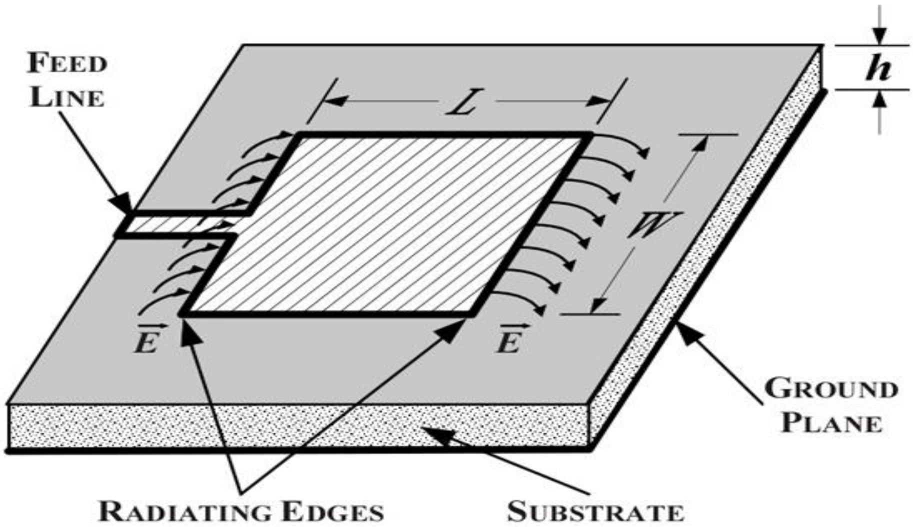


Figure 14 – Microstrip antenna

The length L determines the frequency of operation of the patch antenna in Figure 14. The central frequency will be generally determined by:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \quad (7.1)$$

According to the equation above, the microstrip antenna should have a length equal to one half of a wavelength Within the dielectric (substrate) medium.

For the optimum operation and performance of an antenna, the feeding of the antenna is a crucial stage as it is directly related to input impedance matching. These antennas' input impedance is defined by their geometric shape, dimensions, substrate material properties, feeding type, and feeding location. The antenna's size can be minimized to a large extent using a high permittivity substrate, however these approaches limit the antenna's radiation efficiency and impedance bandwidth. A microstrip antenna's average bandwidth ranges from 1% to 3%. Many optimization approaches have been proposed to address these constraints. The dimensional geometry of the radiating patch can be taken as rectangular, circular, square, elliptical, triangular, dipole, or ring in form. The shape of the patch is essential for analysing the antenna's performance and other characteristics.

8.2 FEEDING TECHNIQUES

Feeding methods are divided into two groups as contacting and non-contacting. Coaxial probe, microstrip line, aperture coupled, and proximity coupled are the four different types of feeding methods.

8.2.1 COAXIAL PROBE FEED

The inner conductor of a coaxial cable is linked to the antenna's microstrip patch, while the outer conductor is connected to the ground plane in this feeding technique. In most cases, the feed networks are segregated from the microstrip patch, but not in this technique. The advantages of the coaxial feeding technique are minimal spurious radiation, ease of manufacturing, and efficient feeding. The coaxial probe feed is shown in the Figure.

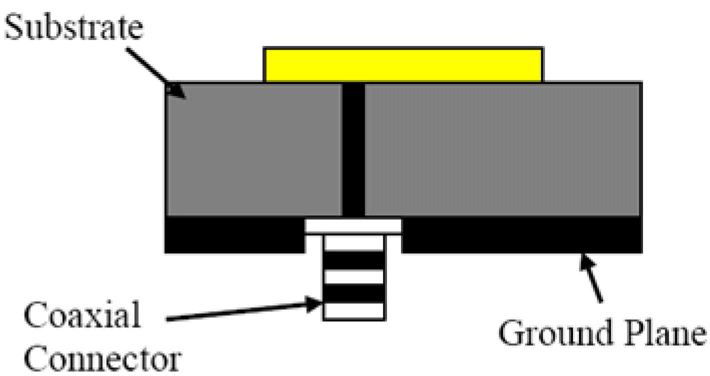


Figure 15.: Coaxial Probe Feed

8.2.2 MICROSTRIP LINE FEED

The microstrip patch is linked directly to the conducting microstrip feed line in this feeding technique. The feed line differs from the microstrip patch in terms of dimensions. Fabrication and matching is easy. The microstrip line feed is as shown in Figure.

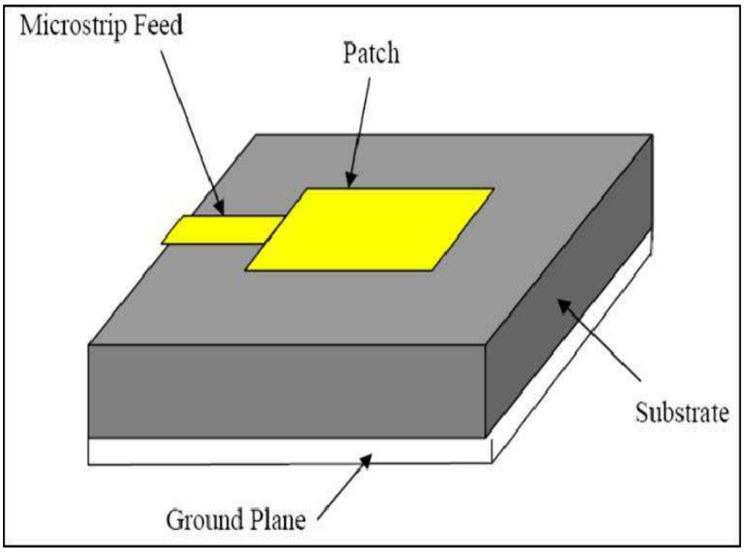


Figure 16.: Microstrip Line Feed

8.2.3 APERTURE COUPLED FEED

This feed consists of two substrates that are distinct from one another and separated by a ground plane. The microstrip patch and feed line are connected via a slot in the ground plane in this approach. The aperture coupled feeding approach has the advantages of less interference and pure polarisation. The aperture coupled feed is as shown in Figure-17.

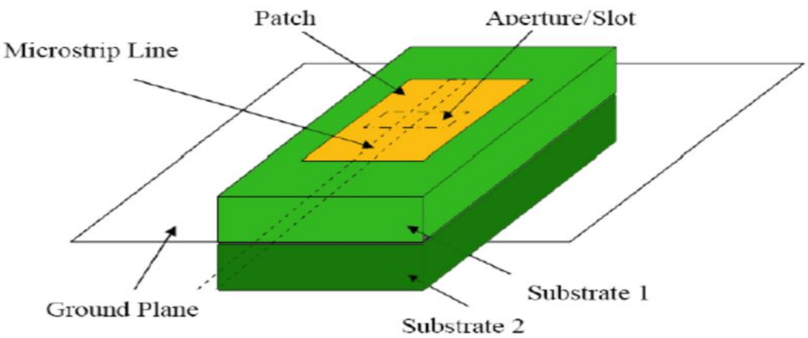


Figure 17.: Aperture Coupled Feed

8.2.4 PROXIMITY COUPLED FEED

In comparison, the manufacturing of this feeding system is a little more difficult. This method employs two dielectric substrates. The feed line is between two substrates, and the microstrip patch is on the top surface of the upper dielectric substrate. It has the widest bandwidth and avoids spurious radiation. The way for proximity coupled feed is as shown below-

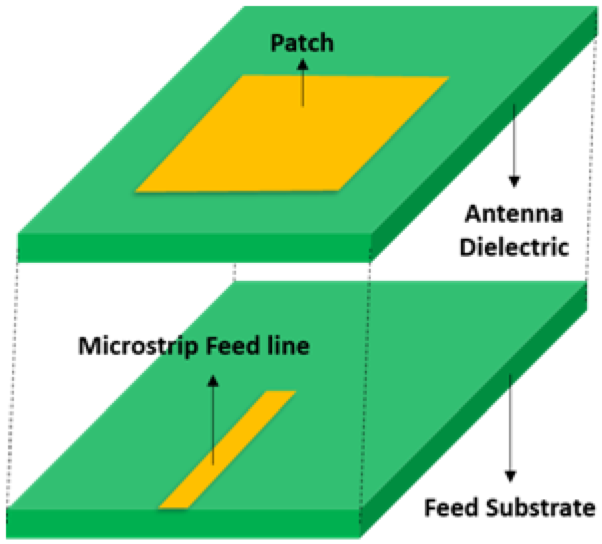


Figure 18.: Proximity Coupled Feed

CHAPTER 9

9.1 ANTENNA WORKING AS IMPLEMENTED IN THE PROJECT -

9.1.1 FRACTAL ANTENNA FOR WPT SYSTEM

A wireless power transfer system (WPT) works in such a way that it facilitates the transfer of power from one end to another through a medium without the use of wires. It first transforms the electrical power into microwave energy, then transfer it through one end into the free space and is received by the receiver end which then converts the EM energy collected into a DC signal using a rectenna. A rectenna is nothing but a system that consists of a Schottky diode followed by pre-rectification and post-rectification filtering circuits. As the wireless market has grown with more compact and portable/wearable devices, here fractal antenna can play a huge role by reducing the size of such conventional antenna without hampering its parameters, for-instance VSWR, return loss, directivity, radiation pattern, and gain.

