

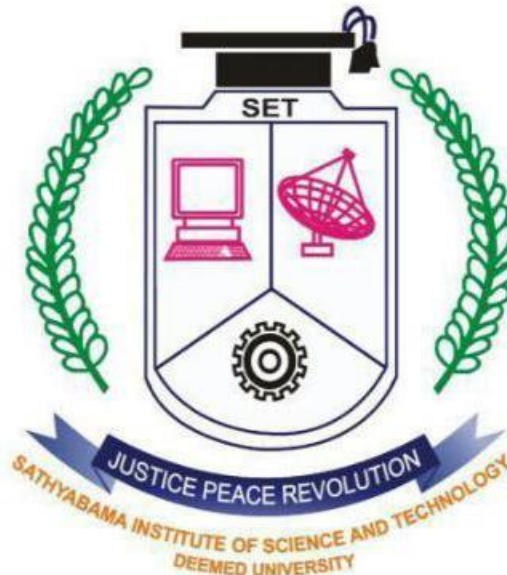
DESIGN AND ANALYSIS OF STACKED IMPEDANCE STRUCTURE OF MICROSTRIP PATCH ANTENNA FOR X-BAND APPLICATIONS

A Project Report Phase – II

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and Communication Engineering

by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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APRIL - 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of CHEERLA SYAMALA (39130089) and BONAGIRI CHANDRA LEKHA (39130078) who carried out the project entitled "DESIGN AND ANALYSIS OF STACKED IMPEDANCE STRUCTURE OF MICROSTRIP PATCH ANTENNA FOR X-BAND APPLICATIONS" under our supervision from November 2022 to April 2023.

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SIGNATURE OF THE CANDIDATES

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ABSTRACT

Like many forms of microstrip patches, the microstrip has received considerable attention. In this work, Stacked Impedance structure of Microstrip Patch Antenna for X- band Application is designed. The various antenna parameters such as return loss, VSWR, bandwidth, gain and directivity are analysed and measured using HFSS. The proposed antenna is designed using Taconic substrate and the simulated results are obtained. The antenna has a miniaturized structure for easy manufacture and is fed laterally by a feed strip line.

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CHAPTER-1

INTRODUCTION TO ANTENNAS

1.1 GENERAL INFORMATION

Now a days in wireless communication technology, Microstrip patch antennas are used by many researchers. Any wireless communication system's fundamental components, antennas serve as both transmitters and receivers of electromagnetic waves. The advantages of microstrip antennas are their low cost, compact design, simplicity in manufacturing, and potential for structural miniaturisation. They do, however, have several shortcomings, such as poor gain and bandwidth. Several studies have been conducted to enhance these sorts of antennas' performance for use in developing communication applications. Different strategies have been proposed in this respect, including the usage of slots and shortening ground planes, among others.

A portion of the electromagnetic spectrum's microwave radio sector is the X band. In communication engineering, the X band's frequency range is typically defined between 7.0 to 11.2 GHz without strict adherence to specific values. The IEEE defines the range of frequency for radar engineering as 8.0 to 12.0 GHz.. All of the frequencies in this spectrum are used by the US military, although only a few transmissions on each frequency. An X band low-noise block converter's usual local oscillator frequency is 6300 MHz's These two frequency ranges each have a 500 MHz width. The 8/7 GHz X band is a set of frequency bands widely used in satellite communication systems in engineering. In addition, a variety of radar systems, including continuous-wave, pulsed, single-polarization, dual-polarization, synthetic aperture radar, and phased arrays, use the X band. X band radar frequency sub-bands are commonly employed in civil, military, and governmental organizations for a range of applications, including weather monitoring and vehicle speed detection for law enforcement purposes.

1.2 TYPES OF ANTENNAS

Antennas come in a variety of varieties, here are the items that are listed:

1.2.1 On the Basis of Radiation:

- *Omni-directional antennas*: which broadcast and receive essentially in all directions, are also known as weakly directional antennas.
- *Directional antenna*: These devices, also called beam antennas, emit and receive energy in a certain direction. Directional antennas are designed to cover a specific area or optimize electromagnetic field coupling in the direction of the receiving station.

1.2.2 On the Basis of Aperture:

- *Wire Antennas*: This type of antennas are ubiquitous and may be seen on vehicles, structures, ships, aeroplanes, and more, the general public is familiar with these sorts of antennas.
- *Aperture Antennas*: The increasing demand for more sophisticated antenna designs and higher frequency usage has led to greater recognition of these antennas compared to their lesser-known past. Due to their simplicity of mounting aboard spacecraft and aeroplanes, they are more helpful in certain applications.
- *Microstrip Antennas*: Government, commercial, and space uses all employ these antennas. They are made up of a grounded substrate and a metallic patch. These antennas are mounted on the exterior of high-performance airpla.
- *Array Antennas*: When a single antenna cannot provide the necessary radiation characteristics, an array, or collection of radiating elements, is utilised. The positioning of the arrays should result in maximum radiation in one or more specific directions and minimal radiation in other directions when the radiation accumulates up.

1.2.3 On the Basis of Polarization:

- *Vertically polarised antenna*: This type of antenna is said to be linearly polarised if it transmits and receives in the vertical E direction. An antenna is

referred to as horizontally polarised if it is transmitting or receiving in the horizontal E direction.

- *Circularly polarised antenna*: An antenna is said to as circularly polarised if it can transmit and receive E field vectors in any direction. In today's wireless landscape, the primary requirement is for antennas to be as compact as possible. Therefore, microstrip antennas are the most favourable option among the available antenna structures when considering their application in WLAN.

1.3 ANTENNA PARAMETERS

1.3.1 Return Loss

When attaching an antenna, return loss is a crucial factor. It's used to explain how signal sources' input and output work. Impedance matching and the maximum transfer of power theory are strongly related to return loss. When there is a mismatch between the generator and the load, not all available power is transferred. The antenna's ability to transfer power from the source to the antenna is also determined by the return loss.

The return loss, or RL, displays the signal's intensity in relation to the incident signal in decibels. The power reflected back to the source antenna (P_{ref}) divided by the power incident on the antenna (P_{in}) is used to determine the return loss. The ratio of P_{in} to P_{ref} needs to be high for efficient power transfer. If the return loss is modest, standing wave phenomena or resonances may take place and lead to a gain or ripple in frequency. Microstrip patch antennas are constructed using the response of S_{11} versus frequency, which is known as the return loss. A return loss value of -10 dB is generally considered sufficient for most real-world circuits.

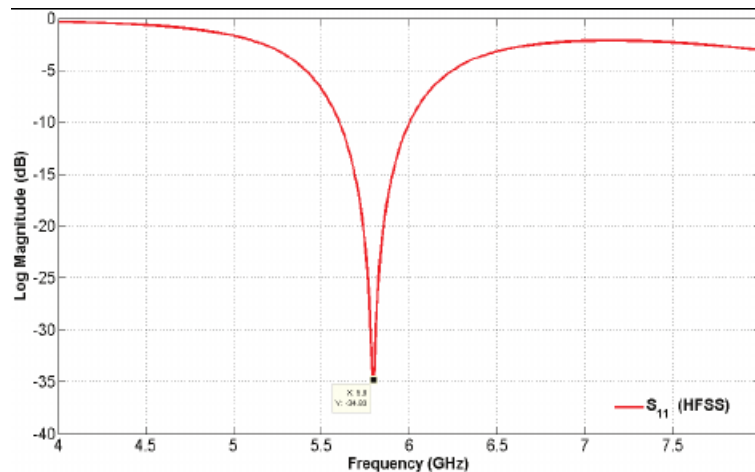


Fig: 1.1: Return loss plot

1.3.2 Voltage Standing Wave Ratio (VSWR)

Determines how effectively radio frequency (RF) power is transmitted from its source through a transmission line to an antenna.

- In an ideal system, all RF energy is transported across a "loss-less" line, but in practise, transmission flaws such mismatched impedance result in RF energy being reflected back to the source.
- This difference between the transmission line's highest and minimum voltage is expressed as VSWR.

VSWR ranges from a ratio of 1, which denotes a system with no interconnect impedance, to an extreme mismatch, where VSWR can be as high as. Antennae in communications systems are normally acceptable if their VSWR value is 2 or below.

The antenna receives more power and is more efficiently impedance-matched to the transmission line as the VSWR decreases. A reduced VSWR also lessens the antenna's reflections. An antenna operates best when the VSWR is less than 1.0, which is the minimal value at which no power is reflected.

1.3.3 Gain

The power gain of an antenna, which is a vital performance metric in electromagnetics, is the product of its directivity and electrical efficiency. The gain of a transmitting antenna represents its efficiency in converting input power into

radio waves traveling in a specific direction, whereas the gain of a receiving antenna determines its ability to convert radio waves from a specific direction into electrical power. If no direction is specified then "gain" refers to its maximum value. The radiation pattern illustrates the gain as a function of direction.

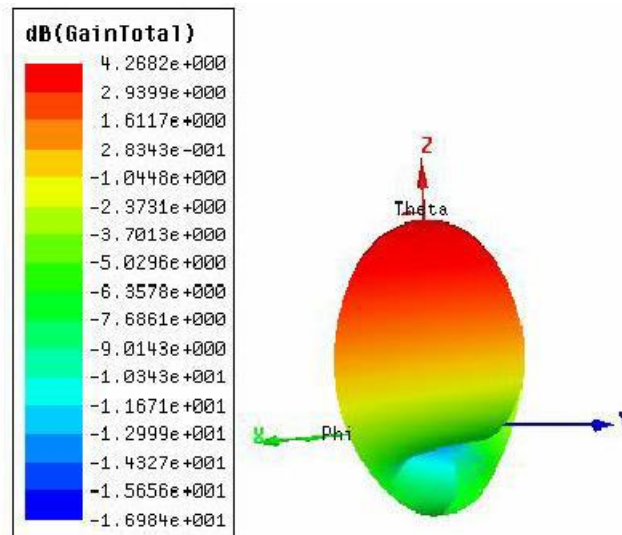


Fig:1.2: Gain plot

Gain and directivity are correlated, thus the Antenna Efficiency Factor is $G = kD$.

k or η : Antenna Efficiency Factor ($0 \leq k \leq 1$), dimensionless. For lossless antenna k or $\eta = 1$. Gain is never more than the directivity D in reality.

1.3.4 Directivity

Larger values indicate more focused beams whether expressing directivity as a regular number that represents the ratio or in dB. An antenna with a directivity of 1 (0 dB) would radiate equally well in all directions. Due to the absence of energy transmitted in the z-direction, the Hertzian dipole previously described has a directivity of 1.5 (1.76 dB).

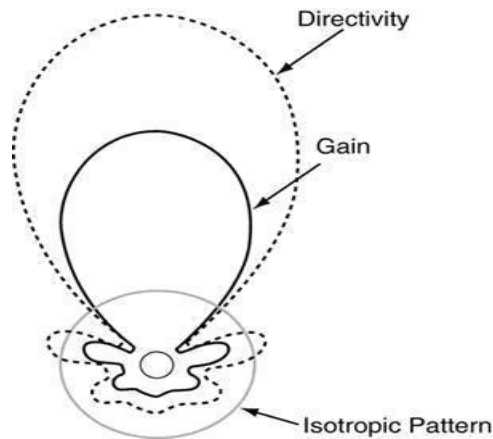


Fig:1.3: Directivity of an Antenna

Depending on their directivity, antennas can be utilised in a wide variety of applications, such as

- Information is transmitted and received from all directions almost equally by low-directivity antennas. Due to the changing direction between the transmitter and receiver in most mobile applications, such antennas prove to be useful.
- High-directivity antennas must be pointed at another antenna in order to send and receive information across longer distances. They are applied in long-term setups like satellite television.

1.3.5 Radiation Pattern

Antennas output or reception power is a function of its radial distance and angular location. A three-dimensional graph of power against elevation and azimuth angles is an excellent way to visualise the radiation pattern, however E-plane or H-plane diagrams, in which one angle is kept constant while the other is changed, are more frequently used. The term "radiation pattern" refers to a graphical representation of how an antenna radiation characteristics vary with spatial coordinates. The term "radiation pattern" describes the directionality of the radio wave intensity coming from the antenna.

