OPTIMIZATION OF E-SHAPED MICROSTRIP PATCH ANTENNA FOR C BAND APPLICATION

A Project and Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

By

Ikbal Hasan

ID: 172-33-449

Supervised by

MD. ASHRAFUL HAQUE

Assistant Professor

Department of EEE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FACULTY OF ENGINEERING

DAFFODIL INTERNATIONAL UNIVERSITY

April 2021

CERTIFICATION

This is to certify that this thesis entitled "**Optimization of E-Shaped Microstrip Patch Antenna for C Band Application**" is done by the following student under my direct supervision and this work has been carried out by him in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 21 April 2021

.

Signature of the candidate

____

Name: Ikbal Hasan

ID: 172-33-449

Countersigned

____

Md. Ashraful Haque
Assistant professor
Department of Electrical and Electronic Engineering
Faculty of Science and Engineering
Daffodil International University.

CERTIFICATE OF APPROVAL

The project and thesis entitled **"Optimization of E-Shaped Microstrip Patch Antenna for C Band Application,"** submitted by **Ikbal Hasan** bearing student ID No: 172-33-449, Session: Summer 2017 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 10 March 2021.

Board of Examiners

____

Md. Ashraful Haque Coordinator

Assistant Professor

Department of EEE, DIU

____

Dr. Md. Alam Hossain Mondal Internal Member

Associate Professor

Department of EEE, DIU

____

Dr. M Abdur Razzak External Member

Professor

Department of EEE, IUB

DEDICATION

This thesis is dedicated to my beloved parents and my younger brother for their endless love, support and encouragement.

Declaration of Candidate

It is here by declared that this thesis or any part of it has not been submitted elsewhere for the award of any Degree or Diploma.

Md. Ashraful Haque, Supervisor
Associate Professor
EEE Department, DIU

Ikbal Hasan
Student ID: 172-33-449
Academic Year: 2016-2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ε_r	Dielectric Constant
LAN	Local Area Network
WLAN	Wireless Local Area Network
Wi-Fi	A popular synonym for "WLAN"
GHz	Giga Hertz
IEEE	Institute of Electrical and Electronics Engineers
Mbits/s	Mega Bits per Second
MMIC	MilliMeter-wave Integrated Circuits
IE3D	Moment of Method Based EM Simulator
HTS	High Temperature Superconductor
PCB	Printed Circuit Board
3D	Three Dimensional
2D	Two Dimensional
BW	Bandwidth
RL	Return Loss
VSWR	Voltage Standing Wave Ratio
MIC	Microwave Integrated Circuits
Q	Quality Factor
RF	Radio Frequency

ACKNOWLEDGEMENTS

I express my actual appreciation and commitment to the proposal supervisor Md. Ashraful Haque for his action in this field of ask about, for his productive heading, backing and affection for the productive finishing of this work. His true affectability and kind perspective ceaselessly engaged me to do the presentation work emphatically. I express our appreciation to Prof. Dr Md Shahid Ullah, Head of the Dept. of Electrical and Electronic Engineering, DIU, for giving us with best workplaces inside the Division and his helpful recommendations. I might also want to express gratitude toward Dr. Md. Alam Hossain Mondal Associate Professor, Department of Electrical and Electronic Engineering, DIU, for his heading and proposals in our work.

Last yet not slightest, i would want to thank every one of my sidekicks and well-wishers who were incorporated clearly or indirectly in successful fruition of the show work.

Ikbal Hasan

Student ID: **172-33-449**

Optimization of E-Shaped Microstrip Patch Antenna for C Band Application

Abstract

There is an expanding interest for more up to date microwave and millimeter-wave frameworks to address the arising media transmission difficulties regarding size, transfer speed and gain. Along these lines, the radio wires are broadly used to fulfill requests for satellite correspondence. In satellite correspondence, various applications are accessible in various recurrence ranges. Analysts have unfriendly insight to improve transfer speed and gain all the while for Microstrip Patch antenna (MPA) under C band recurrence range. A recently construction of E molded MPA has been proposed whose thunderous frequencies are 4.75 GHZ, 6.10 GHz and 7.25 GHz separately with wanted data transmission of about 4.00 GHz. It is covering the recurrence goes from 4.00 GHz to 8.00GHz. The element of planned radio wire comprises of 34×16.5×5 mm3 where RT/droid utilized as substrate with dielectric consistent 2.2. This band is broadly utilized for some satellite correspondences transmissions, some Wi Fi devices, some cordless phones, and some climate radar frameworks.

