Design of an E shaped microstrip patch antenna for ku band application.

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Certification

This is to certify that the thesis entitled, "**Design of an E shaped microstrip patch antenna for ku band application**" submitted by **Dipta Nath & Prasanjit Biswas** in partial fulfillment of the requirements for the award of Bachelor of Science Degree in ELECTRICAL AND ELECTRONIC ENGINEERING at the Daffodil International university, Ashulia is an authentic work carried out by him under my supervision and guidance. To the best of our knowledge, the documentation shown in the thesis has not been provided to any other university or institute for the purpose of getting a degree or diploma.

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LIST OF ABBREVIATIONS

RMPA	Rectangular Microstrip Patch Antenna
MPA	Microstrip Patch Antenna
GHz	Giga Hertz
IE3D	Moment of Method Based EM Simulator
EM	Electro-Magnetic
GPS	Global Positioning System
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
RF	Radio Frequency
VSWR	Voltage Standing Wave Ratio
PCB	Printed Circuit Board
MP	Microstrip patch
WiMAX	Worldwide Interoperability for Microwave Access
RFID	Radio Frequency Identification
MIMO	Multiple-Input Multiple-Output
MHz	Mega Hertz
NASA	National Aeronautics and Space Administration
2D	Two Dimensional
3D	Three Dimensional
Dg	Directivity Gain
Rp	Radiation intensity for Particular angle of antenna
Ra	Average Radiation intensity
Bw	Bandwidth
Fu	Upper Frequency
Fl	Lower Frequency
Fc	Center Frequency
RL	Return Loss

LIST OF SYMBOLS

λ	Wavelength
π	Pie
f	Frequency
C	Speed of light
Γ	Reflection coefficient
ρ	Magnitude coefficient
R	Resistance
L	Inductance
C	Capacitance
G	Conductance
Z_0	Impedance
ω	Angular frequency
ε_r	Relative dielectric constant
eff	Effective dielectric constant
$\tan\delta$	Loss tangent
h	Height
fr	Resonant frequency
V_0	Velocity of light
	Effective length
	Angle

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ABSTRACT

A new modified E shape specific Microstrip patch antenna (MPA) is developed and evaluated for Wi-Fi applications in this article. The planned antenna works between 12 and 19 GHz with a return loss of less than -10 dB, covering the entire KU band with high gain. The proposed antenna is modeled using HFSS simulation software on a Rogers RT/duroid 5880 substrate with a dielectric constant of 2.2 and a thickness of 1.575 mm. The proposed antenna has a total area of 30×30 mm^2 and a useful bandwidth of 7 GHZ. Here 11×14×0.035 mm^3 is the size of the antenna that has been installed. Satellite communication, downlink, satellite television, NASA’s data tracking all benefit from the planned antenna, which resonates at 12.32 GHz, 13.88 GHz, 15.68 GHz, 16.88 GHz for HFSS and gain and directivity are 10.58 dB and 10.22 dBi, respectively .Better return loss and VSWR (2) are obtained by simulations. The same design has also been analyzed by using CST Studio Suite to exhilarate the performance of the proposed antenna.

CHAPTER 1

OVERVIEW

1.1 Introduction

Wireless networking is becoming an increasingly important aspect of the communications sector. In our culture, it has been user-friendly and indispensable in our everyday lives. It brings us a modern sense of versatility and has revolutionized the way we do almost all. Microstrip patch antennas (MPA) are commonly used in a variety of industries, and they have piqued the interest of researchers due to properties such as low profile, ease of fabrication and integration with circuits, and ease of mounting on vehicles [9, 22]. MPA's amazing properties help with tactical applications like rockets, spacecraft, and ships, as well as industrial applications like wireless telephone phones, mobile satellite systems, and global positioning systems. The proper antenna is chosen based on the application's specifications, such as cost, height, gain, bandwidth, efficiency, radiation pattern, frequency band, and coverage, and it reduces power consumption and increases transmission efficiency. Wi-Fi is the fastest-growing component of modern wireless networking, providing consumers with the mobility, freedom, and versatility to travel across a large coverage area while remaining connected to the network [1]. The electromagnetic spectrum has been reserved worldwide for all forms of electromagnetic (EM) radiation dependent on EM wave wavelengths and frequencies where antennas can function for wireless local area network connections (WLAN), satellite, and other applications. The material that can be used to make such antennas is partly determined by the operating frequency selection. There are a variety of materials used in antennas, including RT duroid, Arlon Cu, glass, steel plate, and modern artificial materials known as meta-materials that possess peculiar properties not found in nature. The efficiency of antennas can be increased by using meta-materials in their construction. Antenna architecture, on the other hand, is one of the most difficult facets of radio frequency (RF) design. The antenna has a significant impact on the range and efficiency of an RF link [24]. A single band MPA is planned for WLAN use in this article. Using a variety of techniques to design MPAs opens up the potential of improving antenna characteristics such as antenna height, gain, bandwidth, and directivity etc.

1.2 Background

G.A. Deschamps [22] was the first to develop the MPA principle in the 1950s. Many authors designed the first practical microstrip antenna since the evolution of printed circuit board (PCB) technology in the 1970s, and explained the radiation of the patch antenna from the ground plane by a dielectric substrate for various aspects. As a result, Munson built an antenna for rockets and missiles, which opens up a vast testing field all over the world [24]. A microstrip antenna is made up of a patch, which is a very thin metallic strip that is mounted on a ground plane. The dielectric layer separates the conducting patch from the ground plane [antenna theory pdf]. In MPA geometry, there are several radiating configurations such as rectangular, square, and so on, which are covered extensively in chapter 2. Microstrip antennas with a low profile planar configuration can easily be formed to conform to the host plane. Researchers have been drawn to microstrip antennas because they can be used by both civilian and military uses, such as handheld systems, radio frequency identification (RFID), global positioning systems (GPS), WLAN, Wi Max, Wi-Fi, satellite communication, radar systems, and missile control systems [22-24].

Microstrip antennas allow for a wide range of design possibilities, which is still being explored. Modified MPA shapes, such as rectangular or circular length (L) or radius (r) measurements, can aid in obtaining suitable resonant frequencies [23]. The most famous microstrip antennas are rectangular and circular patches. The efficiency factor (Q) is the distance between the conducting patch and the ground plane, and it can minimize the antenna's bandwidth. It (Q) can be minimized by raising the thickness of the dielectric substrate. However, the major drawback However, there is a significant disadvantage.

The performance shortens as the thickness increases, indicating low power gain, extra radiation from the feed and junction points [22]. The substrate permittivity affects the bandwidth and gain (εr).

1.3 Literature Review

In recent years, a technical movement has focused much effort into the design of microstrip patch antennas for advantages such as low cost, light weight, and the ability to sustain high efficiency over a broad frequency spectrum[5]-[9]. Patch antennas, on the other hand, have low gain and a narrow bandwidth. Several methods have been used to solve these disadvantages, including changing and mixing patch shapes, cutting slots, raising substrate thickness, and adding parasitic elements [10]-[15]. Designing an E-shaped patch antenna [16], [17], or changing the ground plane [5], [7], or a U-slot patch antenna [18] or T type patch antenna [19]-[22] are examples of patch form modification. The authors of [16] say that a patch antenna can increase bandwidth by up to 30%, whereas an E-shaped Microstrip antenna can increase bandwidth by more than 30% as compared to a standard MPA. The key goal of this paper is to create a E-shaped patch antenna that will increase bandwidth.

[19] proposes a E-shape microstrip patch antenna with 11×14×0.035 mm3 measurements for wide bandwidth, which is needed for fourth generation wireless systems. The E form antenna's operating frequency is 2.4 GHz. This E shaped antenna for satellite applications at V downlink, satellite television, NASA’s data tracking -band has been proposed in [11] with 30×30 $mm2$ dimension. The patch antenna consists of an E shaped model with bandwidth from 12 to 19 GHZ and resonate at 12.32 GHz, 13.88 GHz, 15.68 GHz, 16.88 GHz for HFSS and gain and directivity are 10.58 dB and 10.22 dBi, respectively with voltage standing wave ratio of less than 2 (VSWR<2). In [14] However, there are many different radio frequencies which are actually developed for several communication purpose such as the frequency range of L-band is 1 to 2 GHz and this antenna has been designed for Mobile satellite service (MSS). Consequently, S-band (2-4 GHz) (used for MSS, NASA, deep space research), C-band (4-8 GHz) (used for FSS), X-band (8-12.5 GHz) (used for FSS military, terrestrial earth exploration, and meteorological satellites), Ku-band (12.5-18 GHz) (used for FSS, broadcast satellite service (BSS)), K-band (18-26.5 GHz) (used for FSS, broadcast satellite service (BSS)), K-band (18-26.5 GHz) (used for BSS, FSS) and Ka-band (26.5-40 GHz) (used for FSS). The main objective of this designed is to compare the base design in [9] to transmit very low power in order to acquire high data rate without confusing other surrounding wireless communication systems, to obtain higher bandwidth. The designed antenna with a compact sized rectangular shape achieved more bandwidth.

1.4 Aim and Objectives

The aim of this study is to improve the MPA characteristics' performance in the KU band. The goals are listed below.

- Antenna return loss reduction (S11).
- Create an MPA with increased bandwidth to cover the entire KU-band.
- Enhancement of the built antenna's gain.
- HFSS Software verification.

1.5 Methodology

The efficiency of the Microstrip patch antenna (MPA) has been improved in the KU-band frequency domain. Adding two portions of plow to MPA yields a sufficient result. To achieve our qualifying goals, basic procedures have been clarified step by step.

Step 1: Specifying the length (L) and basic structure of a simple rectangular MPA (W).

Step 2: Increasing the bandwidth of the antenna by using E shape.

Step 3: For improved performance, modify and add a plow-shape section to the E-shape patch.

Step 4: Evaluate the output of each built antenna in terms of antenna characteristics, especially bandwidth, gain, and return loss.

Step 5: Evaluate the proposed antenna parameters in light of existing literature.

1.6 Thesis Organization

There are five key chapters in this study, as well as a reference section.

The introduction, history, literature review, aims, and scope of the thesis are all covered in **Chapter 1**.

In **Chapter 2**, the basic fundamentals of the MPA are explained through brief literature studies. It also goes through the related literature on slot-based KU-band MPA architecture.

The design procedure for the proposed antenna using the line feeding technique is defined in **Chapter 3**.

The proposed E shape patch antenna is discussed in **Chapter 4** with a comparison of the HFSS Software and the CST Studio Suite, a return loss graph, bandwidth for all individual antennas, average and vector current distribution, and 2D and 3D radiation patterns. A brief comparison of current papers and the proposed antenna was also conducted.

Finally, **Chapter 5** concludes the work and discusses potential work possibilities.

CHAPTER 2

Literature Studies

2.1 Antenna parameters:

An antenna, which acts as a transducer, converts electrical energy into electromagnetic energy and vice versa. It is essential to understand certain observable properties in order to decide if the antenna design is good or poor. It is necessary to comprehend the various antenna parameters that aid in determining the design's strengths and weaknesses. These antenna parameters are dependent on one another. As a result, make sure that all of the parameters are tailored for the antenna you're building. If the Return loss is greater than -10 dB, for example, the designing antenna will not function and the VSWR will be greater than 2.

2.1.1 Antenna Field regions:

Antenna field regions are important since an antenna begins to radiate after a fixed distance from the antenna. They are divided into three main areas:

- Regions that are reactive

- Radiating near field / Fresnel area

- Far field

The far field regions are the most important since they specify the antenna radiation pattern and most of the other parameters. Antennas, on the other hand, are used to provide long-distance contact. As a result, the antenna field regions are critical.

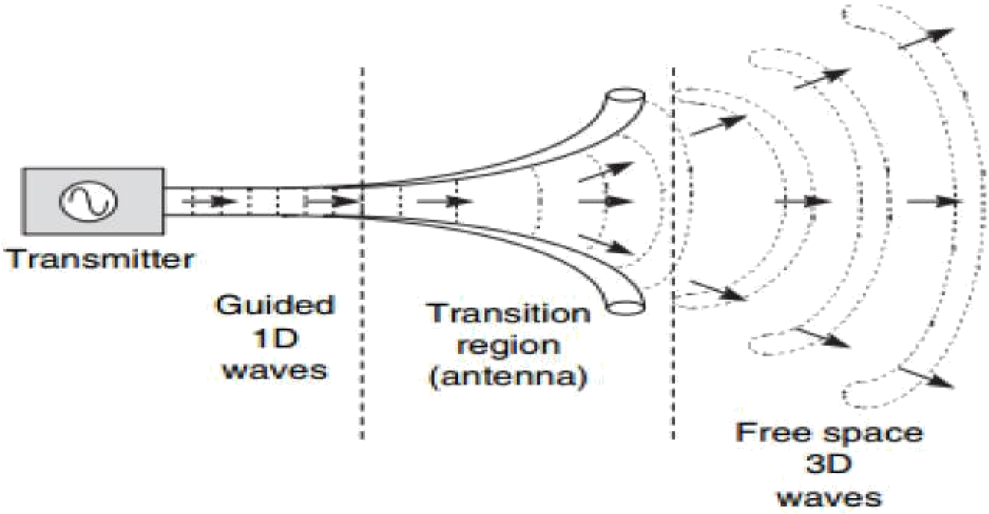


Figure 2. 1 Antenna radiation

Antennas field components have electric and magnetic fields. These fields are referred to as radiative and reactive fields, respectively. The distance ‘r' in the denominator equation of the reactive field variable is of the order of two or higher. The radioactive component also has a distance component with ‘r' of the first order. As a result, as the distance between the two points grows, the reactive component of the field dies, but the reactive component remains. Near field regions are described as reactive and radiating near field / Fresnel regions, respectively. Far field refers to the total spectrum of two times the wave length to infinity.