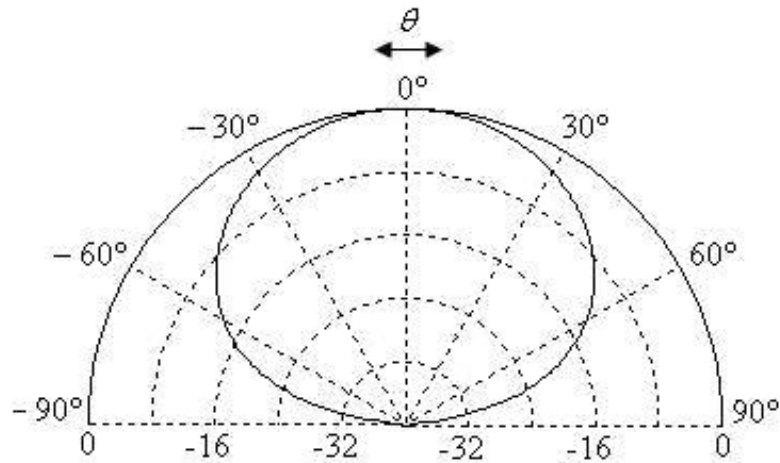


Fig:1.4: Radiation Pattern of Microstrip Antenna

Calculating the radiation pattern of microstrip patch antenna is straightforward, but accurate calculations rely on identifying the electric field radiation source at the gap between the edge of the microstrip element and the ground plane.

1.3.6 Impedance Matching

Impedance matching is the process of adjusting the impedance of a load (such as an antenna or a transmission line) to match the impedance of a source (such as a radio transmitter), in order to minimize signal reflection and maximize power transfer between the source and the load. The goal of impedance matching is to ensure that the maximum amount of power is delivered to the load and that the transmission line is operating at its maximum efficiency.

1.3.7 Efficiency

Antenna efficiency is a simple measurement of how effectively antenna converts its electrical power feed to it into electromagnetic radiation. It is defined as the ratio of the radiated power to the total input power, which includes both the radiated power and any power that is dissipated as heat or reflected back to the source. A perfectly efficient antenna would have an efficiency of 100%, meaning that all of the input power is converted into radiated power. However, in reality, no antenna can be perfectly efficient, and some amount of power is always lost due to various factors such as resistive losses, dielectric losses, and mismatch losses. Antenna efficiency is an important parameter to consider in antenna design, as higher efficiency leads to better signal strength, range, and overall performance of the antenna system.

1.3.8 Polarization

The polarisation of the wave that an antenna transmits or radiates is referred to as the antenna's polarisation. The antenna's polarisation will always follow the direction of the highest gain when the direction is not specified. A rectangular patch with traditional feeding is known to radiate linearly.

However, by making minor adjustments to the feeding methods or the patch itself, circular polarisation can be achieved. The primary benefit of employing circular polarisation is that it allows the receiver to always receive a signal from any direction of transmission.

1.4 MICROSTRIP PATCH ANTENNA

1.4.1 INTRODUCTION

Microstrip antennas, which are planar resonant cavities, emit and lose energy from their edges. Printed circuit techniques can be utilized to manufacture low-profile, cost-effective antennas by etching them onto flexible materials in a repeatable manner. The antennas made on compliant substrates endure extremely high levels of stress and vibration. Mobile communication base station manufacturers often use sheet metal to produce antennas and mount them on foam or dielectric posts in various ways as a cost-saving measure for substrates and etching. Additionally, this resolves the issue of surface wave radiation generated by a thick dielectric substrate used to enhance bandwidth.

A Microstrip patch antenna's most fundamental component is a dielectric substrate with a ground plane on bottom side and a radiating patch on top side. Constructed from conductive materials such as copper or gold, the patch can take on any shape. The dielectric substrate usually has the feed lines and radiating patch photo-etched onto it. Antenna arrays and their feeding networks can be photoetched onto the substrate. A variety of antennas are made available by microstrip circuits thanks to the use of straightforward photoetching processes.

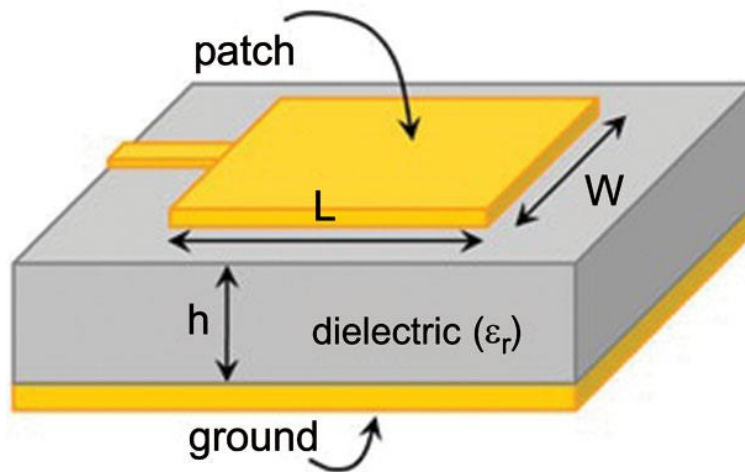


Fig: 1.5: Microstrip patch antenna

Figure 1.6 illustrates various common shapes of the patch, such as square, rectangular, circular, triangular, and elliptical, which aid in analysing and predicting its performance

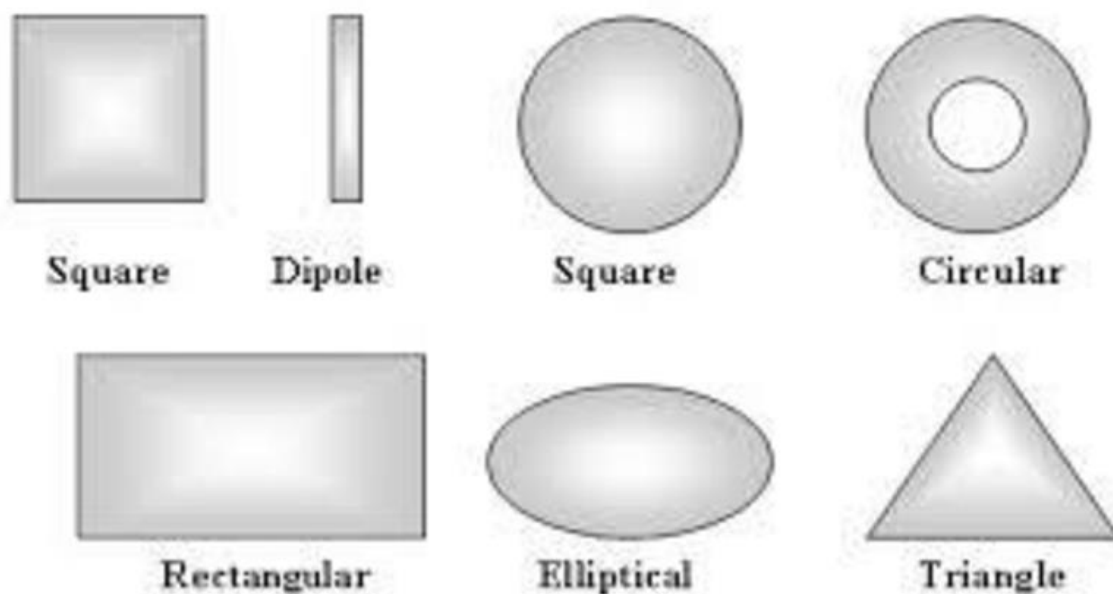


Fig: 1.6: Types of patch designs

Fringing fields around the edges of a patch antenna cause it to radiate. Matching the impedance of the patch to create resonance within the cavity leads to peak efficiency. In contrast, normal transmission lines have low power radiation due to counteracting fringing fields. Radiation occurs at open circuits and corners, but the

amount is dependent on the radiation conductance load relative to the patches. If there is no proper matching, there will be little power radiation. The edges of the patch are seen as slots that rely on the cavity's internal fields for excitation. To analyse an arbitrarily shaped patch, it can be considered as a resonant cavity with metal (electric) walls and a ground plane, and magnetic or impedance walls around the edges.

In order to obtain the best possible performance from an antenna, it is recommended to utilize a thick dielectric substrate with a low dielectric constant, as it leads to enhanced radiation, greater bandwidth, and increased efficiency. Nevertheless, this approach results in a larger antenna size. For the purpose of designing a more compact Microstrip patch antenna, higher dielectric constants can be utilized, but this comes at the expense of efficiency and a narrower bandwidth. Hence, it is necessary to strike a balance between the size and the performance of the antenna.

1.4.2 APPLICATIONS OF MICROSTRIP PATCH ANTENNA

1.4.3 ADVANTAGES OF MICROSTRIP ANTENNA

Following are some of the main benefits of microstrip patch antennas:

- Low volume and light weight.
- A planar structure with a low profile that is simple to adapt to the host surface.
- Can be produced in big quantities due to low manufacturing costs.
- Allows for both circular and linear polarisation.
- MICs (microwave integrated circuits) may be integrated with ease.
- Able to operate on two and three frequencies.
- Mechanical construction when attached to solid surfaces.

1.4.4 DISADVANTAGES OF MICROSTRIP ANTENNA

Following are some of their main disadvantages of microstrip antenna:

- Limited bandwidth
- Ineffective
- Small Gain

- Radiation from feeds and connections that is unnecessary
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

Antenna quality factor (Q) of microstrip patch antennas is extremely high. A big Q results in a limited band width and poor efficiency since Q stands for the antenna's losses. Q can be decreased by increasing the dielectric substrate's thickness. However, when the thickness rises, a growing portion of the source's overall power is absorbed by the surface wave. Finally scatters at the dielectric bends and degrades the antenna properties, it might be considered an undesired power loss. However, by using a photonic bandgap structure, surface waves can be reduced. By employing an array arrangement for the elements, further issues like poor gain and limited power handling capacity may be resolved.

CHAPTER-2

LITERATURE SURVEY

2.1 INFERENCES FROM LITERATURE SURVEY

Based on earlier research on microstrip antennas, this part discusses the literature review on microstrip patch antennas. According to the study, The microstrip patch antenna presents several discernible benefits such as being lightweight, low-cost, having a low profile, a planar, easy conformability, superior portability, suitability for arrays, easy fabrication, and seamless integration with external circuitries, among other advantages. These qualities make it an unequivocal choice. Although the standard microstrip antennas offer numerous benefits, they also have three main drawbacks: a limited bandwidth, poor gain, and a relatively large size. These drawbacks frequently have a negative effect on the antenna efficiency.

One of these antennas' primary limitations is their limited bandwidth. The most direct way to increase bandwidth is to thicken the substrate, but this has the major drawback of decreasing efficiency because a large portion of the input power is lost in the resistor, which reduces the amount of power left for the antenna to radiate. Additionally, lowering the height of the structure can seem like a good idea, but it might result in a smaller impedance bandwidth and worse radiation efficiency. Realising small antennas while keeping performance attributes sometimes involves a trade-off. For microstrip antennas, the bandwidth is most optimal with low dielectric constant substrates since some of the total power available for direct radiation gets confined along the substrate surface. To overcome this limitation, several improved techniques are employed to provide wide-impedance bandwidths, such as utilizing high permittivity dielectric resonators for microstrip patch antennas. The radiation efficiency and bandwidth are increased in comparison to this single-pin-shortened three-dielectric layer substrate without losing the price and operational benefits. Due to its special features, another use of electromagnetic band gap (EBG) structures has received a lot of interest recently in the microwave world. These structures, which are periodic in nature and have a band gap that prevents all electromagnetic surface waves from propagating within, are very useful for applications involving high frequencies like mm wave, sub-mm wave, terahertz (THz) wave, and optical

waves. It is also generally known as an antenna array is a useful tool for increasing gain.

Mainly reduction in size of traditional microstrip antennas, especially at lower microwave frequencies, is the final limitation imposed by the correlation between operating frequencies and antenna electrical size. Other than typical guiding and/or filtering structures, the size behaviour of electromagnetic waves. The dual array patch antenna's feed line can be successfully etched with dummy Electromagnetic Band Gap (EBG) patterns. These fake EBG patterns are condensed, tiny in size, and have a considerable gain in bandwidth (a bandwidth increases of 48.8%). Impedance matching avoids the necessity for an impedance matching circuit, preserving the radiation characteristics. Additionally, the application of IM techniques is independent from the selection of the patch substrate. In a similar vein, Ultra-Wide Band (UWB) may be attained by including L, U, T, and inverted T slots onto microstrip antennas. Popular omnidirectional microwave antennas have slots.