CHAPTER 1

OVERVIEW

1.1 Introduction

Wireless communication is the quickest developing portion of the correspondence business. It has gotten so pervasive in our general public and fundamental for our day by day lives. It gives ease, uncommon feeling of versatility to us and altered approach to do nearly everything. Some new - applications, including remote sensor organizations, mechanized roadways and production lines, keen homes and apparatus, and far off telemedicine are arising for research where receiving wire is a fundamental and clear part in remote correspondence framework. A radio wire is an electrical segment that is expected to communicate and get electromagnetic energy from the space encompassing it, to build up a remote association between least at least two gadgets. The receiving wire's exhibition is for the most part portrayed by some fundamental terms as radio wire productivity, gain and radiation design. Overall electromagnetic range has been allotted for a wide range of electromagnetic (EM) radiation dependent on EM wave frequencies and frequencies where radio wires can work as per the uses of remote correspondence framework like cell phones, base stations remote neighborhood associations (WLAN), and satellite and so on the working recurrence choice for specific radio wires to some degree decides the material that can be utilized to create the receiving wire. Materials incorporate flex, artistic, steel plate, RT droid, or some wire material. Lately, new counterfeit material known as metamaterial has been presented which displays strange properties that are not accessible in the nature. It is a composite design of metallic example which influence the infinitesimal properties of the host medium and produces negative viable permittivity and porousness. Radio wire execution can be improved by planning receiving wire with metamaterial. In any case, receiving wire is perhaps the most confounded parts of radio recurrence (RF) plan; it is likewise presumably the most neglected piece of a RF plan. The reach and execution of a RF connect are fundamentally reliant upon the receiving wire. Notwithstanding, it is regularly ignored until the finish of the plan and expected to find a way into whatever space is left, regardless of how negative to execution that area might be. Most recent couple of years radio wire planning acquires a lot of need to media transmission specialists. Particularly radio wire scaling down and multifunctional framework turned into the most critical and fascinating points with regards to related fields. The longing for little and adaptable receiving wires is expanding each day, in light of receiving wire plan it can work at various radio frequencies. Microstrip Patch Antenna (MPA) has gotten generally mainstream to receiving wire planner because of its minute designs. Contrasted and the ordinary radio wire, it has more multilateral benefits for planer profile, capacity to work in microwave recurrence range, similarity with molded surface, modest to fabricate and particularly simple to amass in coordinated circuit innovation [1]. Planning MPA utilizing different strategies opens the chance in improvement of radio wire trademark like receiving wire transfer speed, acquire, directivity, little size, tunable operational recurrence and so on

1.2 Background

In 1950s the theoretical thought of microstrip receiving wire was first presented by G. A. Deschamps. After the advancement of the printed circuit board (PCB) innovation during the 1970s, Howell and Munson built up the primary down to earth microstrip receiving wire, which opens broad space of exploration everywhere on the world [1]. The essential construction comprises of a directing patch of any non-planar or planar math on one side of a dielectric substrate and a ground plane on opposite side. The key emanating structures for microstrip receiving wires are primarily rectangular and roundabout in math; regardless, complete rundown of the calculations alongside their remarkable highlights are accessible in section 2. The position of safety planar design of microstrip receiving wires can be effortlessly made conformal to have plane. That is the reason it has the wide field of utilization for the regular citizen and military applications like TV, broadcast radio, versatile frameworks, radio-recurrence recognizable proof (RFID), Wi-Fi, Wi-Max, different information various yield (MIMO) frameworks, worldwide situating framework (GPS), satellite correspondences, observation frameworks, vehicle impact evasion framework, bearing establishing, radar frameworks, far off detecting, organic application like natural imaging, rocket direction etc. and still the work is going on the microstrip receiving wires for discovering new uses of it by having more coordination [1].

The design and execution of such microstrip receiving wires is a continuous space of exploration. Adjusted arrangements and different states of MPA like rectangular or three-sided with various element of length (L) can assist with getting alluring full frequencies. The rectangular and round patches are the fundamental and most generally utilized microstrip receiving wires. The transmission capacity of microstrip receiving wires is firmly impacted by the hole between the directing patch and the ground plane. A more modest hole stores more energy in the fix capacitance and inductance and emanates less. Subsequently, the quality factor (Q) of the radio wire increments, showing a tight radiation data transmission. This Q can be decreased by expanding the thickness of the dielectric substrate, yet the significant detriment of expanding thickness is the diminished productivity since the huge segment of the info power is scattered in the resistor which removes the accessible Power that can be transmitted by radio wire. It likewise displays low force acquire, additional radiation from its feeds and intersection focuses [1]. The substrate permittivity (εr) of the microstrip radio wire likewise influences the resounding data transfer capacity and gain. It is hard to accomplish standard radio wire gain and transmission capacity trademark in same MPA under C band locale.

