Design and analysis of T-shape Microstrip antenna for WLAN and C band application.

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Science

In

Electrical and Electronic Engineering

By

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18th October 2020

Daffodil International University

18th October 2020

Certification

This is to certify that the thesis entitled, "**Design and analysis of T-shape microstrip antenna for WLAN and C band application**" submitted by **Subroto Kumar** 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 my/our knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

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My Parents

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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
ε_{eff}	Effective dielectric constant
$\tan\delta$	Loss tangent
h	Height
fr	Resonant frequency
V_0	Velocity of light
L_{eff}	Effective length
φ	Angle

ACKNOWLEDGEMENT

I express our sincere gratitude and indebtedness to the thesis supervisor **Md. Ashraful Haque,** for his initiative in this field of research, for his valuable guidance, encouragement and affection for the successful completion of this work. His sincere sympathy and kind attitude always encouraged us to carry out the present work firmly. I express our thankfulness to **Prof. Dr. Md. Shahid Ullah**, Head of the Department of Electrical and Electronic Engineering, DIU, Ashulia for providing us with best facilities in the Department and his timely suggestions. I would also like to thank **Md. Ashraful Haque,** Assistant Professor, Department of Electrical and Electronic Engineering, DIU, Ashulia for his guidance and suggestions in our work. I would also like to thank Zeland Software for providing the simulation package. I am very grateful and thanks to **Abu Saleh** to helping me so much for teaching about CST software.

Last but not least we would like to thank all my friends and well-wishers who were involved directly or indirectly in successful completion of the present work.

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ABSTRACT

In this paper, a new formation of modified T shape simple Microstrip patch antenna (MPA) is designed and analyzed for Wi-Fi applications. The proposed antenna operates between the frequencies of 4 GHz to 8 GHz with return loss below -10 dB which almost covers entire C band with standard gain. Besides the proposed antenna is designed to operate at C band and WLAN (802.11/a/b/g) frequency bands by feeding a coaxial probe and the MPA is simulated on Zeland IE3D simulation software using Arlon cu 217LX (lossy) substrate with dielectric constant of 2.2 and thickness of 2.425mm. The dimension of designed antenna consists of 20 × 10× 2.425 mm^3. The proposed antenna resonates at 5.121 GHz for IE3D and 5.78 GHz for CST which can be used in Satellite applications, aircraft, space craft and wireless communication such as WLAN, WiMAX and Wi-Fi. The noted gain and directivity are 5.42929 dB and 6.16506 dBi respectively at 5.121 GHz and Gain and directivity are 4.47 dBi and 5.46 dB respectively at resonant frequency 5.78 GHz for CST. Through simulations better return loss and VSWR (<2) is achieved.

CHAPTER 1

OVERVIEW

1.1 Introduction

Wireless communication is rapidly growing part of the communication industry. It has become user-friendly in our society and essential for our daily lives. It gives new sense of mobility to us and revolutionized way to do almost everything with great pleasure. Microstrip patch antennas (MPA) are widely used in ubiquitous industry and it has skimmed attention of the researchers because of various properties like low profile, easy fabrication and integration with circuits, easily mountable on vehicles etc. [9, 22]. These magnificent properties of MPA contribute in the military applications such as missiles, space craft, aircraft and also in the commercial areas such as cellular mobile communications, mobile satellite system and global positioning system. The selection of proper antenna depends on the requirements of the application such as cost, size, gain, bandwidth, efficiency, radiation pattern, frequency band and coverage and it will reduce power consumption and improve transmission efficiency. Wi-Fi is the fastest growing part in the modern wireless communication which gives the users the mobility, freedom and flexibility to move around within a broad coverage area and still be connected to the network [1]. Worldwide electromagnetic spectrum has been allocated for all types of electromagnetic (EM) radiation based on EM wave wavelengths and frequencies where antennas can operate according to the applications of wireless local area network connections (WLAN), and satellite etc. The operating frequency selection for certain antennas in part determines the material that can be used to produce the antenna. There are many materials which is used in antenna such as RT duroid, Arlon Cu, ceramic, steel plate and new artificial materials known as meta-materials has been introduced which exhibits unusual properties that are not available in the nature. Antenna performance can be improved by designing antenna with meta-materials. However, antenna is one of the most complicated aspects to radio frequency (RF) design. The range and performance of a RF link are critically depend on antenna [24].

In this paper, a single band MPA is designed for WLAN application. Designing MPA using several techniques opens the possibility in enhancement of antenna characteristic such as antenna size, gain, bandwidth, directivity etc.

1.2 Background

In 1950s the incorporate concept of MPA was first introduced by G.A. Deschamps [22]. After the evolution of the printed circuit board (PCB) technology in 1970s, many authors have developed the first practical microstrip antenna and described the radiation of the patch antenna from the ground plane by a dielectric substrate for different aspects. In view of, Munson developed an antenna on rockets and missiles, which opens comprehensive area of research all over the world [24]. A microstrip antenna consists of a very thin metallic strip known as patch placed on a ground plane. The conducting patch and ground plane are separated by dielectric substrate [antenna theory pdf]. There are many radiating structures in geometry for MPA such as rectangular, circular etc. which are widely discussed in chapter 2. The low profile planar configuration of microstrip antennas can be shaped conformal to host plane without any trouble. Many applications of microstrip antenna have drawn attention of researchers as they can work not only for civilian but also for military purpose such as mobile system, radio frequency identification (RFID), global positioning system (GPS), WLAN, Wi Max, Wi-Fi, satellite communication, radar system and missile control system etc. [22-24].

The variety in design that is possible with microstrip antennas is an ongoing area of research. Modified shapes of MPA such as rectangular or circular dimensions of length (L) or radius (r) can help to get desirable resonant frequencies [23]. The rectangular and circular patches are the most commonly used microstrip antennas. The gap between the conducting patch and ground plane known as quality factor (Q) which can reduced the bandwidth of antenna and it (Q) can be reduced by increasing the thickness of the dielectric substrate. However, the major drawback of increasing thickness is the efficiency shorten and it also indicates low power gain, extra radiation from its feed and junction points [22]. The bandwidth and gain also depends on the substrate permittivity (εr).

1.3 Literature Review

In recent years, the technological trend has focused much effort attempt into the design of microstrip patch antennas for its advantages such as low cost, light weight, capable of maintaining high performance over a large spectrum of frequencies[5]-[9]. However, low gain and narrow bandwidth are the main disadvantages for patch antenna. To overcome this drawbacks there have been taken several techniques such as modifying and combining patch shape, cutting slots, increasing the substrate thickness, introducing parasitic element [10]-[15]. Modifying patch's shape includes designing an E-shaped patch antennas [16], [17] or modifying ground plane [5], [7] or a U-slot patch antenna [18] or T shape patch antenna [19]-[22]. In [16] authors claim that patch antenna gives bandwidth up to 30% while E-shaped microstrip antenna can enhance bandwidth above 30% compared to regular MPA. The main objective of this paper is to design a T shape patch antenna to enhance bandwidth.

A T-shape microstrip patch antenna for broad bandwidth which is required for fourth generation wireless systems has been proposed in [19] with 37.21×28.89×1.6 mm^3 dimensions. The operating frequency of the T shape antenna is 2.5 GHz with return loss -13.63 dB, VSWR less than 2, bandwidth 123 MHz, and the dielectric constant as well as thickness of the antenna is 4.2 and 1.6 mm respectively. A wide Ku-band microstrip patch antenna using FR-4 substrate slab backed by a PEC ground plane has been proposed in [21] with the dimensions 20×20×1.625 mm^3 of the antenna. For improving the bandwidth and gain of antenna two rectangular patch ending with in form of the T shape were introduced. The proposed antenna exhibits a wide bandwidth of 7.5 GHz and gain 5 dB. The proposed antenna resonant at 15.8 GHz to 18.8 GHz with return loss -17 dB. In [14] the proposed antenna is the investigation of an inset fed wideband circular slotted patch antenna which is suitable for 5.2 GHz satellite C-band applications and the dimension of the antenna is 44 × 56.4 mm^2. The proposed antenna have improved efficiency (97%), gain (8.17 dB), directivity (8.22 dB) and return loss (-21.79). In the proposed antenna have about 92% impedance bandwidth in the frequency range 3.94 to 10.65 GHz where the author used a folded-patch feed, U-shaped slot, one shorting pin on the edge of aperture and an E-shaped edge to improve the bandwidth. The size of the antenna reduced by using two shorting pins and V-shaped slot patch. The compact wideband antenna was also achieved operating in 4-14.4 GHz whereas the patch's dimension improved from 18 × 15 mm^2 to 15 × 15 mm^2 of the basic antenna on 7 mm thickness of an air substrate. UWB patch antennas [5] are extensively used in the recent years in different fields of communication for their small size, low cost and better performance. They are mainly used for their different frequency operation. However, the proposed antenna used a line-fed and a single tri-arm resonator below the patch to achieve dual band notch and a wide bandwidth of 2.98-10.76 GHz with two notched bands operating at 3.5 and 5.5 GHz. A compact quad-band MPA for S and C band application has been proposed in [11] with 30 × 30 × 4.4 mm^3 dimension. The quad band antenna have two rectangular notches. The simulated impedance bandwidths of the proposed antenna at -10 dB are 100 MHz (4.65-4.75 GHz), 170 MHz (5.04-5.21 GHz), 120 MHz (5.64-5.76 GHz) and 130 MHz (6.24-6.37 GHz). The C-band is used for satellite communication, whether for full-time satellite TV networks or raw satellite feeds which is commonly used in tropical rainfall areas since it is less capable to rain fade than Ku-band. C-band have the frequency range of 4-8 GHz.

1.4 Aim and Objectives

The aim of this research is to acquire better performance of the MPA characteristics under C band. The objectives are given below.

- To reduce antenna return loss (S11).
- Design a MPA with enhance bandwidth which cover entire C-band
- Gain improvement of the designed antenna
- Verifying by CST Studio Suite

1.5 Methodology

All the augmentation in performance of Microstrip patch antenna (MPA) have been done under C-band frequency domain. Adding two portion like plow in MPA leads us enough suitable result. Elementary procedures have been explained step by step to gain our eligible objectives.

Step 1: Designing a simple rectangular MPA with basic structure by defining its length (L) and (W).

Step 2: Using T shape in the antenna to enhance the bandwidth.

Step 3: Modifying and adding plow-shape portion in the T-shape patch for better results.

Step 4: To analysis the performance of the designed antenna individually in term of antenna characteristic especially bandwidth, gain and return loss.

Step 5: Comparing the proposed antenna parameters with current literature.

1.6 Thesis Organization

This thesis is parted into five main chapters and the reference section.

Chapter 1 discusses about the introduction, background, literature review, objectives and scope of the thesis.

Chapter 2 explains brief literature studies of the MPA in order to get basic fundamentals. It also discusses the relevant literatures on designing C-band MPA using slot.

Chapter 3 describe the design procedure of proposed antenna using line feeding technique.

Chapter 4 includes comparison between CST studio suite and Zeland IE3D simulator, return loss graph, bandwidth for all individual antennas, average and vector current distribution, 2D and 3D radiation patterns for the proposed T shape patch antenna. A brief comparative study also has been made between current papers and proposed antenna.

Finally, **Chapter 5** gives a conclusion of the work and scope for future work considerations.