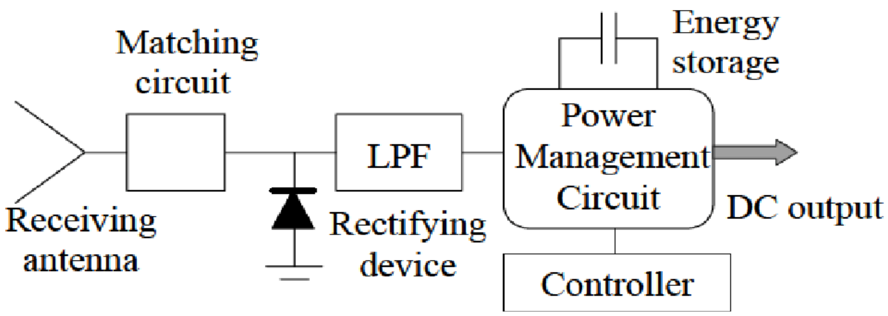


Figure 19- Circuit diagram of WPT

9.1.2 FRACTAL ANTENNA FOR HEALTH MONITORING SYSTEM

Here, The implemented fractal antenna is incorporated to be used in a health monitoring system, where a non-invasive glucose level monitoring biosensor is complemented to tackle the everyday hurdle of diabetic patients. It works in such a way that a wearable consists of a biosensor that radiates EM wave into the human body part that the wearable is in contact with and using the understanding of, EM wave travels differently in different di-electric medium, a similar concept is applied where a diabetic person has more glucose saturation in its blood than a normal person, thereby it changes the dielectric constant of the medium having high glucose level in blood. Hence, studying the return loss parameter, S21 gives a definite signature for a type of medium. Therefore, the reflected EM wave is studied using various post-processing algorithms to differentiate their signatures for diabetic patients and a normal human being. This is where the fractal antenna can play a major role in the transmitting and receiving section, minimizing the antenna size, as it facilitates more compactness of the whole wearable device for more portable and convenient use.

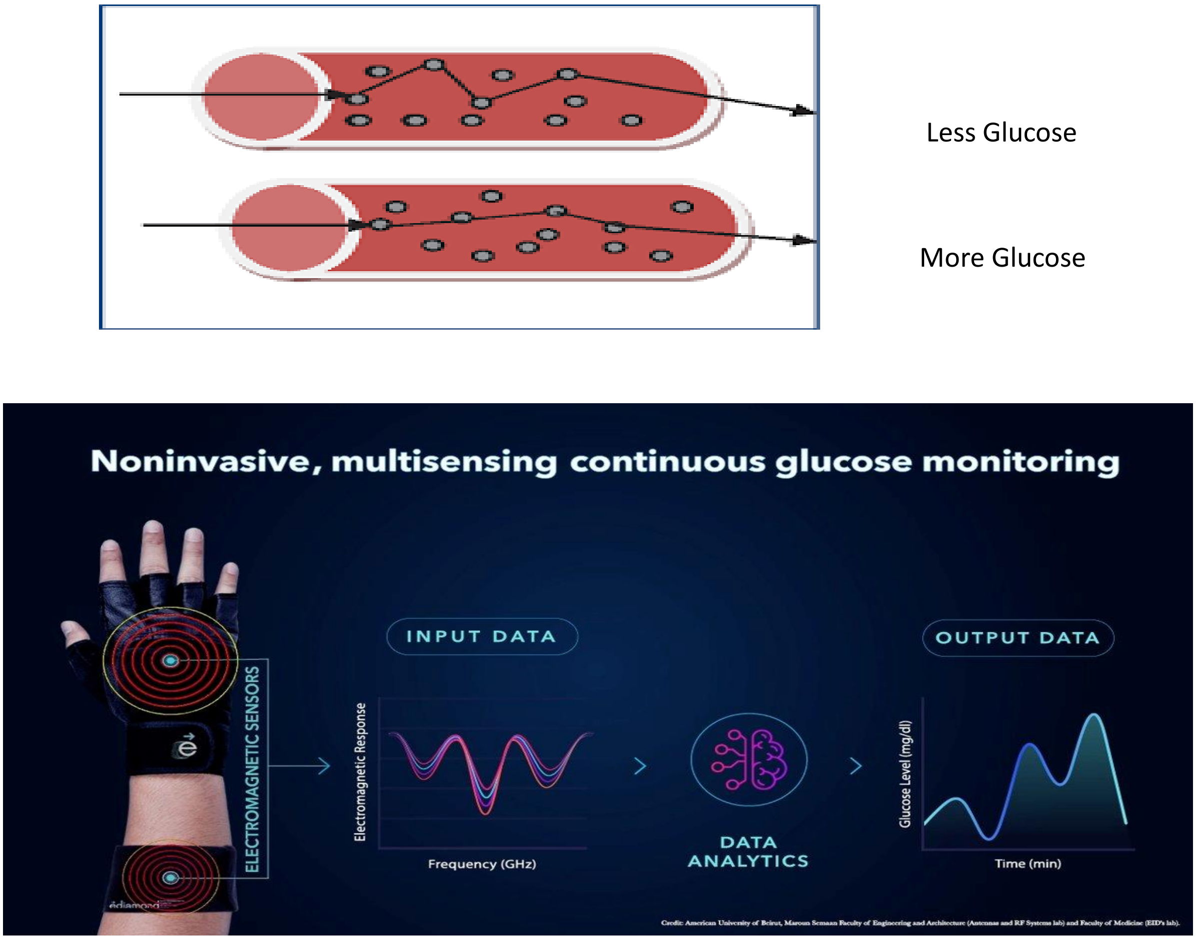


Figure 20- EM wave through blood containing different concentration of glucose level

9.1.3 FRACTAL ANTENNA FOR MODERN DAY COMMUNICATION SYSTEMS

Practical example are-

Wireless charging dock for smartphones or wearables.

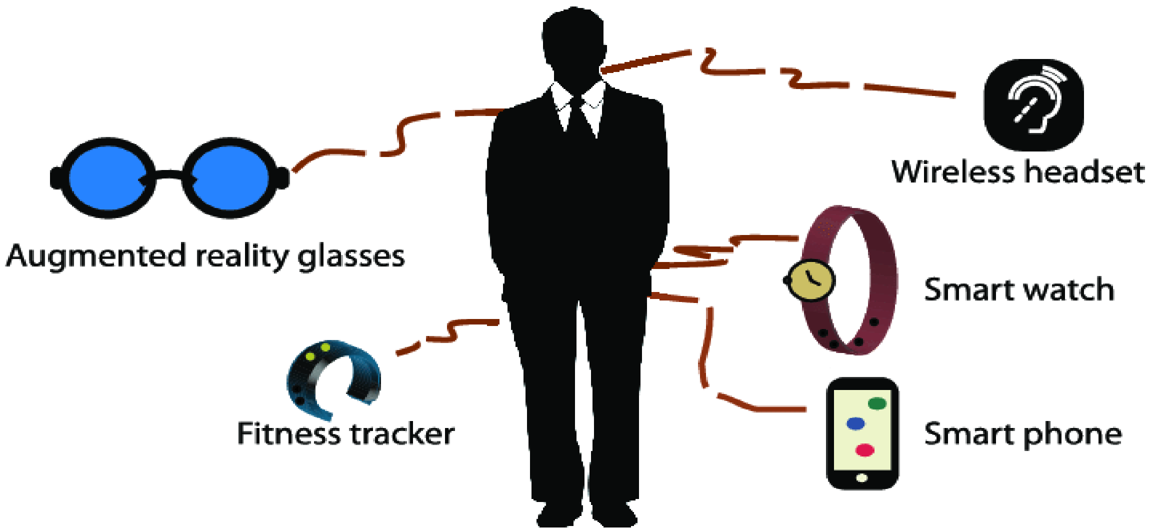


Figure 21- Practical use of fractal antenna in various devices

Figure 22- Fractal antenna application in WPT

9.1.4 BANDS OF SPECTRUM IN WIRELESS COMMUNICATION AND THEIR USES-

VLF (Very low frequency) which falls in the range of 3Hz to 30 kHz which has application in the maritime communication preferably for submarines. [11]

LF (low frequency) band starts from 30 kHz to 300MHz is another vital band of frequency which uses the Earth's atmospheric level of ionosphere for its long distance communication and military application purposes like submarines or RFID tags used in vehicles or access cards, therefore has applications in near field communication and low frequency radio broadcasting.