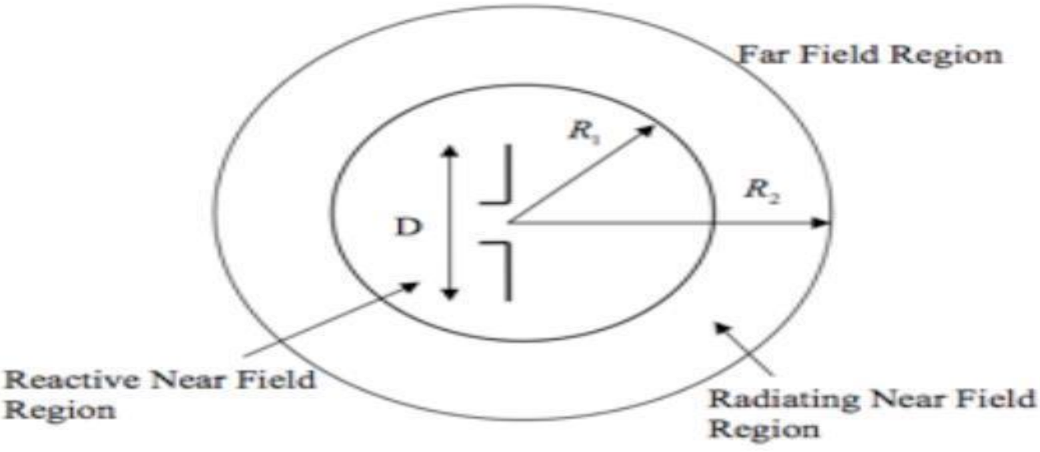


Figure 2.2 near field and far field regions.

2.1.2 Radiation pattern:

Radiation is primarily emitted when a flowing current encounters a sudden discontinuity. The delegation of antenna radiation intensity with respect to the space coordinate scheme is known as the radiation pattern. Antennas are classified as directional or omnidirectional based on their radiation pattern. The antenna is considered omnidirectional as it radiates uniformly along the azimuthal angle but varies with elevation of angle sinusoidal. If, on the other hand, an antenna radiates with a higher directivity at a certain angle in comparison to other angles, it is said to have a higher directivity. It is said that the antenna is directional. The term "directivity" refers to the antenna's directionality. The radiation pattern can be shown in two dimensions, three dimensions, or as a polar plot. The plots are shown below.

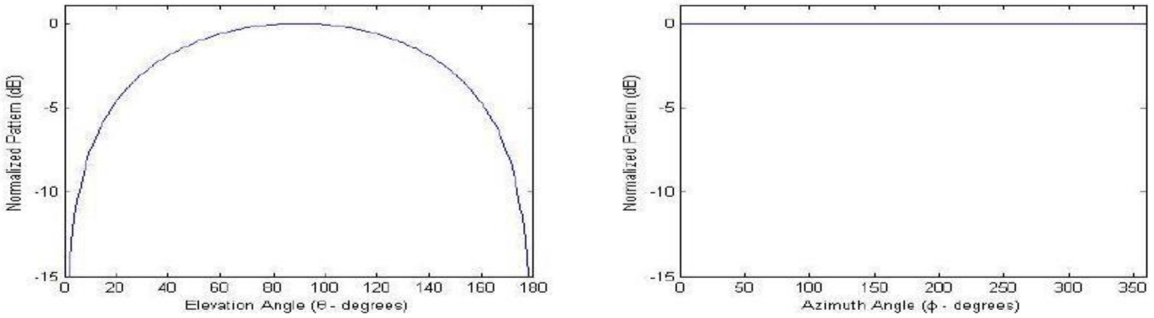


Figure 2. 3 Radiation pattern

2.1.3 Directive gain:

Another antenna that radiates differently at different angles is the directive antenna. Directive gain is the ratio of an antenna's radiation intensity at a specific angle to the average radiation intensity in all directions. It's written as dBi.

$$\text{Directive Gain at an angle} = \frac{\text{Radiation intensity at that particular angle}}{\text{Average radiation intensity}}$$

2.1.4 Directivity:

A directional antenna that is dependent on a higher angle of radiation intensity than all other directions. When the directivity gain of a directional antenna stays at a specific direction for optimum radiation, this is referred to as directivity of directional antenna gain.

2.1.5 Antenna Efficiency:

In any device, when applied power is not equal to received power, loss occurs. Antenna, on the other hand, has two defeats. One is due to an impedance mismatch between the antenna and the free space. Another reason is that since the antenna is made of a conducting material, the input power is not radiated. Antenna efficiency is the ratio of an antenna's output power to its input power.

$$Antenna\ Efficiency = \frac{Output\ power}{Input\ Power} \times 100\%$$

2.1.6 Antenna gain:

An antenna gain is the antenna's directivity when the antenna efficiency is taken into account. The ideal case for an antenna is directivity, while the actual case is gain. As a result, if all of the input power to an antenna is radiated, the gain and directivity will be the same. Since there are often losses associated with antennas in practice, gain would be less than directivity.

Antenna Gain = Antenna Efficiency *Directivity

2.2 Matching and Reflection:

As electricity is applied to a device, the system absorbs the power. As a result, there is a significant difference between applied and out control. If the system absorbs marginal power, some of it reflects back due to matching, although no reflection occurs in the system due to mismatching of the transmission line with the antenna.

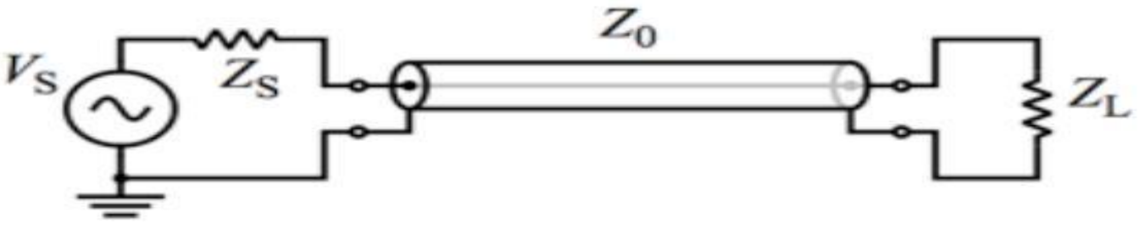


Figure 2. 4 Circuit Diagram of Load impedance, Source and Transmission line

A given equation can be used to calculate the reflection. The co-efficient of reflection is

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

The reflection coefficient (a+jb) is a complex number. If the imaginary part is 0 and the real part is 1, then

The reflection coefficient is -1, indicating that the line has been short-circuited (maximum negative reflection).

The reflection co-efficient is zero, indicating that the line is perfectly aligned (No reflection occurs).

The line is open circuited with antenna and the reflection coefficient is 1. (positive reflection).

The reflection co-efficient is a complex number that changes on a regular basis. The reflection coefficient can be graphically expressed using a smith map, as shown in the figure.

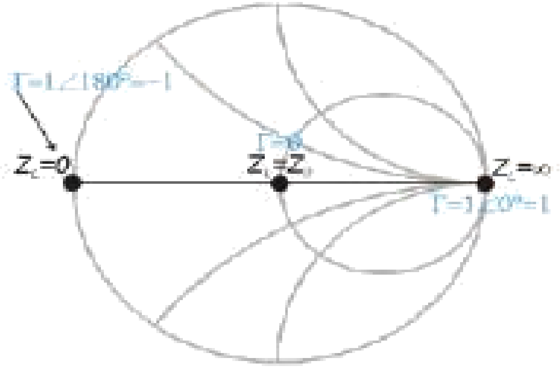


Figure 2. 5 Smith Chart

2.2.1 Voltage Standing Wave Ratio (VSWR):

There is no reflection generated there due to a mismatch of transmission line with antenna, or there is a massive amount of reflection produced there due to perfect matching of transmission line with antenna. By measuring VSWR, it is possible to determine how much load impedance reflection is mismatched. VSWR is known as the ratio of maximum to minimum voltage. It's possible to write it mathematically as,

$$VSWR = \frac{Maximum\ voltage\ of\ standing\ wave}{Minimum\ Voltage\ of\ standing\ wave}$$

When the VSWR value is 1, it means that the transmission line and antenna are perfectly balanced. The VSWR 2 value is regarded as a good match.

2.2.2 Return loss/S parameters:

Return loss, also known as S-parameters, is the amount of power expressed in the transmission line. It's also known as the scattering parameter, and it's measured in decibels (dB). In math, it's written as

$$RL_{\mathrm{dB}} = -20\log_{10}\left|\Gamma\right|$$

The following is the relationship between the reflection coefficient and the VSWR:

$$VSWR = \frac{1-\tau}{1+\tau}$$

By reducing the number of variables in the equation written as

$$Return\ Loss = -20\log\frac{VSWR-1}{VSWR+1}\ dB$$

2.2.3 Bandwidth:

The distance between the lowest and highest frequency ranges within an antenna's operating range is referred to as bandwidth. The S11 parameter bandwidth is the frequency range with a return loss of less than -10 dB. There are several types of bandwidth, each based on a different parameter. Impedance bandwidth is constant, while Affectivity and Directivity bandwidth are also known as gain bandwidth. Impedance bandwidth is determined by a variety of factors, including dielectric materials and ground plane scale. Impedance bandwidth was estimated at -6 dB return loss. The flowing equation can be used to measure the desired bandwidth.

$$\mathrm{BW}_{Broadband} = \frac{f_H}{f_L}$$

$$BW_{narrowband}(\%) = \left(\frac{f_H - f_L}{f_C}\right) \cdot 100$$

Where,

$f_H = The\ Upper\ Frequency,$

$f_L = The\ Lower\ Frequency,$

$f_C = The\ Center\ Frequency.$

2.3 Introduction of Microstrip patch antenna:

Microstrip patch antennas are becoming increasingly common in the millimeter-wave frequency range [24-26]. Patch materials, dielectric materials, and ground materials make up the microstrip patch antenna. The conducting materials that are mounted on the dielectric materials make up the antenna patch. As seen in the diagram, ground is a conducting material that is connected to substrate materials, and substrate is positioned between patch and ground.

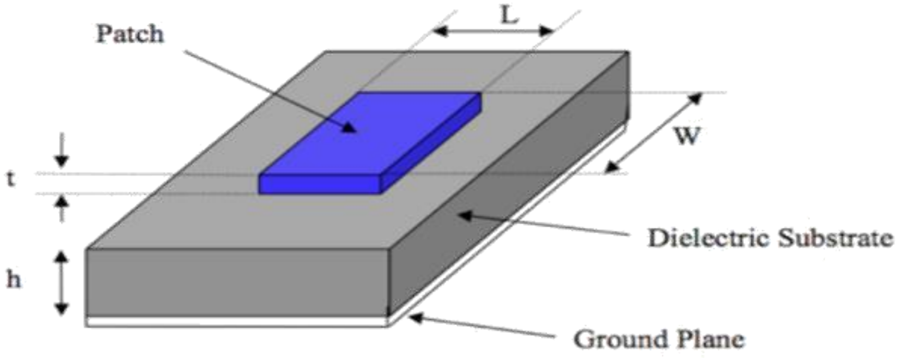


Figure 2.6 a microstrip patch antenna

Microstrip patch antennas come in a variety of shapes, including rectangular, rectangle, circular, triangular, and elliptical, as seen in the diagram.

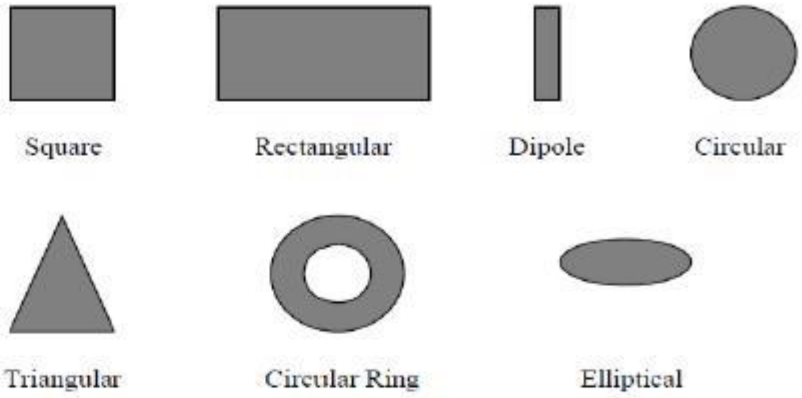


Figure 2.7 Different shape of Microstrip patch antenna

2.3.1 Advantage and Disadvantage:

Because of its many features, the microstrip patch antenna is becoming increasingly common. The benefits of microstrip patch antennas are mentioned below [27].

- Small volume and light weight
- Low-profile design that can be easily conformed to the host surface
- Because of the low cost of fabrication, it can be produced in large quantities.
- Both linear and circular polarization should be supported.
- It's easy to combine with a microwave integrated circuit (MICs)
- Dual and triple frequency service capabilities
- When fixed on a rigid board, it is mechanically stable.

When compared to traditional antennas, microstrip patch antennas have more flaws. The following are some of the big disadvantages mentioned by [27] and Garg et al [28].

- A limited bandwidth
- Ineffectiveness
- Gain is minimal.
- Radiation from feeds and junctions that isn't required
- Except for tapered slot antennas, poor end fire radiator
- Ability to handle a low amount of power
- Excitation by surface waves.

The downside of a Microstrip patch antenna is its narrow bandwidth, which occurs for a variety of reasons, the most important of which is the broad quality factor. Microstrip patch antennas with a high quality factor have a narrow bandwidth and low performance. The thickness of the substrate layer may be increased to reduce the quality factor. However, increasing the thickness of the substrate layer resulted in additional issues such as lower gain and power handling capability. The use of an array design for the components solves these issues.