CHAPTER 2

Literature Studies

2.1 Antenna parameters:

The Electrical energy converts into Electromagnetic energy and vice versa by an antenna which works as like transducer. It should to know about some measurable properties to determine whether design of antenna Good or bad. It needs to understand about antennas different parameters that help to realize the strength and weakness of the design. These parameters of antenna are depend on one another. Consequently, it should be make sure that all the parameters are optimized to the designing antenna. For example, if the Return loss is greater than -10 dB then the designing antenna doesn't work and VSWR value will be than 2.

2.1.1 Antenna Field regions:

The Antenna field regions is important because an antenna start radiated after fixed distance from antenna are divided into three principle regions:

- Reactive regions
- Radiating near field / Fresnel region
- Far field

Due to determine the antenna Radiation pattern and most of the other parameters the far field regions is the most important. On the other hand, antennas are used to build communication from long distance. Therefore, the antenna field regions is the important things.

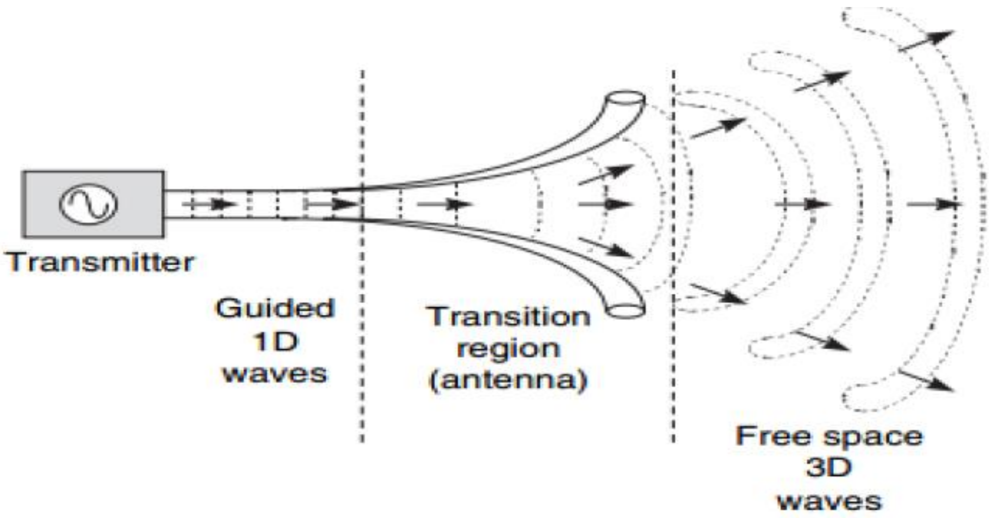


Figure 2. 1 Antenna radiation

Electric field and magnetic field are Antennas field component. These termed are act as radiative fields and reactive field respectively. In the reactive field component is the distance 'r' in the denominator equation which is the order of two or higher than two. There is a distance component in the radioactive component also having 'r' of the first order. For this the reason if the distance increase the reactive component of the field dies but reactive component remains. Generally, the reactive regions and radiating near field / Fresnel regions both are called as near field regions. Total range two times of wave length to infinity is called far field.

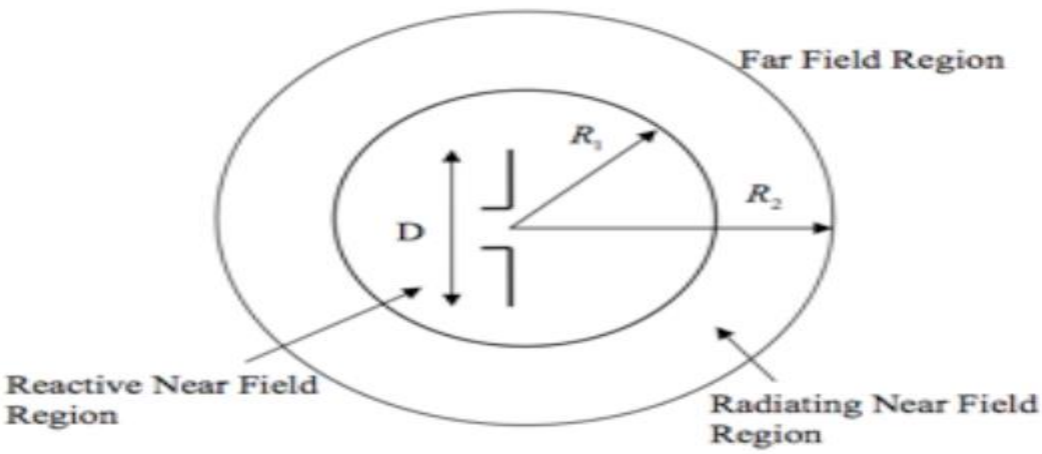


Figure 2.2 near field and far field regions.

2.1.2 Radiation pattern:

Mainly the radiation is produced when the flowing current feel sudden discontinuity. Radiation pattern is the delegation of antennas radiation intensity with respect to space co-ordinate system. According to the radiation pattern, antennas characteristics are normally directional or omnidirectional. When antenna radiate equally along azimuthal angle but varies with elevation of angle sinusoidal, the antenna called omnidirectional one. On the other hand, if an antenna radiates with higher directivity at any particular angle with respect to others angle. The antenna said to be directional. The directionality of antenna is known as directivity. The radiation pattern can be display as 2D plot, 3D plot or polar plot. Plots are given below.

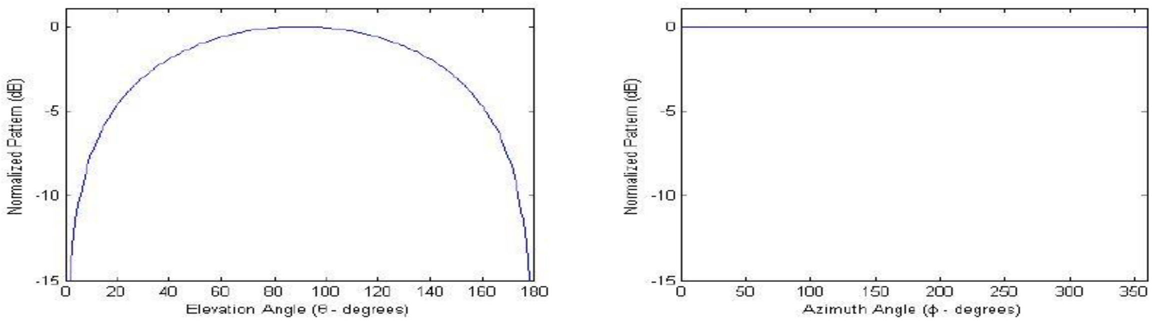


Figure 2. 3 Radiation pattern

2.1.3 Directive gain:

The directive antenna is another antenna which radiates differently at different angle. The ratio between radiation intensity of antenna at a particular angle and average radiation intensity in all direction is known as Directive gain. It’s express as dBi.

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

2.1.4 Directivity:

An antenna which is directional and depend on the angle of radiation intensity that's higher than all other direction. For maximum radiation if directivity gain of directional antenna stay at the direction then it's called directivity of directional antenna gain.

2.1.5 Antenna Efficiency:

When apply power that's applied power could not be equal to getting power causes of loss occurs in any system. Similarly, Antenna also have two losses. One is the due to mismatch of impedance with antenna and free space . Another is due to not radiated input power for being a conducting material of antenna. The ratio between output power of and antenna and input power is called Antenna efficiency.

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

2.1.6 Antenna gain:

An antenna gain is the directivity of antenna taking into consideration the antenna efficiency. It can be said that directivity of antenna is the ideal case and gain is the real case. So, if it can be ensure that all input power to an antenna will be radiated then gain and directivity will be same. As in practical case, there always be losses associate with antenna and gain will be lesser than directivity.

Antenna Gain = Antenna Efficiency *Directivity

2.2 Matching and Reflection:

When applying power to any system, the system absorbed the amount of power. That's why there is huge difference between applied power and out power. If the system absorbed the negligible power, then some of power reflect back due to matching and due to mismatching to transmission line with antenna no reflection occurs in the system.

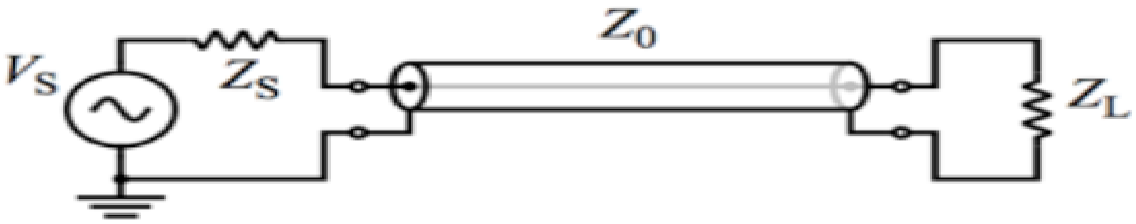


Figure 2. 4 Circuit Diagram of Load impedance, Source and Transmission line

The reflection can be measured by given equation. The reflection co-efficient is

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

The reflection co-efficient is complex number (a+jb). If the imaginary part is 0, then if

The reflection co-efficient = -1; the line is short circuited (maximum negative reflection).

The reflection co-Efficient = 0; the line is perfectly matched (No reflection occurs).

The reflection co-efficient = 1; the line is open circuited with antenna (positive reflection).

The reflection co-efficient is complex number and it is change with varying frequency. The reflection co-efficient can be expressed graphically by using smith chart like as given figure.

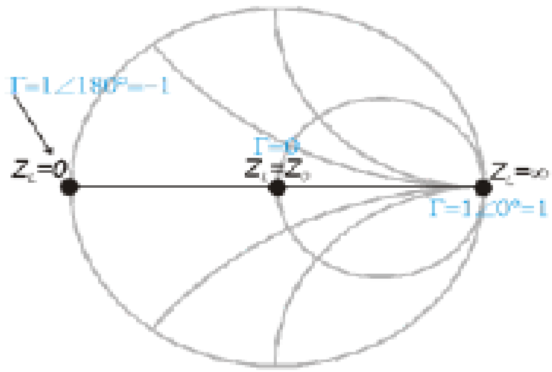


Figure 2. 5 Smith Chart

2.2.1 Voltage Standing Wave Ratio (VSWR):

Due to mismatch of transmission line with antenna, no reflection produced there or due to perfect matching of transmission line with antenna, huge amount of reflection produced there. By calculating VSWR, it can be realize that how much Reflection of load impedance is mismatched. VSWR is the ratio between Maximum voltage and minimum voltage. Mathematically can be written as,

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

The value of VSWR is 1, means perfectly matched transmission line with antenna. The value of VSWR 2 is accepted as good match.

2.2.2 Return loss/S parameters:

Return loss or S-parameters is a power which is reflected in the transmission line. It's also called as scattering parameter and the measuring units is dB. Mathematically written as

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

The relationship between reflection co-efficient and VSWR is:

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

By simplifying the equation written as

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

2.2.3 Bandwidth:

The distance from minimum frequency range to maximum frequency within the performing of antenna is called bandwidth. The frequency range which return loss is less than -10 dB is called S11 parameter bandwidth. There are several kinds of bandwidth depending on different kinds of parameter. Among them Impedance bandwidth is fixed and Affectivity bandwidth and Directivity bandwidth are also called as gain bandwidth. Impedance bandwidth depend on large number of parameters such as Dielectric materials, size of ground plane. Impedance bandwidth measured within the return loss of -6 dB. A desire bandwidth can be calculate as the flowing equation;

$$BW_{Broadband} = \frac{f_H}{f_L}$$

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

Where,

f_H = *The Upper Frequency,*

f_L = *The Lower Frequency,*

f_C = *The Center Frequency.*

2.3 Introduction of Microstrip patch antenna:

The popularity of microstrip patch antenna increase day by day for it used in millimeter-wave frequency range [24-26]. The microstrip patch antenna made of Patch materials, dielectric materials and ground materials. The patch of antenna is the conducting materials which placed on the dielectric materials. Ground is a conducting materials which is connected with substrate materials and substrate is placed between patch and ground like as the figure.