MF (Medium frequency) Band which starts from 300 KHz to 3MHz usually has applications in AM communication, Aircraft and coast Guards in military services

HF (high frequency) band of frequency ranges from 3 MHZ to 30 MHz and is known as short wave propagation due to which it is reflected back by the ionosphere level of Earth's atmosphere and is usually have applications in long distance communication like in aviation industries and in short distance mobile communication techniques such as NFC (near field communication) and for weather broadcasting stations.

One of the most important band of frequency is VHF (Very high frequency) band which operates in the range of 30 MHz to 300 MHz and usually has applications in analog TV broadcasting, Air Traffic control for establishing communication with aircraft and in crucial medical equipment like for MRI (magnetic resonance imaging) and widely used in military applications.

The modern day communication technologies such as GPS Navigation, Wi-Fi , WiMAX, Bluetooth connectivity and latest generation of mobile communication such as GSM, LTE and CDMA all are being made possible with the introduction of UHF (ultra high frequency) which place the most important band of frequency for modern day wireless communication systems that starts from the frequency range of 300 MHz to 3 GHz

SHF (super high frequency) that ranges from 3 GHz to 30 GHz has applications in line of sight communication where transmitter and receiver are established for point to point communication technique, also has applications in satellite Communications and modern day Digital TV broadcasting which is usually known as DTH services (Direct to home), modern day Wi-Fi Technologies which works on 5 GHz channel and everyday household applications such as in microwave oven.

EHF (extremely high frequency) band is the highest band of frequencies which ranges from 30 GHz to 300 GHz and is believed to make future communication requirement possible of large band with high data rate such as 5G communication and future systems and also has earlier applications in radio astronomy and weather analysis.

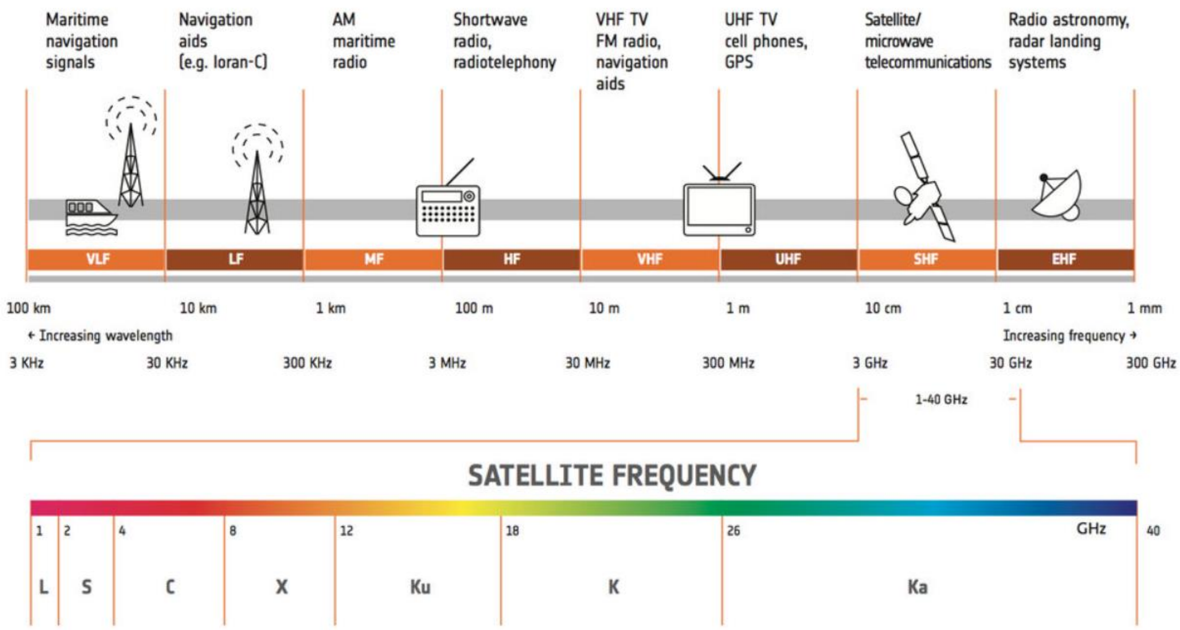


Figure 23: Band of frequency and their applications

The frequency range under SHF (super high frequency) which starts from 3-30 Ghz range has a sub-division called satellite frequencies, such L-band which starts from 1-2 GHz and has applications in GPS technology satellite, S-band which starts from 2 GHz to 4 GHz which is usually used by NASA for International Space Station communication and space crafts, C-band communication starts from 4-8 GHz for satellite communication, direct to Home DTH services, X-Band which starts from 8 GHz to 12 GHz and has been primarily used by military services, weather analysis and applications for air traffic control. Also, by police law enforcement for vehicle speed detection.

Ku-Band which starts from 12 to 18 GHz is mostly used for satellite communication and Ka-Band which starts from 26 to 40 GHz, is another satellite communication technique for higher uplink and downlink frequencies for higher resolution services.

In this Project an antenna is designed so that it can have applications in S-Band, C-Band, WiMAX, Satellite communication and ISM (Industrial, scientific and medical) bands which includes **900 MHz, 2.4 GHz, 5.2 GHz, and 5.8 GHz**. Here, ISM band plays a significant role as we are designing an antenna to be used in healthcare monitoring system, namely Non-invasive glucose level monitoring system and for wireless power transfer system.

CHAPTER 10

10.1 ANTENNA DESIGN AND SIMULATION:

A fundamental rectangular microstrip patch antenna is simulated carrying out the standard procedures of the HFSS manual. [4] For the simulation purpose the parameters that are taken into consideration are-

Table 2: Considerate design parameters of antenna

S.No	PARAMETER	DIMENSIONS
1	dielectric constant of εr	4.4
2	Substrate thickness of h	1.52mm
3	Resonant frequency of fr	2.5GHz

The 0th iterated, HFSS simulated rectangular patch antenna design is showed in the following Figure 24.

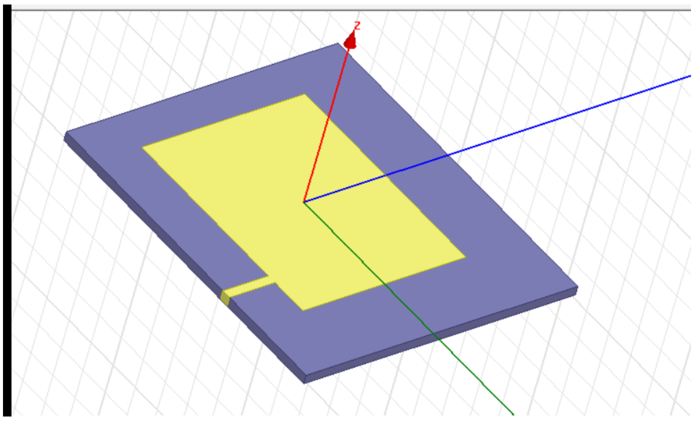


Figure 24:0th iteration of proposed antenna

The dimensional parameters and characteristic parameters that are taken into consideration for the proposed antenna rectangular microstrip patch antenna are shown below table 3.

Table 3: Design parameters of antenna

S.NO	PARAMETER	DIMENSIONS
1	Length of the ground & substrate	54.36mm
2	Width of the ground & substrate	46.72mm
3	Length of the patch	37mm
4	Width of the patch 2	28mm
5	Length of feed	8 mm
6	Width of the feed	1.52 mm

Here, the desired fractal geometry based microstrip patch antenna is produced by caring out few processes called iterative stages, which is initialised first by making a cut of regular rectangular geometry on a given basic rectangular patch. Thereby, the physical parameters of the antenna are so taken and further optimized that it can has application in our desired resonant frequency of 2.3 GHz for each iteration stages.

Therefore, after designing the desired antenna using the simulation software Ansys HFSS, The following antenna parameters are analysed for verifying the performance of the antenna without affecting its previous standards-

- Return Loss (RL) ,
- Voltage Standing Wave Ratio(VSWR),
- Gain ,
- Directivity etc.