Rectangular microstrip patch radiates loaded with an active negative capacitor and composite-resonator microstrip antennas employing metamaterial resonators that offer high gain and broad bandwidth may be used to add negative capacitor/inductor. Another issue that has to be resolved is the standard microstrip antenna element's poor gain. "Topology optimization" is a commonly used term to refer to design optimization methods that allow for the manipulation of both the shapes and connections of individual components within a device. Examples of array topologies include twin patch antenna arrays.

The material distribution strategy, in which the design domain is broken into tiny parts that together constitute a picture of the device, is the most used method for doing topology optimisation. The bidirectional radiation pattern has been eliminated using the cavity backing approach, which results in a better gain than a traditional microstrip antenna. An alternate method of gain augmentation is lens covering. The radiation beam from the radiator elements can be focused using lenses having a conventional profile, such as hemi-elliptical, elliptical, hyper-hemispherical, and extended hemispherical lenses. By integrating microstrip radiator components with a dielectric lens, the integrated microstrip lens antenna may be used as a composite

antenna. The rectangular antenna (RMSPA) should have a wavelength of around a half-guided wavelength. Wheeler and Chu mathematically investigated this restriction.

One of the efficient methods for reducing the size of microstrip antennas is inductive or capacitive loading. By employing composite metamaterial resonators, microstrip antenna size may be reduced. Due to the fact that magnetic substrates may offer broader bandwidths than dielectric substrates, substrates have been frequently used to miniaturise antennas. Fractal geometries (topologies), which are made up of self-similar patterns, have made it possible to miniaturise antennas in new ways.

From the comments above, it is clear that a variety of techniques and materials are employed to enhance the capabilities of antennas. However, there should be some correlation between the microstrip antennas' bandwidth, gain, and size. Improvement in one antenna feature is typically followed by a reduction in the performance of its other properties, according to the prior study. The earlier study recognised that if their other property performances regularly fall along with an improvement in one antenna property.

For instance, when an antenna's size is decreased, its gain and bandwidth are typically sacrificed. Therefore, consideration for future advancements of microstrip antennas must be more thorough and suitable.

This paper was published in the year 2018 by Hal Appa R. Gajera at University of Mysore Hassan. The study suggests a design for a dual-band microstrip patch antenna, which incorporates a circular top conducting layer and is suitable for X-band applications. The suggested micro strip patch antenna and conventional patch antenna have both been designed for 10GHz. The circular superconducting layer antenna proposed exhibits dual-band resonance at frequencies of 9.39 GHz and 11.65 GHz, whereas the conventional antenna has a single-band resonance at 9.88 GHz. Additionally, the suggested antenna offers strong gains of 6.10 dB and 7.11 dB.

The title of the paper published in 2019 by Md. Abdur Rahman Chowdhury at International Islamic University Chittagong. For X-band satellite applications, a small In this study, an E-shaped microstrip patch antenna with high gain has been proposed and designed. A 50-centimeter microstrip line feed is used to feed the

antenna, and the structural design and modeling are carried out using the CST Microwave Studio simulation program. The proposed antenna has a ground plane of dimensions 17.485 mm by 15.297 mm, and the patch measures 7.885 mm by 6.597 mm, with a thickness of 1.67 mm. Multiple dielectric substrates technology is utilized to enhance the antenna's gain. The proposed antenna exhibits a resonance frequency of 9.792 GHz, a high gain of 6.01 dB, and strong directivity of 6.78 dB, with a low return loss of -18.44 dB. Its operational bandwidth is around 610 MHz, ranging from 9.49 GHz to 10.1 GHz, and the antenna has a small surface area. Its straightforward design and low profile make it ideal for easy construction, and it is suitable for X-band satellite applications, including military, weather monitoring, and single and dual polarization.

A Penta band microstrip patch antenna has been created by Praveen Kumar Chakravarty for 2021. The prototype features many rectangular patches that are organised in a way that appears to have a U-shaped slot between them. The following antenna has a volume of $30 \times 38 \times 0.8 \text{ mm}^3$ and the ground size is kept constant with the substrate's base measurements. These bands are covered by the C and X band applications offered by the IEEE. The importance of the proposed antenna is that its straightforward, small form may be used for a variety of purposes, including space communication, keyless entry systems, and terrestrial communication. The study conducted for the design leads to the conclusion that the more erratic the design, the more radiations will travel through it. Additionally, if a design contains several rectangular patches, it creates multi-band characteristics.

This paper was published in the year 2021 by Puli mi Swetha at K. S. R. M. College of Engineering. This essay is an example of Line feed for microstrip Ansys High Frequency Structure Simulator, a simulation programme, was used to create RMSA. In order to facilitate dual band operation and increase bandwidth for X-band applications, it includes an H-shaped slot with an inner ring. The simulated results show how well the antenna performs in terms of the S11 parameter. The proposed design has a maximum gain of 8.62 dB, a low return loss, and a large bandwidth in the desired frequency range. It resonates at 9.36 and 11.31 gigahertz. The design of the suggested antenna takes into account SWR, return loss, directivity, gain, radiation pattern, and bandwidth.

In this article Mukesh Kumar at SKIT Jaipur in 2021 examined This study proposes the design of a circular-shaped microstrip patch antenna suitable for X-band and Ku-band applications. The antenna utilizes an FR4 dielectric substrate that is 1.56 mm thick and has a dielectric constant of 4.4. The coplanar patch antenna measures 40 mm by 40 mm, with the ground plane and patch being parallel to each other. The antenna exhibits resonance at two frequencies, namely 9.8 GHz and 13 GHz, corresponding to the Ku-band and X-band, respectively. At these frequencies, the return losses are approximately -32 dB and -34 dB, respectively, with gains of 6 dB that increase with frequency. The proposed antenna is developed, optimized, and evaluated using the CST Simulator, with the radiation pattern curves for the dual-band frequencies being presented.

Md. Samsuzzaman of Patuakhali Science and Technology University wrote this article in 2017. The construction of a small tuning fork shaped microstrip patch antenna for radar and satellite applications. Modelled for use in X band communications, the antenna that is being offered. The antenna is made up of an N-shape element and a patch with the form of a tuning fork. The prototype's antenna is 24 mm x 18 mm in size and is made of Rogers RT/druid 5880 materials that are 1.57 mm thick. The substrate has a dielectric constant of 0.0009 and a relative permittivity of 2.2. A 50 microstrip line provides the excitation. HFSS software has been used to model and examine the results of the given antenna. The results shows it has 10 dB return loss and covers the X-band frequency range of 8.0 to 11.10 GHz. The antenna is capable of being used for satellite and radar applications in the X-band because to its 5.28 dB average gain and steady emission patterns across the operational spectrum.

Good antenna performance with a range of applications is required by current microwave communication systems. To cut down on resource and installation costs, one antenna should replace the need for several others. The idea of a multiband antenna develops as a result. The design of a dual band antenna has received attention in this work This study proposes an improved dual-band operation in the C-band and X-band using a modified E-shaped small probe-feed microstrip antenna, which offers enhanced bandwidth and outperforms previous dual-band designs in terms of return loss, VSWR, and gain. The simulation and analysis are carried out using HFSS 13.0, which reveals two resonant frequencies of 4.8 GHz

and 6 GHz in the C-band and 9.2 GHz in the X-band, making it superior to earlier studies, despite being designed for dual-band operation. The performance of the multilayer E-shaped antenna is affected by the shape of the conducting patch, the location and dimensions of the layers, and the location and dimensions of the probe feed. The antenna operates at 4 GHz and provides a 7 dB gain increase.

This paper was published in the year 2017 by Amite Desai at Goa College of Engineering. In this research, a pentagon shape of microstrip patch antenna operating at 7.5 GHz is introduced. The antenna has a return loss of -43.48 dB, gain of 3.498 dB, and directivity of 6.8627 dB. To improve the antenna's gain and directivity, a 1x2 and 1x4 array of the standard patch antenna is created. Furthermore, a dual-band antenna operating in C band and X is designed using the Durer pentagon fractal geometry and varactor diodes. This dual-band antenna is suitable for satellite communication and RADAR applications in defence and secure communication. The IE3D EM simulator is used antenna's performance in terms of return loss, impedance bandwidth, gain, and directivity.

This paper was published in the year 2018 by KM Jyoti Singh at MMMUT Gorakhpur. This study is to examine a circular microstrip antenna featuring single band characteristics for various applications, including Bluetooth Microstrip, Wi-Fi, Ultra-wideband, and X-band. The antenna design incorporates circular slots, crescent-shaped slots, and L-shaped slots in the circular radiation patch, as well as two I-shaped defects in the ground plane, which is truncated at its upper corners. Impedance bandwidth ranges from 2.35 to 12.9 GHz, with the exception of the frequency in the 2.9 to 3.8 GHz single-notch bands. Compact in size, the suggested antenna measures 32mm by 36mm by 1.6mm. With the exception of the single band rejection, VSWR 2 for the whole operating frequency spectrum. By running the simulation.

In this research, an annular ring-shaped Microstrip patch antenna that is further manufactured using the stacking process is designed and studied. It was our idea for the S band at 2-4 GHz. Instead of a straightforward conventional ground structure, the DGS (faulty Ground Structure) suggests a faulty ground structure. The developed design is successful in producing a discrete return loss. We

manufactured the prototype using FR4 epoxy and stacked it while simulating it on HFSS. The suggested antenna successfully attained a 165 MHz bandwidth.

This paper was published in the year 2020 by s jayasri at galgotias university. In order to obtain a broad bandwidth and high gain, this work uses a Broadband Stacked Microstrip Patch Antenna construction with a microstrip feeding approach. The suggested stacking antenna operates in the C band frequency range of 4GHz to 10GHz. The influence of inter-element distance on antenna performance (directivity, input impedance, and radiation efficiency) is investigated using a parametric approach. The obtained findings demonstrate that large directivities may be attained over short distances in the case of the completely driven element. The typical Ku Band for satellite communication is known to work worse in bad weather than the C Band. The HFSS Tool is used to assess the antenna's parameters.

2.2 EXISTING METHODOLOGY:

A partly reflecting surface (PRS)-based high-gain polarised X-band antenna design has been proposed. The initial investigation on the antenna focused on analyzing how the size of the parasitic elements within the structure affects the antenna's radiation pattern parameters. Subsequently, the most optimal arrangement of these elements was identified. The suggested antenna offers circular polarisation in the frequency range 8-9 GHz and a broad bandwidth with return loss above 10 dB of 20%. The resulting design is lightweight (29.7 g) and small (62 62 22.2 mm), making it appropriate for usage in CubeSat X-band communication systems as well as applications for drones and high-altitude pseudo-satellites (HAPS).

2.2.1 Drawback of Existing Methodology:

- It's designed in superstrate substrate, so the cost of the antenna is very high.
- Less impedance matching
- Due to superstrate the absorption and reflection loss of the antenna is very high.
- Due to high loss, efficiency of the antenna also low.

2.2.2 Problem Statement:

- High frequency access couldn't meet the characteristics impedance.

- Due to impedance mismatch, heavy backlogs produced it led to huge transmission loss.
- Due to heavy transmission loss, the generated power of the antenna also, so the coverage area minimised.

CHAPTER-3

AIM AND SCOPE

3.1 AIM

To design the Stacked impedance structure of microstrip patch antenna with a small size having less return loss and with more gain and directivity for X-band applications.

3.2 OBJECTIVE:

This work's goal is to replicate, create, and verify the performance of stacked impedance structure of microstrip patch antenna for X-band applications. The actions listed below will help you reach this objective:

- Mathematical calculations of the length and width of patch and ground , Microstrip feed line, copper thickness, and Effective Dielectric Constant of Microstrip Patch Antenna.
- Simulation of stacked impedance structure of antenna for X-band applications using HFSS simulation software.
- Analysis of the VSWR, return loss, gain, bandwidth, radiation pattern, current distribution, input impedance, and other properties of the rectangular microstrip patch antenna.
- Creation of a rectangular Microstrip patch antenna for the operating frequency and parameter analysis.

verification of the simulation's findings using the constructed Microstrip patch antenna.