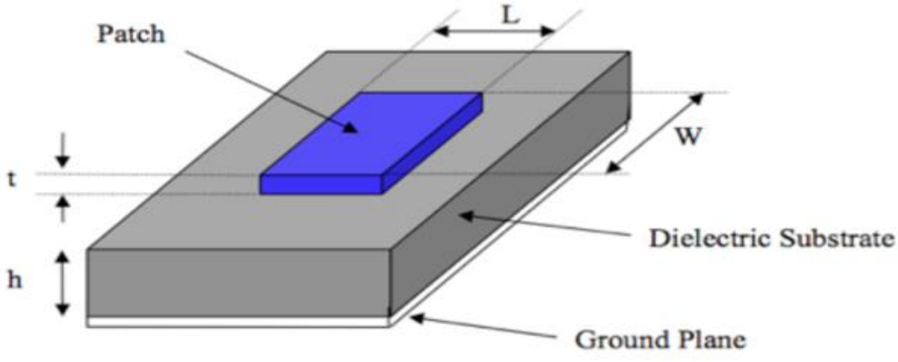


Figure 2.6 a microstrip patch antenna

There are different shape of microstrip patch antenna such as rectangular, square, circular, Triangular and Elliptical like as the given figure

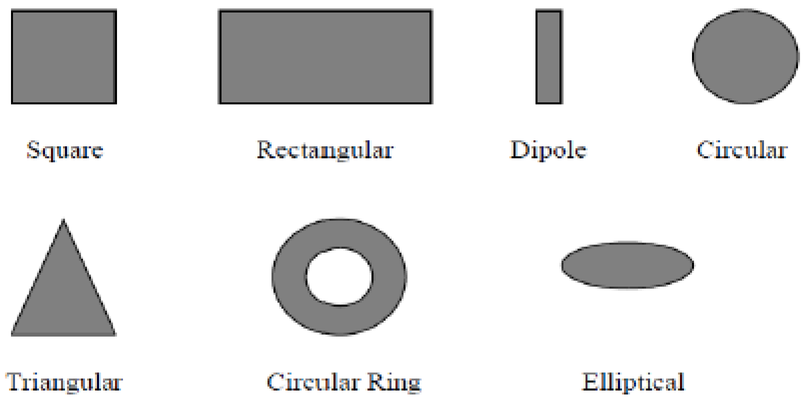


Figure 2.7 Different shape of Microstrip patch antenna

2.3.1 Advantage and Disadvantage:

At present, the microstrip patch antenna becoming more and more popular because of having many facilities. Microstrip patch antennas advantages are given below [27]

- Light weight and low volume
- Low profile configuration which can easily made to conformal to host surface
- Low fabrication cost, hence can be manufactured in large quantities
- Support both, linear as well as circular polarization
- Can be easily integrated with microwave integrated circuit (MICs)
- Capable to dual, triple Frequency operation
- Mechanically robust when mounted on rigid surface

Microstrip patch antenna is suffer from more drawbacks as compare to conventional antenna. Some of the major disadvantage discussed by [27] and Garg et al [28] are given below

- Narrow bandwidth
- Low efficiency
- Low gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity
- Surface wave excitation.

Narrow bandwidth of Microstrip patch antenna is the disadvantage which is occurs due to various reason among them large quality factor is principle reason. Large quality factor of Microstrip patch antenna represent Narrow bandwidth and low efficiency. Quality factor can be reduced by increasing thickness of the substrate layer. But increasing thickness of substrate layer created another problems such as lower gain and lower power handling capacity. These problems are overcome by using an array configuration for the elements.

2.4 Basic principle of operation:

The basic form of antenna like as a given figure. In this figure, the middle conductor of a coax serves as the feed probe to couple eletromagnetic energy in or out of the patch. After feeding to the pach antenna is feel discontinuity then it produced electromagnetic field there. At middle of the patch Electric field is zero,maximum at one side and negative at opposite. These are continously change side according to the instantenuos applied signal.

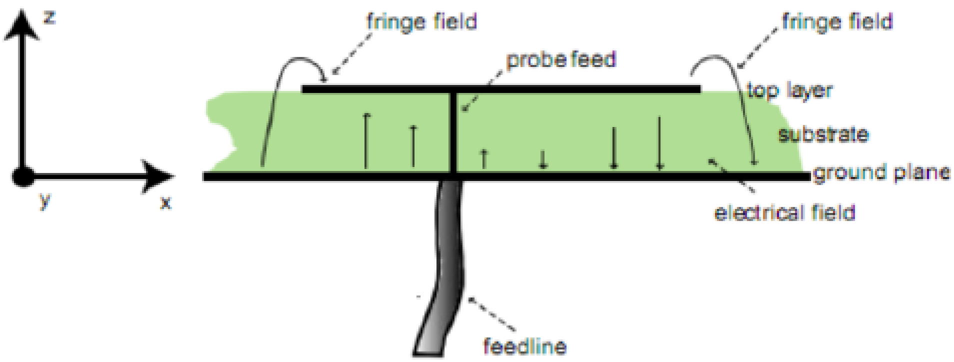


Figure 2.8 Side view of microstrip patch antenna

2.4.1 Feeding technique:

Antenna feeding is the process by which patch of antenna is excited. Microstrip patch antennas are excited or feeding in various ways. There are two kinds of feeding techniques. One is contacting and another is non-contacting feeding.

2.4.2 Contacting feeding:

The contacting feeding is the process by which power is being feed directly to radiating patch through the connecting elements such as microstrip line. Again, the contacting feeding techniques can be sub-divided into two techniques.

- Microstrip feed line
- Coaxial feed line

2.4.3 Microstrip feed line:

Feeding microstrip patch of antenna is directly with transmission line like as figure .

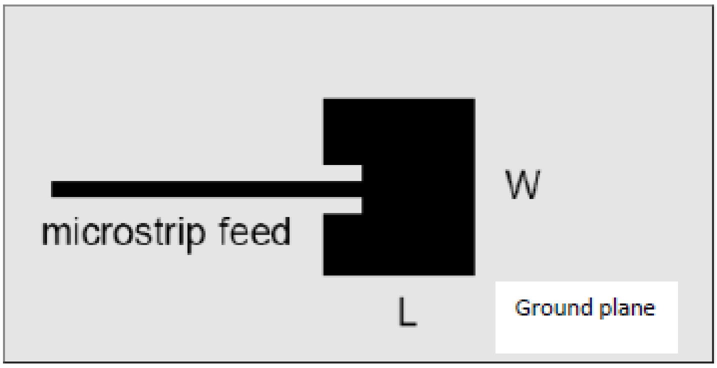


Figure 2.9 Microstrip feeding of patch antenna

There are various advantage and disadvantage of Microstrip feed line method.

Advantages:

- Easy to fabricate
- Easy to impedance matching
- Easy to model

Disadvantages of this method:

- Make surface wave
- Limited bandwidth
- Asymmetric structure which is responsible to cross polarization

2.4.4 Coaxial feed:

In coaxial feeding method, drilling a hole in substrate and ground so that patch is excited or feed directly contacting through the hole like as the given figure.

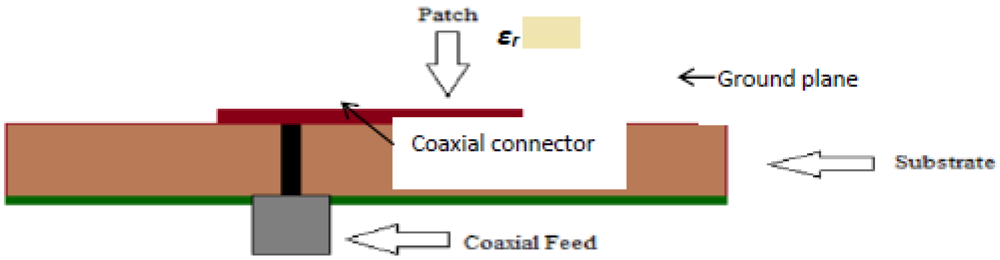


Figure 2.10 Coaxial feed

Advantages:

- It is Easy to match
- It is Easy to fabricate
- Low spurious radiation

Disadvantages:

- Difficult model when Epsilon r >0.02 lamda
- Limited bandwidth
- Cross polarization

2.4.5 Non-contacting:

The non-conducting is the process by which power is being fed indirectly patch with transmission line is called non-contacting method.

The non-contacting technique sub-divided into techniques.

- Aperture-coupled feed: The aperture coupled is different structure in which two different substrate is used and these two substrate layer is separated by ground plate. The patch is placed on the top substrate layer and transmission line is connecting with last layer of substrate like as the given figure.

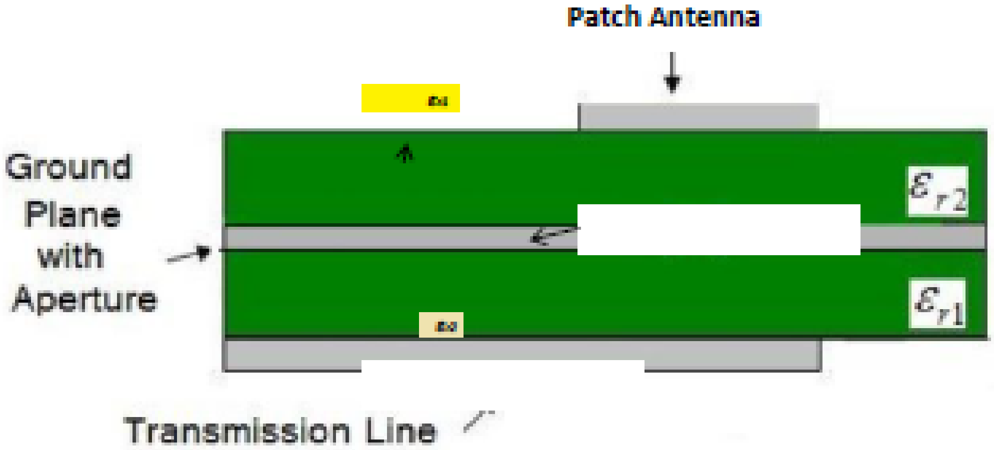


Figure 2.11 Aperture-coupled feed

- Proximity coupled feed: The proximity coupled feed is known as Electromagnetic coupling. In this technique two substrate layer is used like as aperture coupled feed techniques but these are separated by transmission line like as the given figure.

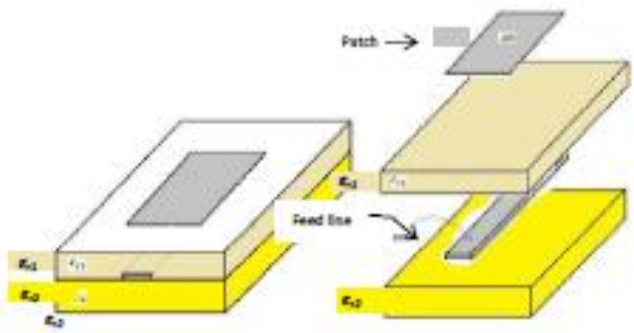


Figure 2.12 Proximity coupled feed

CHAPTER 3

DESIGN OF THE PROPOSED PATCH ANTENNA

In literature review (Chapter 1) it has been audited that the antennas, functioning in C-band region, gain and bandwidth are systematically poor in some antenna. Therefore, the indispensable focus of this thesis is to design a MPA having improved bandwidth and gain in C-band region. In this chapter antenna designs are demonstrated in chronological order where bandwidth expansion of the proposed antenna are observed in the single patch antenna.

