Design a Hybrid Fractal Antenna for Wireless Applications

A PROJECT REPORT
Submitted by

AJMAL ABDUL AZEEZ K.S **Reg. No.9517202103009**
MITHRESH RAJ R **Reg. No.9517202103082**

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Examiner-1 **Examiner-2**

ABSTRACT

The creation of Hybrid fractal antenna for wireless application by superimposing Hilbert curve on Minkowski curve known as Hilbert Minkowski Antenna (HMA) is the subject of this study. The antenna was designed using HFSS software. FR4 material with 4.4 dielectric constant is used as a substrate material. The design protocol calls for products with a maximum exterior dimension of 37mm by 50 mm by 1.6 mm. Fractal antenna research has great effect in the area of science and engineering. There are many fields such as telecommunication, military, medical and commercial applications that use fractal antenna. There are different techniques for the design a patch antenna but fractal antenna is the one of the most popular technique because of its two important properties- self-similarity and space filling property. The Hybrid Fractal Antenna achieves gain of 7.5 dB operates at 12 frequency bands. MATLAB and HFSS are used to carry out the analysis (High Frequency Structural Simulator).

ACKNOWLEDGEMENT

First and foremost, we express out whole-hearted gratitude to the **Almighty** for his shower of blessing on us in finishing this project successfully. With immense pleasure and pride we would like to thank our Parents who had sacrificed a lot in making us to reach this position.

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CHAPTER I

INTRODUCTION

In present era, electronic devices have become compact in size and loaded with various features. Due to this only one antenna is required to fulfill the demands of multiple wireless applications. Thus, the demand of multiband antenna is increasing day by day. Earlier, more than one antenna was required for different applications. However, in these days, multiband antenna has replaced these multiple antennas by a single one. Fractal antenna research has great effect in the area of science and engineering. There are many fields such as telecommunication, military, medical and commercial applications that use fractal antenna. The French mathematician B.B.Mandelbort discovered fractal antenna.

There are different techniques for the design a patch antenna but fractal antenna is the one of the most popular technique because of its two important properties- self-similarity and space filling property. Self-similarity depends on iteration number. These two properties make fractal antennas compact in size; operate at different frequency bands and reduced weight as compared to simple patch antennas. Different geometries are used for the design a fractal antenna.

1.1 Hybrid Fractal Antenna

Fractal- a **fractal** is a geometric shape containing detailed structure at arbitrarily small scales, usually having a fractal dimension strictly exceeding the topological dimension. Many fractals appear similar at various scales, as illustrated in successive magnifications of the Mandelbrot set. This exhibition of similar patterns at increasingly smaller scales is called self-similarity, also known as expanding symmetry or unfolding symmetry; if this replication is exactly the same at every scale

Formation of hybrid fractal curve:

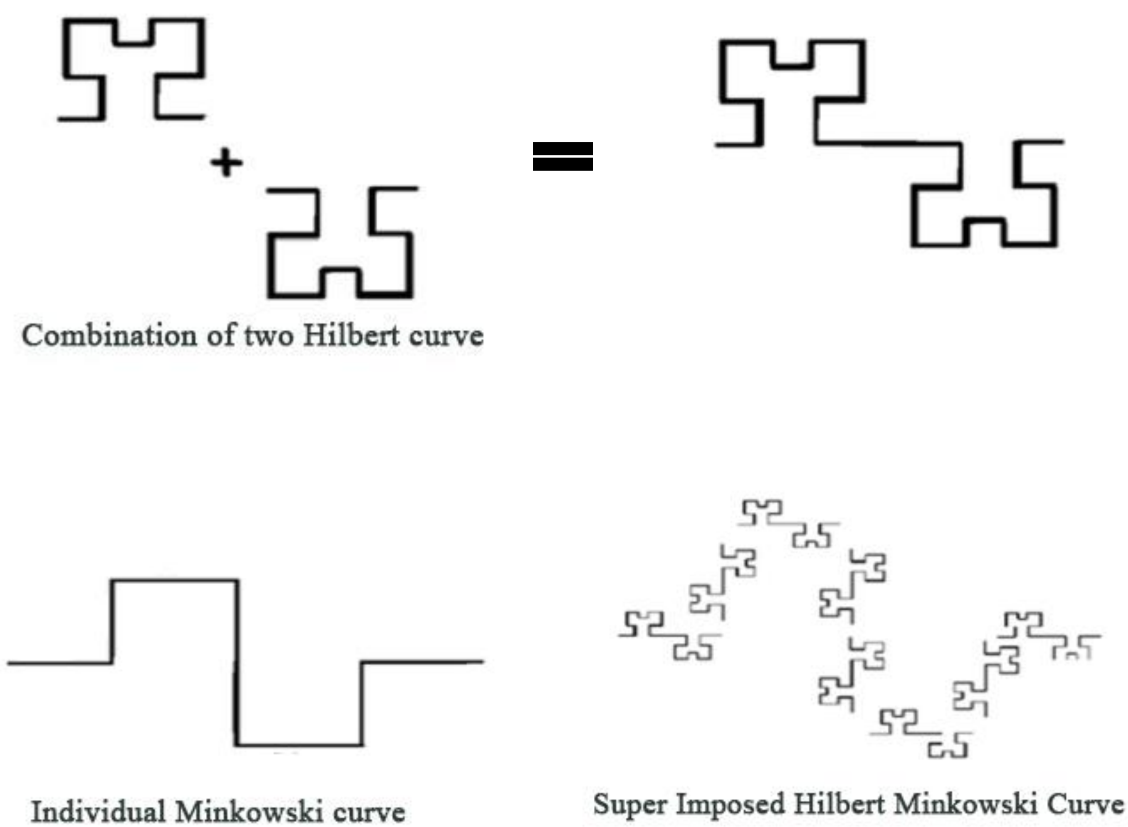


Fig 1.1 Formation of hybrid curve.