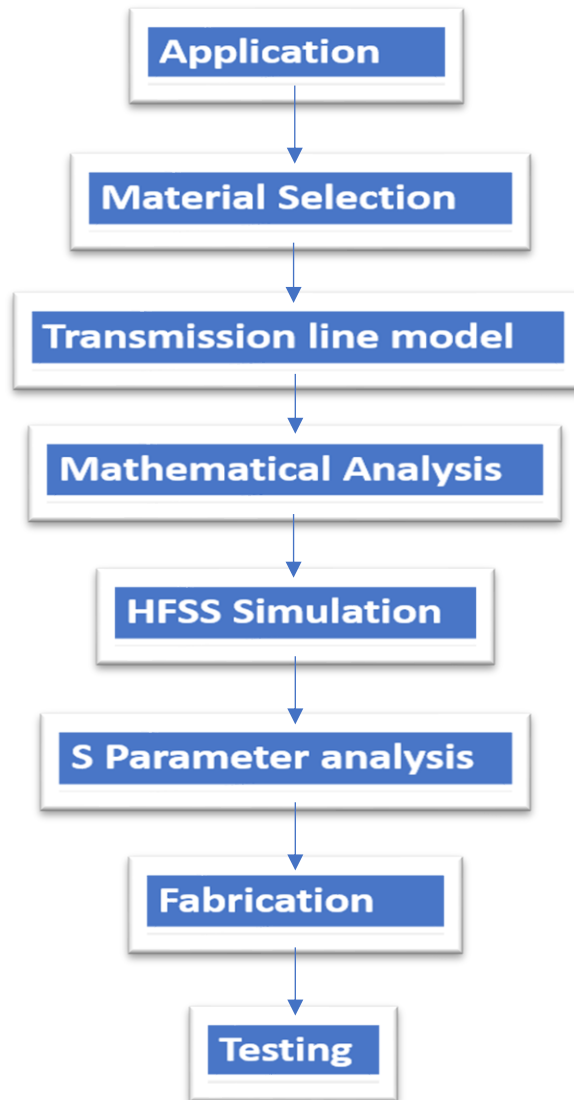
3.3 SCOPE OF THE DESIGN

The main scope is to design an antenna with different and unique patch structure along with a good result in return loss, gain, directivity and efficiency parameters.

CHAPTER-4

DESCRIPTION OF PROPOSED ANTENNA

4.1 DESIGN FLOW CHART



4.1.1 Application

- ❖ The operating frequency of an antenna is the frequency at which it is designed to operate efficiently. The choice of operating frequency is critical in determining the antenna's performance in terms of its radiation pattern, impedance matching, and bandwidth.

- ❖ Here operating frequency describes about what area of application that antenna is designing. operating frequency of proposed antenna is 9.5 GHz. Which comes under x band frequency range. X-band frequency is a segment of the electromagnetic spectrum that ranges from 8.0 to 12.0 gigahertz (GHz).
- ❖ Some applications that the proposed antenna works like Military radar systems, Satellite communication, weather radar, Wireless communication, medical applications.

4.1.2 Material Selection

- ❖ The substrate material is important part in determining the performance of an antenna. It is important because it affects the electrical properties of the antenna, such as its impedance, bandwidth, radiation efficiency, and pattern.
- ❖ Substrate material that going to use in the proposed antenna is Taconic which as relative permittivity 2.2. which as a wide advantage of using it as a substrate material in antenna designing like High dielectric constant, Low Loss Tangent, Stable Dielectric Properties, Consistency, Compatibility with High-Frequency Applications.

4.1.3 Transmission Line Model

- ❖ The transmission line model is a mathematical model used to analyse the behaviour of electromagnetic waves propagating along a transmission line. In the context of antennas, it is used to analyse the performance of the antenna's feedline, taking into account physical properties such as length, impedance, and dielectric constant. The model provides insight into the voltage and current distributions along the feedline, and can be used to optimize its design for optimal antenna performance, particularly at high frequencies.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

- ❖ Where, ϵ_{eff} = Effective dielectric Constant

ϵ_r = Dielectric Constant of substrate

h = Height of the dielectric substrate

w = Width of the patch

4.1.4 Mathematical Analysis

1. wavelength

$$\lambda = c / f$$

2. Width

$$w = \frac{\lambda}{2} \sqrt{\frac{2}{\epsilon_r + 1}} \text{ mm}$$

3. Fringing Effect

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}}$$

4. Length:

$$L = L_{eff} - 2\Delta L$$

5. Thickness:

$$h = \frac{0.0606\lambda}{\epsilon_{reff}} \text{ mm}$$

6. Ground and Substrate Dimensions:

$$L_g = L + 6h \text{ mm}$$

$$W_g = W + 6h \text{ mm}$$

7. Feed:

$$L_f = \frac{\lambda_g}{4}$$

$$W_f = L_f/2$$

4.1.5 HFSS Simulation

- ❖ HFSS (High-Frequency Structure Simulator) is a powerful electromagnetic simulation software widely used for designing and analysing various electromagnetic structures, including antennas.
- ❖ With HFSS, users can model complex 3D geometries, simulate electromagnetic fields and analyse antenna performance. The software is capable of simulating a wide range of frequencies, from radio frequency (RF) to microwave and millimetre-wave frequencies.
- ❖ The proposed antenna is designed using the HFSS software.

4.1.6 Parameter Analysis

- ❖ After designing a simulation, it's important to analyse the parameters used by identifying key parameters, setting reasonable ranges, checking for dependencies, running sensitivity analyses, and verifying results. This ensures that the simulation accurately represents the scenario being modelled and the results are reliable.
- ❖ Many parameters are analysed after completion of simulation design like Return loss, VSWR, Gain, Directivity, Radiation Pattern, etc.

4.1.7: Fabrication

4.1.7.1 Top View

Semi triangled 2x1 array antenna with U-shape patch structure is placed on the top of the substrate.

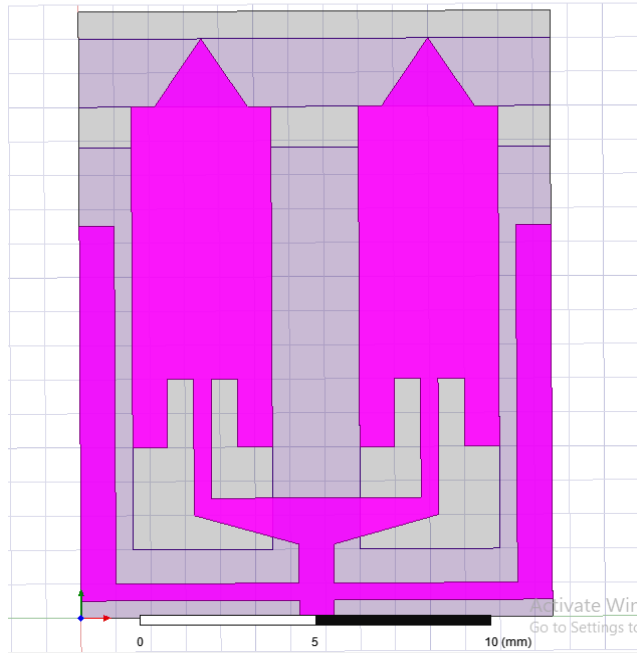


Fig: 4.1: top view of the antenna

4.1.7.2 Bottom View

E&I shaped ground structure placed at bottom of the substrate.

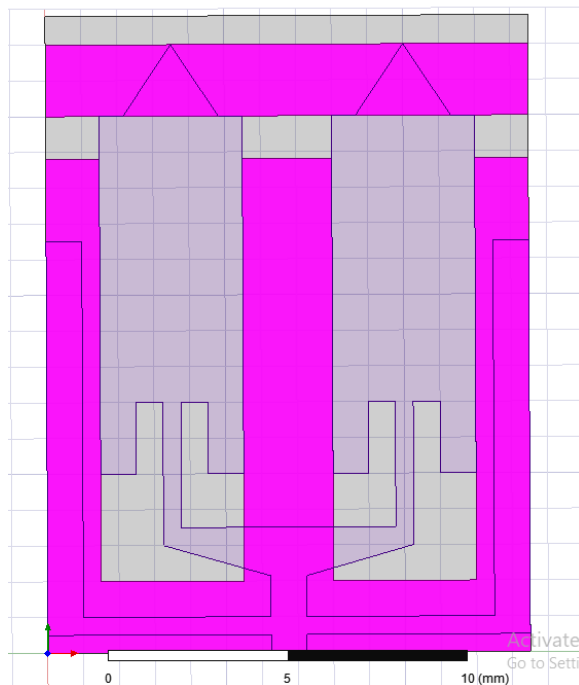


Fig: 4.2: Bottom view of the antenna

4.1.8 Testing

- ❖ Testing the fabricated antenna in its operating frequency and compare the simulation results with testing results.

4.2 DESIGN CALCULATIONS

The project's software component focused on determining the radiation pattern and return loss curve of a number of straightforward rectangular patch antennas. The main variables for building a rectangular microstrip patch antenna are:

- ❖ Frequency (f): The antenna's resonance frequency has to be properly chosen.
- ❖ Substratum dielectric constant (r): An antenna's size is constrained by a substrate with a high dielectric constant.
- ❖ Height of the substrate (h): The antenna must not be bulky in order to be employed in some applications (such as mobile phones). To achieve this, the height of the substrate must not be greater than a few millimetres.

This patch is intended for satellite links and wireless communication and 9.5 GHz was chosen as the device's operating frequency as a result. Its specifications include

4.2.1 Patch Calculations:

$$C=3 \times 10^8 \text{ mm/s}$$

$$h = 1 \text{ mm}$$

$$f = 9.5 \text{ GHz}$$

$$C = \text{Velocity of light}$$

$$f = \text{Frequency in GHz}$$

$$h = \text{Thickness of material}$$

$$r = \text{Dielectric constant of material (Taconic)}$$

$$\text{where } r = 2.2$$

$$f = c/\lambda \quad (4.1)$$

$$\lambda = 31.57 \text{ mm}$$

$$w = \frac{\lambda}{2} \sqrt{\frac{2}{\epsilon_r + 1}} \text{ mm} \quad (4.2)$$

$$w=12.47 \text{ mm}$$

ϵ_{reff} =Effective Dielectric Constant

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \quad (4.3)$$

$$\epsilon_{reff}=1.428$$

ΔL = Normalized extension in length

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (4.4)$$

$$\Delta L= 0.5839 \text{ mm}$$

L_{eff} = Effective length

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}} \quad (4.5)$$

$$L_{eff}= 13.209 \text{ mm}$$

$$L = L_{eff} - 2\Delta L \quad (4.6)$$

$$L=12.0412 \text{ mm}$$

The transmission line model's equations and the aforementioned parameters allow us to derive

$$\text{Length of the patch}=12.0412 \text{ mm}$$

$$\text{Width of the patch}=12.47 \text{ mm}$$

Substrate Calculation:

$$h = \frac{0.0606\lambda}{\epsilon_{reff}} \text{ mm} \quad (4.7)$$

$$h=1.289 \text{ mm}$$

$$L_g = L + 6h \quad (4.8)$$

$$L_g=18.04 \text{ mm}$$

$$W_g=W+6h \quad (4.9)$$

$$W_g=18.47 \text{ mm}$$

The substrate calculations values are given as

Length of the substrate=18.04 mm

Width of the substrate=18.47 mm

4.2.2 Feed Line Calculation:

$$\lambda_g = \frac{\lambda}{\sqrt{\epsilon_{reff}}} \quad (4.10)$$

$$L_f = \frac{\lambda_g}{4} \quad (4.11)$$

$$L_f=6.603 \text{ mm}$$

$$W_f = L_f/2 \quad (4.12)$$

$$W_f=3.3 \text{ mm}$$

Length of the feed line=6.603 mm

Width of the feed line=3.3 mm

Table 4.1: Design Specifications

Sl. No	Description	Symbol	Unit
1	Patch length	L_p	12 mm
2	Patch width	W_p	8 mm
3	Ground length	L_g	17 mm
4	Ground width	W_g	14.5 mm
5	Feed line length	L_f	2 mm
6	Feed line Width	W_f	1 mm
7	Substrate height	H	1 mm
8	Substrate length	L	17.8 mm
9	Substrate width	W	14.5 mm
10	Substrate material	Taconic	
11	Resonant Frequency	9.5 GHz	
12	Relative permittivity	ϵ_r	2.2

4.3 SIMULATION SOFTWARE

A sophisticated electromagnetic modelling programme called HFSS (High-Frequency Structure Simulator) is frequently used for developing and accessing different electromagnetic structures, including antennas.