To design our desired proposed antenna Zeland IE3D simulator has been used. All the antennas are simple and have the capability to operate for C-band application.

3.1 Specifications

Our fundamental objectives is to design a patch antenna that can accomplish all the Hi-speed WLAN standards available throughout the globe in the 5-6 GHz ranges. More specifically our patch antenna should justify [23]:

- European 802.11a or 5.725-5.825 GHz band
- Middle-eastern WLAN or 5.47-5.825 GHz band
- USA 802.11a or 5.15-5.35 GHz band

- Currently approved IEEE 802.11j or 4.9-5.1 GHz band

Overall, our proposed antenna design should provide at least -10 dB return loss for the entire band of 4.05 GHz to 8.35 GHz and VSWR also should be less than 2. However, Arlon cu 217LX(lossy) substrate with dielectric constant of 2.2 has been selected as dielectric material for our proposed antenna. As a starting reference [19] we are going to use the T-shape structure and its parameters to design a simple form of T-shape patch antenna. Then optimization is done by changing various parameters to find out the most perfect antenna for our desire operation. After finding out the parameters which can produce an acceptable return loss for 4 GHz to 8 GHz range, we proceed to observe radiation pattern, current distribution and vector distribution of the proposed antenna.

3.2 Microstrip Patch Antenna Dimension

Patch width has a minor effect on the resonant frequency and radiation pattern of the antenna and it also affects the input resistance and bandwidth to a larger extent. However, the radiation depends on the antenna width and length. The width of antenna is directly proportional to power radiation, bandwidth of antenna, and radiation efficiency and inversely proportional to resonant resistance. To determine micro-strip patch antenna's length by given equation.

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}} \qquad (3.1)$$

Where speed of light is denoted by c, resonant frequency f_r and dielectric constant ε_r.

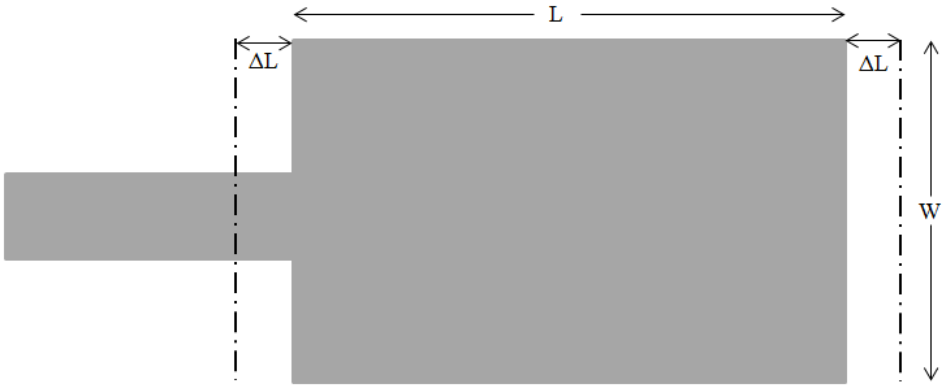


Figure 3.3(a) Microstrip Patch Antenna Dimension

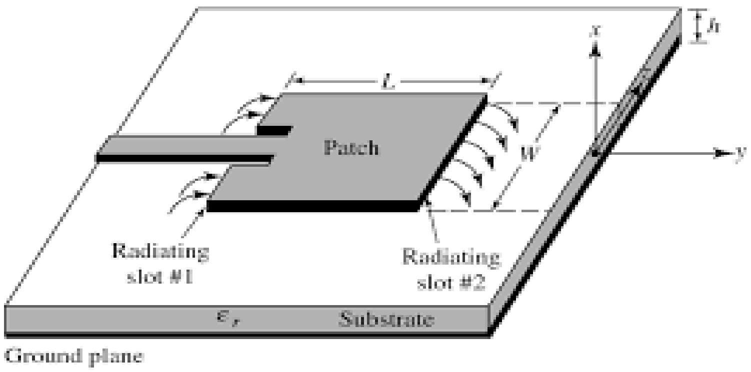


Figure 3.3(b) Radiation flow from patch to ground

For efficient radiation, width of patch is given by:

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

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]:

$$L_{eff} = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}} \sqrt{\mu_o \varepsilon_o}} \qquad (3.4)$$

Now the actual length of patch can be expressed by

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}} \sqrt{\mu_o \varepsilon_o}} - 2\Delta L \qquad (3.5)$$

Where, length extension is as follows [22].

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

The ground plane of the MPA is larger than the patch by approximately six times of the thickness of substrate all around the fringe which can be expressed as follows:

Lg = 6h + L (3.7)

Wg= 6h + W (3.8)

3.3 Design of MPA

The simulation result and the design of the MPA are placed in this section. The fundamental parameters of an antenna to check the operation of an antenna at desired band are return loss, VSWR, gain and directivity accordingly. We can noticed that the designed antenna resonates at 5.121 GHz with a maximum return loss of -31.3 dB.

To understand parametric analysis of microstrip patch antenna, a reference antenna deign is given below. In which a single band RMPA is designed in **Figure 3.3(c)** and it can be seen in **Figure 3.3(d)** that the designed antenna resonates at 1.7 GHz with a minimum return loss of -12.7 dB.

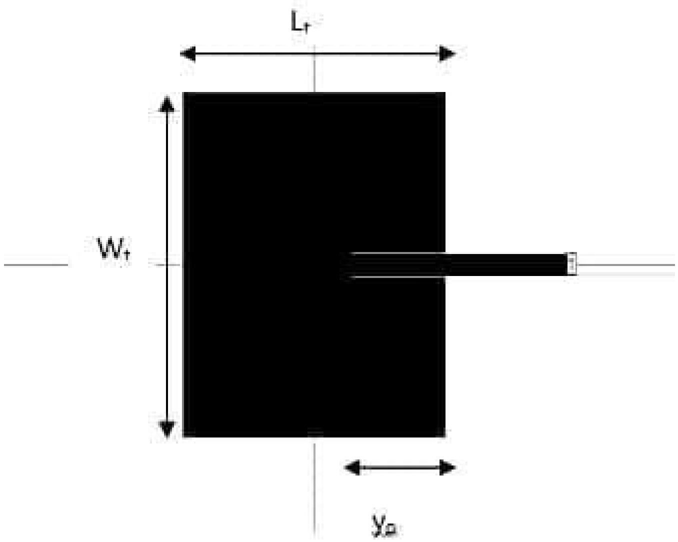


Figure 3.3(c) Design of the single band RMPA

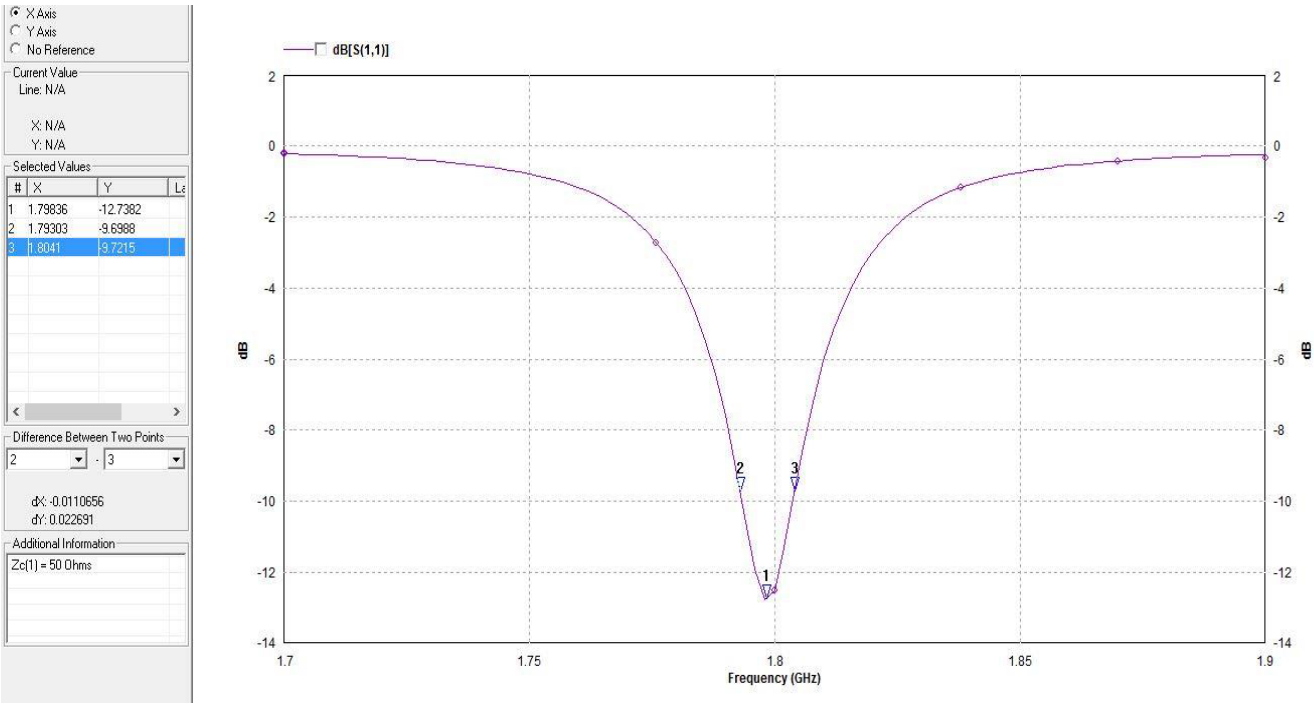


Figure 3.3(d) Return loss of the single band RMPA

To achieve our desired antenna and frequency band, we developed T-shape antenna with adding extra plow-shape in the proposed antenna. The proposed antenna is shown in Figure 3.3(e) and the desire bandwidth and return loss graph is shown in Figure 3.3(f). The measuring unit of dimension of proposed antenna is millimeter (mm).