2.4 Basic principle of operation:

Antennas in their most basic form, as seen in the diagram. The middle conductor of a coax is used as a feed probe to couple eletromagnetic energy into or out of the patch in this illustration. After feeding the pach antenna, it detects a discontinuity and generates an electromagnetic field. In the center of the patch, the electric field is zero. Maximum on one side, and negative on the other. These are constantly changing sides in response to the applied signal.

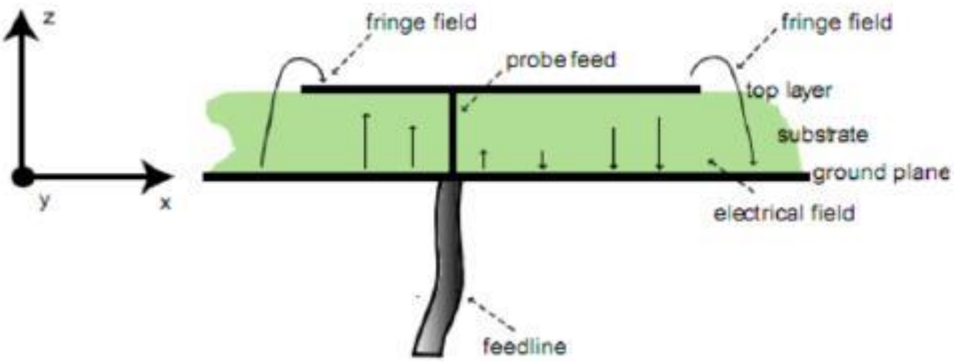


Figure 2.8 Side view of microstrip patch antenna

2.4.1 Feeding technique:

Antenna feeding is the method of energizing a patch of antenna. Various methods are used to excite or feed microstrip patch antennas. Feeding methods are divided into two categories. There are two types of feeding: contacting and non-contacting.

2.4.2 Feeding by contact:

Power is fed directly to the radiating patch by connecting elements such as microstrip lines in a method known as contacting feeding. The contacting feeding strategies can be split into two categories once more.

- Microstrip feed line
- Coaxial feed line

2.4.3 Microstrip feed line:

As shown in Figure, the antenna's microstrip patch is fed directly from the transmission line.

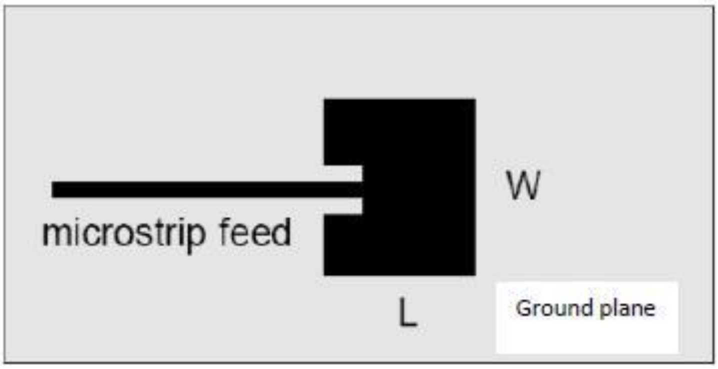


Figure 2.9 Microstrip feeding of patch antenna

The Microstrip feed line approach has a number of benefits and drawbacks.

Advantages include:

- Fabrication is simple.
- Impedance matching is easy.
- Modeling is easy.

The following are some of the method's drawbacks:

- Make a wave on the surface
- A constrained bandwidth
- Cross polarization is caused by an asymmetric structure.

2.4.4 Coaxial feed:

In the coaxial feeding process, a hole is drilled in the substrate and ground so that the patch is excited or the feed is directly contacted through the hole, as seen in the diagram.

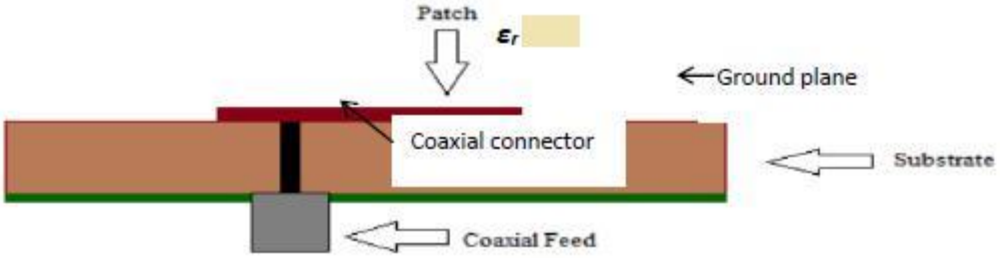


Figure 2.10 Coaxial feed

Advantages include:

- It is simple to match
- It's simple to make.
- Low levels of erroneous radiation

Disadvantages:

- When Epsilon r >0.02 lamda, the model becomes difficult.
- A constrained bandwidth
- Cross polarization

2.4.5 Non-confrontational:

The non-conducting method refers to the process of power being fed into a transmission line through an indirect patch.

Techniques is subdivided from the non-contacting technique.

- Aperture-coupled feed: An aperture-coupled feed is a unique arrangement in which two different substrate layers are used and separated by a ground plate. As seen in the diagram, the patch is mounted on the top substrate layer, and the transmission line is connected to the last substrate layer.

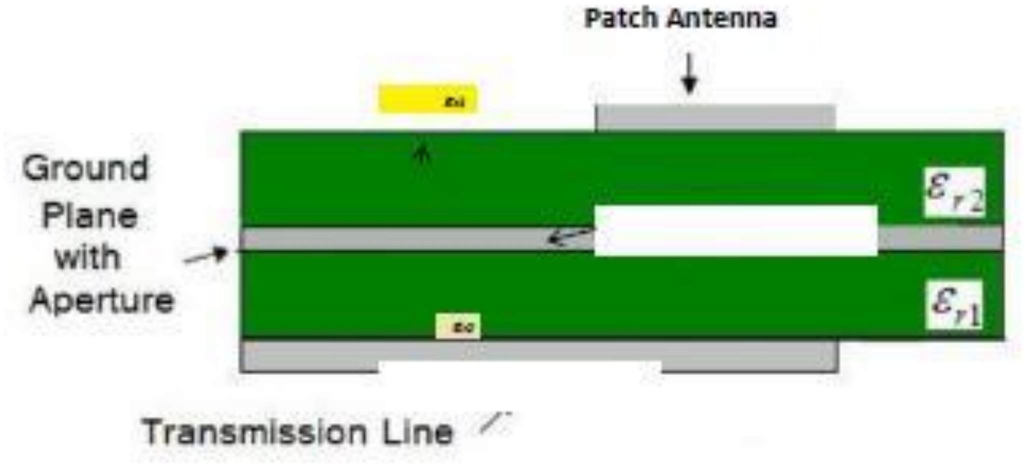


Figure 2.11 Aperture-coupled feed

- Proximity coupled feed: Electromagnetic coupling is another name for proximity coupled feed. Two substrate layers are used in this method, similar to aperture coupled feed techniques, but they are divided by a transmission line, as shown in the diagram.

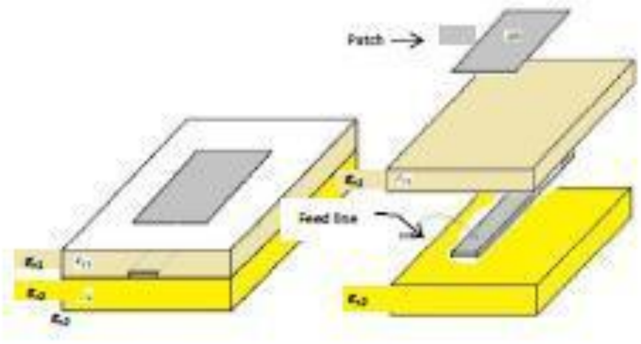


Figure 2.12 Proximity coupled feed

CHAPTER 3

DESIGN OF THE PROPOSED PATCH ANTENNA

The antennas that operate in the KU-band region have systematically low gain and bandwidth, according to the literature review (Chapter 1). As a result, the primary goal of this thesis is to design an MPA with increased bandwidth and gain in the KU-band region. In this chapter, antenna designs are shown in chronological order, with the proposed antenna's bandwidth expanding in the single patch antenna.

The CST suite simulator was used to develop our desired proposed antenna. All of the antennas are straightforward and capable of operating in the KU-band.

3.1 Specifications

Our main goal is to create a patch antenna that can support all of the Hi-speed Satellite communication that are currently in use around the world in the 14-14.5 GHz range. Our patch antenna, in particular, should explain [23]:

- European 802.11a, or 10.7-12..75 GHz band
- In the Australia 11.70-12.75 GHz band
- 11.7 – 12.2GHZ band in the United States
- Currently approved IEEE 12-18 GHz band

Overall, our proposed antenna configuration should have a return loss of at least -10 dB for the entire band of 12 GHz to 19 GHz, with a VSWR of less than 2. However, for our proposed antenna, an Rogers RT/duroid 5880 substrate with a dielectric constant of 2.2 has been chosen as the dielectric material. We'll use the E-shape structure and its parameters to build a simple type of E shape patch antenna as a starting point [19]. The antenna is then optimized by adjusting different parameters to find the best antenna for our intended service. After determining the parameters that generate an appropriate return loss in the 12 GHz to 19 GHz range, we examine the proposed antenna's radiation pattern, current distribution, and vector distribution.

3.2 Microstrip Patch Antenna Dimension

Patch width has a small impact on the antenna's resonant frequency and radiation pattern, but it has a greater impact on the input resistance and bandwidth. The radiation, on the other hand, is dependent on the antenna width and length. Power radiation, antenna bandwidth, and radiation efficiency are all directly proportional to antenna distance, while resonant resistance is inversely proportional. Using the specified equation, calculate the length of a microstrip patch antenna.

$$L = \frac{c}{2fr\sqrt{\varepsilon_r}}$$

Where c stands for the speed of light, fr for the resonant frequency, and r for the dielectric constant.

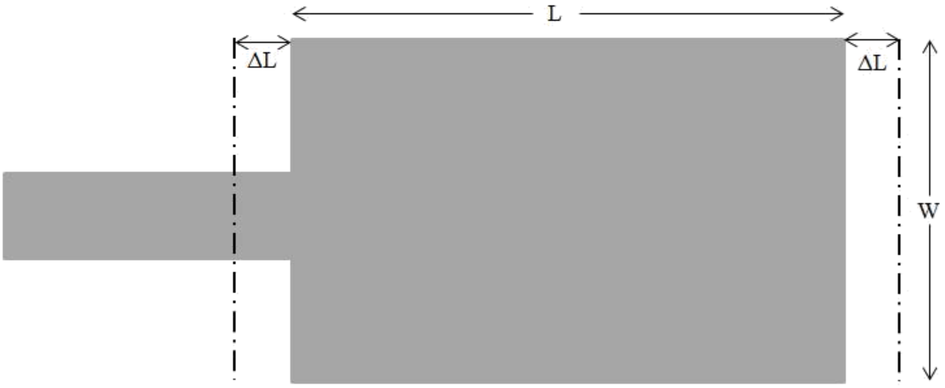


Figure 3.3(a) Microstrip Patch Antenna Dimension

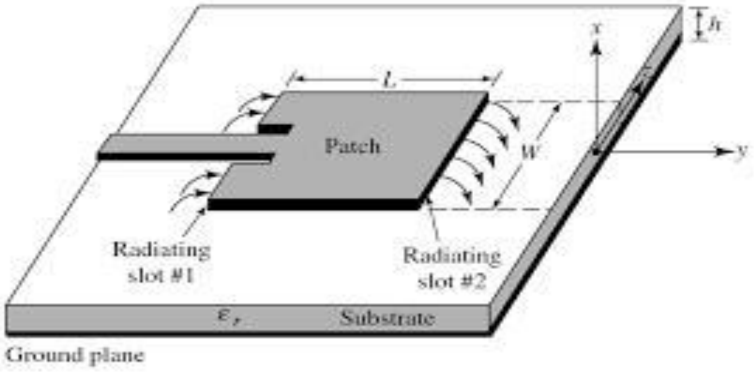


Figure 3.3(b) Radiation flow from patch to ground

For efficient radiation, width of patch is given by:

$$w = \frac{v_0}{2fr}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (3.2)$$

Here, V_0 = velocity of light = 299792458 m/sec, $f\,r$ = resonance frequency and ε_r = relative dielectric constant of substrate.

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \qquad (3.3)$$

Where, ε_{eff} = Effective dielectric constant, h = Height of dielectric substrate. For a given resonance frequency f_r, the effective length of patch is given by [7]:

$$L_{eff} = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\mu_0\varepsilon_0}} \tag{3.4}$$

The patch's actual length can now be represented by

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \tag{3.5}$$

Where, length extension is as follows [22].

$$\Delta L = 0.421h\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)} \tag{3.6}$$

All along the fringe, the ground plane of the MPA is approximately six times the thickness of the substrate, that can be expressed as follows:

$$Lg = 6h + L \tag{3.7}$$

$$wg = 6h + w \tag{3.8}$$

3.3 Design of MPA

This section contains the simulation results as well as the MPA design. Return loss, VSWR, gain, and directivity are the fundamental parameters of an antenna to verify its activity at the desired band. The engineered antenna resonates at 5.121 GHz with a maximum return loss of -31.3 dB, as can be shown.

A reference antenna design is given below to help explain parametric analysis of microstrip patch antennas. In Figure 3.3(c), a single band RMPA is designed, and the designed antenna resonates at 1.7 GHz with a minimum return loss of - 12.7 dB, as shown in Figure 3.3(d).