➢ Top

➢ Bottom

x

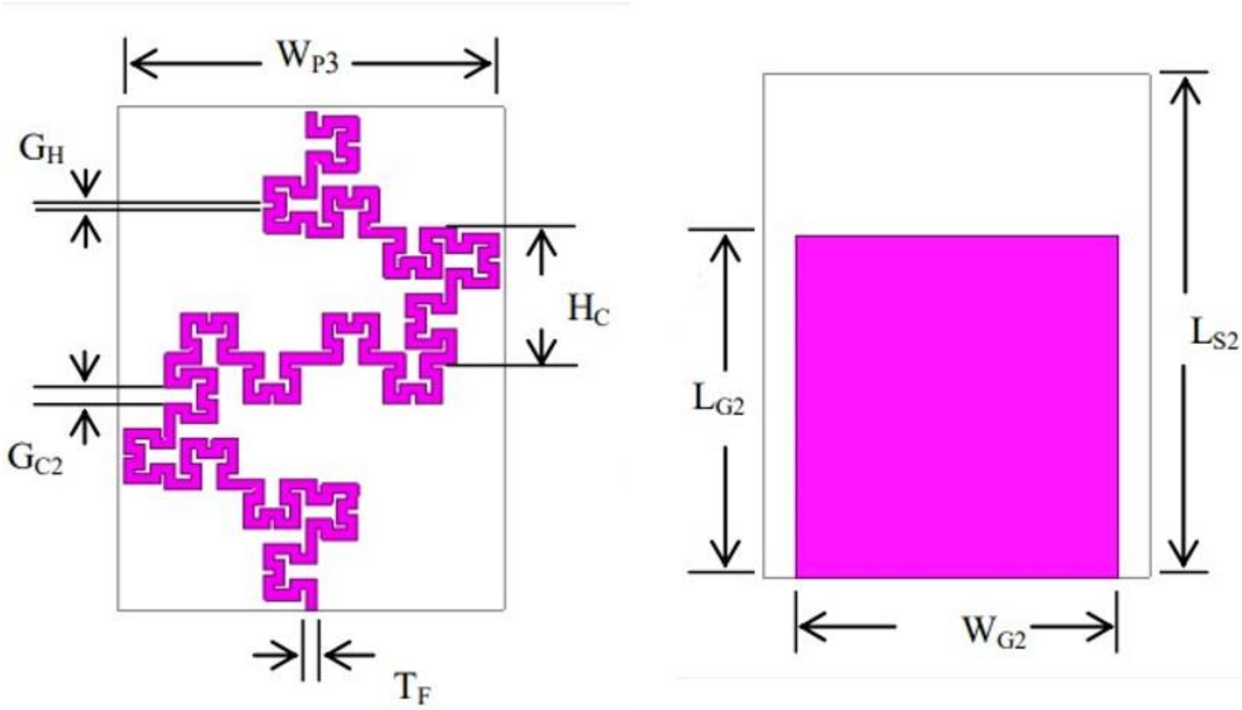
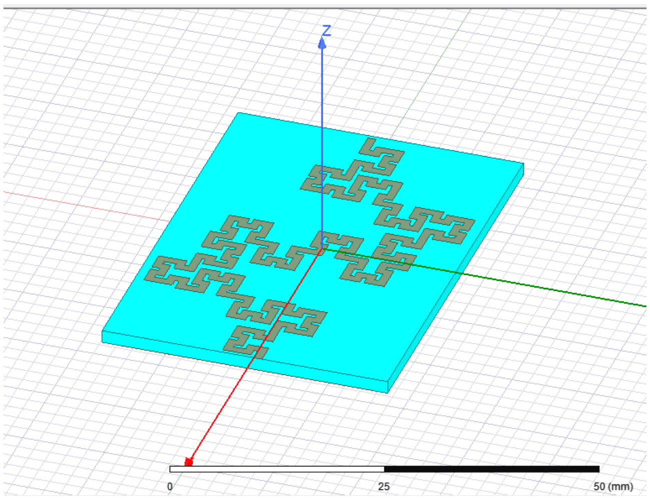


Fig 1.2 Parameters of design.

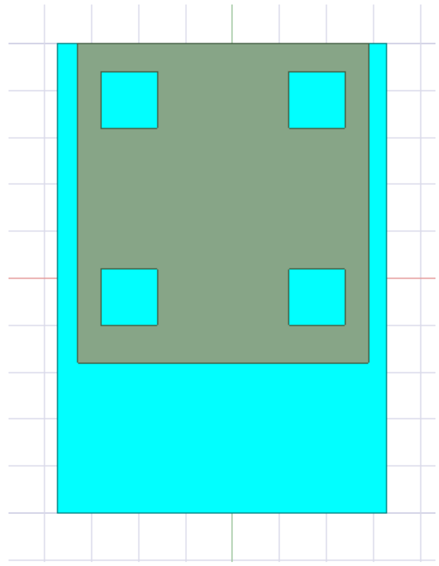
Parameters of HMA	Dimensions in mm
Length of patch (LP2)	48.5
Width of patch (WP2)	32
Length of curve (LC2)	14
Width of patch (WP3)	36
Length of Hilbert curve (HC)	13.5
Gap between Hilbert curves (GH)	0.5
Thickness of feed (TF)	1
Space between Hilbert curve (GC2)	1.5
Width of ground (WG2)	31
Length of ground (LG2)	34
Length of substrate (LS2)	50

Table 1.1 Parameters of Antenna

HFSS Design:



Top View



Bottom View

Fig 1.3 HFSS Design

- As the previously designed HFSS design has low gain value, the rectangular slots (6mm X 6mm) are made in ground plane.

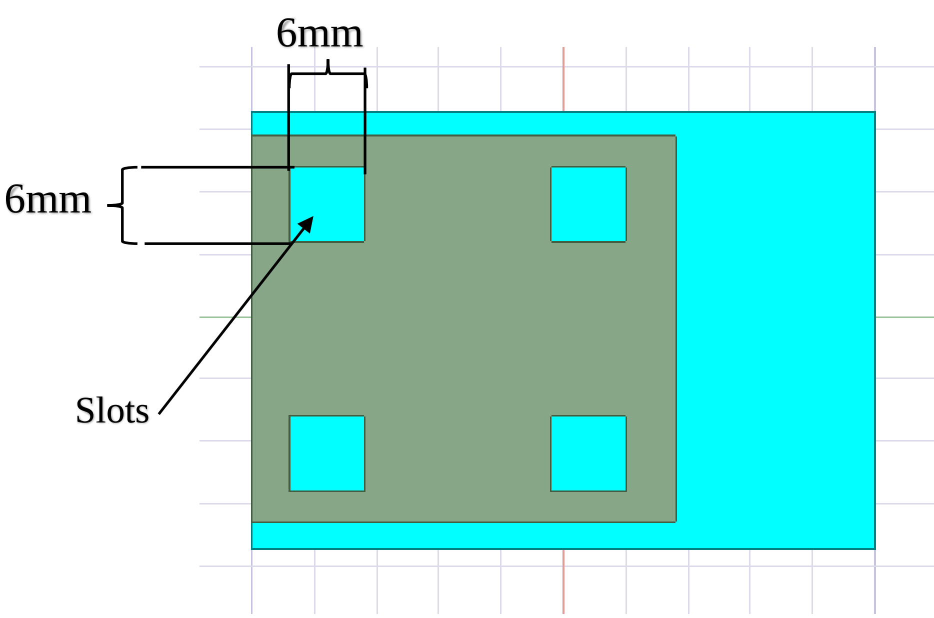


Fig 1.4 Slots

Formula:

Width of the patch: $$W = 2f\frac{C}{2fr\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

EFFECTIVE DIELECTRIC CONSTANT:

$$\varepsilon_{reff} = \frac{(\varepsilon_v + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{h}{\omega}\right]^{-\frac{1}{2}}$$

'W' the width of the patch

'C' the velocity of light = 3x108 m/s

'fr' the resonance frequency

'εr' the dielectric constant

'εreff' the effective dielectric constant

'h' the height of dielectric substrate

Advantages:

- The Hybrid fractal antenna is a multiband antenna operates in 12 different frequency which is suitable for wireless application like mobile,etc.
- The major advantage of this superimposition is that the length of antenna conductor is immensely increased as the length of single Minkowski curve based antenna cannot be increased beyond certain limit.
- The most notable advantage of Hybrid fractal antenna is its low profile, and its high gain.