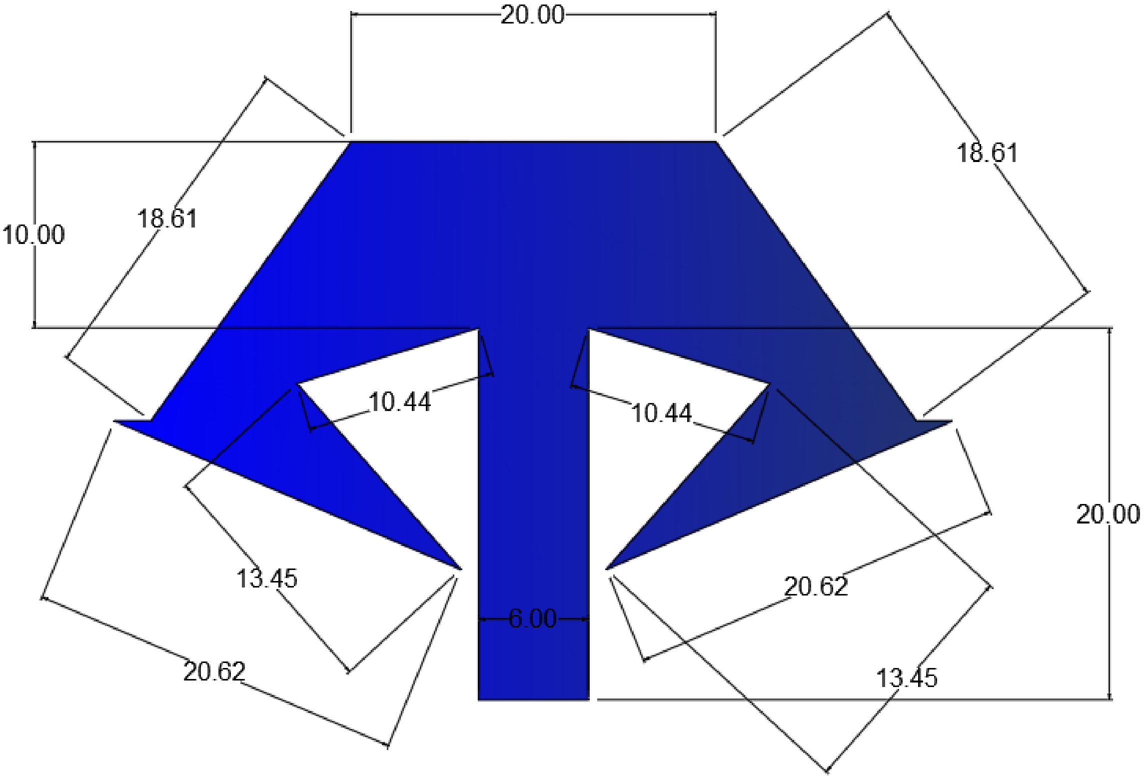


Figure 3.3(e): The design of the proposed antenna

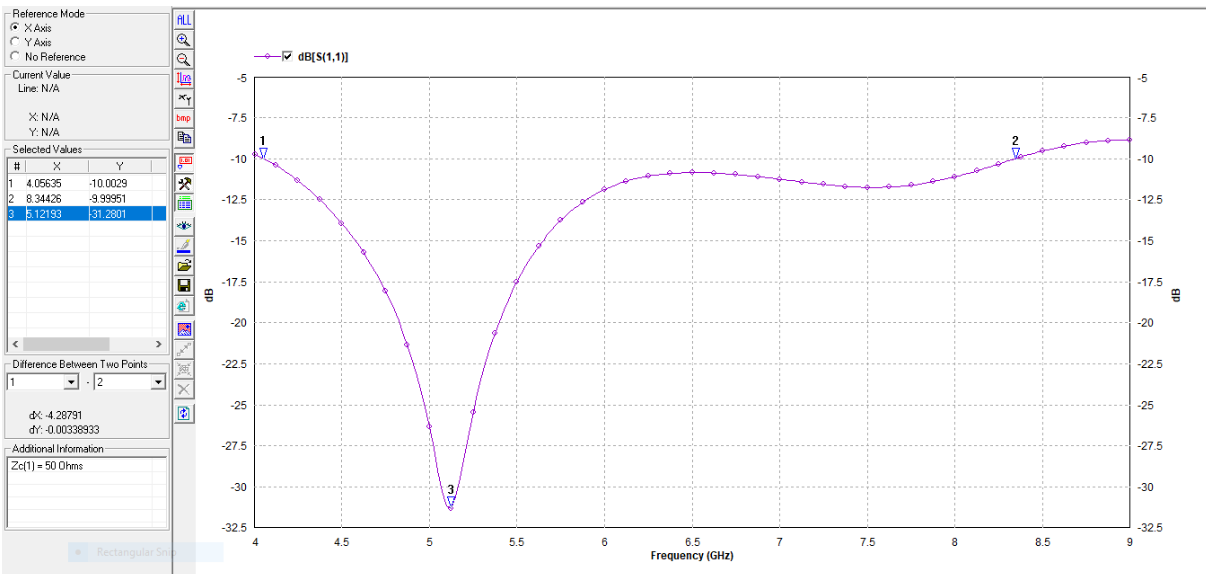


Figure 3.3(f): The desire return loss graph

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Simulated Results of the Proposed Antenna using IE3D Zeland

The software used to simulate the MPA is Zeland IE3D simulator which is a full-wave electromagnetic simulator based on the method of moments and it's also analyzes 2D/3D and multilayer structures of ordinary shapes. Besides, it can be used to determine return loss, gain, VSWR, current and vector distributions as well as the radiation patterns and also plot S_{11} parameters. However, the proposed antenna performance metrics such as return loss, gain, directivity, bandwidth, average current distribution, vector current distribution, 2D/3D radiation patterns are simulated by using IE3D simulator. The same performance metrics are also simulated by using CST Studio Suite simulator software for comparison purpose that will be discussed in this chapter.

To achieve the primary objective of the thesis acute simulation have been done to get the desirable antenna for C band application. Adding extra portion in simple T shape patch have been designed where gradual enhancement in bandwidth has been observed. In the proposed antenna rectangular patch has been modified by slot cutting technique for better antenna performance where the bandwidth of the proposed antenna has been increased strongly due to the properties of slots. The proposed antenna has bandwidth of 4 GHz and it can cover 100% of C band frequency range at 5.12 GHz resonant frequency. Therefore, the proposed antenna has the ability to support WLAN applications as well as uplink and broadcasting satellite service, GPS, fixed microwave, mobile satellite, and radio navigation.

In the previous chapter an acute simulation has been done to optimize the antenna for the frequency range of 4-8 GHz (bandwidth of 4 GHz) and as a result we have fixed an antenna having an area of 20*10mm^2 with lower than -10 dB return loss which can be very effective for USA 802.11a or 5.15-5.35 GHz band and Middle-eastern WLAN or 5.47-5.825 GHz band standards. The simplicity of designed antenna generates robust and useful operations for the C band applications. Now as our simulated antenna covers all the WLAN standards, we should review our antenna operation in each of the standards by our antennas average and vector current distribution and 2D/3D radiation patters for a frequency in each bands. The current distribution demonstrates the antenna form and supports to understand the density and direction of the present movement inside the patch at particular frequencies. It also illustrates how several part of the antenna acts for various operating frequencies. 2D/3D radiation pattern exhibits us how antenna radiates its output signal with a graphical representation. However, 2D radiation pattern gives information about the gain and directivity gain of E-H fields where as 3D radiation pattern can demonstrate the directivity and emission style.

4.1.1 Average Current Distribution

The average current distribution mainly illustrate antennas side actually which is radiating and which is non-radiating. Therefore, we will simulate our antenna at 5.12 GHz frequency with 10 cells per wavelength and then we will observe the current distribution over the antenna surface.

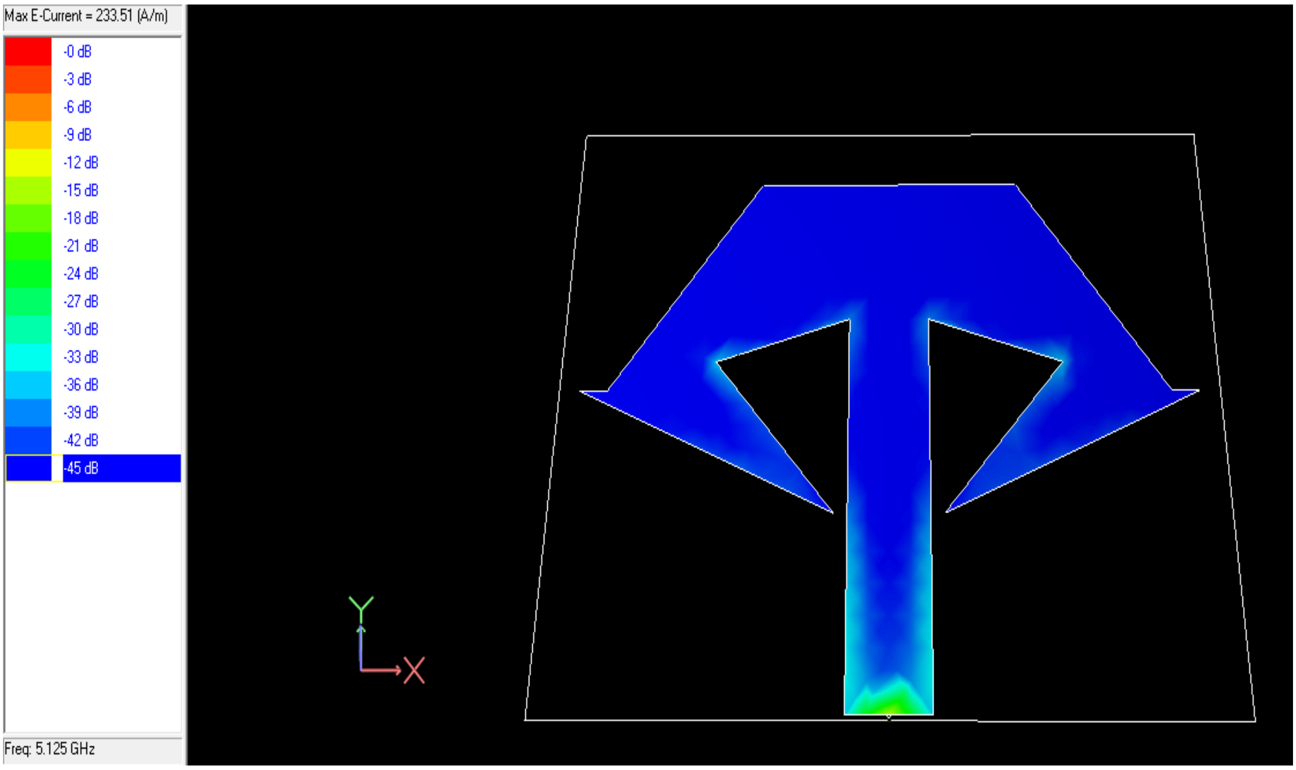


Figure 4.1 Average current distribution of proposed antenna at 5.125 GHz

The average current density on the surface of all the antennas is demonstrated in above figure at 5.125 GHz. For all frequencies current distribution are mostly in green or in blue color corresponding to an amplification of from -30 dB to -45 dB which means for all frequencies in the range of 4-8 GHz our antenna can work smoothly as transmitter or a receiver.

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.