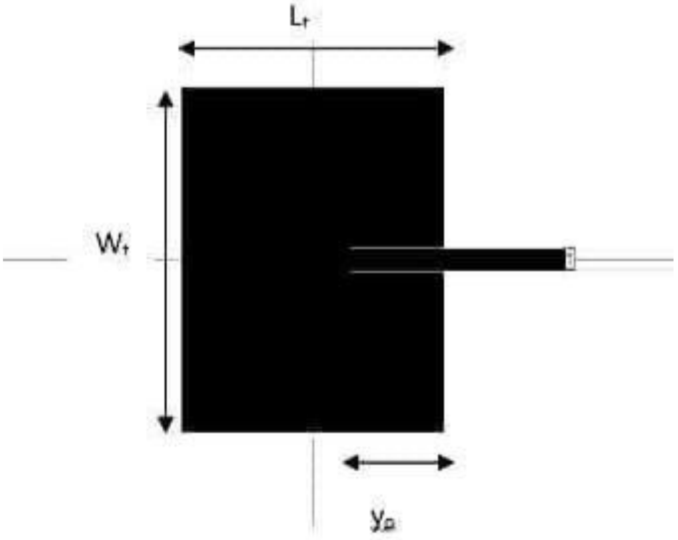
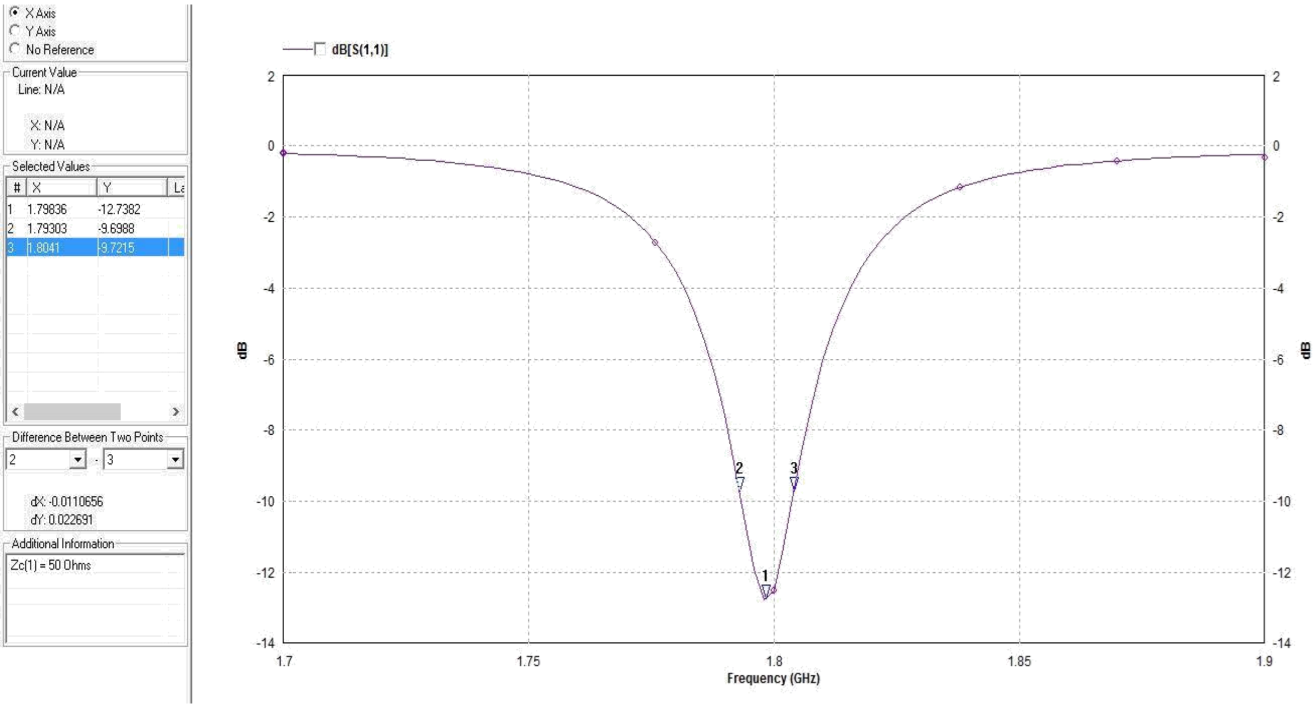


Figure 3.3(c) Design of the single band RMPA



● X Axis
○ Y Axis
○ No Reference

Current Value
Line: N/A
X: N/A
Y: N/A

Selected Values

#	X	Y	La
1	1.79836	-12.7382	
2	1.79303	-9.6988	
3	1.8041	-9.7215	

Difference Between Two Points
2 - 3
dX: -0.0110656
dY: 0.022691

Additional Information
Zc(1) = 50 Ohms

Figure 3.3(d) Return loss of the single band RMPA

We built E-shape antenna with an extra plow-shape in the proposed antenna to achieve our desired antenna and frequency band. Figure 3.3(e) depicts the proposed antenna, while Figure 3.3(f) depicts the desired bandwidth and return loss graph (f). The proposed antenna's dimension is measured in millimeters (mm).

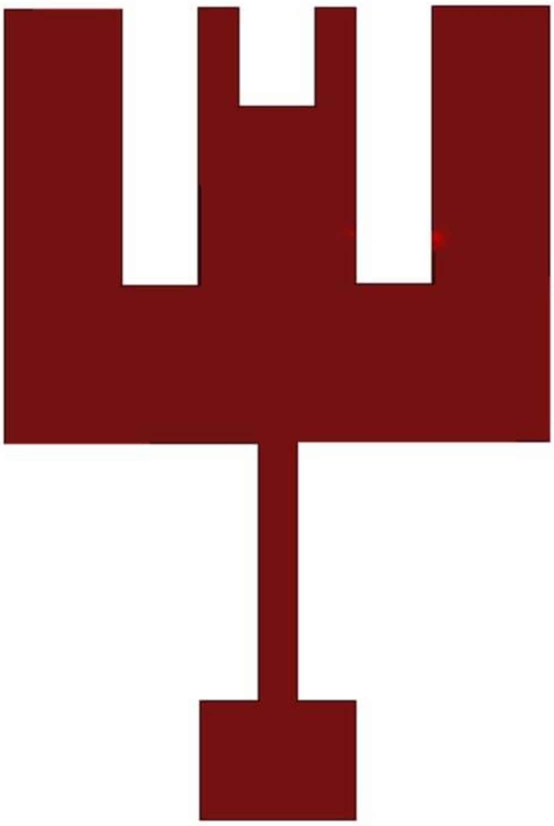
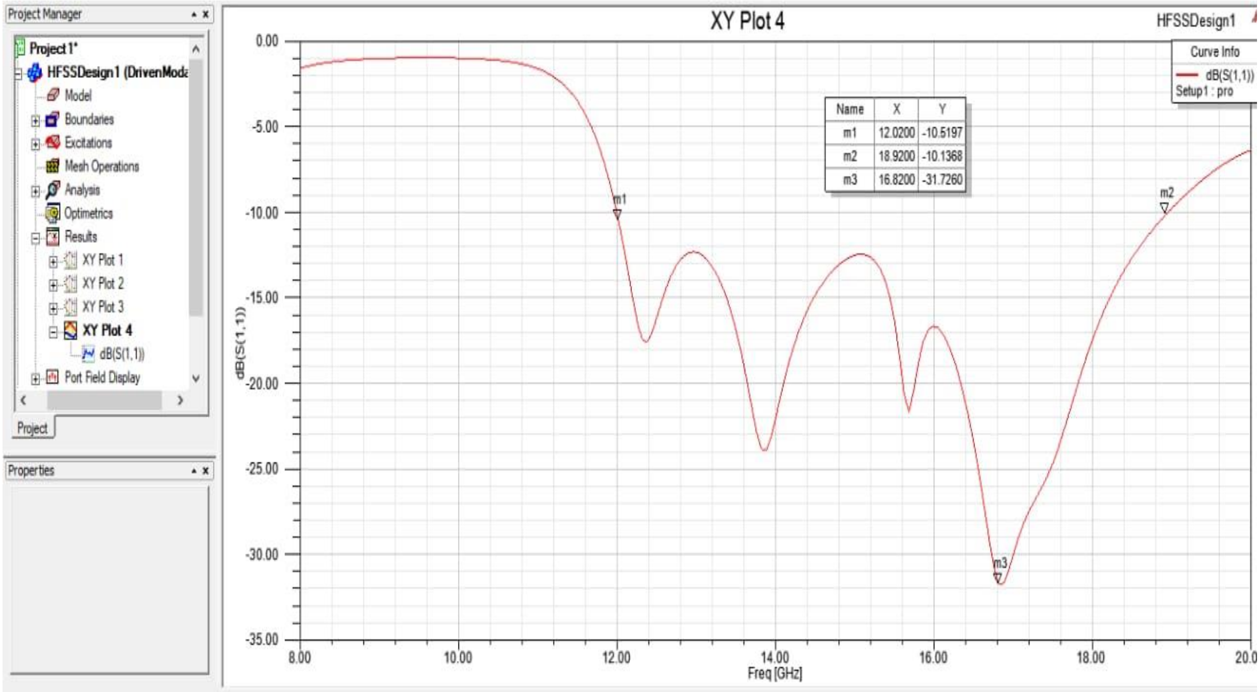


Figure 3.3(e): The design of the proposed antenna



Name	X	Y
m1	12.0200	-10.5197
m2	18.9200	-10.1368
m3	16.8200	-31.7260

Figure 3.3(f): The desire return loss graph

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Results and Discussion of the Proposed Antenna using HFSS Software:

In the previous chapter a vivid simulation has been performed to design the desire antenna for the frequency range of 12-19 GHz. As a result we have found an antenna having an area 30×30 mm^2 with six different notch band. The resonant frequencies are 12.38 GHz, 13.88 GHz, 15.68 GHz, 16.88 GHz lower than -10dB return loss, -17.57dB, -23.91dB, -21.62dB, -31.62dB respectively. In the proposed antenna slot cutting technique has been assigned for better antenna characteristics. Modified **E** shape slots are imposed in this patch antenna to increase the bandwidth. The proposed antenna has bandwidth of 7 GHz and it can cover 100% of **KU** band frequency range, it means antenna has the ability of **KU** band application.

All the antennas are explored by the performance analysis under the HFSS Software. We should examine our antenna operation in each of the standards by our antennas bandwidth, return loss, average current distribution, vector current distribution, 2D, 3D radiation patterns of gain and directivity for a frequency in each bands. The current distribution provides us an insight into the antenna structure by showing the density and the direction of current movement inside the patch at different frequencies. It also gives us how different part of the antenna behaves for different operating frequencies. 2D and 3D radiation pattern demonstrates us how antenna radiates its output signal. 2D radiation profile provides information about the gain and polarization of E-H fields where as 3D radiation patterns can illustrate the directivity and emission style. If all the distribution and pattern at all operating frequencies are found satisfactory only then we can proceed to future works with this simulated model [24].

4.1.1 Average Current Distribution

Average current distribution demonstrates average intensity of the current in terms of colour representation on the patch at each location. It can be noticed from the average current distribution which is radiating and which is non-radiating side. However, the simulation results observed antenna at six different frequencies f = 12.38 GHz, 13.88 GHz, 15.68 GHz, 16.88 GHz with 10 cells per wavelength for better precision and it illustrates the average current distribution over the antenna surface [26].