Disadvantages:

- Because of smaller size design and fabrication of fractal patch is little difficult.

Applications:

- The proposed Hilbert Minkowski Antenna can be used for various wireless applications such as GPS (1.22GHz), Aircraft Surveillance (1.09GHz), Mobile Services such as Radio Microphone and Radio Astronomy, Wireless Microphones, 3G Cellular Communication Mobile uplink (1.90GHz-1.98GHz) and Military Satellite application .

- The minimum value of s11 is -19.37dB, superimposition of two fractal geometries is immensely beneficial in the design of antenna for multiband applications. This research work will open a path for designing fractal antennas that are loaded with other fractal geometries.

CHAPTER 2

LITERATURE SURVEY

In the paper “Minkowski and Hilbert Curves Based Hybrid Fractal Antenna”two types of fractal antennas are designed by I. Singh Bangi, J. Singh Sivia one by superimposing Hilbert curve on Minkowski curve known as Hilbert Minkowski Antenna (HMA) and other by superimposing Minkowski curve on Hilbert curve known as Minkowski Hilbert Antenna (MHA). Both antennas are compared in terms of performance parameters like gain, S11(dB), radiation pattern, current distribution and VSWR all at resonant frequencies. Both antennas are designed using HFSS software.FR4 material is used as a substrate material. Prototype of both antennas are designed, fabricated and tested at Vector Network Analyzer (VNA). It is found that Hilbert Minkowski Antenna has better performance in terms of Gain while Minkowski Hilbert Antenna is better in terms of number of frequency bands. A comparison between the characteristics of individual Hilbert and Minkowski curve based antennas is done with the characteristics of hybridized (MHA and HMA) antennas. It comes out that MHA and HMA have more number of frequency bands than individual Hilbert and Minkowski curve based antennas. A comparison has also been done between simulated and measured results of both antennas. Simulated and measured results for both the antennas are in agreement with each other.

In the paper “HIS based dual band dual polarized Minkowski fractal patch antenna”A compact single probe feed Minkowski fractal boundary patch antenna based on HIS (High Impedance Surface) is proposed by Suman Nelaturi, D Vakula, N Sarma for dual band dual polarization operation. Dual band operation with widened bandwidth at each resonating frequency and dual polarization can be achieved by using the combination of HIS and

Minkowski fractal curves. The 10-dB return loss bandwidth of lower and upper frequency bands are 13.01% and 4.95% respectively. The 3-dB Axial Ratio bandwidth is 3.4% . A microstrip patch antenna being compact, low profile, easy to manufacture and multifunction is the most coveted candidate for modern day wireless communication applications. Dual band dual polarized antennas are mostly used in practical applications. Orientation mismatch between Receiver and used in WLAN, Wi-Fi and WiMAX applications. Rapid growth of modern communication systems brought an ever-increasing demand for compact antennas with reconfigurable characteristics. Recently, a considerable attention has been paid to the minimization of the antenna dimensions or to the improvement of its characteristics . However, an arbitrary reduction of the antenna size can result in increased reactance and deterioration in the antenna efficiency. To minimize the size of the antenna or to improve its characteristics various solutions based on fractal geometries have been recently proposed. Fractal curves, unique for their fractal dimensions, self-similarity, and space-filling properties, offer vast potentials for miniaturization of passive microwave components and antennas. Different fractal geometries, such as Koch, Hilbert, Peano or Sierpinski curves have been used to bring the benefits of the small size, wide bandwidth , or multi-band operation .Transmitter can be avoided by using circularly polarized (CP) Antennas. The CP antennas are widely. A compact single probe feed Minkowski fractal boundary microstrip patch antenna is proposed based on HIS for dual band and dual polarization operation. The 10-dB return loss bandwidth at lower resonating frequency band is 13.01% whereas 4.95% at upper resonance frequency band respectively. The 3-dB Axial Ratio bandwidth is 3.45%. The proposed antenna covers WLAN (2.4 GHz) and WiMAX (3.4 GHz) operating bands.

In the paper “Fractal Dipole Antennas Based on Hilbert Curves with Different Line-to-Spacing Ratio” by Vasa , Goran , Vesna-Bengin demonstrate the influence of the line-to-spacing ratio of the Hilbert fractal antenna to its radiation characteristic. The proposed antennas realized using Hilbert fractal curves of the third order have been designed to operate at 2.45 GHz according IEEE 802.15.1 standard. Due to specific configuration of the Hilbert fractal curves and mutual coupling between fractal segments, the radiation patterns of the proposed antenna can be

significantly changed by changing the line-to-spacing ratio of the Hilbert fractal radiators. The proposed antenna has been fabricated in Low Temperature Cofired Ceramic (LTCC) technology. The measured result of the Hilbert dipole antenna confirmed its good impedance matching and return loss. this paper demonstrate that different radiation characteristics of the Hilbert dipole antenna can be obtained by changing the line-to-spacing ratio of the Hilbert curves. In that manner, the radiation patterns can be significantly changed, for the constant operating frequency. Furthermore, the influence to the antenna impedance and total efficiency have been analysed. The Hilbert dipole antennas with line-tospacing ratio equal to one designed to operate according IEEE 802.15.1 standard has been fabricated in LTCC technology and its measured characteristics confirmed good impedance matching to the input impedance and reflection characteristic.