With HFSS, users can model complex 3D geometries, simulate electromagnetic fields and analyse antenna performance. The software is capable of simulating a wide range of frequencies, from radio frequency (RF) to microwave and millimetre-wave frequencies.

HFSS offers a variety of tools and features for antenna design, such as parameterization, optimization, and tuning capabilities. It can also simulate the performance of antenna arrays, including beamforming and radiation pattern analysis HFSS a versatile tool for antenna designers, providing accurate simulations and extensive analysis capabilities to help optimize antenna designs for various applications.

Designing an antenna in HFSS generally involves the following steps:

1. Create a new project: Open HFSS software and create a new project. Set up the units, frequency range, and other project parameters as required.
2. Create the antenna geometry: Draw the antenna geometry in the HFSS 3D modeler using standard modelling tools such as lines, arcs, and shapes. It is important to ensure the model is properly scaled and positioned with respect to the simulation environment.
3. Define the antenna properties: Assign the material properties, boundary conditions, and excitation sources to the antenna model. This includes defining the type and location of the feed port, and setting the excitation parameters such as frequency, polarization, and power.
4. Set up the simulation: Define the simulation settings such as the frequency range, meshing options, and solver settings.
5. Analyse the results: Once the simulation is complete, analyse the results using the post-processing tools in HFSS. This includes Visualising the radiation pattern, gain, impedance, and other crucial antenna properties. The outcomes can be utilised to improve the antenna's functionality and design.
6. Optimize the design: If necessary, use the optimization tools in HFSS to refine the antenna design and improve its performance. This involves defining the optimization parameters, running the optimization process, and evaluating the results.

4.4 ANTENNA FABRICATION

The photolithographic method is used to create the antennas. This is a chemical etching procedure that removes the metallic layer's undesirable metal areas in order to produce the desired pattern. The type of substrate utilised depends on whether the antenna is biplanar, uniplanar, dual-sided, or single-sided. The most crucial step in antenna design is choosing the right substrate material.

4.5 CHARACTERISTICS OF SUBSTRATE MATERIAL

Taconnic is a brand name for a type of substrate material that is commonly used in antenna fabrication. Some of the key characteristics of Taconnic substrate material include:

1. High dielectric constant: The dielectric constant of Taconic substrate material is high, usually between 3.0 and 3.5. This means that it can store more electric charge per unit volume, which can help to improve the efficiency of an antenna.
2. Low loss tangent: Taconic substrate material has a low loss tangent, typically in the range of 0.001 to 0.003. This means that it can transmit signals with minimal loss of energy, which can help to improve the performance of an antenna.
3. Stable and consistent: Taconic substrate material is known for its stability and consistency, which makes it a reliable choice for antenna fabrication. It is resistant to changes in temperature and humidity, and it has consistent electrical properties from batch to batch.
4. Good mechanical properties: Taconic substrate material is strong, durable, and easy to work with. It can be easily cut, drilled, and shaped to create custom antenna designs.
5. Availability: Taconic substrate material is widely available from a variety of suppliers, which makes it easy to source for antenna fabrication projects. It is also available in a range of thicknesses and sizes to meet the needs of different antenna designs.

Taconic substrate material is a popular choice for antenna fabrication due to its high dielectric constant, low loss tangent, stability, consistency, good mechanical properties, and availability.

CHAPTER-5

RESULTS AND DISCUSSION

5.1 SIMULATION RESULTS OF THE DESIGNED ANTENNA

5.1.1 Return loss:

The ability of an antenna to transfer power from a transmitter to a receiver is gauged by its return loss. It is described as the ratio of the strength of the signal that is reflected back to the transmitter to the strength of the signal supplied to the antenna.

A greater return loss value suggests better performance. Return loss is commonly given in decibels (dB). While a return loss of infinite dB indicates that all of the power is sent without any reflection, a return loss of 0 dB indicates that all of the power delivered to the antenna is reflected back. It aids in evaluating the communication link's quality and the antenna's effectiveness.

According to the figure, the antenna has a better return loss at frequency 12.47, 17, 20.8, 23.42, and 35.57 with return loss of -17.41, -22.34, -28.9, -28.58 and -14.24 respectively.

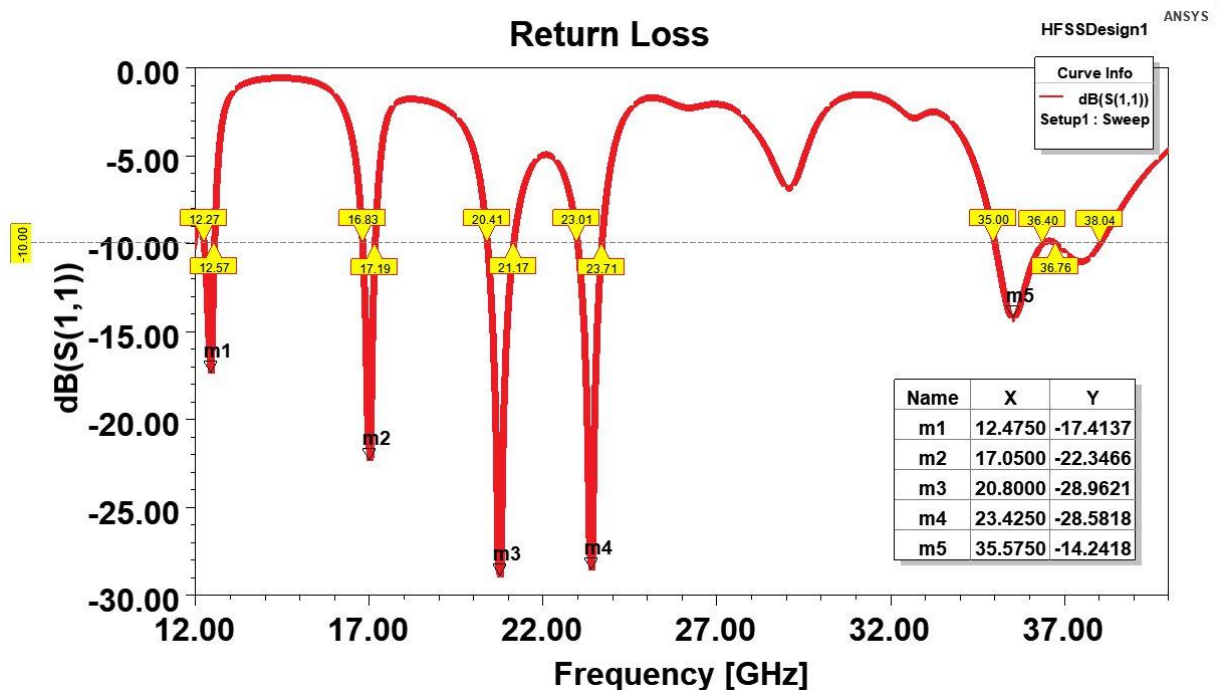


Fig: 5.1: Return loss

5.1.2 VSWR

VSWR is a measure that describes how effectively an antenna transmits and receives radio frequency (RF) energy. In antenna simulation, VSWR is typically one of the key performance metrics used to evaluate the effectiveness of an antenna design. VSWR result of an antenna simulation is typically expressed as a ratio of the maximum voltage to the minimum voltage on the transmission line connected to the antenna. A VSWR of 1:1 indicates perfect matching, which means that all of the RF energy generated by the transmitter is effectively delivered to the antenna and none of it is reflected back. In practice, it is difficult to achieve a perfect match, and VSWR values of 1.5:1 or less are generally considered to be acceptable. Higher VSWR ratios indicate greater levels of impedance mismatch, which can result in a portion of the RF energy being reflected back towards the transmitter instead of being radiated by the antenna. This can lead to reduced performance, lower signal strength, and potential damage to the transmitter. Therefore, a good antenna design will strive to minimize VSWR and achieve as close to a 1:1 ratio as possible.

It can be seen from the figure that the antenna has a lower VSWR value.

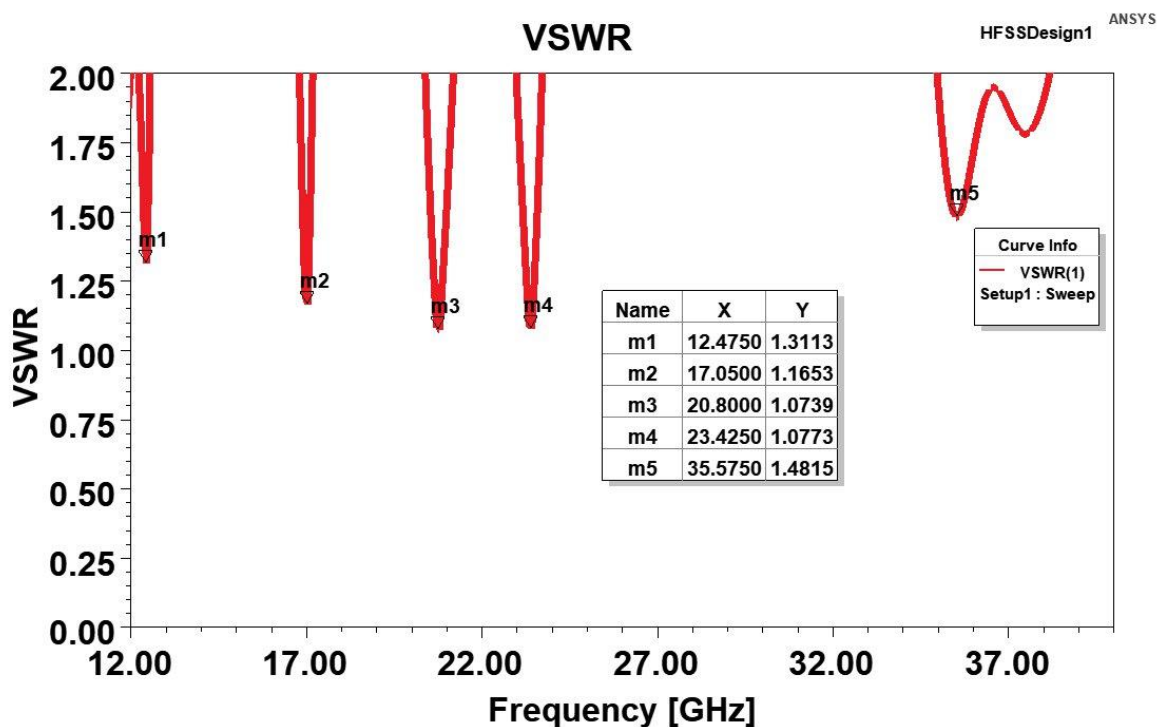


Fig: 5.2: VSWR plot

5.1.3 Gain

Antenna gain is the term used to describe the power transferred towards the peak radiation direction relative to that of an isotropic source.

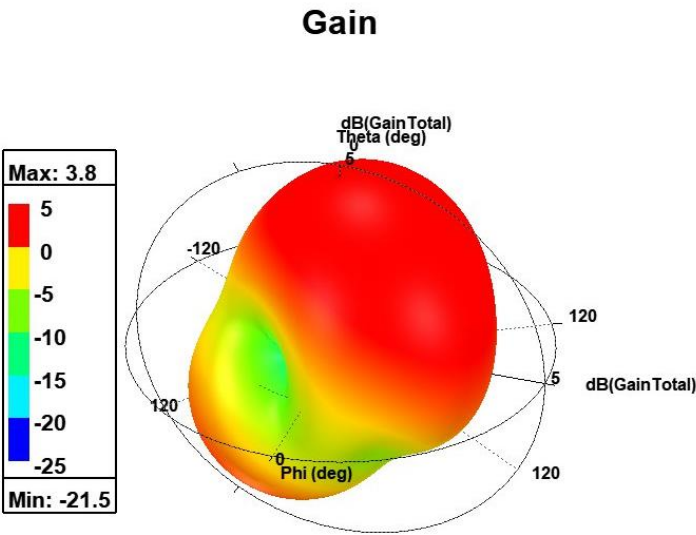


Fig: 5.3: Overall Gain of proposed antenna

5.1.4 Directivity

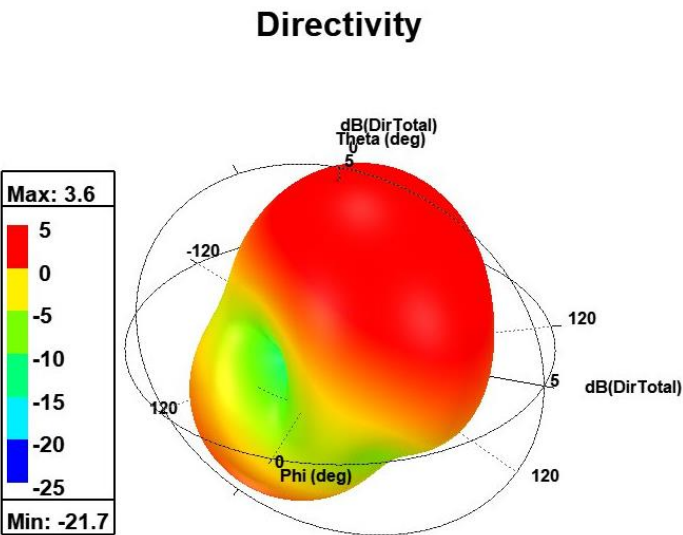


Fig: 5.4: Directivity

5.1.5 Impedance Plot

Impedance plots are crucial for understanding an antenna's behaviour and performance during results analysis. It offers useful details about the antenna's input impedance, including its resonance frequency, bandwidth, and impedance matching properties.