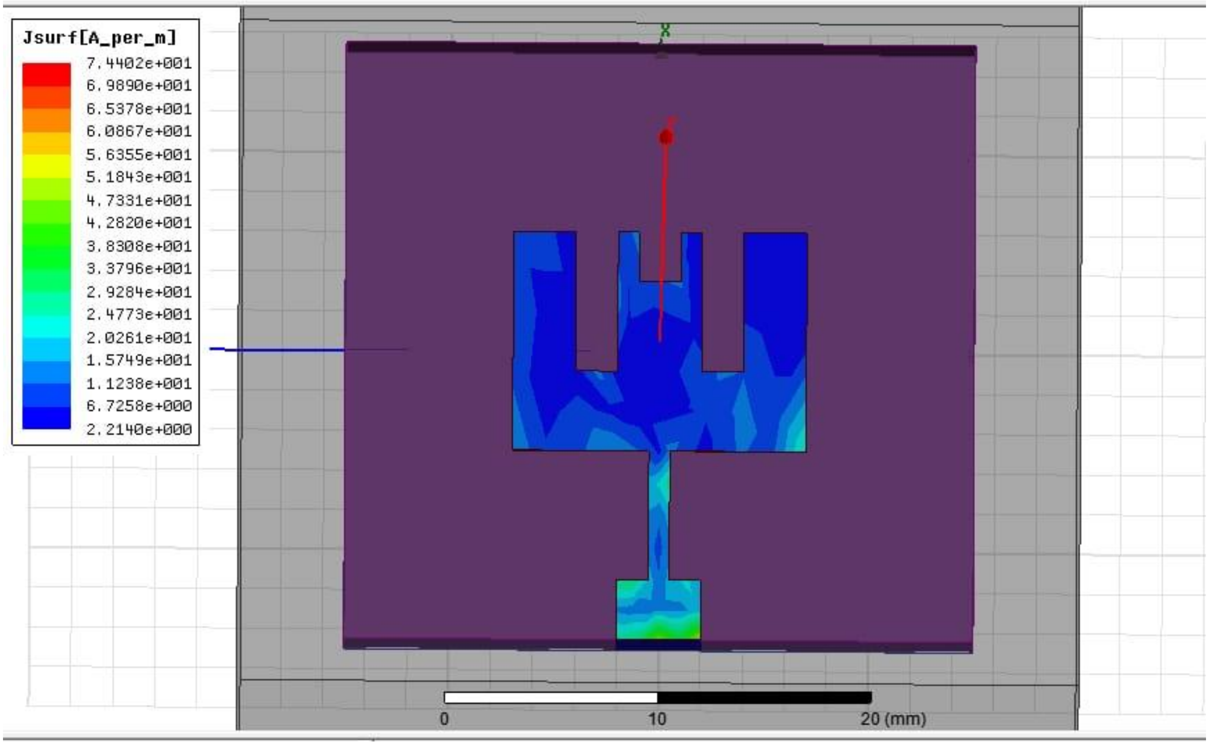


Figure 4.1(a) Average current distribution of proposed antenna at 12.38 GHz

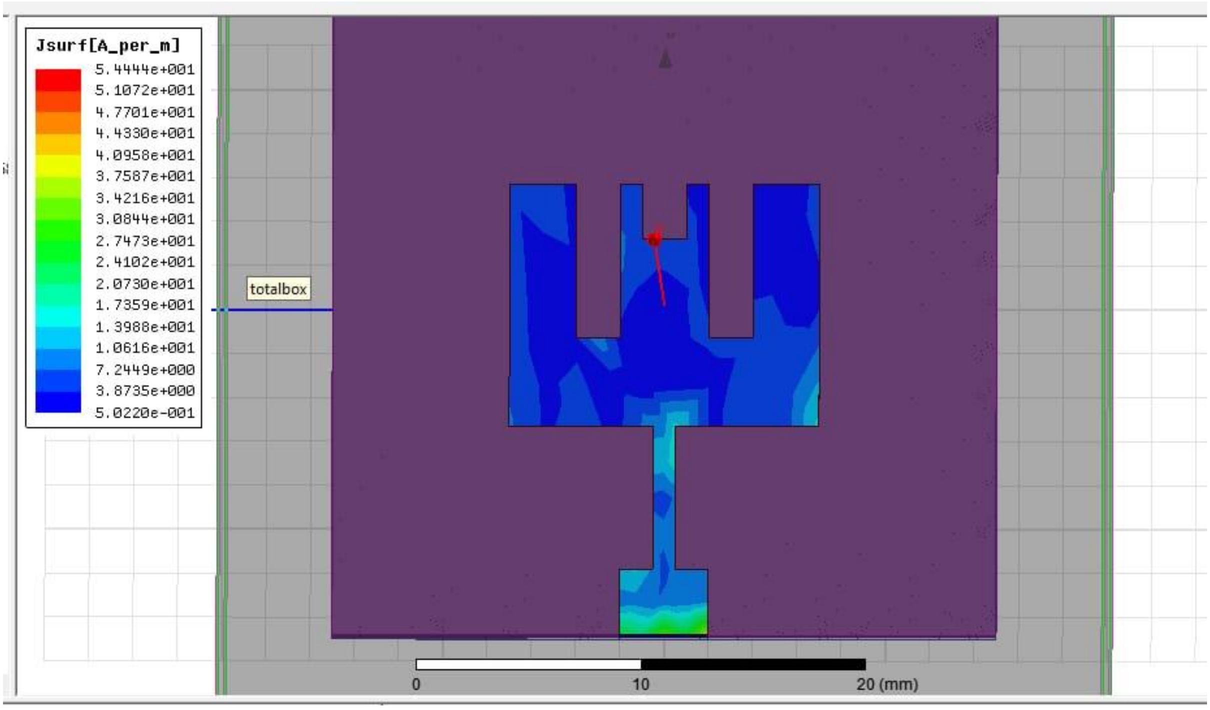


Figure 4.1(b) Average current distribution of proposed antenna at 13.88 GHz

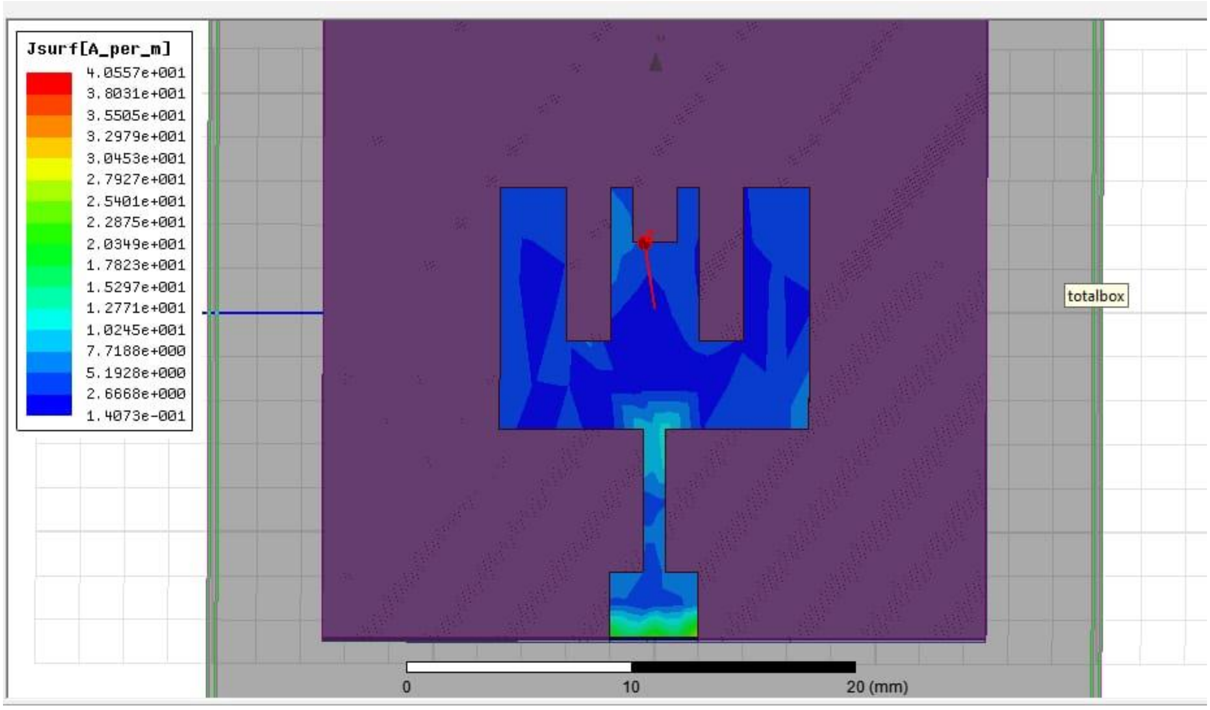


Figure 4.1(c) Average current distribution of proposed antenna at 15.68 GHz

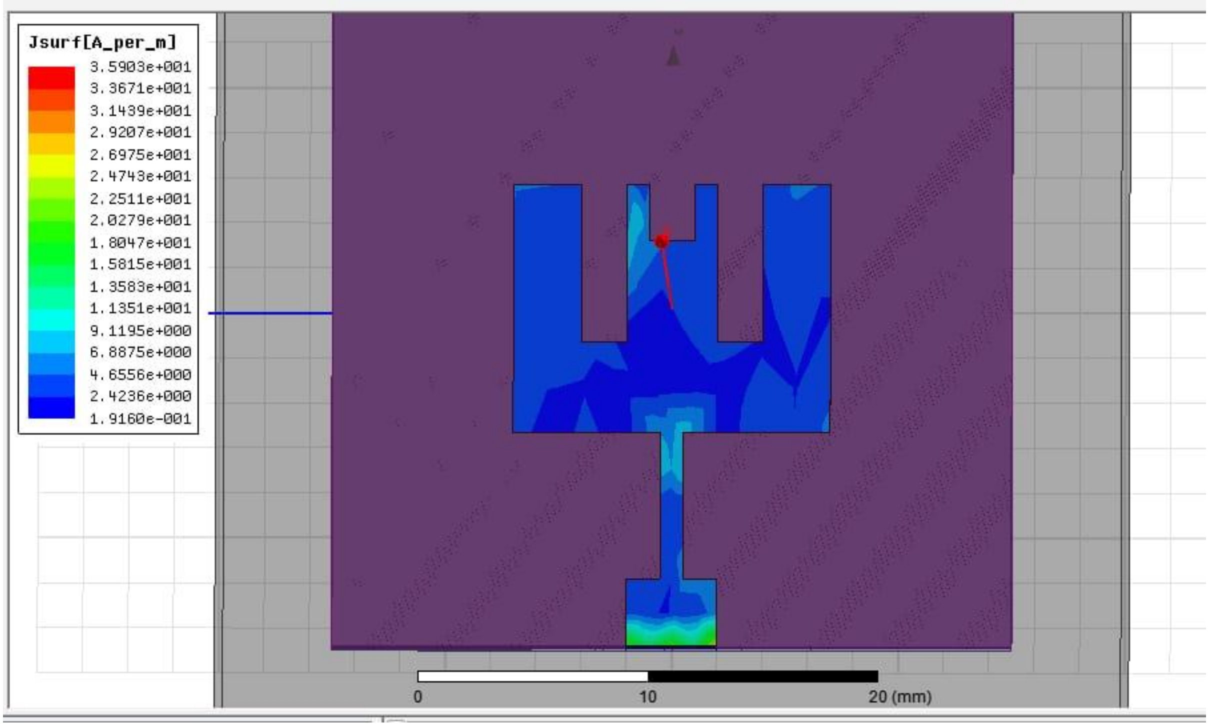


Figure 4.1(d) Average current distribution of proposed antenna at 16.88 GHz

4.1.2 Vector Current Distribution

Vector current distribution illustrates how the current flows in the surface and how the current is distributed of the antenna. It also helps us to determine the polarization of the antenna as well as its give us insight to the pathway and the movement of current at the resonant frequency over the patch surface. For the same frequency we will now compare the vector current distribution on the surface of patch to comprehend the frequency response better.