CHAPTER 3

DESIGN METHODOLOGY

3.1. HFSS Intro:

To compute the electrical behavior of the higher frequency and high-speed components, ANSYS HFSS software uses a 3D full wave Finite Element Method. HFSS is a commercial tool that can also be utilized for the design of RF electronic circuits like filters. Tetrahedron is the basic mesh element. This software can be used in the calculation of antenna parameters such as S-parameters, gain, voltage standing wave ratio, radiation pattern, current and field distributions, antenna efficiency, impedance matching and so on. ANSYS HFSS is a user- friendly software. High accurate results can be obtained with the use of HFSS software. It provides facility to assign boundary, excitations, range of frequencies for precise results. HFSS is the platform where we can model, simulate and can automate easily. Optimization of the antenna performance by simulating and analyzing the parameters separately can be done. The results can be viewed as either as tabular or graphical format. Most options in the HFSS tool are self-explanatory. It also has inbuilt techniques like optimization. For engineers to optimize the designed antenna to a desired dimension, the parametric set up existing in HFSS is highly helpful. 3.1.3 User interface of HFSS The user interface of HFSS is shown in the Fig 3.1, this illustrates the main components in the GUI (Graphical User Interface).

- **3D Modeler window**: The model/ geometry can be created in this region. The framework or the model view region exists in this window.

 Properties window: Two tabs are there in this window – attribute tab and command tab. The selected object's property and the information regarding the material are displayed in the attribute tab. The selected action in the history tab to modify an object or create an object is displayed in the command tab.

 Project manager: The details of project which are currently open get displayed in the project manager window. Each project contains the geometric model of the antenna and the assigned boundaries and excitations and the obtained report in table and graphical format.

 Progress window: The progress of the analysis can be viewed through this window. The percentage of solution or the state of execution can be viewed through this window.

 Message manager: This window displays the progress in written form or text format i.e., whether simulation has completed or not or if there is any error.

 New features and enhancement: Selection, Healing, Visibility, 3D user interface options and 3D modeler options are some of the new features.

o Selection helps in selecting the connected edges, vertices, faces.

o Healing removes the faces, edges and vertices.

o Visibility is used to show/ hide the objects in certain view.

3.2. Design Procedure:

The Hybrid fractal antenna uses FR4 substrate which has a relative permittivity of ε = 4.4. The substrate height is chosen to be as h = 1.6 mm. The overall dimension has been determined as width of the substrate W_S = 37 mm and length of the substrate L_S = 50 mm. the width of ground plane (W_g) is 31 mm and length of ground plane (L_g) is 34 mm of the ground. The dimensions of the fractal patch placed on the top of the substrate were obtained as width of the patch Wp = 32 mm and a length of the patch Lp = 48.5 mm.

3.2.1 HFSS DESIGN:

Fractal Patch:

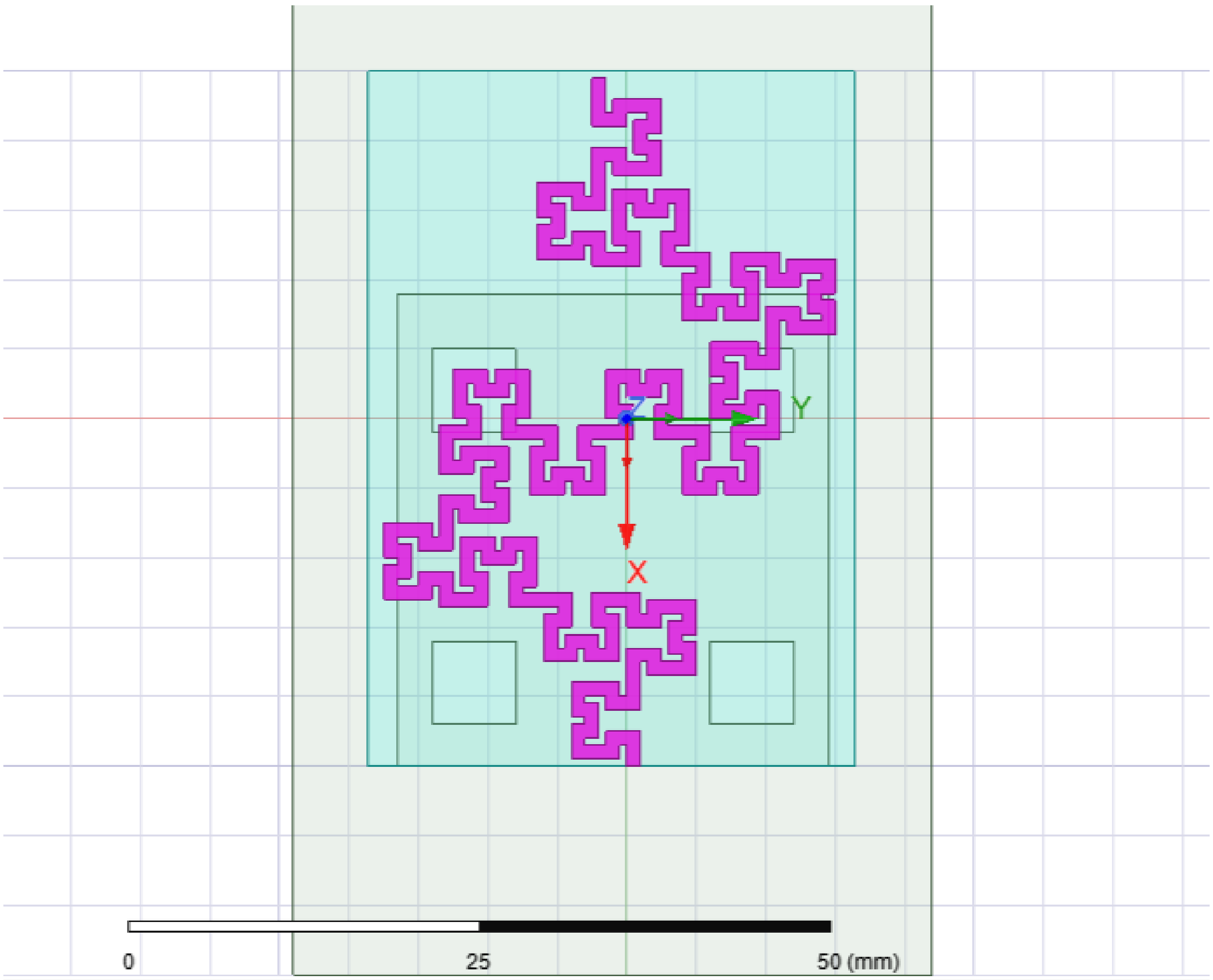


Fig 3.1 Fractal Patch.