10.1.1 <u>THE RETURN LOSS</u>

The return loss property of antenna is defined as

$$RL = -20 \log |r| \qquad (10.1)$$

Figure 25 shows the 1st iteration of fractal antenna and the return loss plot has shown in figure 26. This proposed antenna resonant at four different frequencies as following—
2.31/2.96/4.45GHz corresponding to their respective return loss as -20/-10.2/-10.4/-16 dB.

A return loss is found to resulting best for an antenna performance if it's more and their giving better transmission of energy.

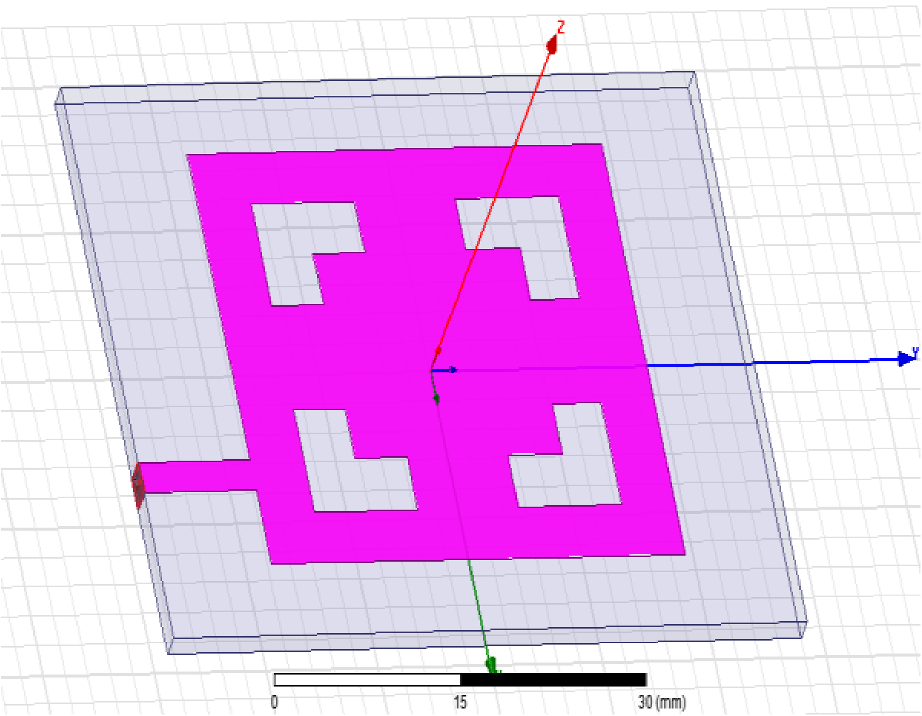


Figure 25: 1st iteration of proposed antenna

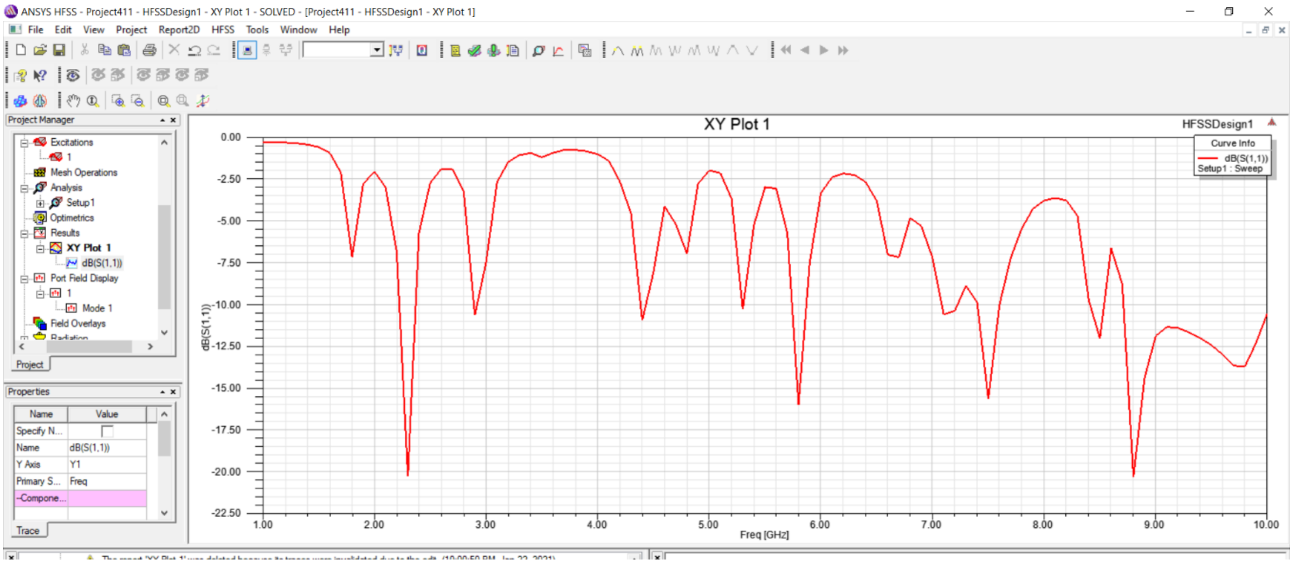


Figure 26- Return loss of 1st iteration proposed fractal achieved at 2.25/2.98/4.49/5.9 GHz

The second iteration of fractal antenna shown in figure 27 and the respective return loss plot is shown by figure 28. From figure return loss of 2nd iteration of proposed antenna is found to be about -12.5/-12.9/-10.2dB with respect to the respective resonance frequencies of 2.28/3.01/5.02GHz.