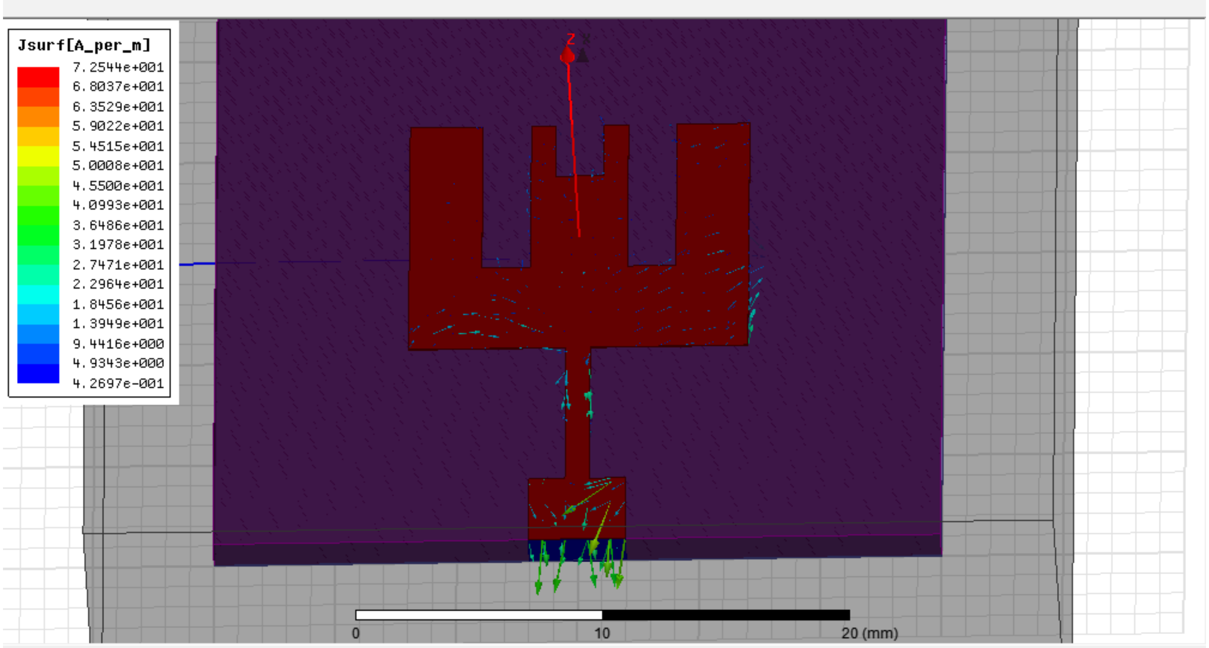


Figure 4.2 (a) Average vector distribution of proposed antenna at 12.38 GHz

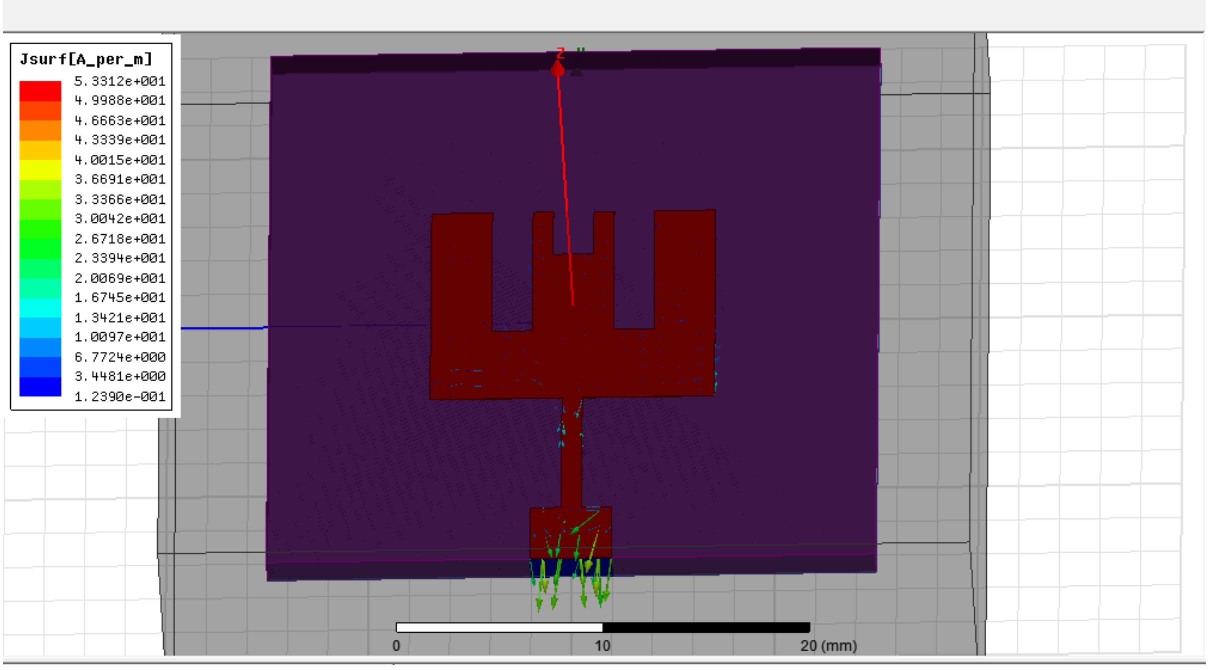


Figure 4.2(b) Average vector distribution of proposed antenna at 13.88 GHz

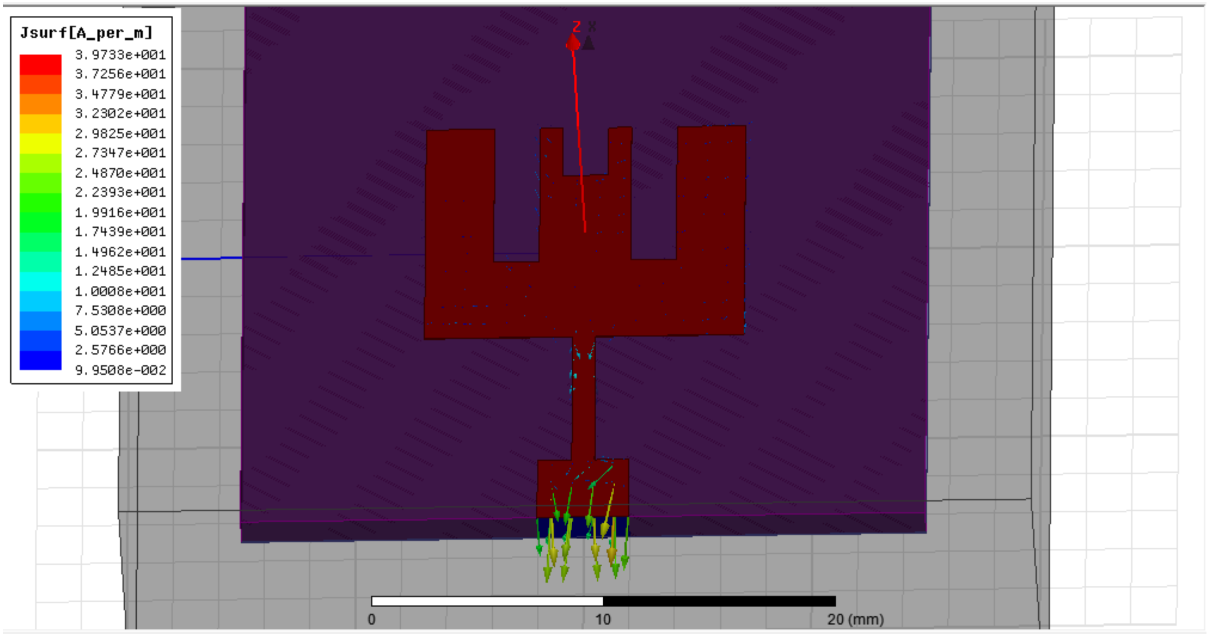


Figure 4.2(c) Average vector distribution of proposed antenna at 15.68 GHz

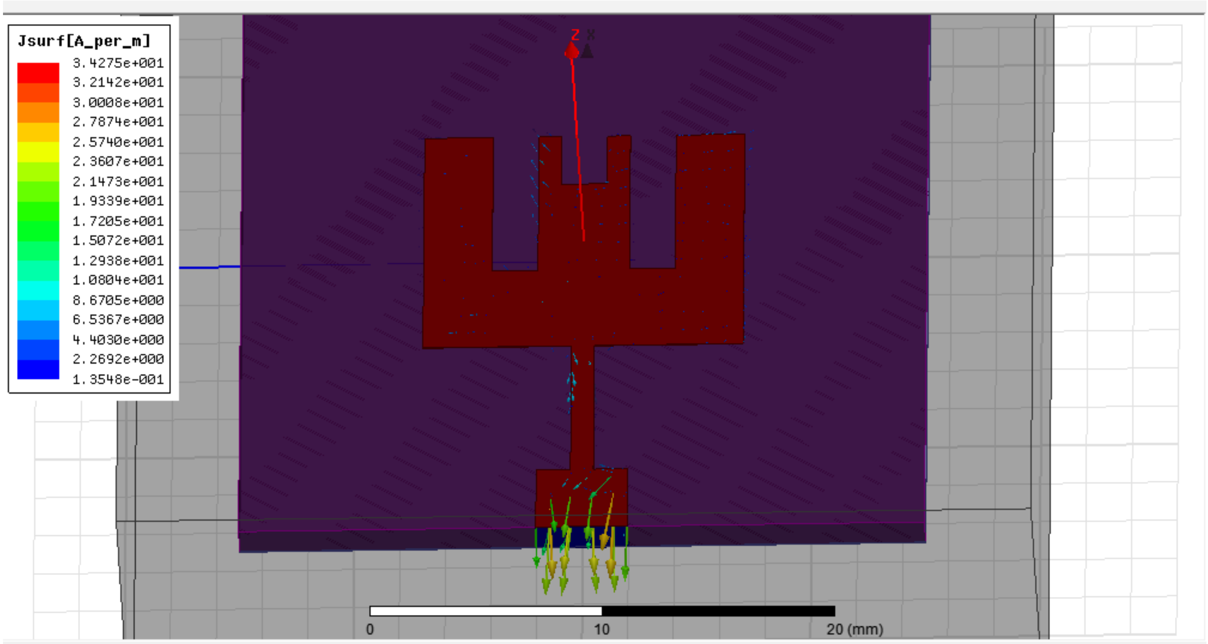


Figure 4.2(d) Average vector distribution of proposed antenna at 16.88 GHz

4.1.3 2D Radiation Pattern

A good antenna should maintain its radiation pattern and polarization throughout the frequency range that it covers. Since a microstrip patch antenna radiates normal to its patch surface, the elevation pattern for φ=0 and φ=90 degrees wold be important. The following Figures below illustrate the gain and 2D polar plot of the designed antenna at resonant frequencies respectively for φ=0 and φ=90 degrees.