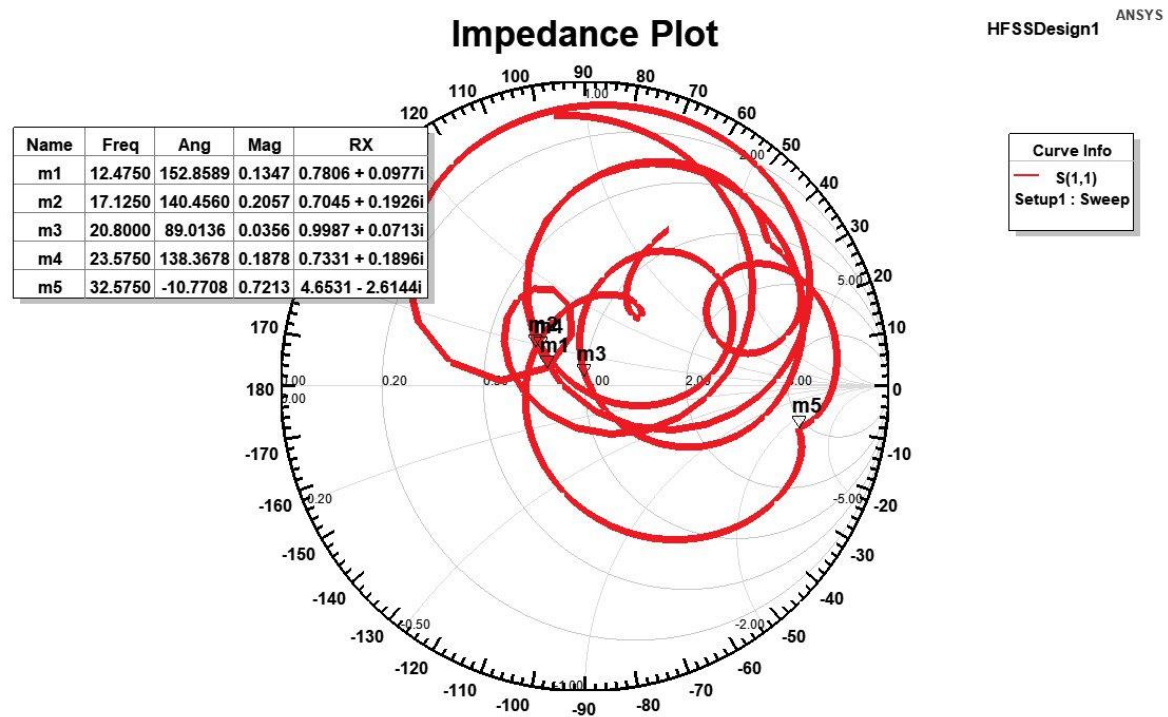


Fig: 5.5: Impedance plot

5.1.6 Radiation intensity

The distribution of electromagnetic energy emitted by the antenna in various directions is depicted in the radiation intensity graph, which may also be used to assess other significant antenna characteristics including directivity, gain, and efficiency.