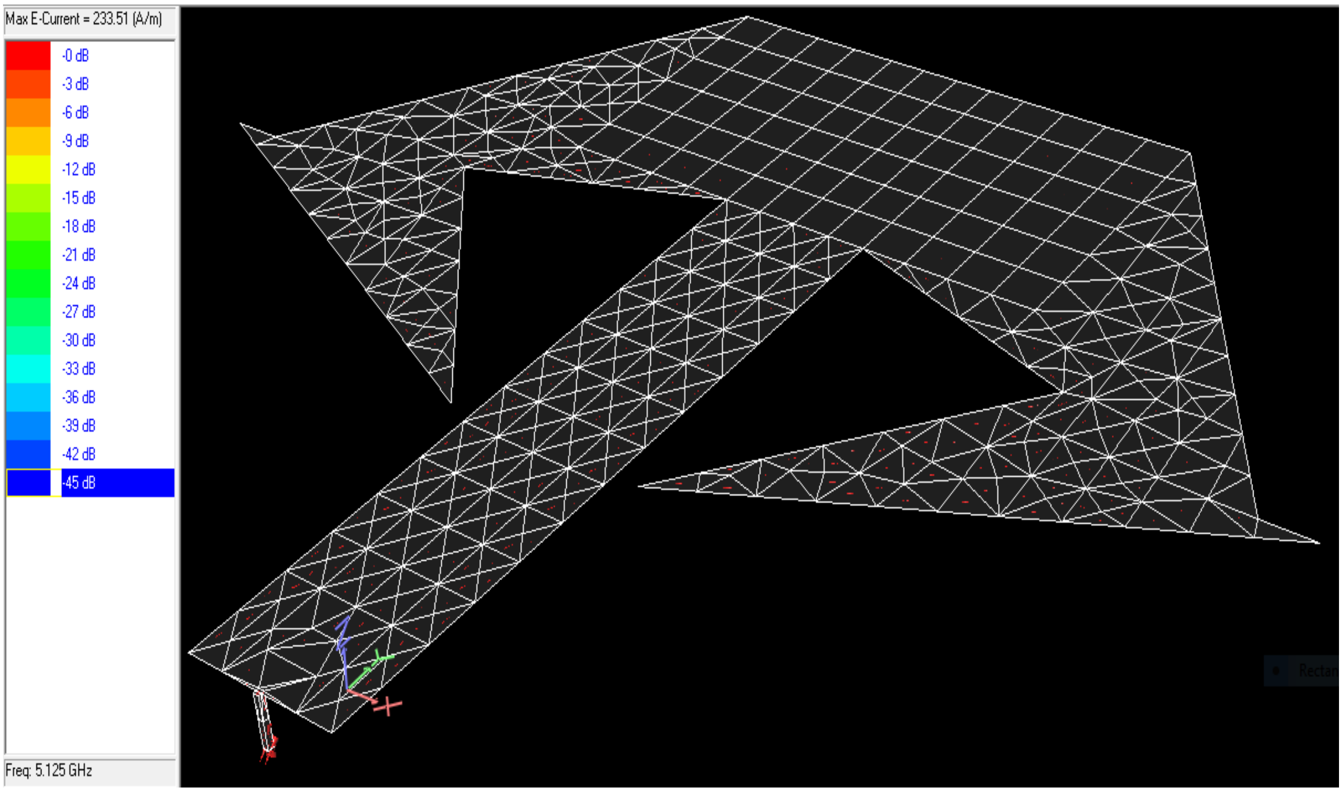


Figure 4.2 Average Vector current distribution of proposed antenna at 5.125 GHz

Vector current distribution of the current over the surface of the patch antenna are illustrated in Figure 4.2(a) at resonant frequency of 5.125 GHz. The size and direction of the vectors indicate the magnitude of the current density at a specific time as well as location.

4.1.3 2D Radiation Pattern

A good antenna should preserve its polarization and radiation pattern throughout the frequency range that it lids. Actually, 2D radiation pattern assistances to comprehend how the antennas are radiating in 3D pattern. However, 2D radiation pattern is used for analytical purposes. Figure 4.3 demonstrates the 2D polar plot of the designed antenna at 5.125 GHz.

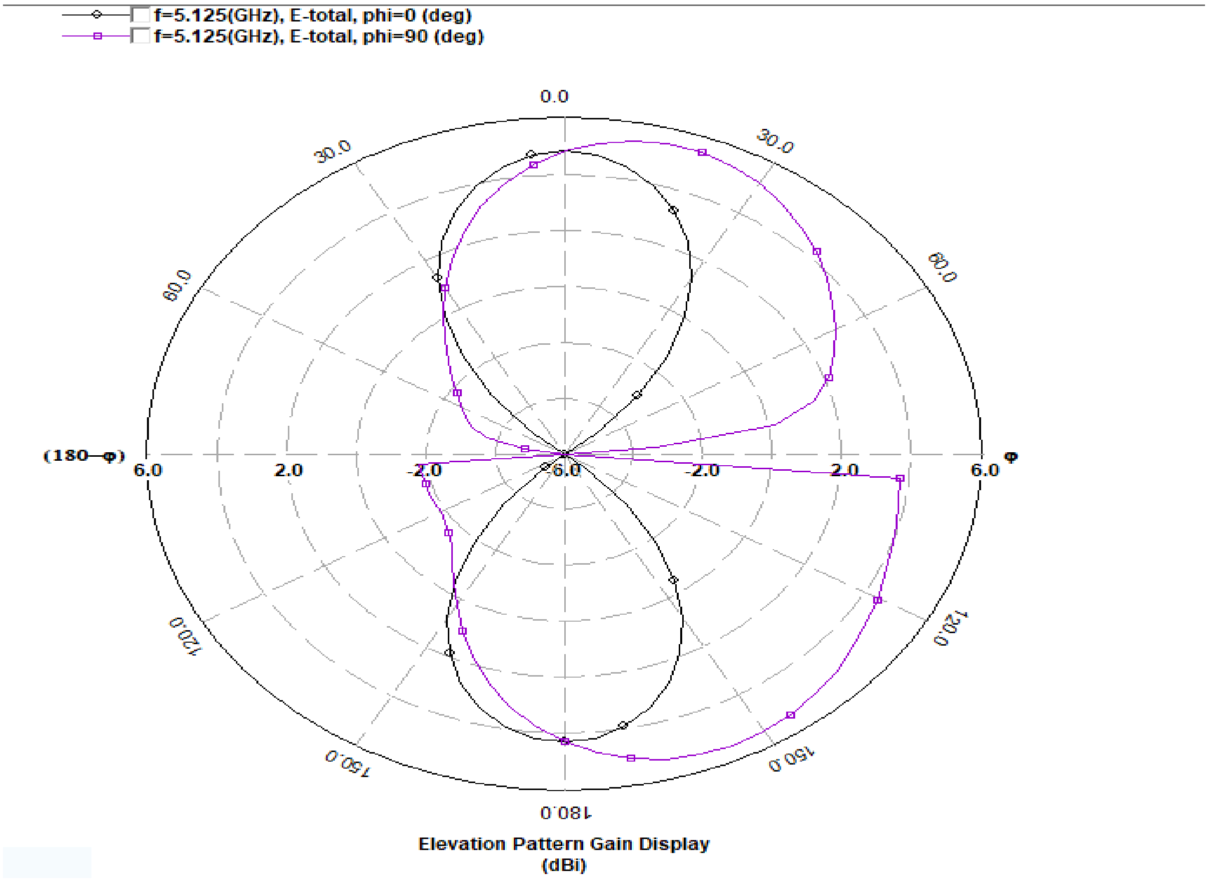


Figure 4.3 2D Radiation pattern of proposed antenna at 5.125 GHz

2D radiation pattern for the proposed antenna at 5.125 GHz resonant frequency is illustrated in Figure 4.3. However, microstrip patch antenna radiates normal to its patch surface where the elevation pattern will be $\varphi = 0$ and $\varphi = 90$ degrees. The maximum gain of the proposed antenna is almost 6 dBi but 5.429 dBi at 5.125 GHz.

4.1.4 3D Radiation Pattern

Similarly, as 2D radiation pattern, a good antenna should preserve its polarization and radiation pattern throughout the frequency range that it lids. To clarify 2D patterns properly, 3D radiation pattern has been used to show the gain or directivity of the antenna. Figure 4.4 demonstrates true 3D radiation pattern at 5.125 GHz resonant frequency of the proposed antenna. The size of the pattern from the origin illustrates how strong the field is at a specific (theta, phi) angle.

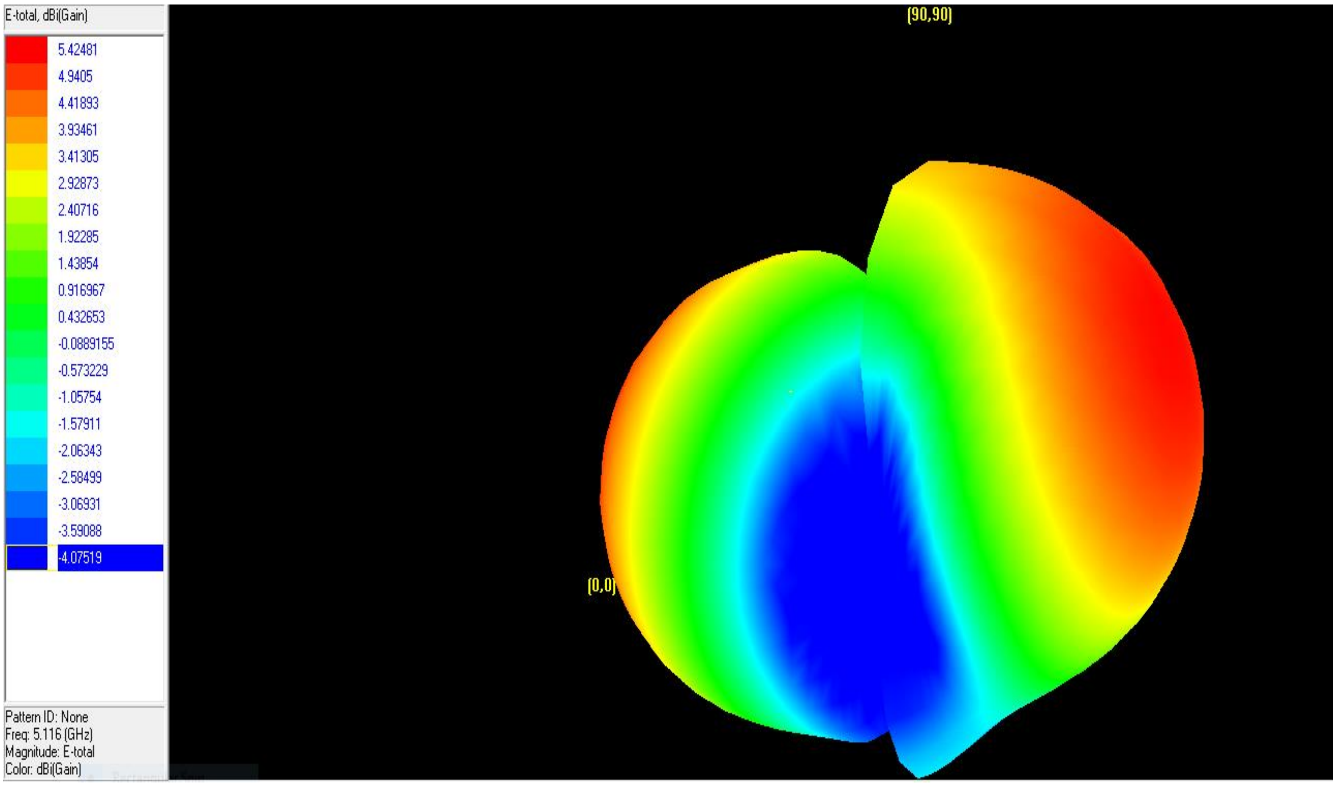


Figure 4.4 3D Radiation pattern of the proposed antenna at 5.125 GHz

The radiation pattern in 3D is achieved as follows in the Figure 4.4 from the different angles on the different axis. We can observe the gain on the left hand side of the Figure 4.4.

4.2 Simulated Results of the Proposed Antenna using CST Studio Suite

For verification, the proposed antenna is also designed by using CST studio Suite software that is similar as Zeland IE3D software and dimension and materials are also same here. It can be shown same results as long as IE3D's designed which is given in figure.