Ground:

Position → (25, 14.5,-1.6) mm

X-Size → -34mm

Y-Size → -31mm

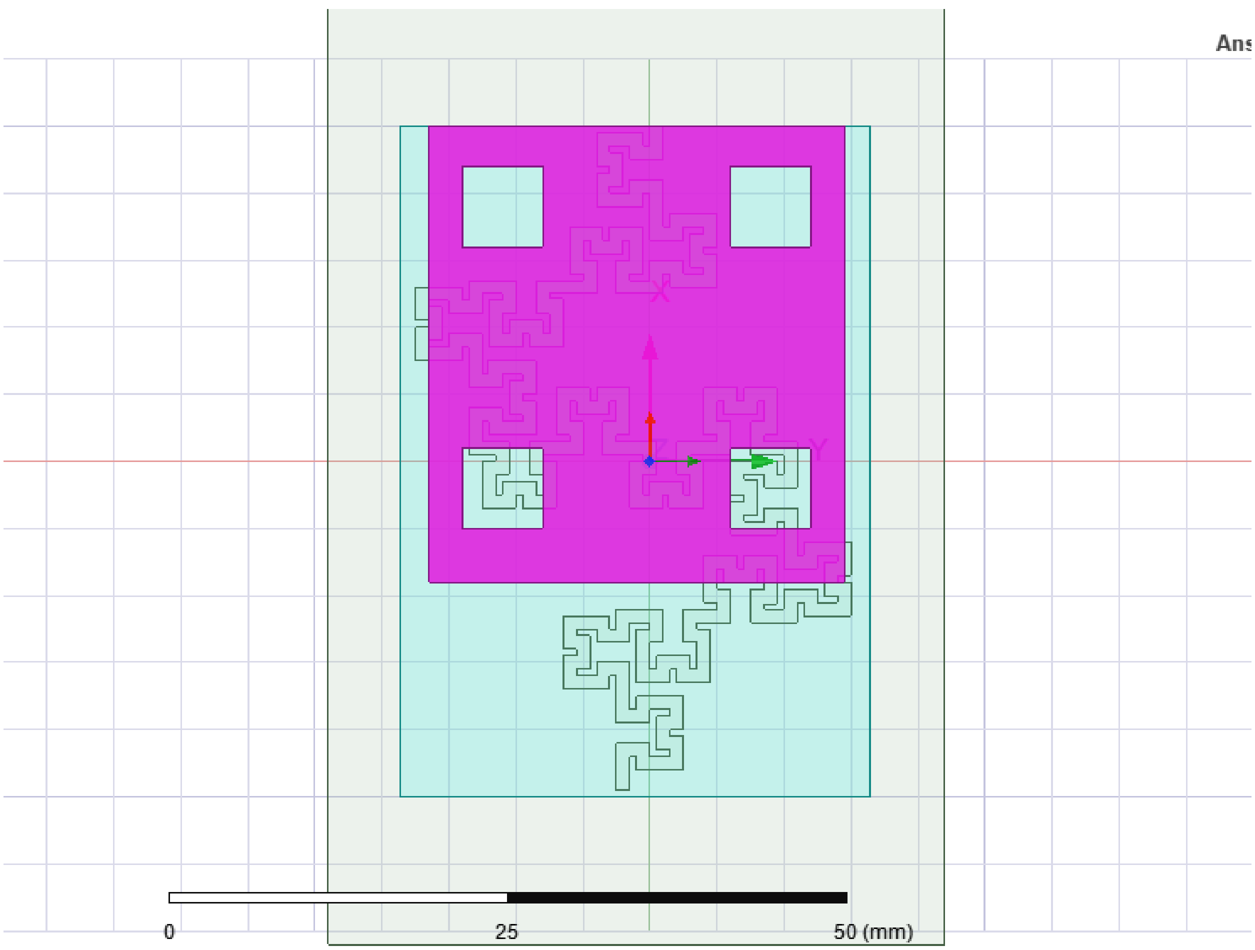


Fig: 3.2 Ground in HFSS

Port:

Position → (25, 0 ,0) mm

X-Size → 1mm

Z-Size → -1.6mm

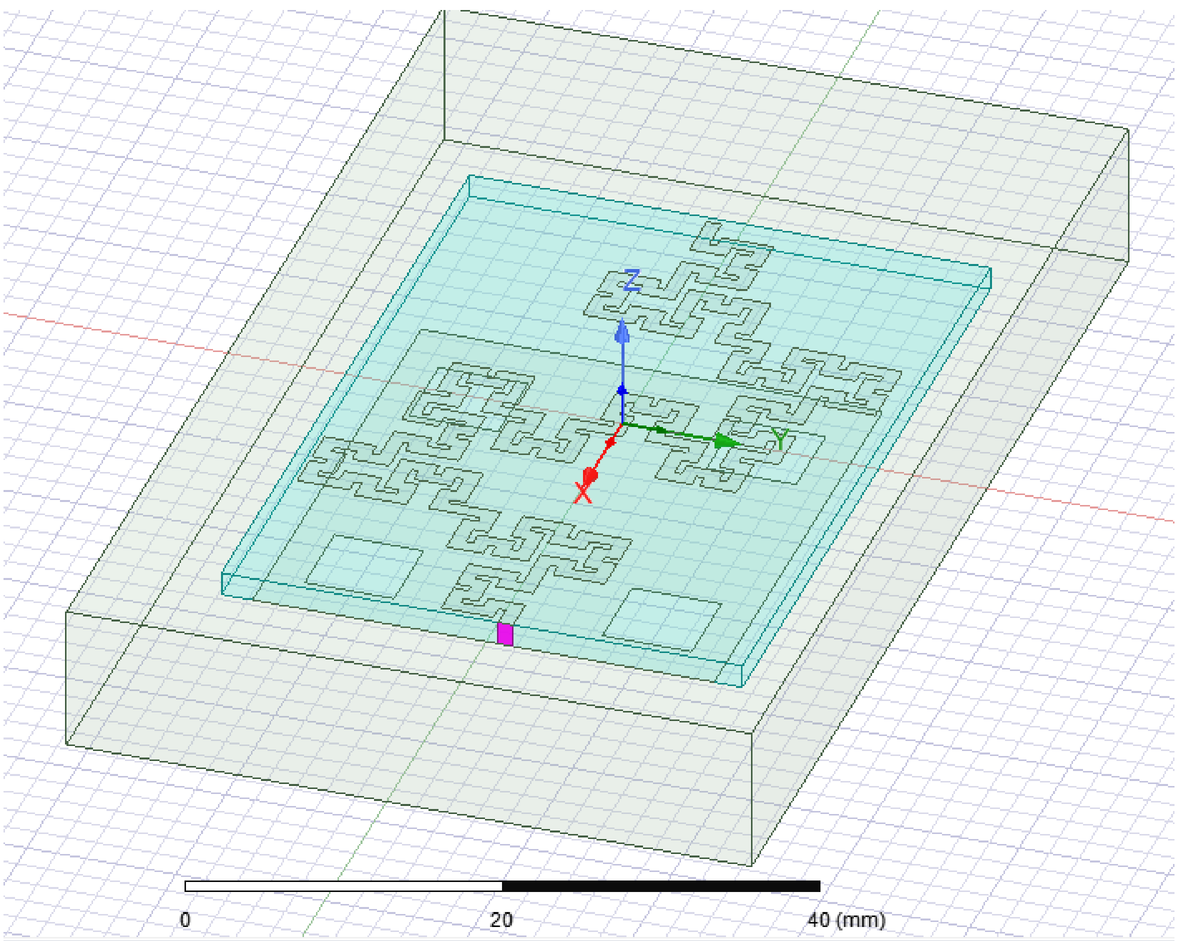


Fig: 3.3 Port in HFSS

Substrate:

Position →(25,-18.6,0)

X-Size → -50mm

Y-Size → 35mm

Z-Size → -1.6mm

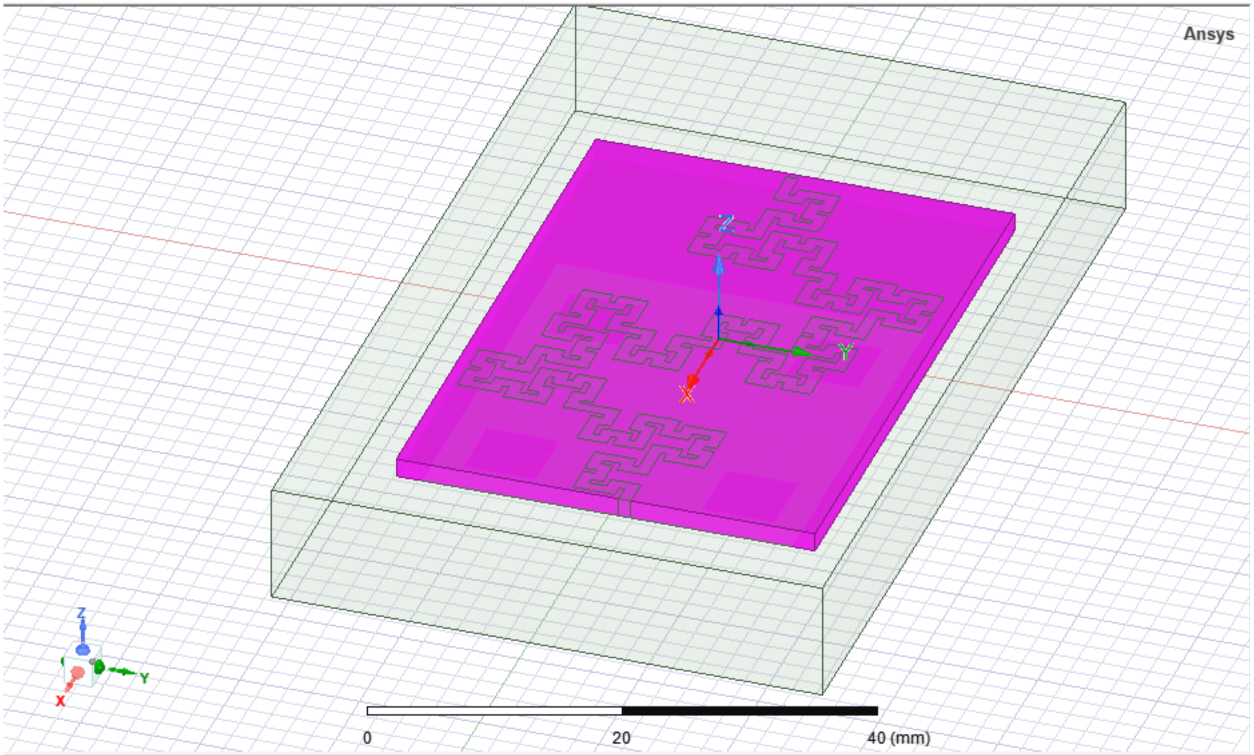


Fig: 3.4 Substrate in HFSS

Final Output:

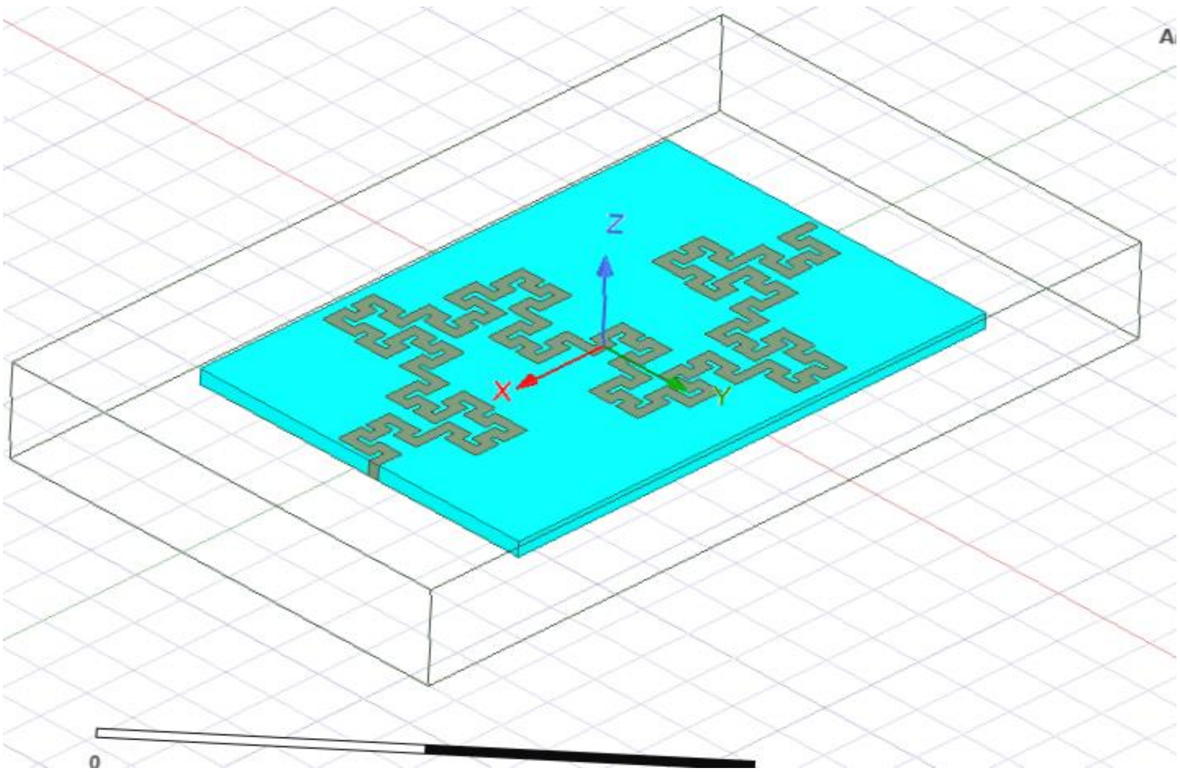


Fig: 3.5 Final output of HFSS design

CHAPTER 4

Results and Discussions

4.1. S parameter characteristic

S11 is known as S parameter or reflection coefficient, is very crucial parameter of microstrip antenna. It shows the relationship between input output terminals of an electrical system or transmission line. It signifies power reflected back at antenna port due to impedance mismatch between antenna and transmission line. S11 values are measured in dB and are –ve. There is minor difference between reflection coefficient S11 and Return Loss (RL). Return Loss is positive. The value of S11 should be below -10dB. The negative sign indicates the power reflected back to the antenna . Small the values of S11 parameter, less the energy is reflected back and better the performance of antenna. The frequency range 1 GHz to 5 GHz is taken for calculating the S11 values of proposed Hybrid fractal antenna. The major variation is exhibited at the lower side of frequency range. Multiple frequency bands are observed in case of Hybrid fractal antenna. The bandwidth of proposed Hybrid fractal antenna is more as compared to individual individual fractal curve based antenna. The Hybrid Antenna has six frequencies at which values of S11 are under the -10 dB value.