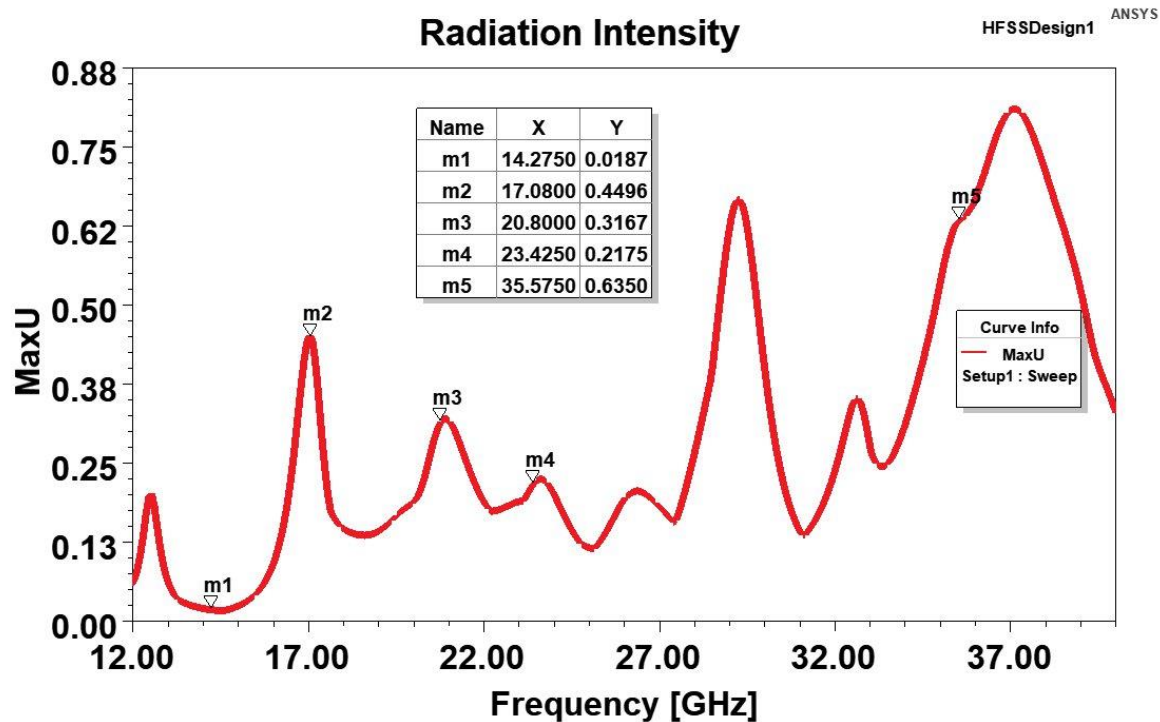


Fig: 5.6: Radiation Intensity

5.1.7 Radiation Pattern

5.1.7.1 Theta 90° and Phi 0° at 12.475GHz

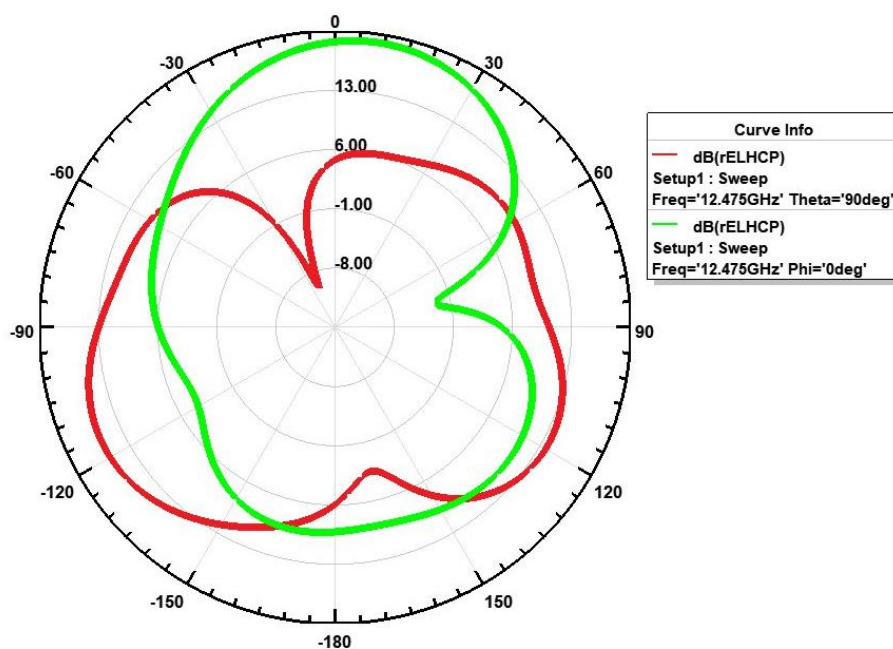


Fig: 5.7: Theta 90° and Phi 0° at 12.475GHz

5.1.7.2 Theta 0° and Phi 90° at 12.475GHz

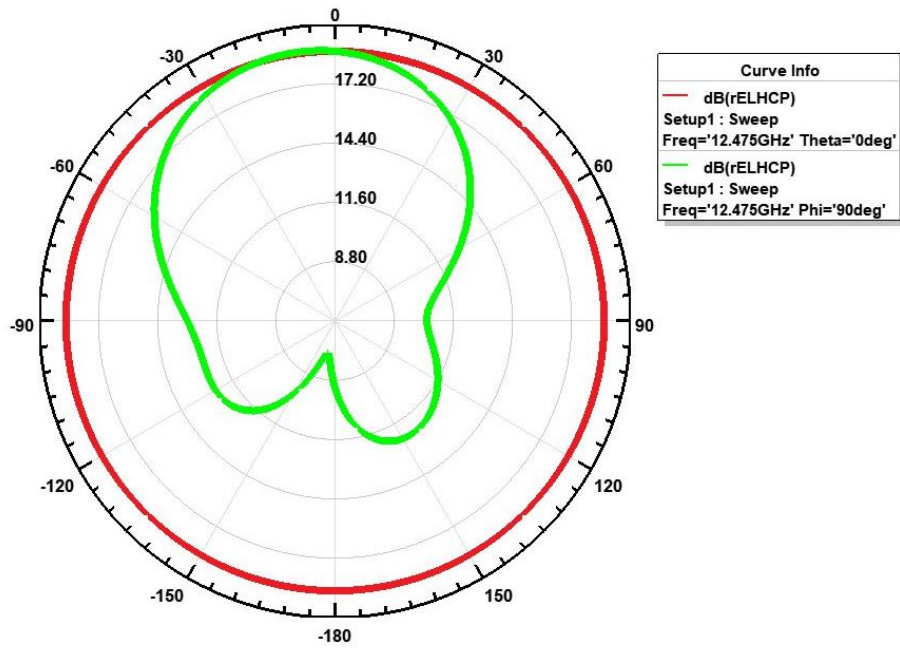


Fig:5.8: Theta 0° and Phi 90° at 12.475GHz

5.1.7.3 Theta 90° and Phi 0° at 17.125GHz

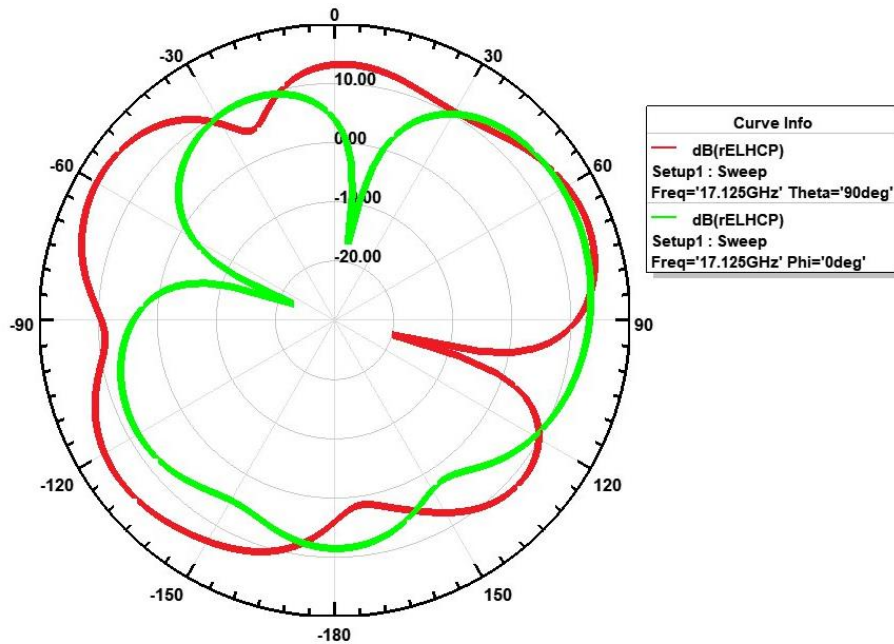


Fig:5.9: Theta 90° and Phi 0° at 17.125GHz

5.1.7.4 Theta 0° and Phi 90° at 17.125GHz

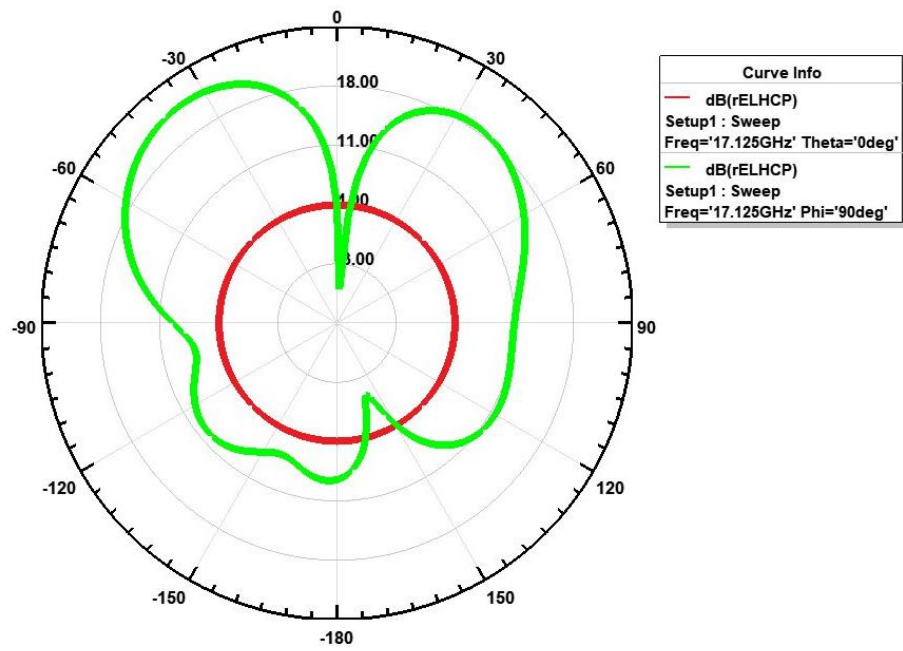


Fig:5.10: Theta 0° and Phi 90° at 17.125GHz

5.1.7.5 Theta 0° and Phi 90° at 20.8GHz

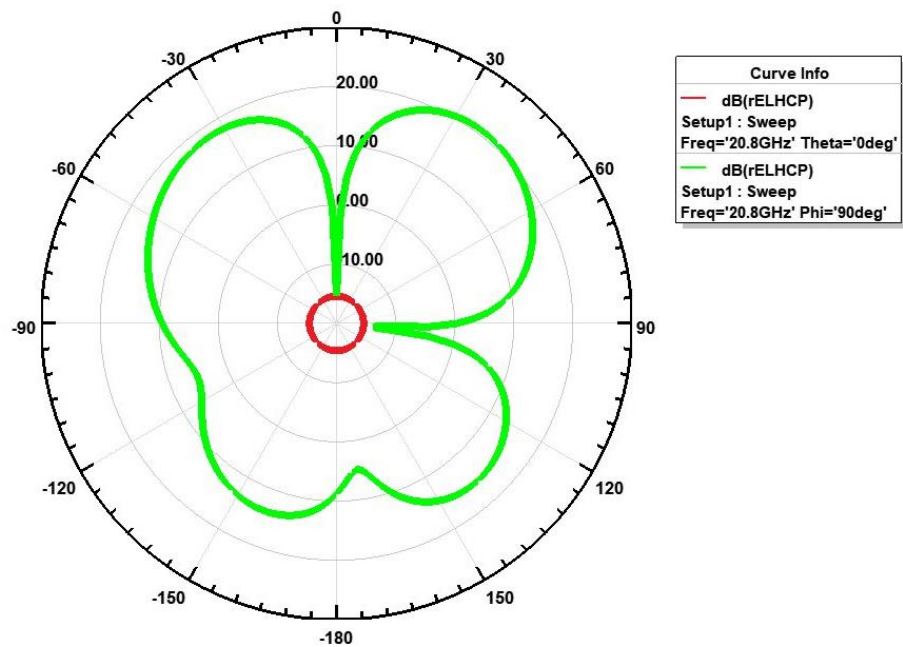


Fig: 5.11: Theta 0° and Phi 90° at 20.8GHz

5.1.7.6 Theta 90° and Phi 0° at 20.8GHz

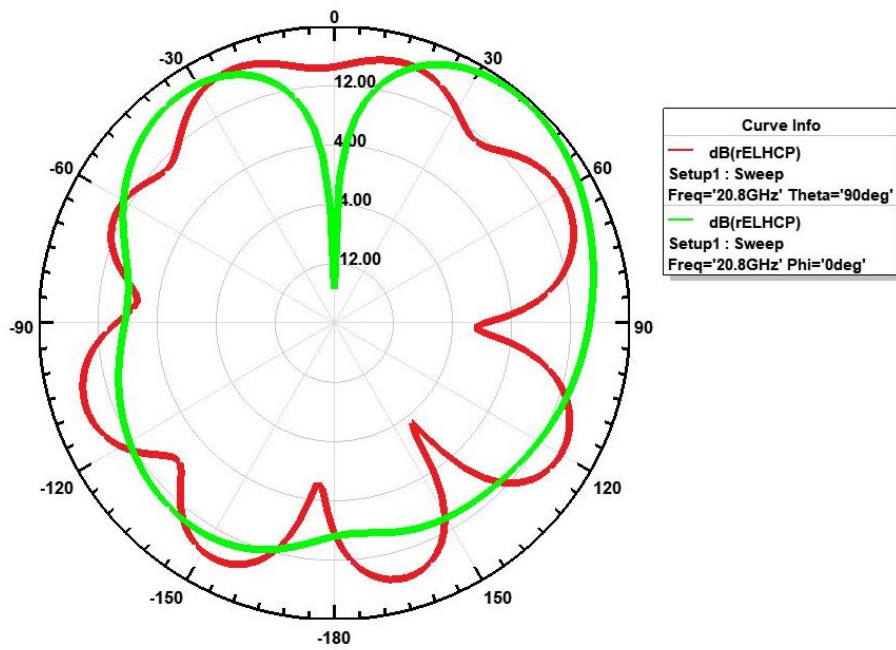


Fig:5.12: Theta 90° and Phi 0° at 20.8GHz

5.1.7.7 Theta 0° and Phi 90° at 23.575GHz

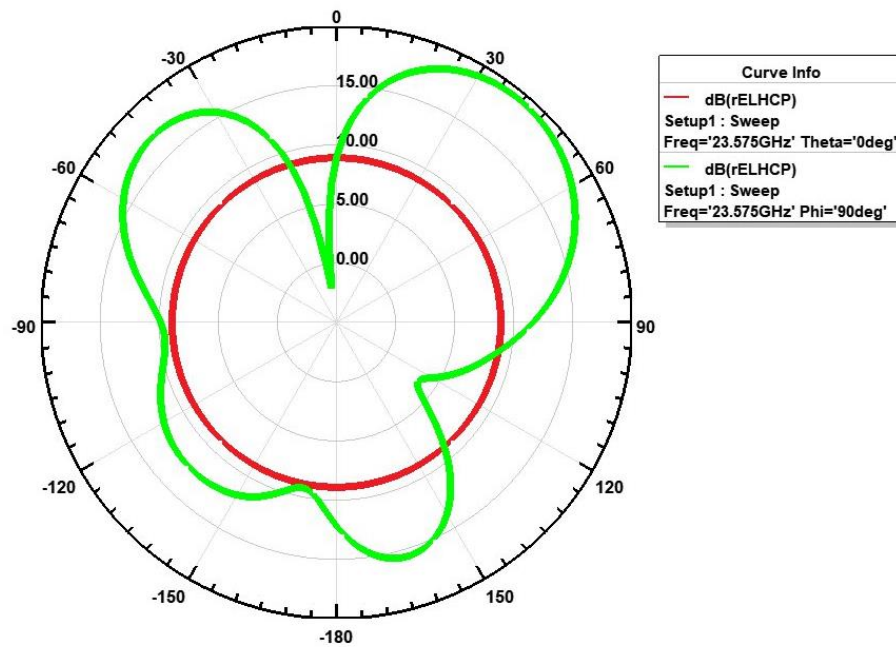


Fig:5.13: Theta 0° and Phi 90° at 23.575GHz

5.1.7.8 Theta 90° and Phi 0° at 23.575GHz

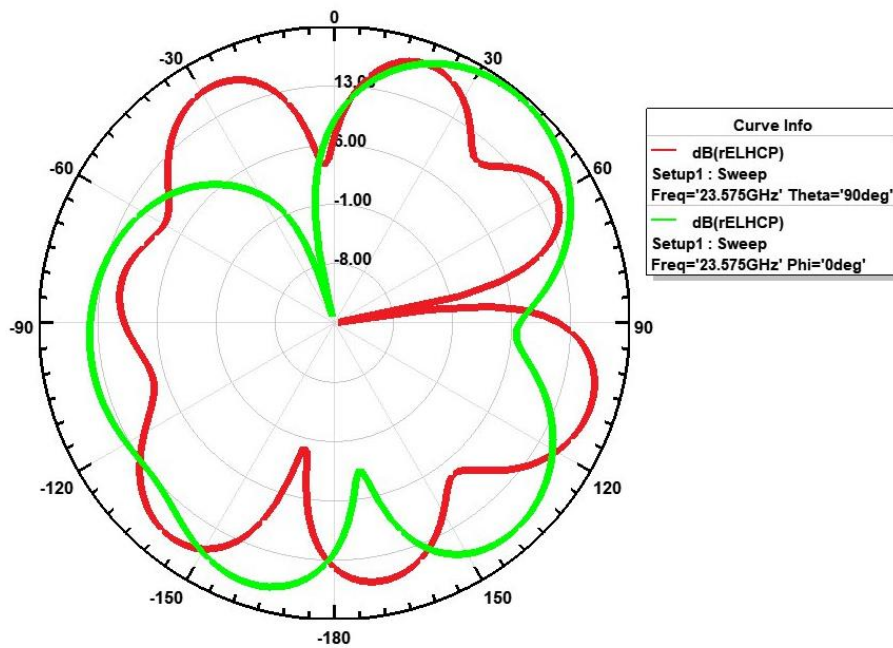


Fig. 5.14: Theta 90° and Phi 0° at 23.575GHz

5.1.7.9 Theta 0° and Phi 90° at 35.575GHz

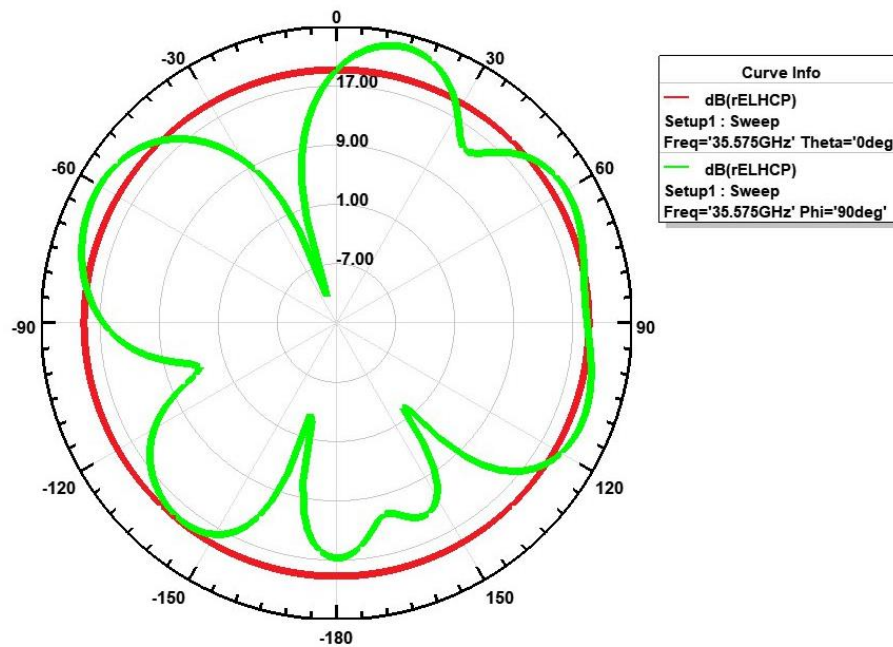


Fig. 5.15: Theta 0° and Phi 90° at 35.575GHz

5.1.7.10 Theta 90° and Phi 0° at 35.575GHz

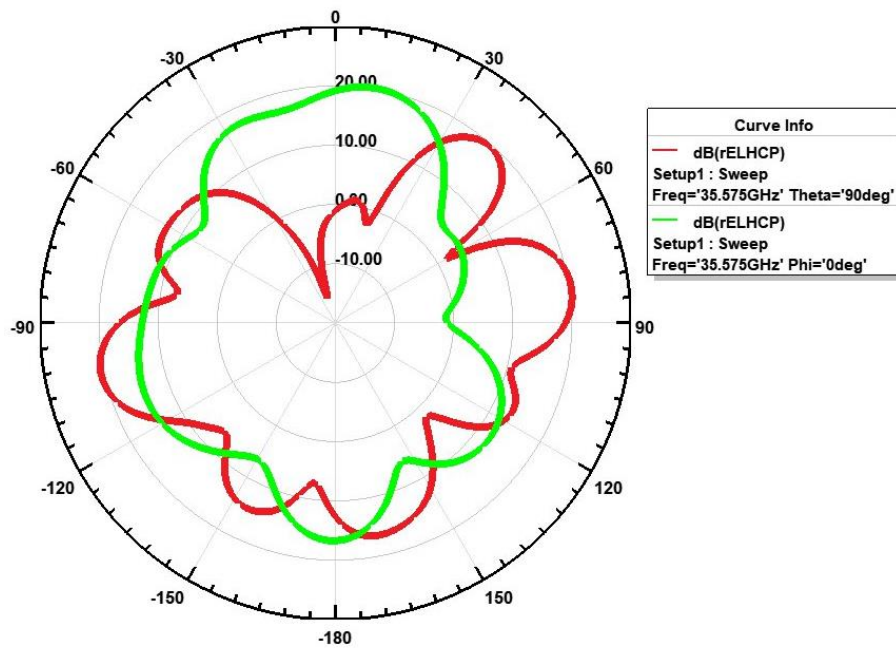


Fig:5.16: Theta 90° and Phi 0° at 35.575GHz

5.2 FABRICATED ANTENNA DESIGN

5.2.1 Design View

5.2.1.1 Front view:



Fig 5.17: Patch design view

5.2.1.2 Back view:



Fig:5.18: Ground view

5.2.2 Testing Results

5.2.2.1 Return Loss

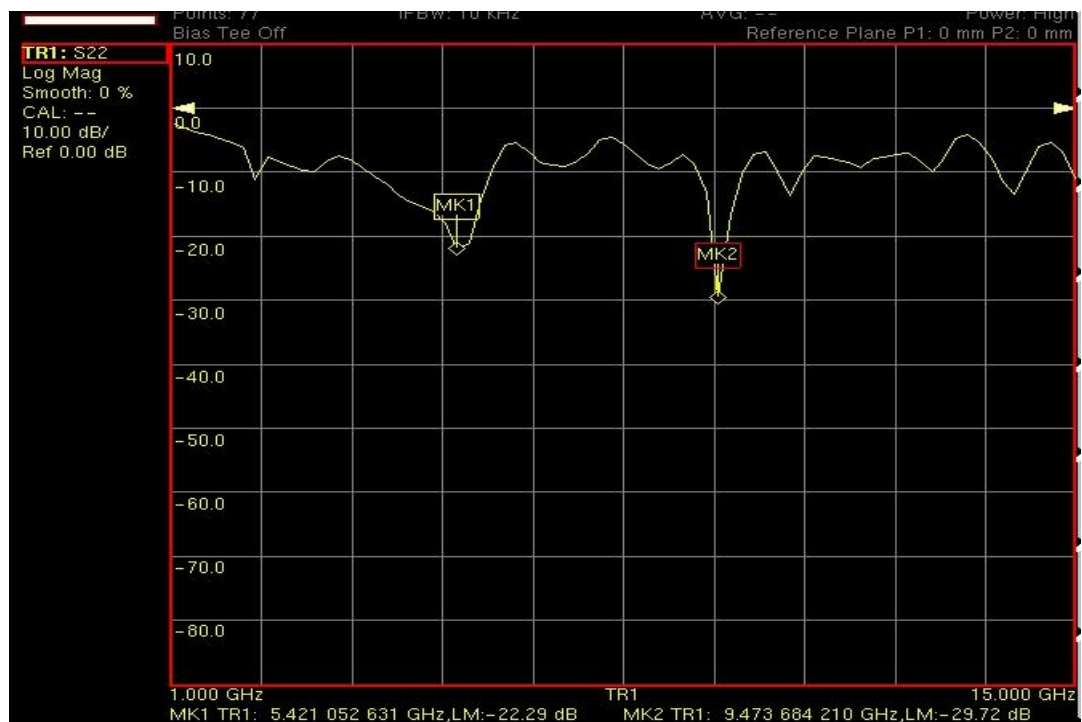


Fig 5.19: Return Loss of Fabricated Antenna

5.2.2.2 VSWR

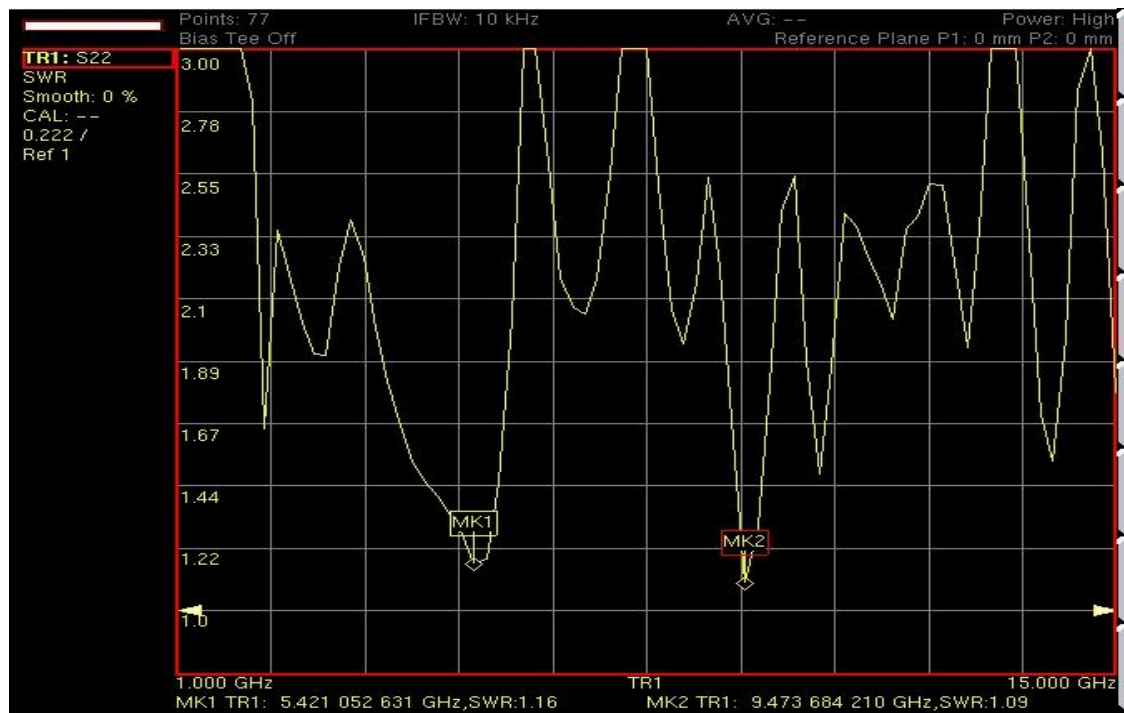