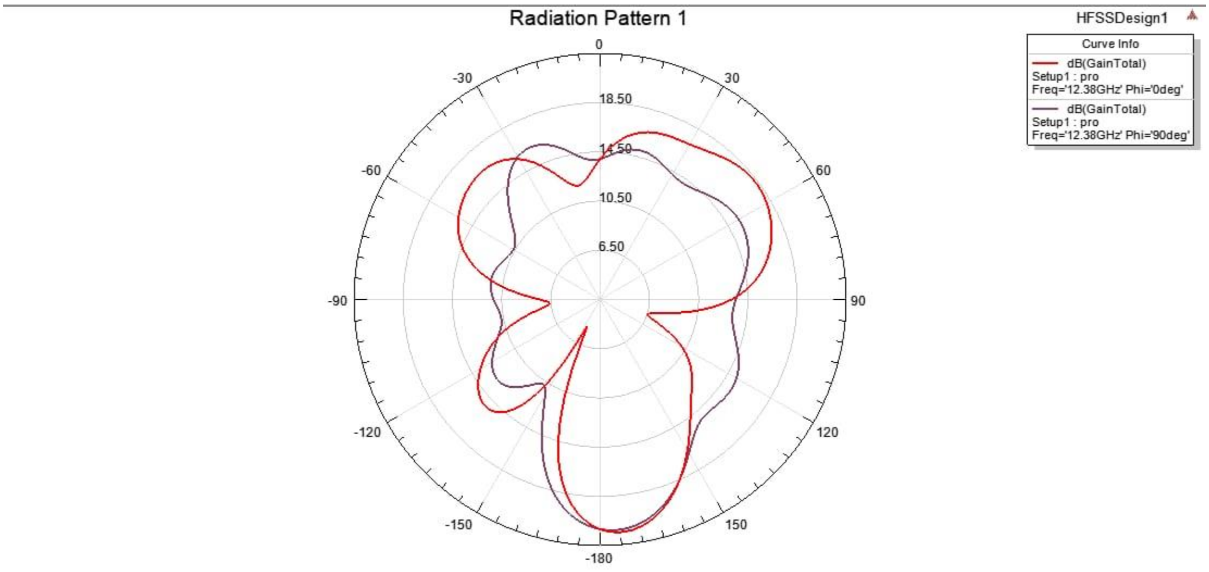


Figure 4.3(a) 2D radiation pattern of proposed antenna at 12.38 GHz

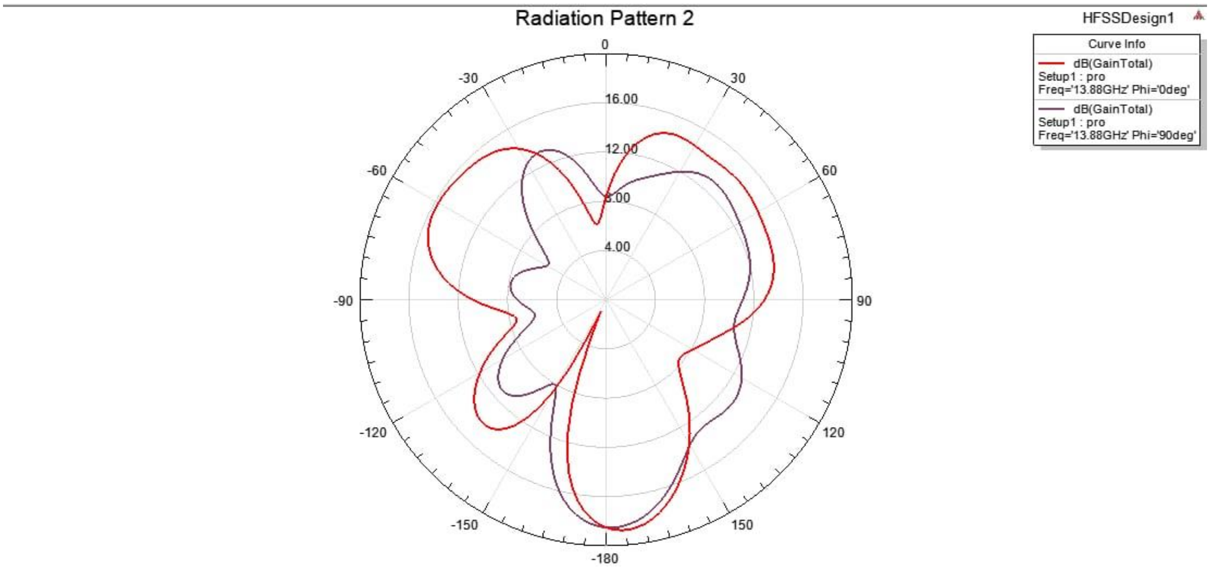


Figure 4.3(b) 2D radiation pattern of proposed antenna at 13.88 GHz

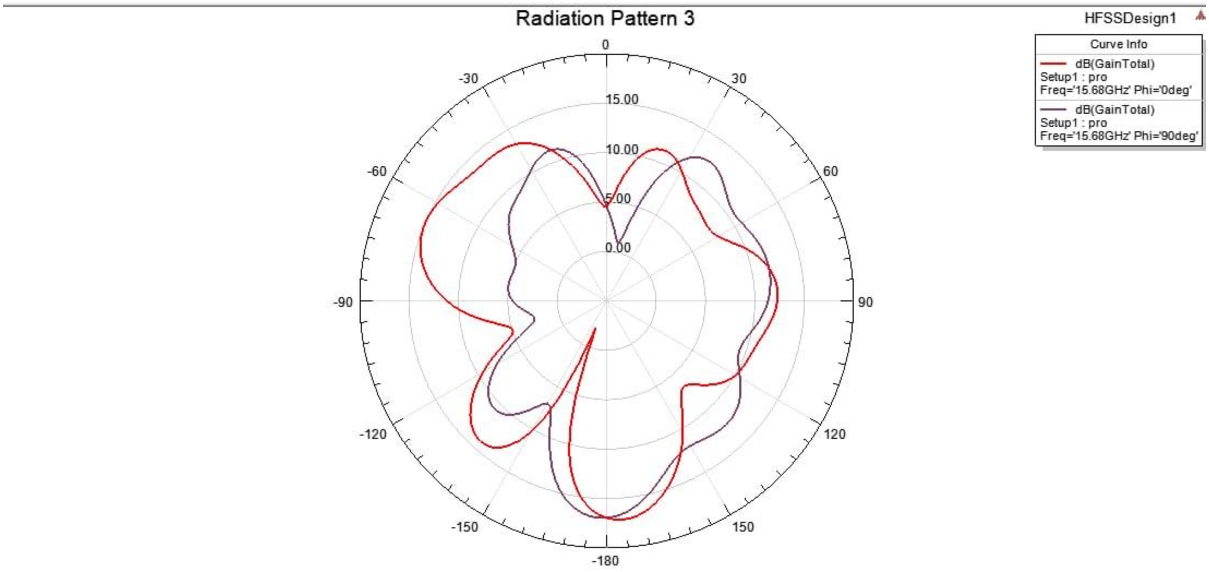


Figure 4.3(c) 2D radiation pattern of proposed antenna at 15.68 GHz

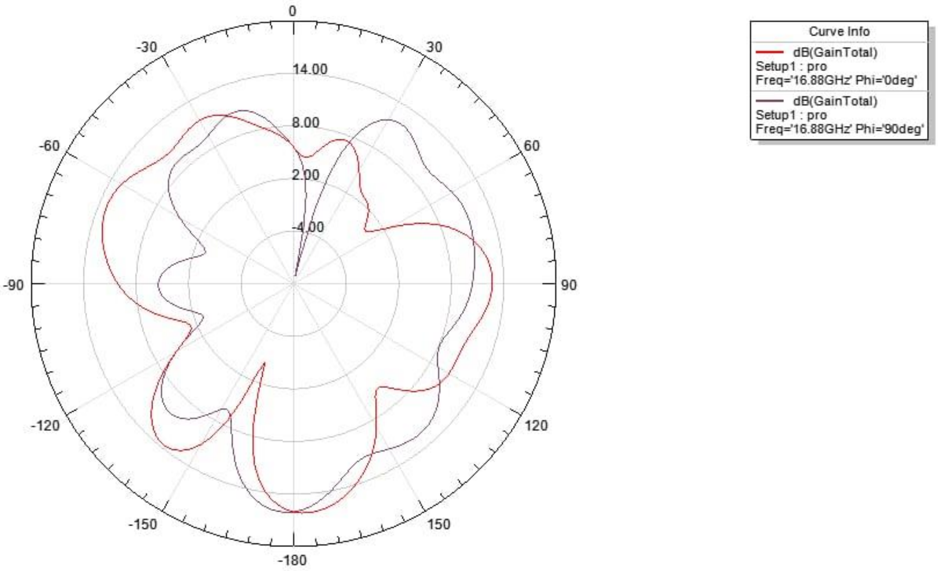


Figure 4.3(d) 2D radiation pattern of proposed antenna at 16.88 GHz

4.1.4 3D Radiation Pattern

3D radiation pattern depicts better understanding of antenna power radiation direction. Following figures illustrate true 3D radiation patterns at six resonant frequencies of the proposed antenna. The size of the pattern from the origin represents how strong the field at a specific (theta, phi) angle [23].