Return loss is the power loss in the signal that is reflected or returned in a transmission line or optical fiber by discontinuity. With an inserted device in the line or with the mismatch in the terminating load, this discontinuity can happen. Return loss is given by the equation,

$$\text{RL (dB)} = 10log_{10}P_{incident}P_{reflected}$$

where,

RL (dB) is the return loss in terms of dB

$Pincident$ is the incident power

$Preflected$ is the reflected power

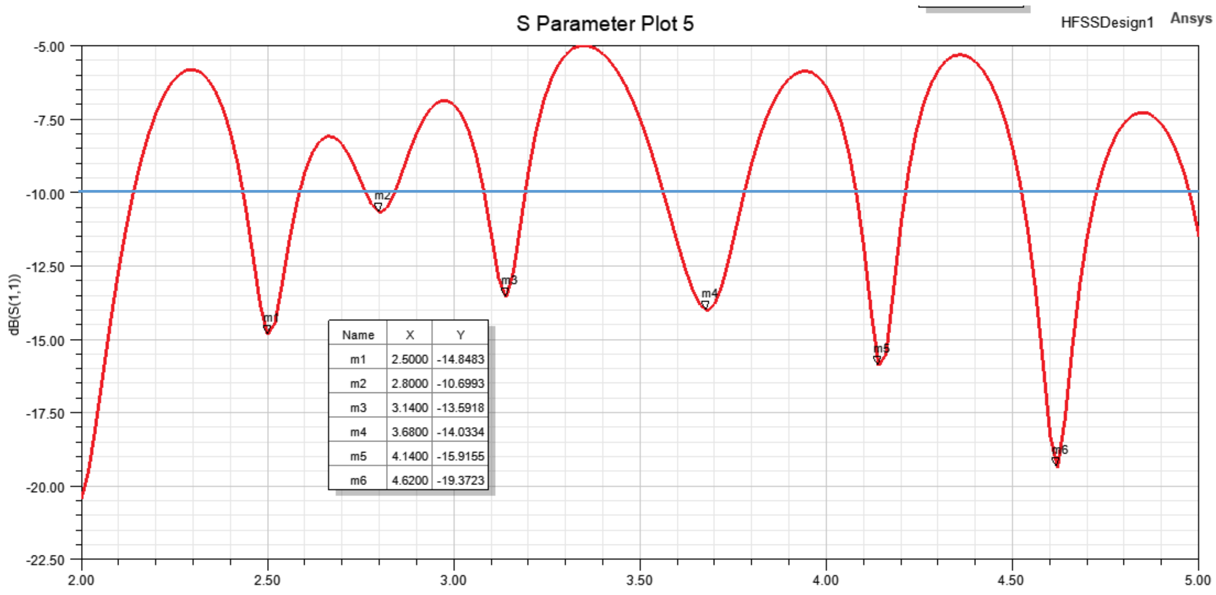


Fig:4.1. S-Parameter obtained from HFSS (at 5.4GHz)

There are six frequencies for HFA at which S11values are less than -10dB. These values of S11 are -14.84dB (at 2.5GHz), -10.69dB (at 2.8GHz), -13.59dB (at 3.14GHZ), -14.03dB (at 3.68GHz), -15.91dB (at 4.14GHz), -19.37dB (at 4.62GHz).

4.2. VSWR

Usually, the standing wave ratio of an antenna is called as the Voltage Standing Wave Ratio (VSWR). The standing wave ratio in terms of current is called ISWR. Squaring the VSWR yields the Power Standing Wave Ratio. The total power reaching the destination end is prevented by impedance mismatch in the transmission line where the radio wave in the cable is reflected back to the source. An infinite SWR is the complete reflection of power reflected from the cable. SWR meter is the instrument used in the measurement of SWR from transmission lines or cables.