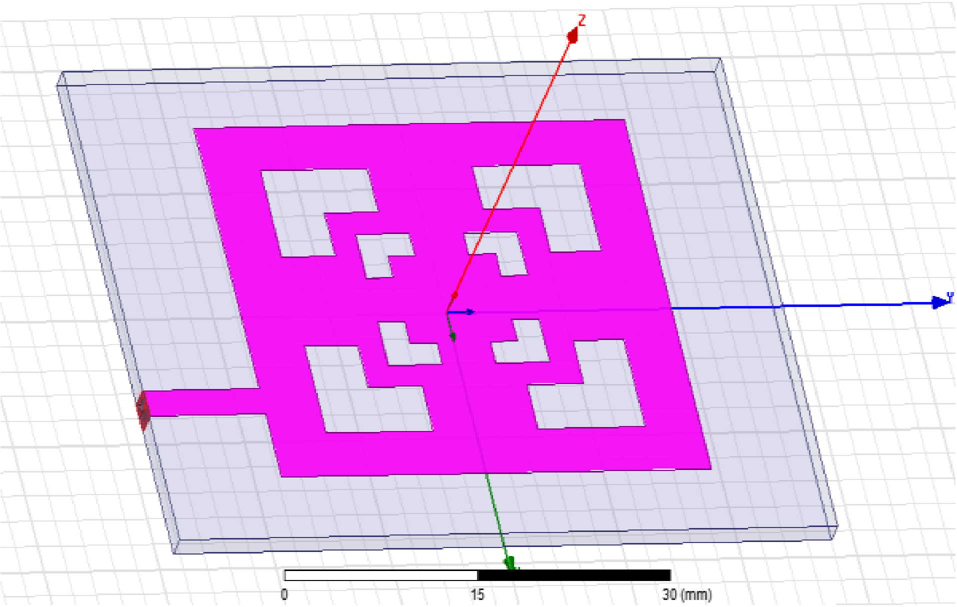


Figure 27: 2nd iteration of proposed antenna

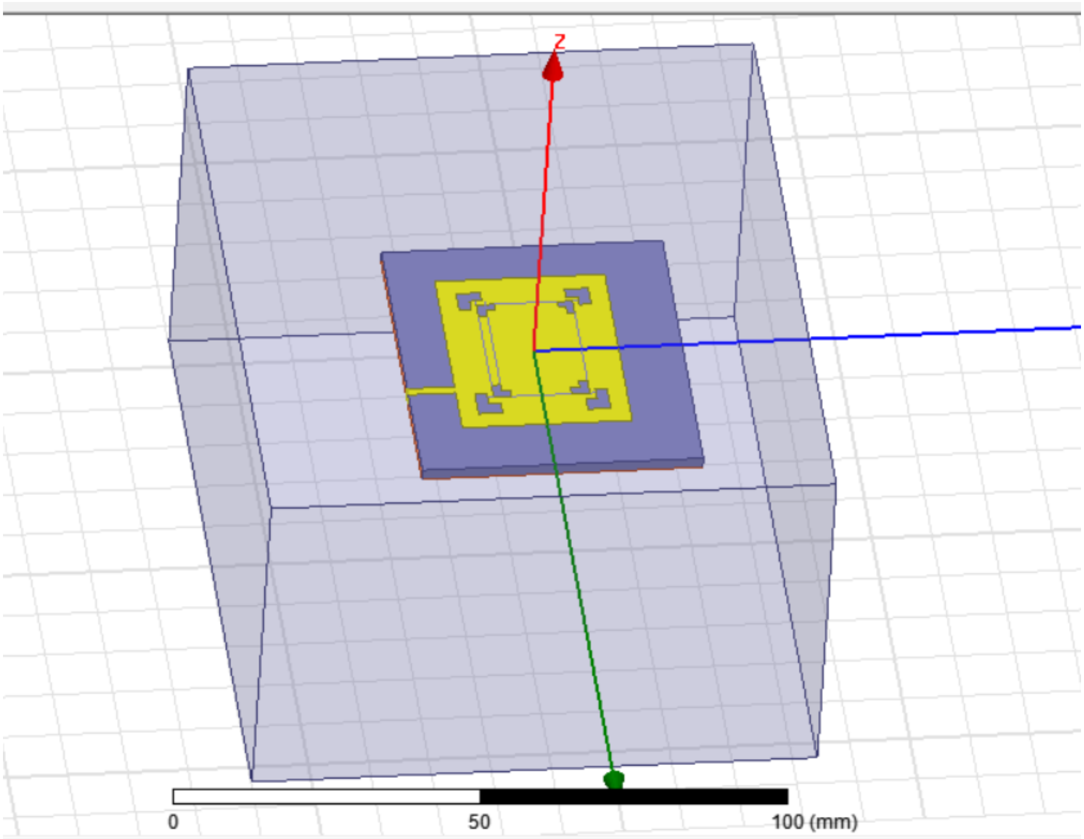


Figure 27: 2nd iteration of proposed antenna

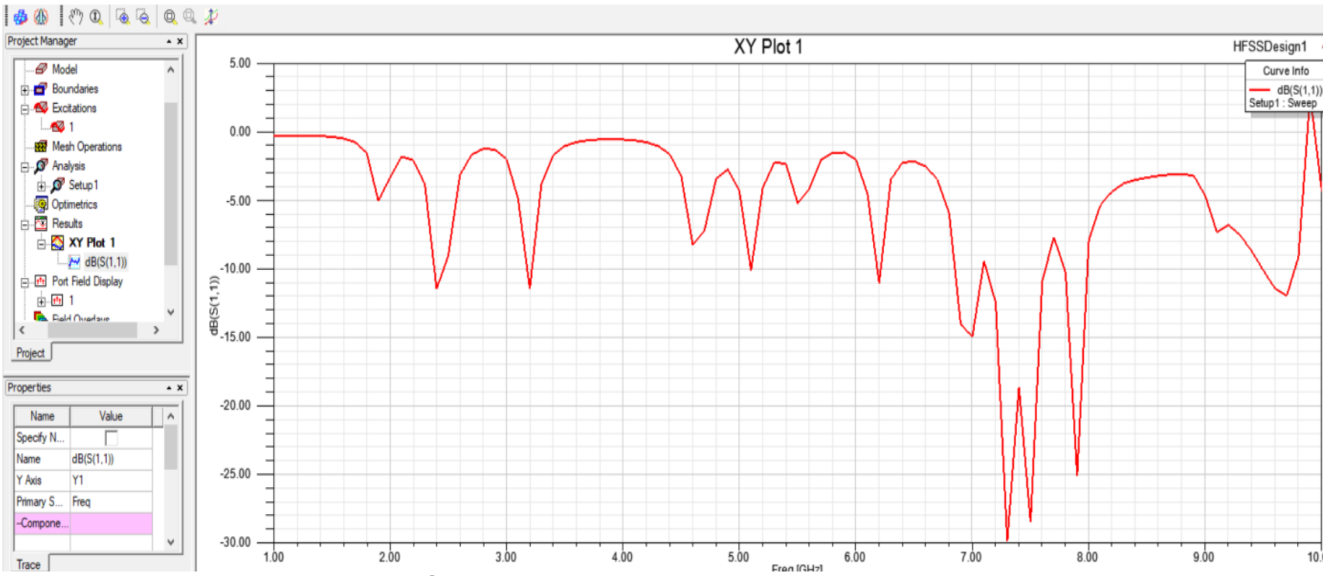


Figure 28- Return loss of 2nd iteration proposed fractal achieved at 2.25/3.2/5.1/7 GHz