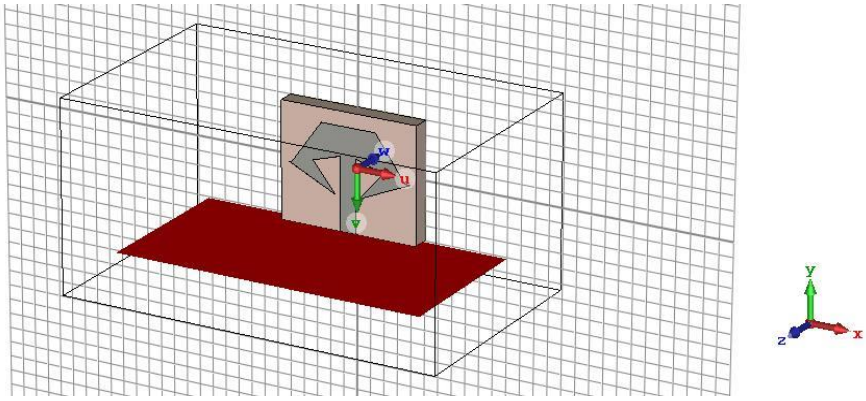


Figure 4.5 Proposed antenna by Using CST

The Following design is obtained by CST software and the return loss graph is similar to the previous result of IE3D.

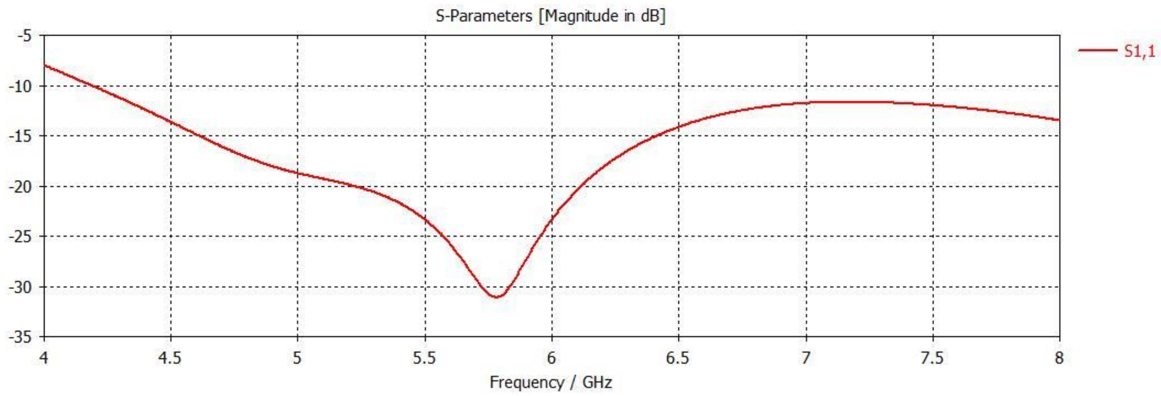
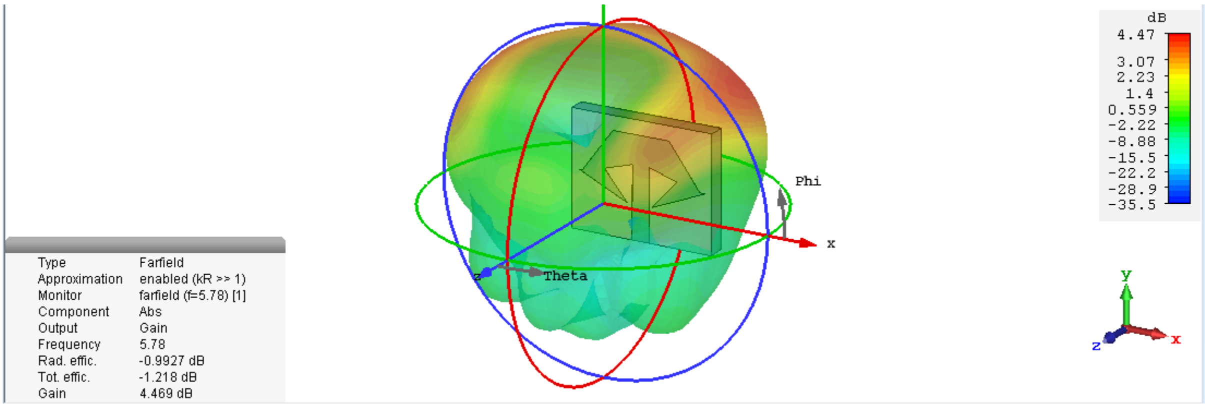


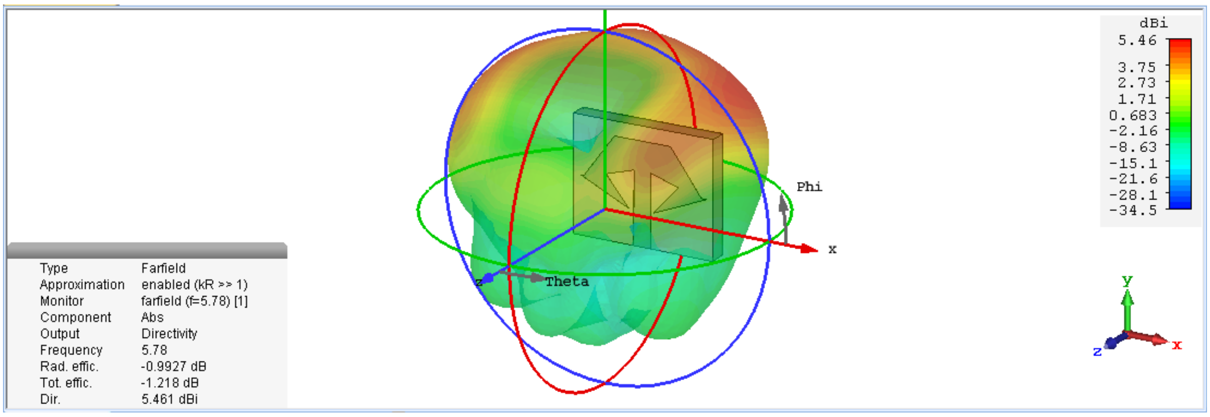
Figure 4.6 S-parameter got from CST

4.2.1 Simulated Radiation Pattern

The designing antenna in CST also have 2D, 3D and polar radiation pattern. This pattern are act for the resonance frequency 5.78 GHz .For this resonance frequency 2D, 3D pattern given below respectively figure 4.5 and figure 4.6.

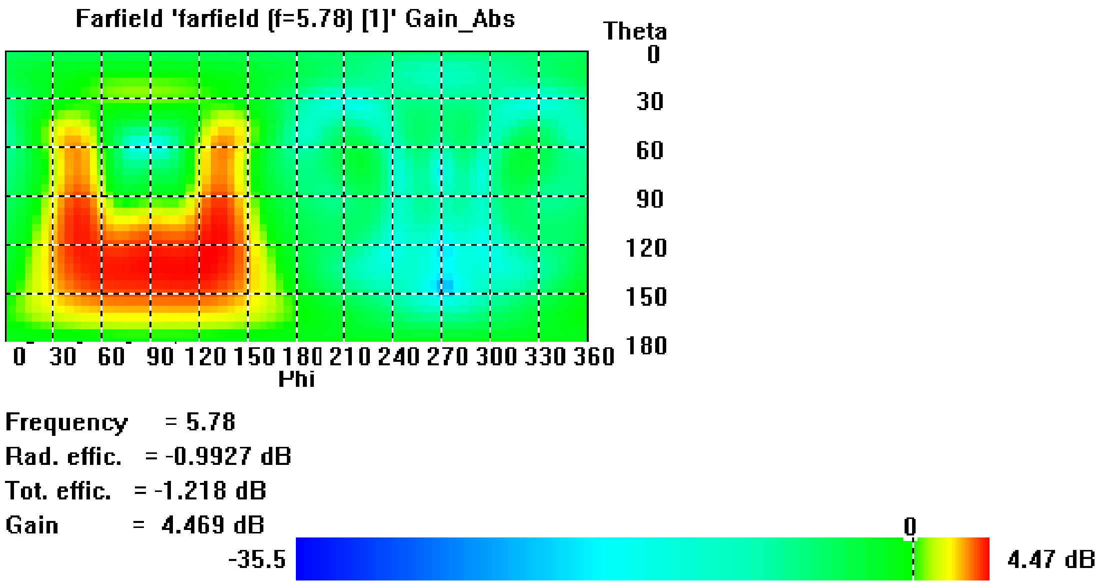


(a)

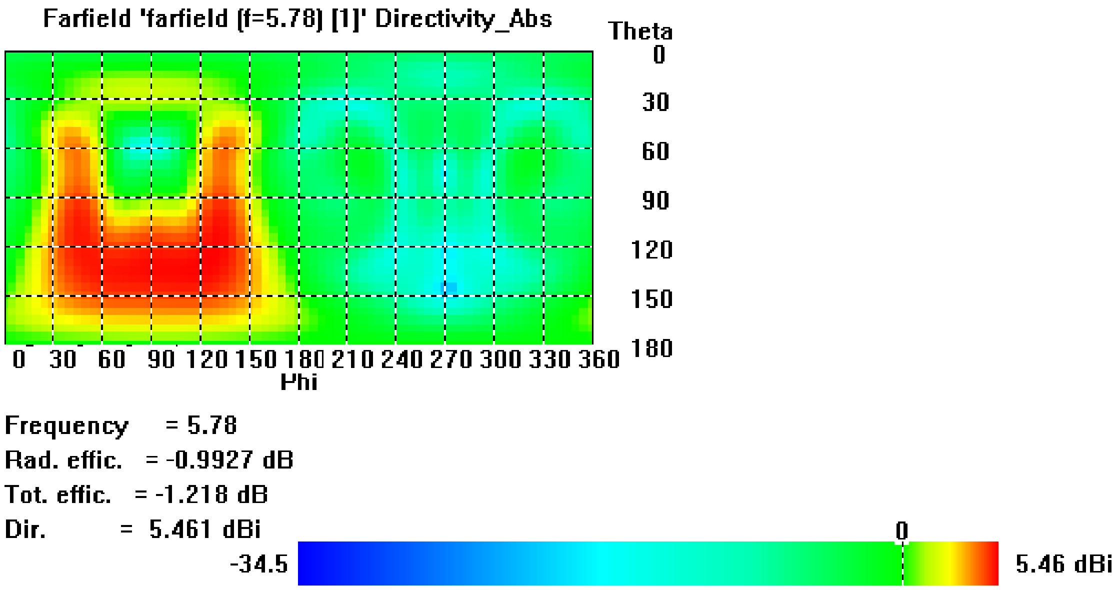


(b)

Figure 4.7: 3D radiation pattern at 5.78 GHz (a) for Gain (b) for Directivity



(a)

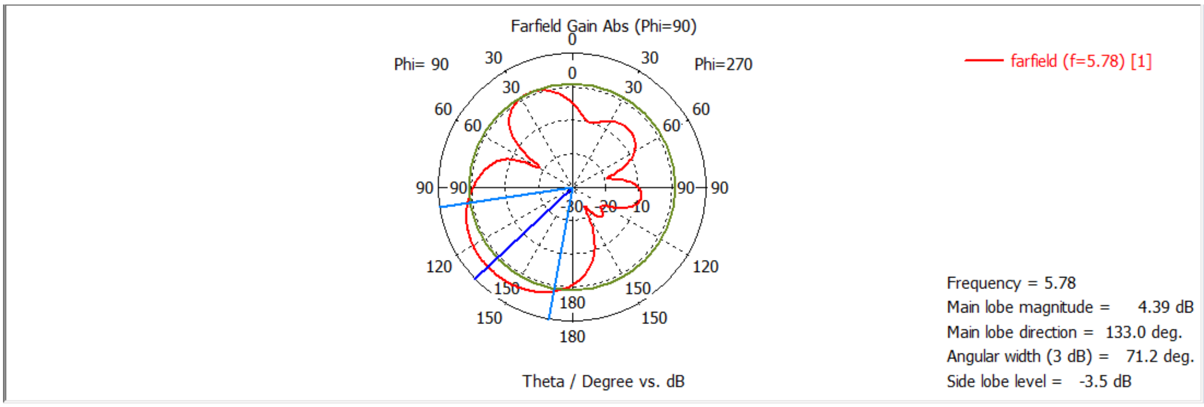


(b)