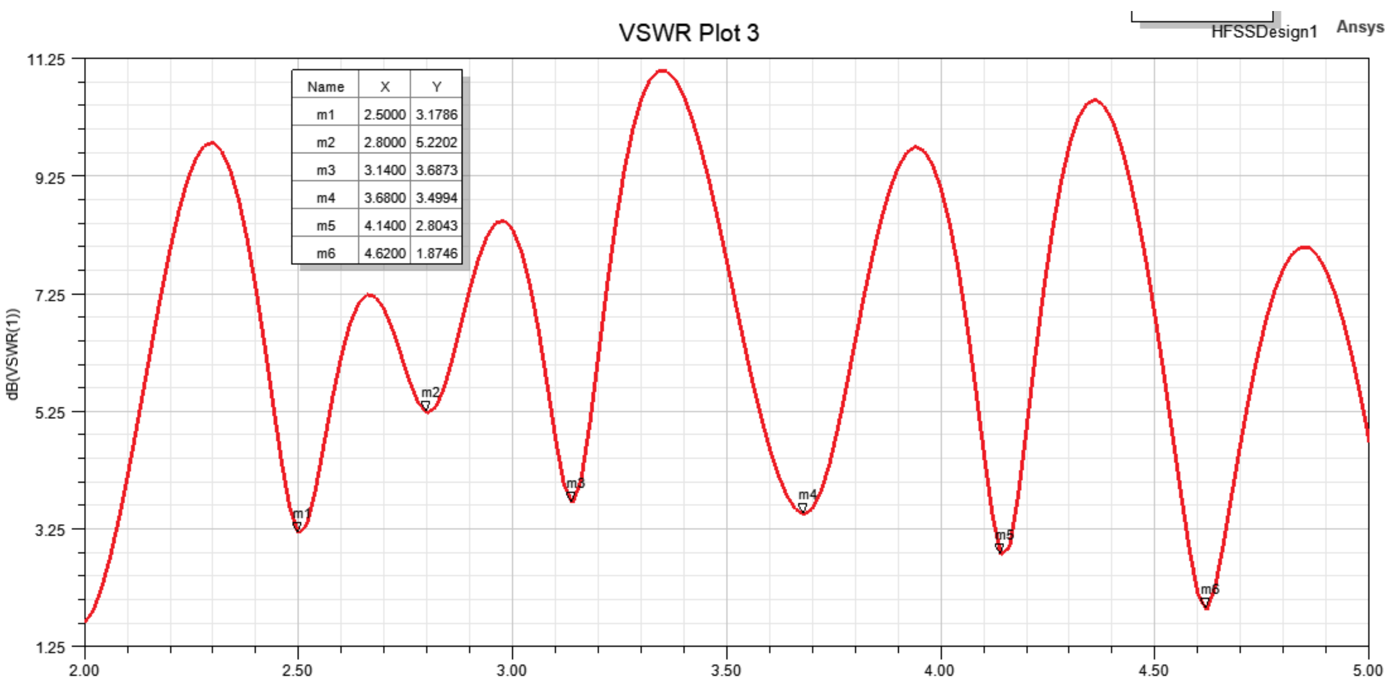


Fig:4.2. VSWR obtained from HFSS (1GHz - 5GHz)

The VSWR of the proposed antenna from the figure we can observe that the VSWR of the proposed antenna is at the resonant frequency of the antenna is 1 which shows the antenna has proper impedance matching at the resonant frequency. minimum of 1.87dB of VSWR at4.62GHz

4.3. Bandwidth:

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

BW%=200*(FH-FL)/(FH+FL)

Bandwidth% = 4.1%

Bandwidth is calculated by taking $F_h = 4.72$GHz and $F_L = 4.53$GHz.

4.4. Radiation pattern:

Graphical representation of the relative field strength that the antenna transmits or receives is called radiation pattern. It is indicated with side lobes and back lobes. Each supplier/user of antenna has different requirements or standards and also different formats for plotting. An antenna's radiation pattern can be defined as the locus of all points in which power emitted per unit surface is equal. The reference in this depiction is usually the best emission angle. The directive gain of the antenna may also be represented as a function of direction. The gain is often represented in decibels. A single graph is sufficient if the antenna radiation is symmetrical about an axis a unique graph is enough i.e., for helical or dipole antennas.

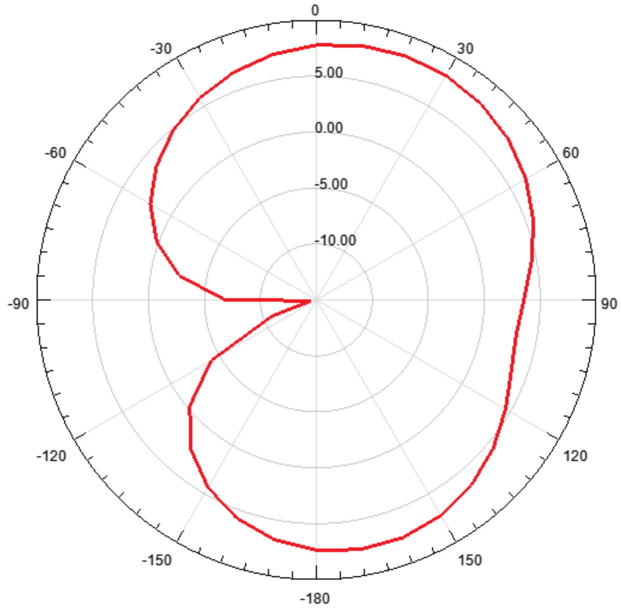


Fig:4.3. Radiation pattern obtained from HFSS (at 5.4GHz**).**

4.5 Antenna gain

Gain is a directional proficiency of antenna which represents the maximum radiated energy in a particular direction. Gain of proposed antennas is calculated using HFSS simulator. The acceptable value of gain is 3dB. 3 dimensional gain patterns for HFA are shown in figure respectively. It is found that a maximum gain of 7.5dB is obtained at 5.4 GHz frequency for Hybrid Fractal Antenna.

$$G=(P/S)_{ant} / (P/S)_{iso}$$

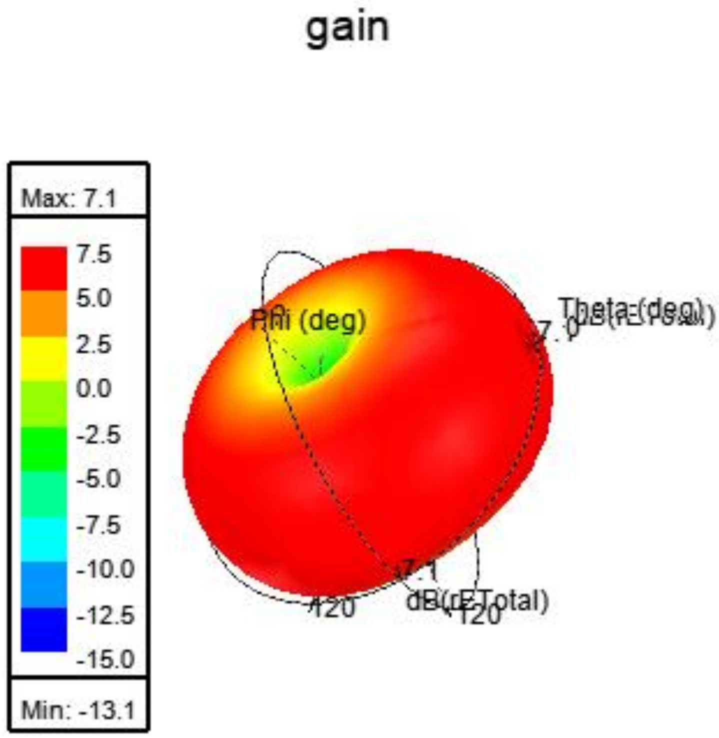


Figure:4.4. Radiation pattern obtained from HFSS (at 5.4 GHz)

Gain can also be given by,

Gain = Directivity × Efficiency

The maximum Gain is 7.5dB at 5.4GHz.

If the gain is higher, then in that particular direction the signal strength is higher.

CHAPTER 5

CONCLUSION:

The Fractal patch of the Hybrid Fractal Antenna is 1.6 mm above the ground, and it is on a FR4 epoxy substrate with a dielectric constant. The hybrid fractal antenna is inexpensive, small, and geometrically appropriate for wireless applications. Standards for wireless compatibility are satisfied by the antenna geometry. The suggested antenna achieves a gain of 7.5 dB and a return loss of 49.867 at the operating frequency of 5.4 GHz. According to the findings of the HFSS simulation. All results show that the antenna matches its impedance and radiation characteristics well at the necessary frequency.

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