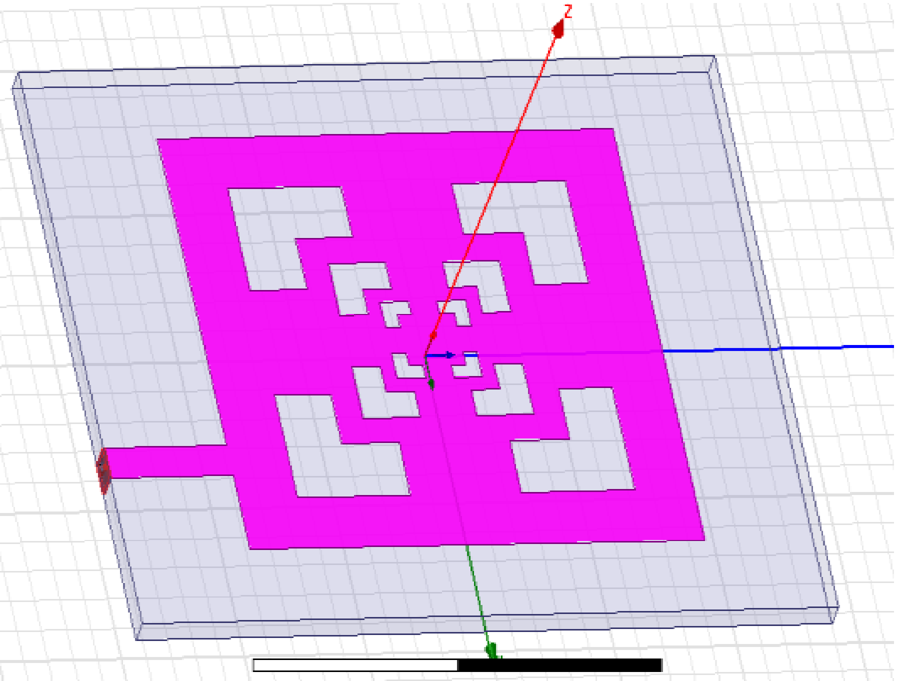


Figure 29: 3rd iteration of proposed antenna

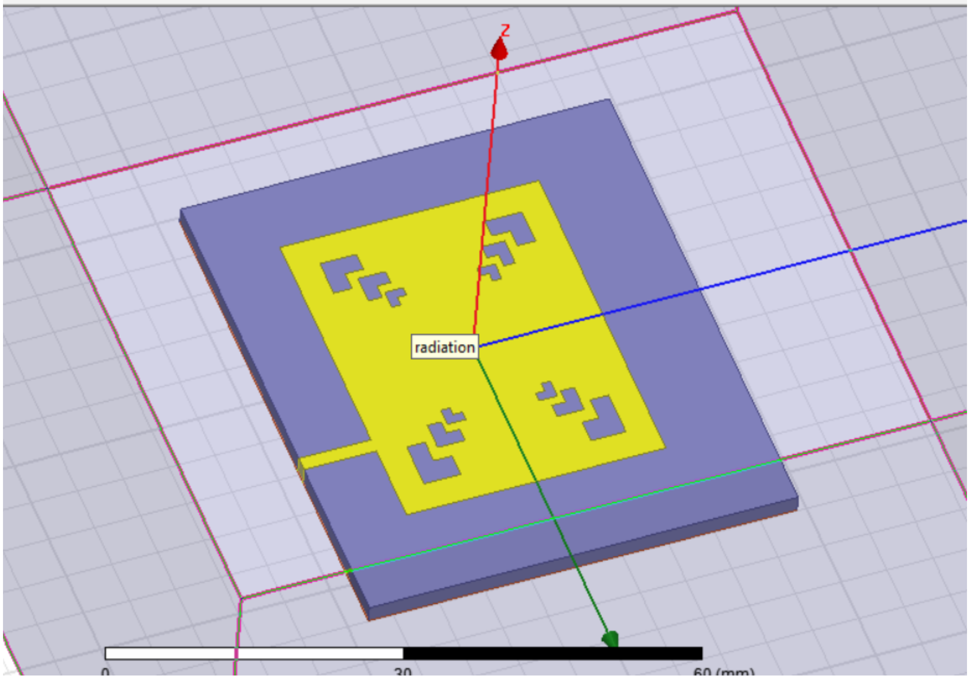


Figure 30: 3rd iteration of proposed antenna

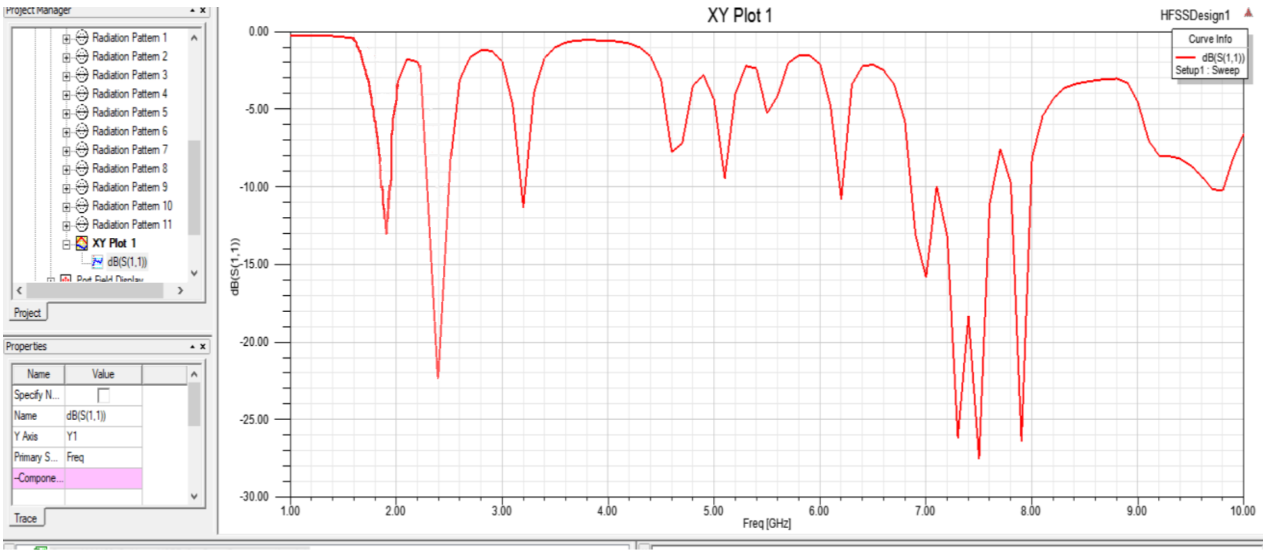


Figure 31- Return loss of 3rd iteration proposed fractal achieved at 1.9/2.4/3.2/4.6 GHz for -13.20/22.5/11.8 dB respectively.

The 3rd iterated fractal antenna presented is shown in Figure 23 and figure 24. The further iteration of presented fractal antenna is finalized till here due to constrain in its dimensions. As beyond a specific level of iteration for a specific geometry, the complexity in the manufacturing and fabricating of the antenna increases. The concluding design of the fractal antenna obtained is resonant at frequencies of 1.9/ 2.4/3.2/4.6 GHz with the corresponding return loss -13.20/-22.5/-11.8 dB, respectively.

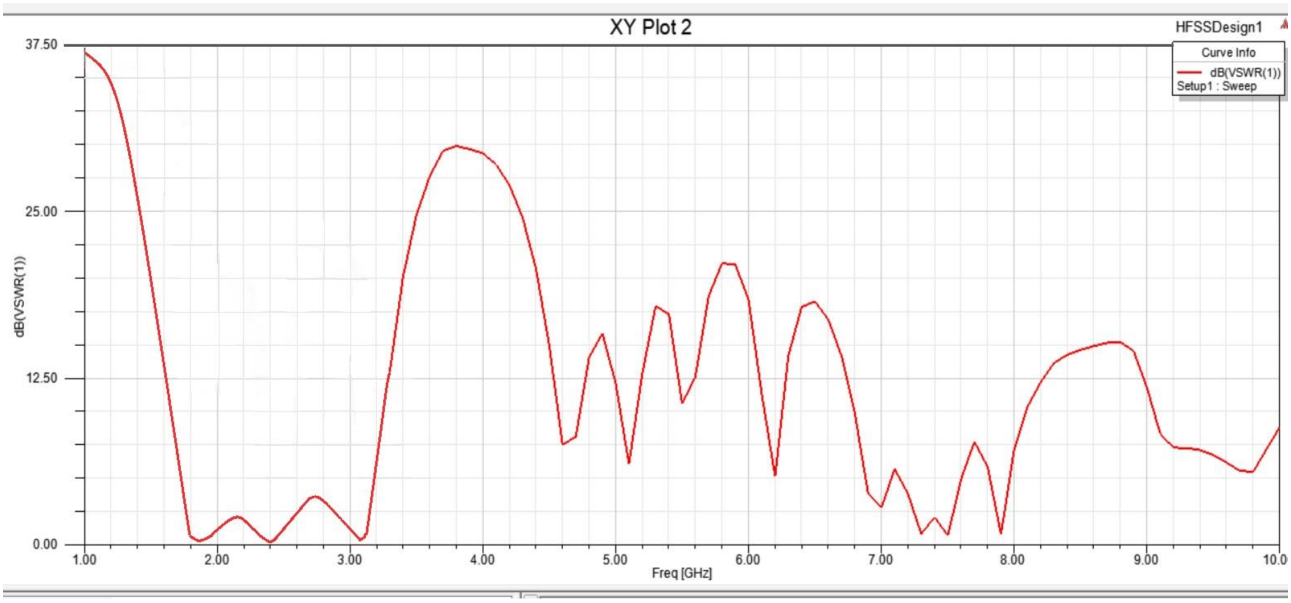


Figure 32- VSWR of 3rd iteration proposed fractal

Figure 8 shows the VSWR of final fractal antenna .

$$VSWR = 1 + \text{г} / 1 - \text{г} \quad (10.2)$$

The antenna property **VSWR** is one of the pivotal parameters that signifies the impedance matching of antenna correctly, with which the performance of the presented antenna is verified in the operated four different frequencies (1.9 to 8 GHz) with corresponding satisfactory result of VSWR in the range of 0 to 2.

In general, a VSWR of below 2 is desired for **best performance.**

10.1.2 The Antenna Gain

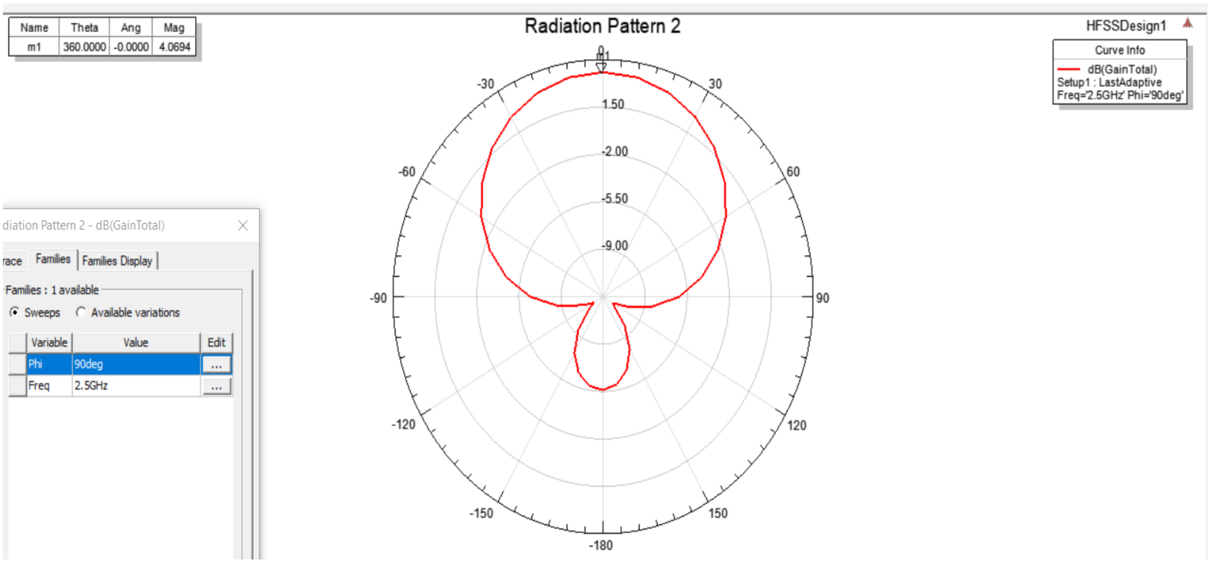
The Antenna Gain signifies the radiation intensity in each direction to the radiation intensity that would be observed by an isotropic source. [4] The corresponding Gain of simulated antenna is shown in Figure 26 in polar plot. In simple Antenna Gain (G) can be given by the relation:

$$G = \varepsilon R D \quad (10.3)$$

As we are considering WPT and health monitoring system as the application of multiband operation, therefore efficiency plays a vital parameter which signify the transmission of the energy required.