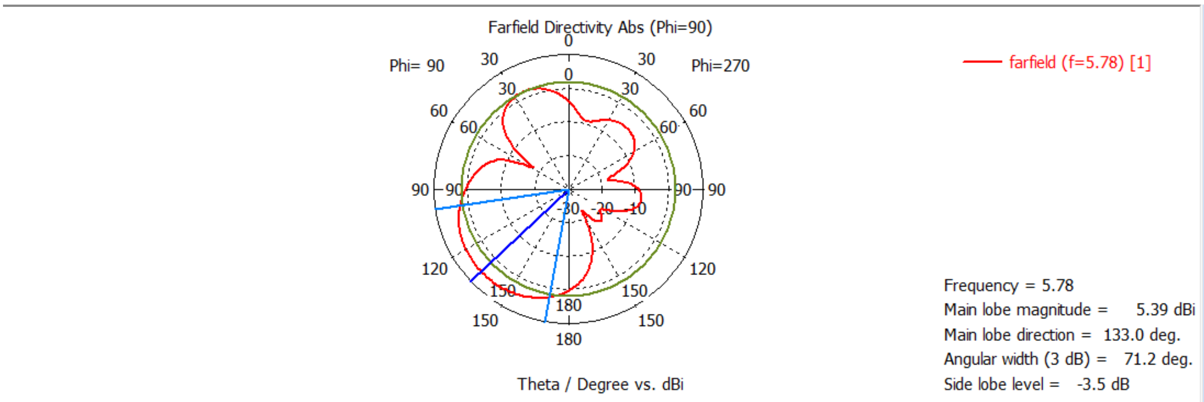
Figure 4.8: 2D radiation pattern at 5.78 GHz (a) for gain (b) for directivity

From the above 2D and 3D radiation pattern it can be observed that in figure 4.5 and 4.6 gain is at the resonant frequency 5.78 GHz. The simulated Directivity in CST at the same resonant frequency is

The simulated 2D polar plot of the radiation pattern of the proposed antenna is demonstrate in figure. The figure illustrates the 3 dB beam width, side lobe level (SLL) main lobe direction and main lobe magnitude. The 3 dB beam width at the resonant frequency of the proposed antenna is 71.2^0.



(a)



(b)

Figure 4.9: Polar plot of the proposed antenna at 5.78 GHz (a) for gain (b) for directivity

It is obvious that the SLL at resonant frequency 5.78 GHz is -3.5 dB. The meaning of SLL is that the higher negative magnitude of SLL means the least amount of power radiates by the antenna side lobe and maximum power of the antenna is radiated by the main lobe.

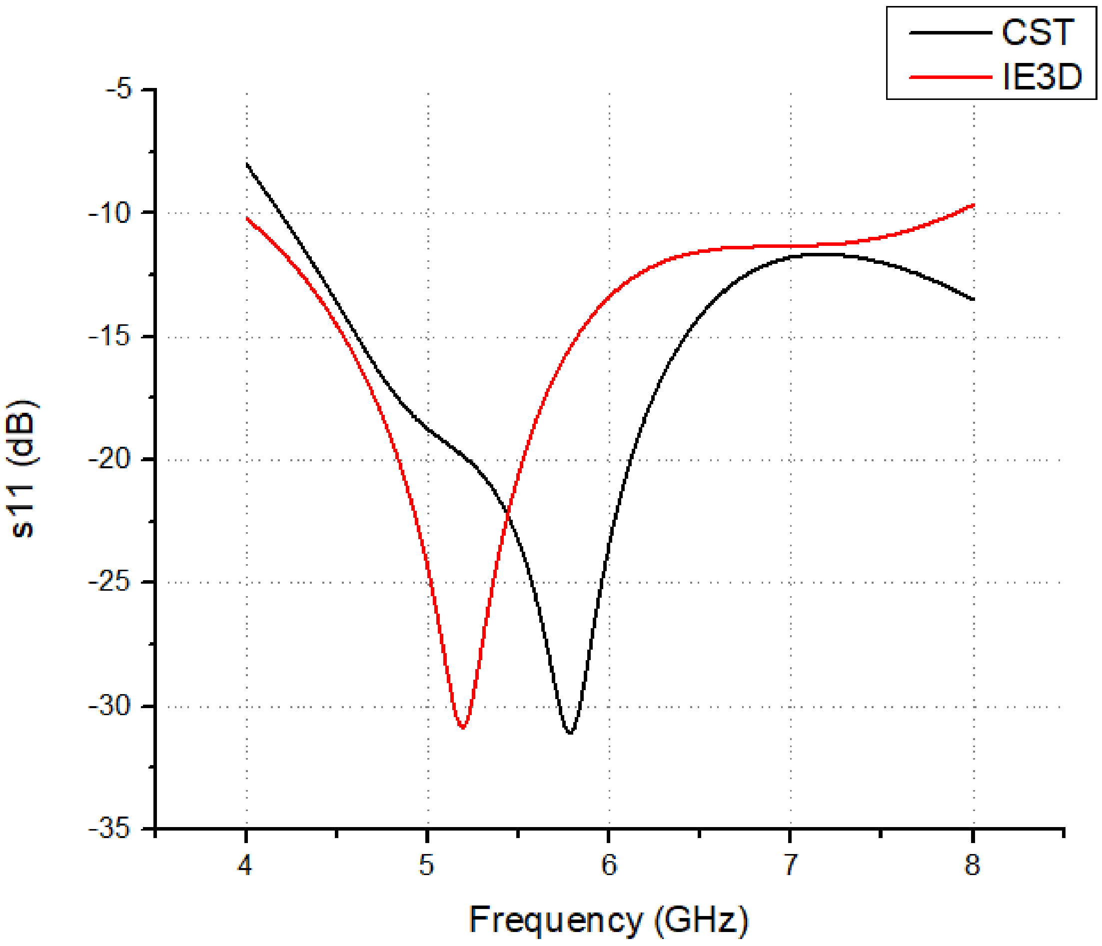


Figure 4.10: Comparative S-parameter of the proposed antenna using IE3D Zeland and CST

Comparative study of the S parameter of the simulated result using both IE3D Zeland and CST is demonstrate in figure 7.The consideration of S parameter is that how antenna impedance matched with the reference transmission line impedance. In usual, the antenna is simulated considering reference impedance Z0 =50 ohm. When the antenna impedance perfectly matched with the reference 50 ohm impedance than the less power is reflected from the antenna port and maximum power is radiated by the antenna in the direction of main lobe. The figure 7 demonstrate that the IE3D and CST both the simulator gives return loss below -10 dB at the frequency range from 4 to 8 GHz. This band of frequency covers the application of C band in wireless communication industry. It can also notice that the lowest return loss within the coverage frequency band of the simulated result at resonant frequency 5.78 GHz is -31.09 dB for CST and almost similar return loss that is -31.29 dB for IE3D at resonant frequency 5.12 GHz.

Table 4.1: The results of proposed antenna after simulation.

Antenna Parameters	RMPA with modified T shape with extra portion as plow
Resonant Frequency	5.125 GHz
Return Loss	-31.29 dB
Bandwidth	4GHz
Gain	5.429 dB
Directivity	6.165 dBi
Efficiency (%)	84.629

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)	5	1.6	1.625	1.5784	8	2.425
Length (mm)	16.5	28.89	20	44	78	20
Width (mm)	34	37.21	20	56.4	100	10
Band Width	4 GHz	123 MHz	7.5 GHz	400 MHz	1.419 GHz	4 GHz
Return Loss	-24 dB	-13.63 dB	-17 dB	-21.79 dB	-53.94dB	-31.29 dB
Gain (dB)	5.34	N/A	3.2	8.044	3.64	5.429
Directivity (dBi)	7.8	N/A	NA	8.22	3.7	6.165

TABLE 4.3: Comparison of the simulated results using IE3D Zeland and CST

Parameter	IE3D Zeland	CST
Return Loss (dB)	-31.29	-31.09
Gain (dB)	5.429	4.469
Directivity (dBi)	6.165	5.461
Frequency (GHz)	5.125	5.78
Bandwidth (GHz)	4.29	5

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Major Contributions of the Thesis

Although narrow bandwidth and low gain are problems of Microstrip patch antenna, Even after that Microstrip patch antenna continuously popular for Low cost, light weight and low profile nature.

In this thesis, the narrow bandwidth and low gain problem for single band (C band) may be overcome in proposed plowing T shape antenna. By adding plow-shape with T-shape, the bandwidth and gain of this designing antenna is improved. So this thesis persuade improving sign the characteristic of rectangle microstrip path antenna adding with plow shape. The dimension of the Rectangle designing antenna is 20×10 mm^2 with a substrate height 6mm, also adding tow plow shape with this rectangle (20×10mm^2) shape both side and transmission line (6×20mm^2) is added the center this rectangle shape. The proposed antennas have ability to provide service, WLAN application as well as uplink and broadcasting, satellite service, GPS, Fixed microwave, mobile satellite and radio navigation. The proposed antenna is cover 100% C band frequency range and resonant frequency is 5.12GHz. The reflection coefficient or return loss at the resonant frequency is -31.29dB and the value of VSWR is less than 2 for whole band. The maximum gain and directivity respectively 5.429dBi and 6.165dBi.

To verify the result got from Zeland IE3D is compared with well-known software CST. The return loss and gain almost same between IE3D and CST's simulated result. The value of VSWR is between 1 and 2 for both software.

5.2 Future Scope of work

In this thesis, we experimented our Microstrip patch antenna and simulated result to develop the band width and antenna parameters. Besides, the major work of this thesis is that fabrication can be done to observe real time performance of the antenna in future. Actually, the desire of fabrication of the proposed antenna can be manufacture commercially for C band application. In addition, slot cutting technique, Array, optimization, Reducing the size and changing the antenna type can be involve to improve performance of the proposed antenna. We can also use Metamaterials as a substrates.

REFERENCES

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

[2] V. H. R. Keerthi, H. Khan, and P. Srinivasulu, “Design of C-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] F. A. Dahri, R. A. Soomro, S. A. Memon, Z. Memon, and M. H. Memon, “An optimized inset feed circular cross strip antenna design for C-band satellite links,” *Int. J. Adv. Comput. Sci. Appl.*, vol. 9, no. 5, pp. 238–242, 2018, doi: 10.14569/IJACSA.2018.090532.

[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] S. S. Amit Kumar, “Designing and Analysis of T-Shape Microstrip Antenna for the 4G Systems,” *Glob. J. Comput. Sci. Technol.*, vol. 13, no. 8, 2013.

[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] P. Singh and S. Singh, “Design and analysis of T shaped broad band micro strip patch antenna for Ku band application,” vol. 5, no. 2, pp. 44–49, 2016.

[22] M. A. Haque, L. C. Paul, R. Azim, M. M. Mowla, A. Saleh, and M. N. Hossain, “A Modified E-Shaped Microstrip Patch Antenna for C Band Satellite Applications.” *IEEE*, 16 April 2020, doi: 10.1109/SPICSCON48833.2019.9065126.

[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.