Fig: 5.20: VSWR of Fabricated Antenna

5.2.2.3 Smith Chart

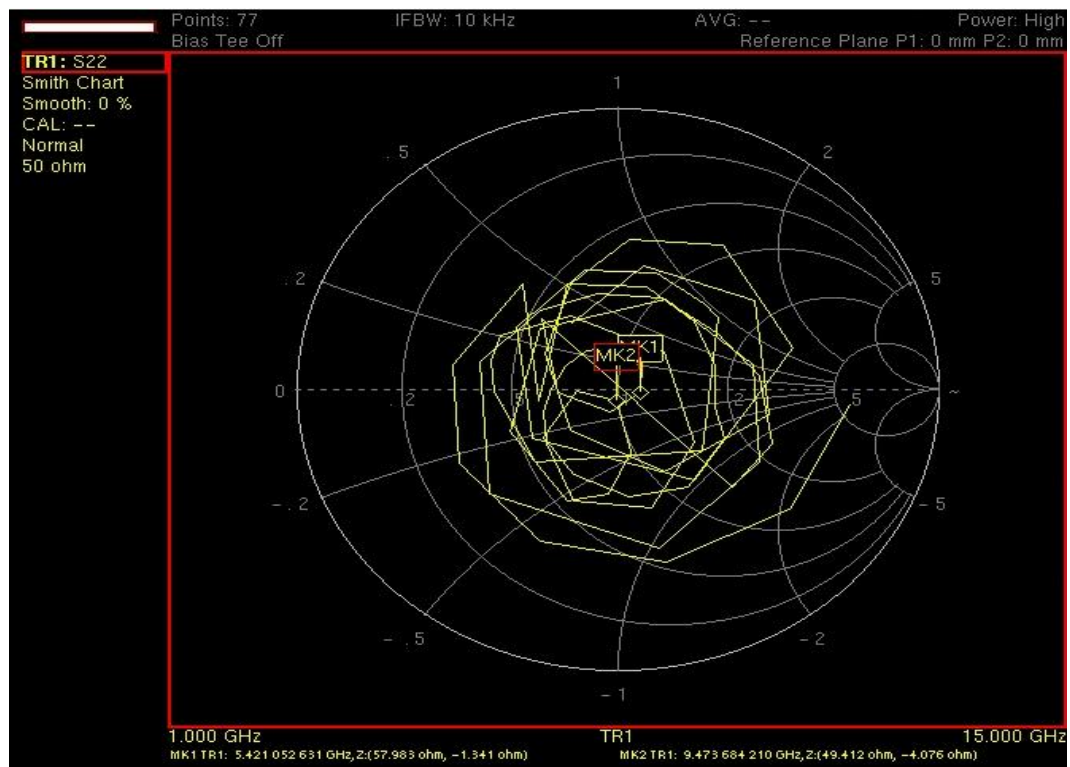


Fig: 5.21: Smith Chart of Fabricated Antenna

CHAPTER-6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Antennas' general operation was known. The key variables that influence design and applications (such as Return Loss curves, Radiation Patterns, Directivity, and Beamwidth) were researched and their consequences were recognised. The Semi triangled 2X1 array antenna with U-shape structure is operated at the wished-for frequency. HFSS software was used to model the patch antenna and achieve the appropriate level of optimisation. We came to the conclusion that the software's outcomes matched those that were theoretically expected.

6.2 CONCLUSION

The proposed antenna is designed by having Semi triangled 2X1 array antenna with U-shape structure patch design and E&I shaped ground structure. The material used for substrate is Taconic having relative permittivity(ϵ_r) 2.2. The size of antenna is extremely small of 13.5mm x 17.5mm x 1mm having multi band characteristics which not only support for x-band but also for various other bands for wireless communications like KU, K and KA. The suggested antenna has a return loss below -15db, gain of 3.8, directivity of 3.6. the antenna has a better efficiency of 94.7%. The HFSS Software was used to design, model, and compute the various antenna parameters for this antenna. This suggested antenna is fed using the lumped port approach, and the return loss, gain, directivity, and radiation pattern are all good. Antenna has a many applications like military, weather monitoring, satellite communication.

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