The antenna **efficiency** parameter is determined by the power radiated by the antenna to the power supplied, which can be illustrated as the ratio of the power radiated to the input power supplied to the antenna -

$$\varepsilon R = Pradiated / Pinput \quad (10.4)$$



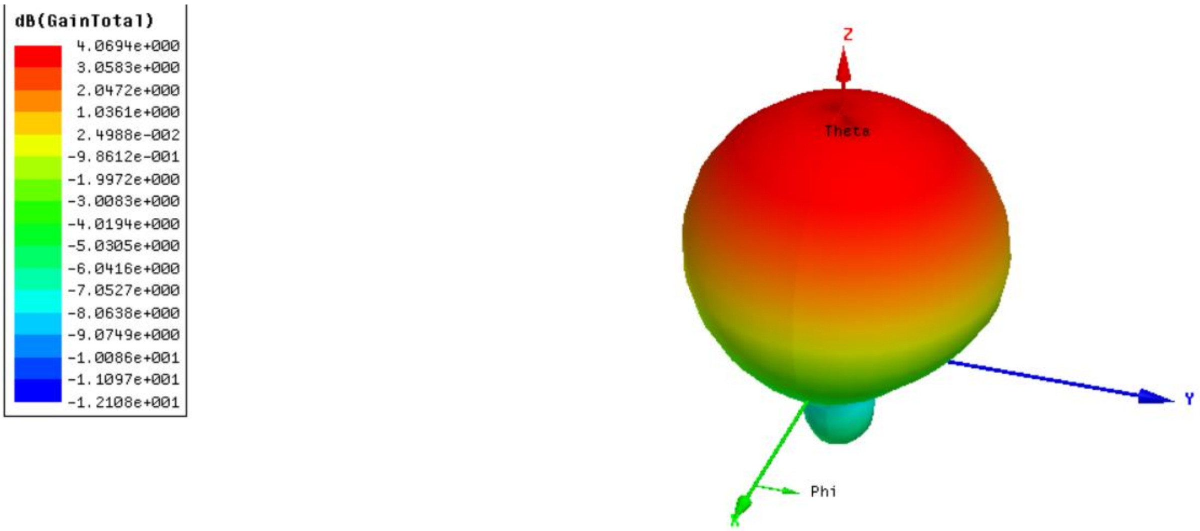


Figure 33: Gain of the proposed antenna

The simulated fractal antenna is observed to have gain parameter of about 4 dB at phi equals to 0/360 degree at 2.26GHz. Here, the antenna Gain parameter is found to be from 2.98 to 4.09 dB in the required four different multiband operating frequencies.

10.1.3 **DIRECTIVITY** is another conventional antenna characteristic that signifies the directional capability of radiation by an antenna towards the desired path. [4] An antenna is said to have zero directionality, if an antenna radiates equally in all directions, Directivity can be given by-

$$D = \frac{1}{\frac{1}{4\pi}\int_{0}^{2\pi}\int_{0}^{\pi}\left|F(\theta,\phi)\right|^{2}\sin\theta d\theta d\phi} \quad (10.5)$$

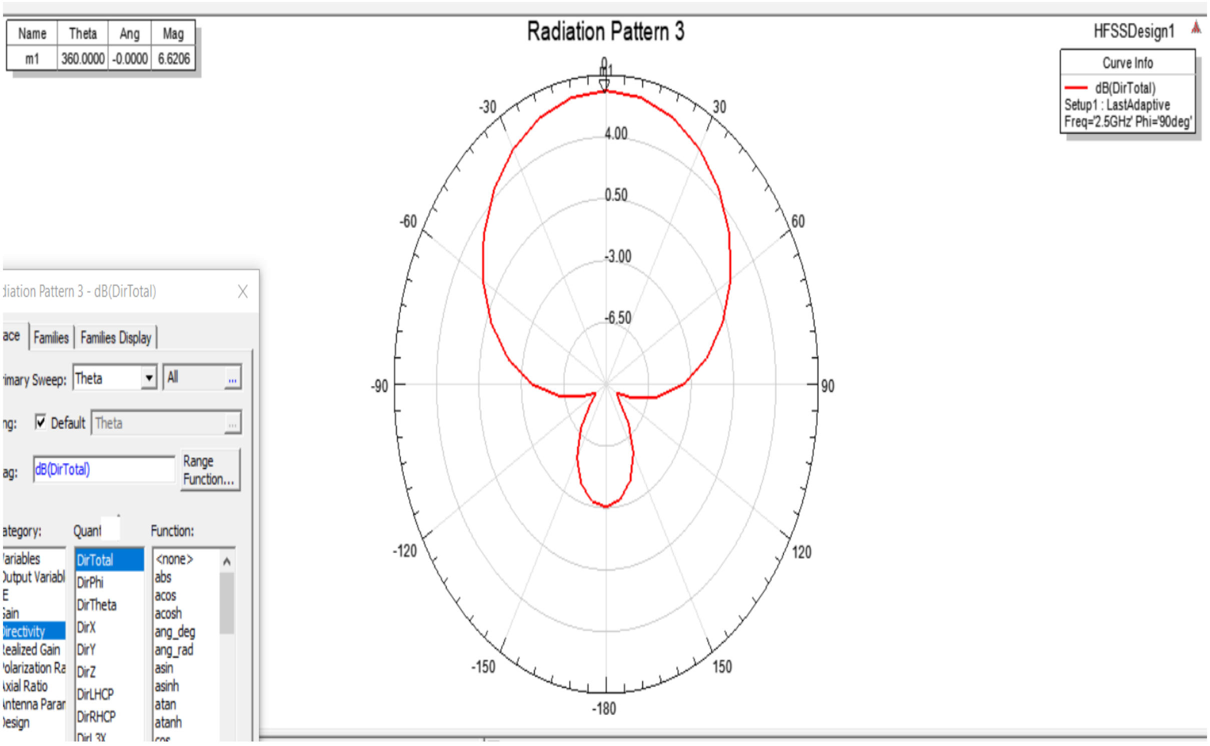


Figure 34- Directivity of the proposed antenna

The Corresponding directivity of the simulated fractal antenna is shown in Figure 10 in the polar plot. It is observed that the simulated antenna has a directivity of about 6.62dB at phi equals 0/360 degrees at 2.26GHz and is not subjected to any variation for the observed four different frequencies. Therefore, all the necessary performance characteristic of the simulated antenna is carried out and it can be justified that the proposed antenna works satisfactory for the required application in WPT and Health monitoring system.

Usually, a **directivity** of 6-8 dB is desired for **best performance** of an antenna.

CHAPTER 11

11.1 SIMULATED RESULTS

- Operated frequency range -1 to 5GHz
- Obtained resonant frequency of - 1.9/2.4/3.2/4.6 GHz
- Therefore, it includes the s-band and C-band applications.

- As the radio frequency range for-
  S-band lies between 2-4 GHz.
  C-band lies between 4-8 GHz .
- WiMAX (Worldwide Interoperability Microwave Access) based on IEEE 802.16 are 2.5/3.5/5.5 GHz

- The proposed antenna can also be used with short range satellite application antennas as it has a frequency resonant at 2.3 GHz.
- Showed a **directivity** of 6-8 dB is desired for **best performance** of an antenna
- The antenna Gain parameter is found to be from 2.98 to 4.09 dB
- Showed a satisfactory result of VSWR in the range of 0 to 2.
- Therefore, the proposed antenna can successfully be used in healthcare monitoring system as it falls under ISM band, thereby is appropriate to be used in medical equipment as per standard law.