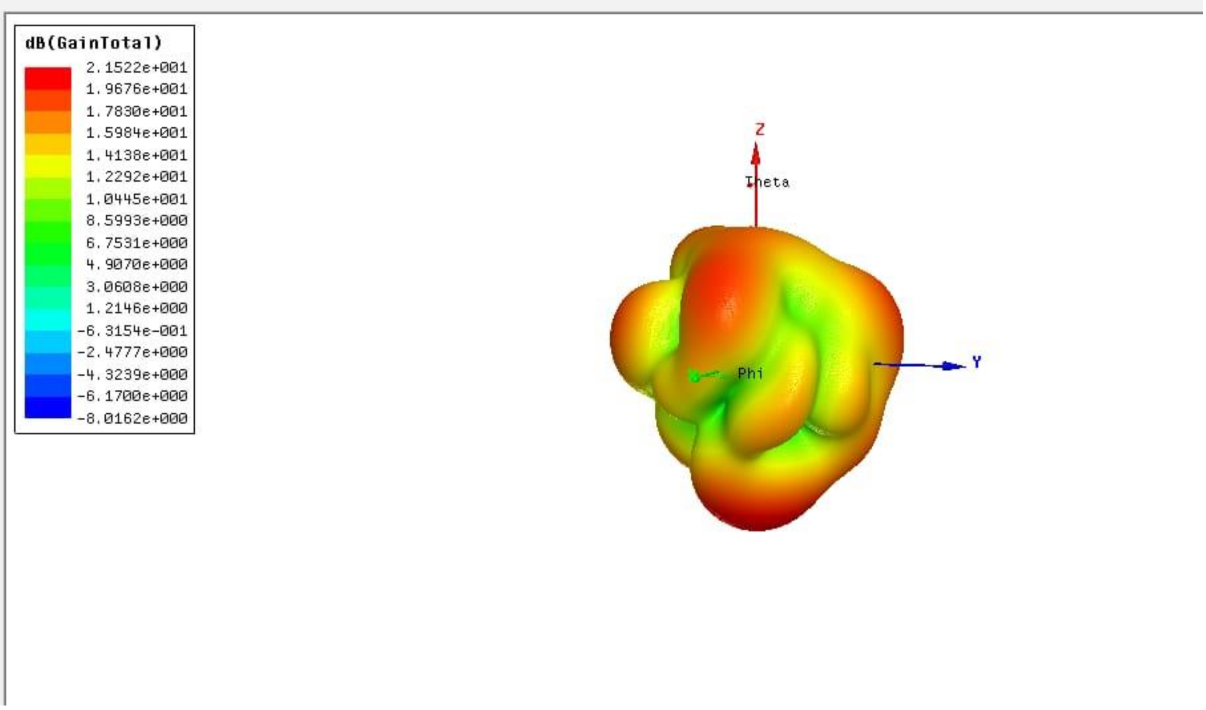


Figure 4.4(a) 3D radiation pattern at 12.38 GHz

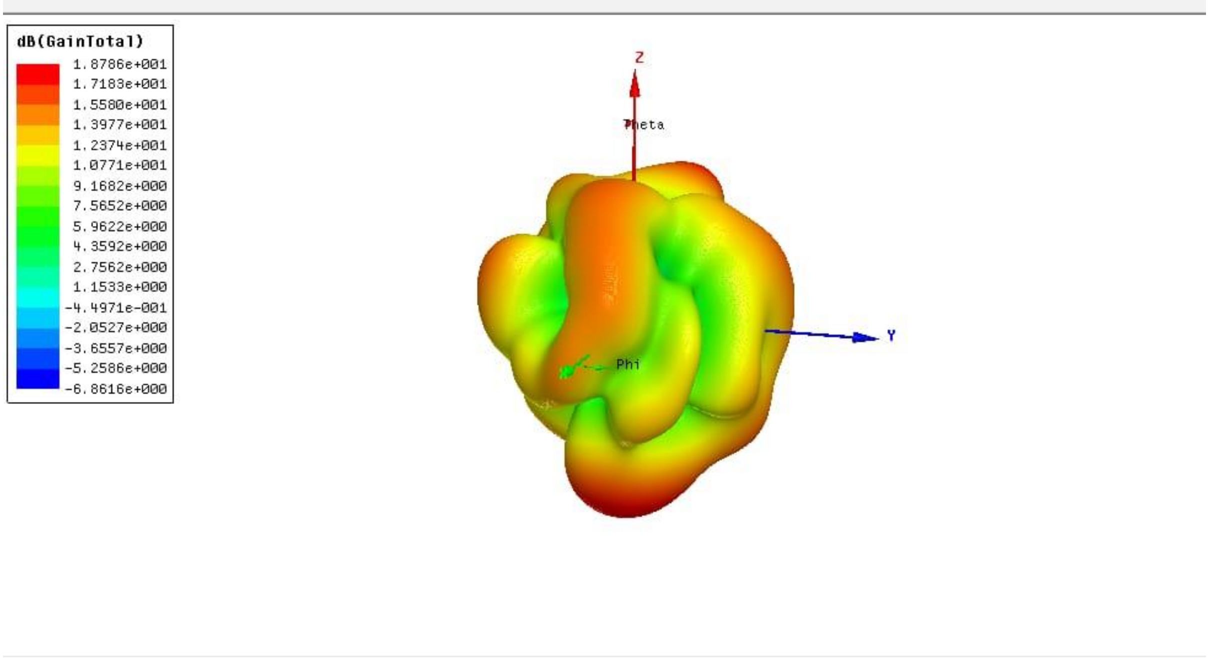


Figure 4.4(b) 3D radiation pattern at 13.88 GHz

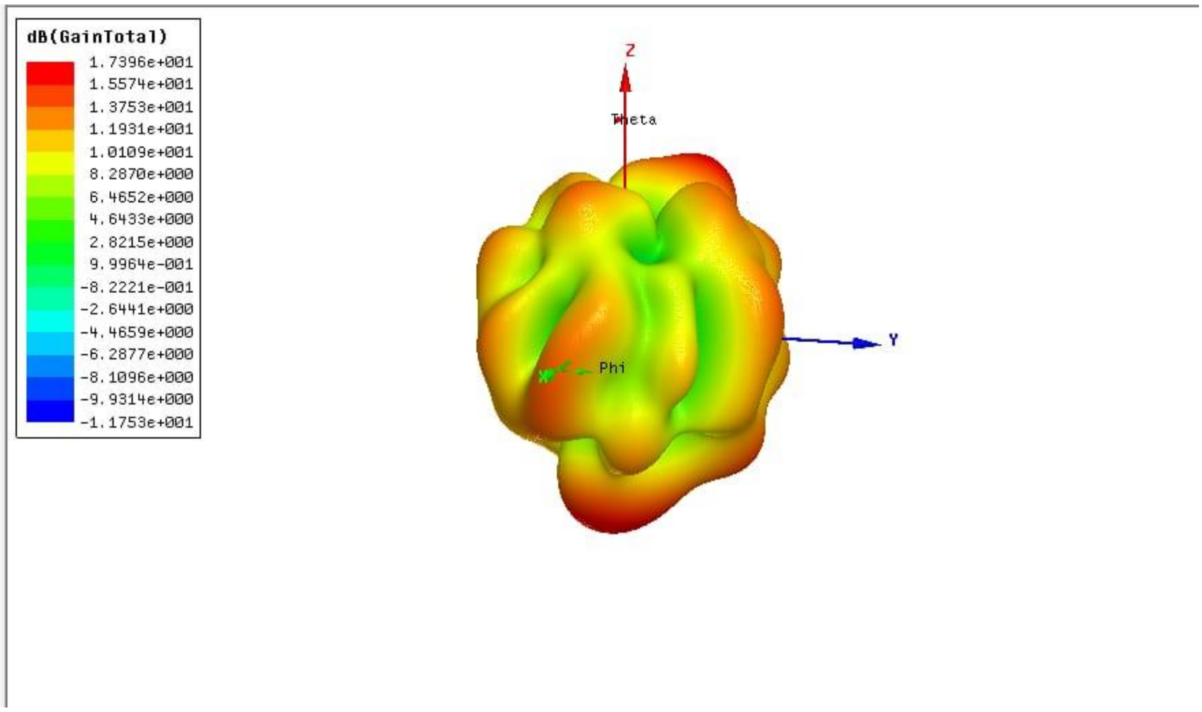


Figure 4.4(c) 3D radiation pattern at 15.68 GHz

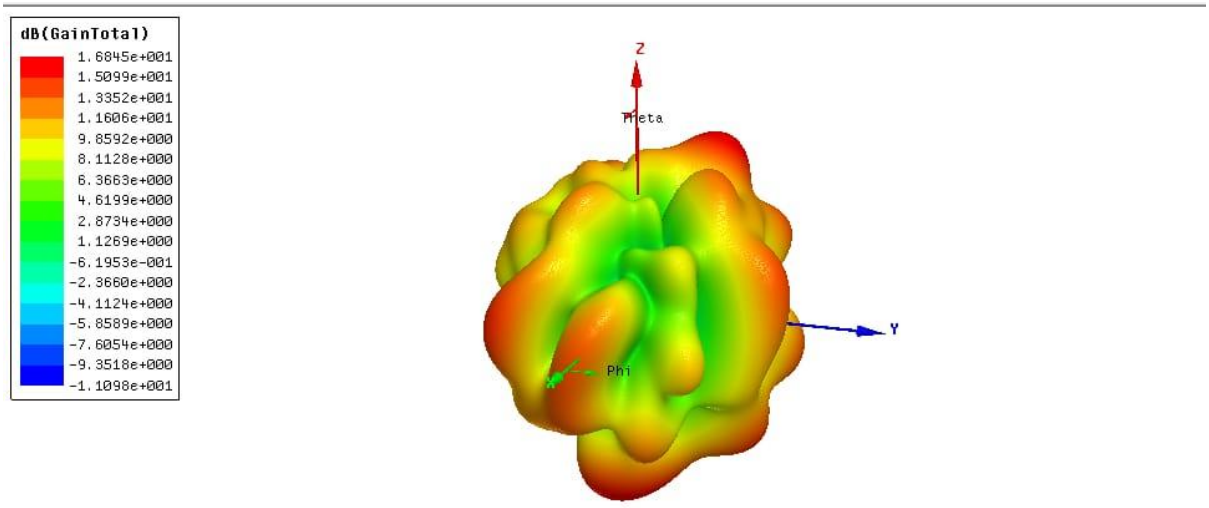


Figure 4.4(d) 3D radiation pattern at 16.88 GHz

4.1.5 Gain and Directivity

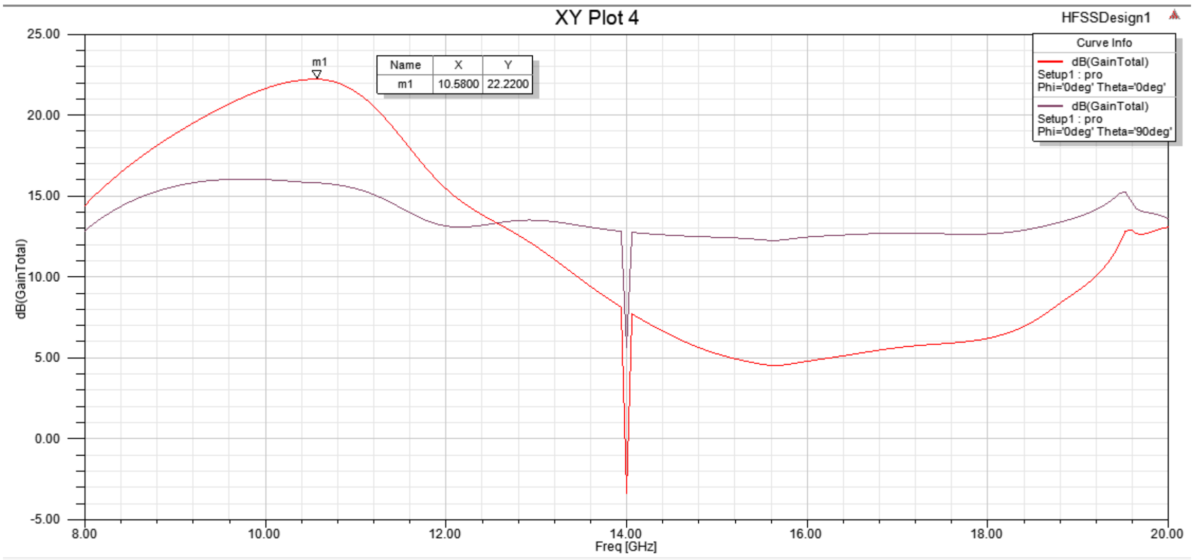


Figure 4.5(a) Frequency Vs Gain

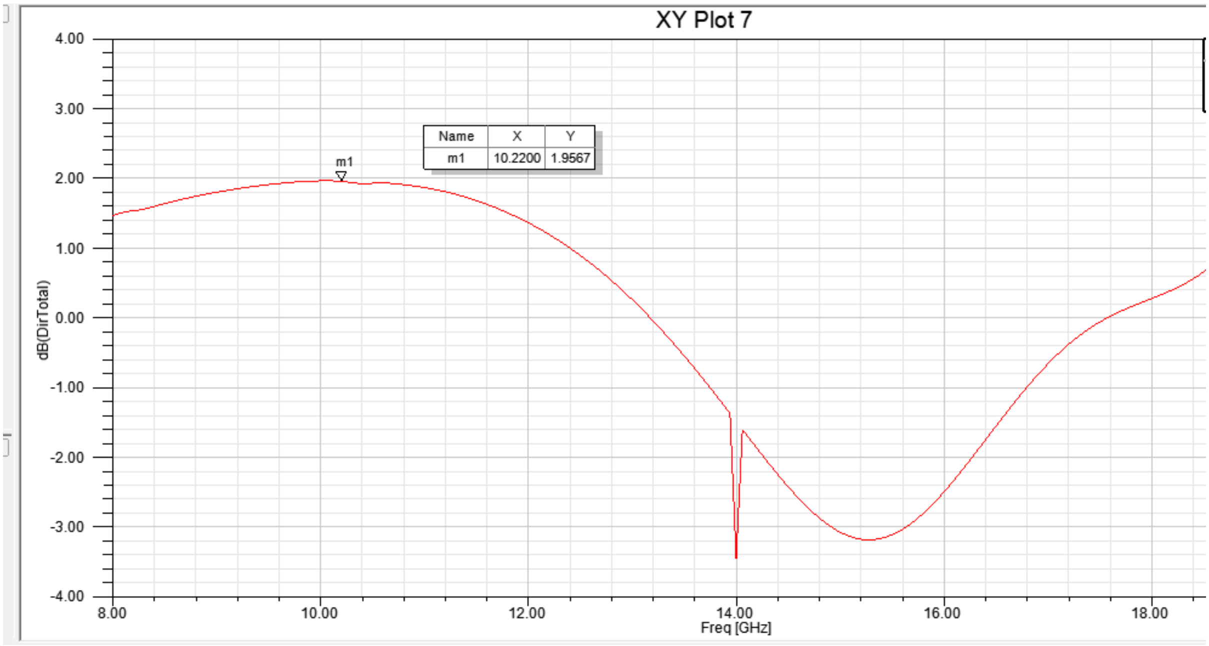


Figure 4.5(b) Frequency Vs Directivity

Table 4.1: The results of proposed antenna after simulation.

Antenna Parameters	RMPA with modified E shape			
Resonant Frequency(GHz)	12.38	13.88	15.68	16.88
Return Loss(dB)	-17.57	-23.90	-21.62	-31.62
Bandwidth	7GHz			
Gain	10.58 dBi			
Directivity	10.22 dBi			
Efficiency (%)	90.71			

TABLE 4.2: Comparison between proposed design and reference based on C band coverage.

Parameters	References					Proposed Antenna
	22	19	21	14	10	
Substrate Height (mm)	1.588	1.59	6.7	1.6	8	1.575
Length (mm)	27.0195	50	36	18.89	78	30
Width (mm)	33.884	48	48	28.5	100	30
Band Width	3.51 GHz	9.2 GHz	7.8 GHz	10.9 MHz	1.419 GHz	7 GHz
Return Loss	-21.4 dB	-14.6 dB	-33 dB	-20 dB	-53.94dB	-31.72 dB
Gain (dB)	8.21	7	5.6	8	3.64	10.58
Directivity (dBi)	8.40	N/A	N/A	8.2	3.7	10.22

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Major Contribution of the Thesis

Microstrip patch antennas are immensely popular for light weight, low cost and low profile. Ultra wide technology is the major challenge of patch antenna to decline drawback (narrow bandwidth and low gain) and improve it. Interference is a significant problem of patch antenna with the subsisting narrow band systems.

In this thesis, the narrow bandwidth and low gain problem for patch antenna has been observed. The slot cutting method is applied in this proposed antenna which affects electromagnetic properties of host medium, therefore it has the working power to improve bandwidth and gain. This thesis narrates a successive improvement in antenna characteristic from a compact microstrip line fed antenna designing process. The bandwidth of the proposed antenna is capitally raised by modified The dimension of the antenna is 30×30 mm2 and 11×14×0.035 mm3 is the installed antenna respectively with substrate height of 1.575mm. The proposed patch antenna covers full KU band with four resonant frequencies at 12.38GHz, 13.88GHz, 15.68GHz.16.88GHz. The reflection coefficient or return loss at these frequencies are -17.57dB,-23.90, -21.62dB, -31.62dB, respectively and VSWR is less than 2 for the whole UWB antenna. Maximum gain and directivity of the structure are 10.58 dBi and 10.22 dBi respectively.

All these optimization have performed using HFSS electromagnetic simulation software. A comparative study with existing literature has been given to understand the effects of various parameters between each other in term of bandwidth, gain, directivity, return loss and size. The consequences of the results are appeased and inspiring. The proposed antenna can be used in several wireless application.

5.2 Future Scope of work

We tested our Microstrip patch antenna and simulated the results to establish the band width and antenna parameters in this thesis. Aside from that, the thesis' main contribution is that fabrication can be done in the future to observe the antenna's real-time efficiency. Actually, the proposed antenna can be manufactured commercially for use in the KU band. Additionally, slot cutting technique, array, optimization, size reduction, and antenna type change can all be used to boost the proposed antenna's efficiency. Metamaterials may also be used as substrates and also we try to verify the same design by CST suite.

REFERENCES

[1] D. R. K.Dinakaran, M.Vajikabanu, Piriyadharsini, “Design of Microstrip Patch Antenna For satelite Applications,” *Ijarece*, vol. 5, no. 1, pp. 38–41, 2016.

[2] V. H. R. Keerthi, H. Khan, and P. Srinivasulu, “Design of ku-Band Microstrip Patch Antenna for Radar Applications Using IE3D,” vol. 5, no. 3, pp. 49–58, 2013.

[3] P. Gour, R. Mishra, A. S. Zadgaonkar, and P. K. Sahu, “Circular polarized broad band microstrip patch antenna for C band,” *Int. J. Control Theory Appl.*, vol. 9, no. 41, pp. 191–197, 2016.

[4] S. K. Padhi, N. C. Karmakar, C. L. Law, and S. Aditya, “A Dual Polarized Aperture Coupled Circular Patch Antenna Using a C-Shaped Coupling Slot,” *IEEE Trans. Antennas Propag.*, vol. 51, no. 12, pp. 3295–3298, 2003, doi: 10.1109/TAP.2003.820947.

[5] R. Azim, M. T. Islam, and A. T. Mobashsher, “Dual band-notch UWB antenna with single tri-arm resonator,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 13, pp. 670–673, 2014, doi: 10.1109/LAWP.2014.2314486.

[6] V. S. Rao, D. R. Jahagirdar, and G. Kumar, “Design and development of Broadband Circularly polarized C-band microstrip antenna array,” *11th IEEE India Conf. Emerg. Trends Innov. Technol. INDICON 2014*, pp. 6–9, 2015, doi: 10.1109/INDICON.2014.7030582.

[7] U. Chakraborty, A. K. Biswas, A. Kundu, and S. K. Ram, “A Wide Band Microstrip Antenna for WLAN, C Band Uplink and Wimax Applications,” *2017 IEEE Int. Conf. Comput. Intell. Comput. Res. ICCIC 2017*, vol. 1, pp. 1–3, 2018, doi: 10.1109/ICCIC.2017.8524210.

[8] S. Rawat and K. K. Sharma, “A compact broadband microstrip patch antenna with defected ground structure for C-band applications,” *Cent. Eur. J. Eng.*, vol. 4, no. 3, pp. 287–292, 2014, doi: 10.2478/s13531-013-0162-1.

[9] W. Afzal, M. Z. Baig, and M. Z. Babar, “Optimization of Microstrip Patch Antenna for C-band and WLAN Applications,” no. July 2017, 2015.

[10] V. Singh, H. Bhatia, P. Kuchroo, and E. Sidhu, “Slotted rook shaped novel wide-band microstrip patch antenna for radar altimeter, IMT, WiMAX and C-band satellite downlink applications,” *Proc. - Int. Conf. Glob. Trends Signal Process. Inf. Comput. Commun. ICGTSPICC 2016*, pp. 334–337, 2017, doi: 10.1109/ICGTSPICC.2016.7955323.

[11] S. Perhirin and Y. Auffret, “A low consumption electronic system developed for a 10km long all-optical extension dedicated to sea floor observatories using power-over-fiber technology and SPI protocol.,” *Microw. Opt. Technol. Lett.*, vol. 55, no. 11, pp. 2562–2568, 2013, doi: 10.1002/mop.

[12] Z. W. Yu, G. M. Wang, and C. X. Zhang, “A broadband planar monopulse antenna array of C-band,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 8, pp. 1325–1328, 2009, doi: 10.1109/LAWP.2009.2038077.

[13] N. M. Thaker and V. Ramamoorthy, “A Review on Circular Microstrip Patch Antenna with Slots for C Band Applications,” *Int. J. Sci. Eng. Res.*, vol. 5, no. 12, pp. 1039–1043, 2014.

[14] Shuchismita Pani, Parameswar Banerjee, “Design and performance analysis of E shaped patch antenna with different feed point for Ku-band application.” DOI: 10.1109/RAECS.2015.7453306.

[15] W. M. Khan and S. M. Gulhane, “Related review on microstrip patch antennas 1,” no. 1, pp. 9–15, 2015.

[16] F. Yang, X. X. Zhang, X. Ye, and Y. Rahmat-Samii, “Wide-band E-shaped patch antennas for wireless communications,” *IEEE Trans. Antennas Propag.*, vol. 49, no. 7, pp. 1094–1100, 2001, doi: 10.1109/8.933489.

[17] A. M. Hadian, H.R. Hassani."Wideband rectangular microstrip patch antenna with U-slot.' Antenna propagation, 2007.

[18] S. Weigand, G. H. Huff, K. H. Pan, and J. T. Bernhard, “Analysis and design of broad-band single-layer rectangular U-slot microstrip patch antennas,” *IEEE Trans. Antennas Propag.*, vol. 51, no. 3, pp. 457–468, 2003, doi: 10.1109/TAP.2003.809836.

[19] Partha kumar deb, Tamasi Moyra , “ Dual Band Multilayer E Shape microstrip patch antenna c and x band”

[20] M. Ismaeel, T. Jayanthy, and S. Sathyamurthy, “Comparison of rectangular and T-shaped microstrip antenna,” *Proc. 8th WSEAS Int. Conf. Electron. hardware, Wirel. Opt. Commun.*, pp. 185–189, 2009.

[21] Mamta Devi Sharma, Abhishek Katariya, “E Shaped Patch Microstrip Antenna for WLAN Application Using Probe Feed and Aperture Feed,” DOI: 10.1109/CSNT.2012.24

[22] Md. Mamun Hossain,Md Abdul Wahed,M.A Motin, “Design and Simulation of an dual frequency E shaped microstrip patch antenna for wireless communication,”

[23] S. M. M. R. Al-Arif, “Design and Analysis of a Wideband Microstrip Antenna for High Speed WLAN,” *Int. J. Comput. Appl.*, vol. 111, no. 12, pp. 16–23, 2015, doi: 10.5120/19590-1355.

[24] Khan, W.M. and S.M. Gulhane, Related review on microstrip patch antennas. International Journal of Industrial Electronics and Electrical Engineering.

[25] Ge, Y.; Esselle, K.P.; Bird, T.S.; , ‘E-shaped patch antennas for highspeed wireless networks,’ Antennas and Propagation, IEEE Transactionson , vol.52, no.12, pp. 3213- 3219, Dec. 2004.

[26] Ang. B. K., & Chung, B. K. (2007). A wideband E-shaped microstrip patch antenna for 5-6 GHz wireless communications. Progress in Electromagnetics Research, 75, 397-407...

[27] Ge, Y., Esselle, K. P., & Bird, T. S. (2006). A compact E-shaped patch antenna with corrugated wings. IEEE transactions on antennas and propagation, 54(8), 2411-2413.

[28] B. Z. Wang, S. Xiao, and J. Wang, “Reconfigurable patch-antenna design for wideband wireless communication systems," Microwaves, Antennas & Propagation, IET , vol.1, no.2, pp.414-419, April 2007.