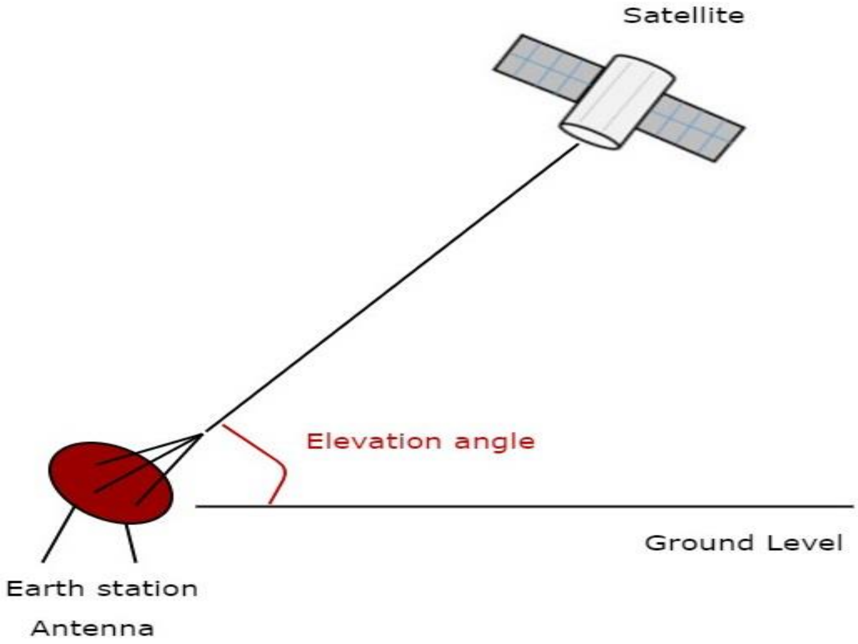


Figure 35: satellite communication

CHAPTER 12

12.1 APPLICATIONS

The designed fractal antenna is specifically for systems such as WPT and health monitoring systems where compactness is made the priority without compromising the performance and the use of fractal-based antenna have successfully achieved that target.

As the world sees a need for more compact and portable devices, especially to keep a check on their health status, calorie intake, or SOS alert to their dear ones in tough times, smart wearable and devices are believed to play a major role in making life a bit more convenient. And therefore, it can be only promised with compact ready and miniature device elements which can be used in day-to-day life effortlessly and economically. Hence, the reduced size of antenna in various biosensors like Non-invasive glucose level monitoring system in a wearable or in WPT system for mobiles and wearable is definitely a way forward.

Besides that, fractal can be used in different communication technologies such as short-range communication, namely WiFi, WiMAX, Bluetooth connectivity, Smartwatch, AR/VR handsets, Machine-to-machine communication, RFID, distributed satellite communication technologies. This is made possible because of the multiband operation of the fractal antenna which makes it realizable for a single fractal antenna to be used in a different range of frequencies as per our requirement.

12.1.1 FEATURES:

- Wideband /Multiband-Instantaneous spectrum access.
- Compact- More tightly designable and usable versatility.
- Fractal loading-Added inductance and capacitance without incorporating additional components.
- Smaller fractal ground with multiband operation characteristics.
- Frequency independent-Consistent performance over huge frequency range.
- New design space-Powerful solutions possible.

CHAPTER 13

CONCLUSION AND FUTURE SCOPE

13.1 CONCLUSION

In conclusion of the implemented project, the proposed fractal antenna designed has specialised application of Multiband operation due to its self-geometry, along with its primary advantage of light weight which can replace conventionally used large antenna with the proposed antenna. Also, due to its special capability of multiband operation it can be used in supporting an extensive amount of wireless technological applications, hence the proposed antenna is found to operate in the frequency range of 2 to 8 GHz, (as obtained 1.9/2.4/3.2/4.6 GHz), providing a promising return loss of -13.20/-22.5/-11.8 dB respectively and the designed antenna have a VSWR in the required range of below 2, which is required to deliver best performance of an antenna. Therefore, the proposed antenna is purposely designed to be used in technologies such as wireless power transfer system, healthcare monitoring system, communication systems operating at S-band, C-band, WiMAX (Worldwide Interoperability Microwave Access) based on IEEE 802.16 and satellite communication.

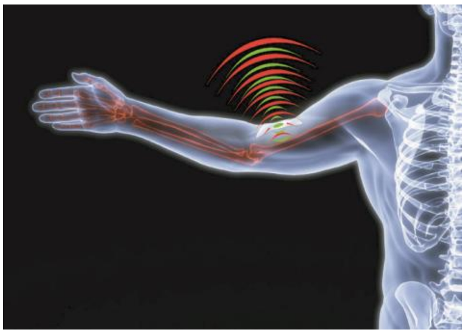
For analysis purpose of the proposed antenna, the antenna parameter performance of the iterated fractal antenna at 1st ,2nd and 3rd order of iteration stages are verified and compared with the well-known conventional fractal antenna. However, the final design of antenna is achieved from the 3rd iteration of normal patch antenna, in such a way that it does not affect the antenna parameters such as return loss, gain, directivity and VSWR. Thus, a fractal antenna is successfully achieved which can provide an alternative yet better performing than a conventionally large antenna.

This study showcases a diverse types of antenna optimization by incorporating fractals that can be used to design an antenna and how these fractals can play very vital role to reduce the size of an antenna and optimize its gain and overall performance. If the number of iterations of fractal increases then the resonant frequency also increases and it gives lower return losses. By the usage of diverse Fractal geometries the multiband and wideband characterisation can be achieved which are used for different applications like wireless power transmission system, short range satellite communication and wireless communication by using different antenna configuration and feeding techniques. It’s very important to select proper feeding technique and proper position of feed for a better impedance matching. In further other types of feeding techniques, different shapes of patch and different substrate materials can be used for the designing and analysing the better performance parameters of antennas.

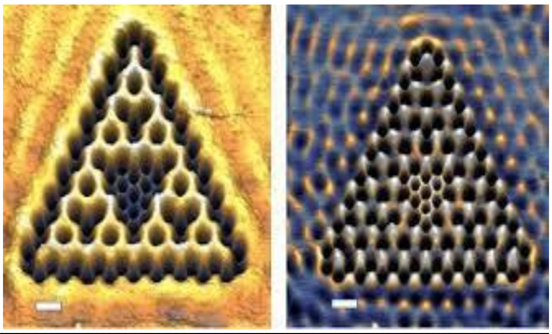
13.2 FUTURE SCOPE

The Future scopes includes the use of miniature Fractal antenna on a human body which would transmit information of health status to smart watches and devices embedded upon. That is, it can be used as a bio-sensor.

Also, It can be used in quantum fractals where the movement of electrons can be varied or absorbed leading to variations in electron circulatory.



BIO-MEDICAL ANTENNA



QUANTUM STRUCTURES

Figure 36- Future scopes

REFERENCES

1. Yogamathi, R., Banu, S., & Vishwapriya, A. (2013, July). Design of fractal antenna for multiband applications. In *2013 Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT)* (pp. 1-5). IEEE.

2. Omer, A. E., Shaker, G., Safavi-Naeini, S., Kokabi, H., Alquié, G., Deshours, F., & Shubair, R. M. (2020). Low-cost portable microwave sensor for non-invasive monitoring of blood glucose level: novel design utilizing a four-cell CSRR hexagonal configuration. *Scientific Reports*, *10*(1), 1-20.

3. Sharma, Manish, Prateek Jindal, and Sushila Chahar. "Design of Fractal Antenna for Multiband Application." *International Journal of Advanced Research in Computer Science and Software Engineering* 4.6 (2014): 854-859.

4. HFSS users manual,2005, version 10, Ansoft Corporation .

5. Balanis.C, 2009,"Antenna Theory and Design" 3rd Edition, McGraw Hill publishing company, New Delhi.

6. Sheik Mohammed.S,K. Ramasamy, T. Shanmuganantham Sheik,2010 "Wireless Power Transmission – A Next Generation Power Transmission System", International Journal of Computer Applications (0975 – 8887) Volume 1 – No. 13.

7. Vinoy.K.J, 2002, "Fractal Shaped Antenna Elements for Wide- And Multi- Band Wireless Applications" A Thesis in Engineering Science and Mechanics, the Pennsylvania State University ,the Graduate School College of Engineering.

8. Body Matched Antennas for Microwave Medical Applications by Xuyang Li

9. Werfelli, H., Tayari, K., Chaoui, M., Lahiani, M., & Ghariani, H. (2016, March). Design of rectangular microstrip patch antenna. In 2016 2nd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP) (pp. 798-803). IEEE.
10. Zhang, K., Li, D., Chang, K., Zhang, K., & Li, D. (1998). *Electromagnetic theory for microwaves and optoelectronics* (pp. 274-283). Berlin: Springer.
11. Reynolds, T. (2004, February). Advanced wireless technologies and spectrum management. In *ITU seminar*.

LIST OF PUBLICATIONS

- A conference paper with the title "DESIGN OF FRACTAL ANTENNA FOR MULTIBAND OPERATION IN COMMUNICATION AND HEALTHCARE" got accepted for IEEE sponsored conference named "2021 IEEE 2ND GCAT, Bangalore (IEEE conference ID: 52182)", to be published soon.
- Published a chapter on "AI powered Healthcare & IOT devices" for Elsevier publications. (ISBN: 9780128185766)
- A conference paper got accepted with the title "Design of fractal antenna for multiband operation in communication" for publication in Springer-Lecture Notes in Electrical Engineering (LNEE) Series.