1.3 Literature Review

Microstrip patch antenna have been notable for its benefits like light weight, low manufacture cost, precisely powerful when mounted on inflexible surfaces and ability of double and triple recurrence tasks [2]. In any case, tight transfer speed came as the significant burden for this kind of radio wire. A few methods have been applied to beat this issue like expanding the substrate thickness, presenting parasitic components for example co-planar or stack design, or adjusting the fix's shape itself. Changing patch's shape incorporates planning an E-formed fix radio wires [3],[4] or a U-opening patch receiving wire [5]-[7]. In [4], creators guarantee that U-opening microstrip radio wire gives transfer speed up to 30% while E-molded fix receiving wire can expand transmission capacity above 30% contrasted with a standard rectangular fix radio wire. Contrasting the two plans, the E formed is a lot less difficult to develop by just changing length, width and position of spaces. All essential microstrip fix receiving wire computation can be alluded in [8]. In this paper, a wideband single fix receiving wire is proposed as in Figure 1. The plan depends on a reconfigurable fix receiving wire in [9] as a plan reference yet no switch is fused in this plan. The fundamental goal of this paper is to streamline the base plan in [9] to get higher data transmission. This single fix receiving wire works at voltage standing wave proportion of under 2 (VSWR < 2).

A super wideband and tri-band Antennas for satellite applications at C-, X-, and Ku groups has been proposed in [20] with 14×5×1.6 mm3 measurement. The super wideband radio wire comprises of an altered rectangular transmitting component with distorted ground plane which gives a wide transmission capacity from 5 to 16 GHz. The U-molded spaces has been acquainted in the emanating patch with get the tri-band recurrence reaction covering C, X and Ku groups independently. The recurrence groups accomplishing were 4.9-7 GHz, 7.92-11.08 GHz and 11.85-15.94 GHz. The radio wires acquire was shifting from 2.3 dBi to 4.5 dBi across the whole data transfer capacity. In [21] a wide Ku-band microstrip fix radio wire utilizing absconded fix and ground has been proposed with a fix size 13×11× 0.035 mm3. For improving the return misfortune and data transfer capacity of radio wire two semi U molded, three U formed openings on fix and one rectangular space in ground were presented. The proposed receiving wire shows wide band from 15.27 to 16.51 GHz with full recurrence at 15.8 GHz where VSWR ≤ 1.1, acquire was 4.45 dB, directivity was 5.17dBi. A fix receiving wire utilizing upset U-opening and L-space for X, C and K-band applications has been proposed in [22] having seven full frequencies as 8.25 GHz, 9.7 GHz, 11.93 GHz, 14.19 GHz, 16.52 GHz, 18.7 GHz and 20.75 GHz, which falls in X, C and K groups. The measurement and gain of the proposed receiving wire was 49.4×41.4×1.6 mm3 and 6.18 dBi. In [23] the proposed fundamental receiving wire has an impedance data transmission of 92% in the recurrence range 3.94–10.65 GHz utilizing a collapsed fix feed, E-formed fix, one shorting nail to the edge of gap and an E-molded edge to upgrade the transfer speed. The size of receiving wire was decreased by utilizing two shorting pins and by applying V-molded space fix took care of by collapsed fix, smaller wideband radio wire was additionally accomplished working in 4–14.4 GHz. The fix's element of the improved receiving wire was 15 × 15 mm2, though the fix's size of the essential radio wire was 18 ×15 mm2 on an air substrate with an absolute thickness of 7 mm. Double band Microstrip Patch radio wires (MPAs) [2] are broadly utilized in the new years in various fields of correspondence for their minimal size, adaptability, ease and elite. They are essentially utilized for their distinction recurrence activity. They can transmit more than one example. By utilizing this double band receiving wire, framework execution can be expanded and it offers dependability to the radio wire creator for interfacing distinctive specialized gadgets with this radio wire for sending and getting signals. The double band E-shape receiving wires are utilized in satellite correspondence and radar framework like secure correspondence, multi recurrence correspondence, object recognition framework, speed test in vehicle and some more. Double recurrence design can be accomplished by utilizing diverse switch state for various recurrence of radiation ahead of time. Diverse radio frequencies are to a great extent created for various correspondence reason. The microwave recurrence range is 3-30 GHz. This receiving wire has been intended for activity in C-band and X-band of microwave recurrence range. The resounding frequencies are 4.8 GHz with transfer speed of 167.7 MHz, 6 GHz with transmission capacity of 58 MHz and 9.2 GHz with transfer speed of 326MHz. In this radio wire two parasitic layers are consolidated for expanding the transfer speed. The C-band of microwave recurrence range is utilized in satellite interchanges, full-time satellite TV organizations or crude satellite feeds. This C-band normally utilized in territories that are dependent upon tropical precipitation, since it is less powerless to rain blur than Ku band. Its recurrence range is 4-8 GHz. The X-band of microwave recurrence range is utilized in military correspondence framework. It can likewise be utilized in radar applications. It has a recurrence scope of 8-12 GHz.

1.4 Problem Statement

The misuse of satellite for correspondence purposes has expanded extensively during the most recent many years, to fulfill the developing interest for significant distance correspondence. As the C-band is as of now blocked, Ku-band is topping off quickly; as of late interest has zeroed in on the use of higher groups. The reception of these groups for satellite correspondence has numerous benefits. These groups offer more extensive transmission capacities, higher information rates, more modest part size, and so forth

Recurrence groups above C-band are viewed as very high recurrence groups. Business satellite transmissions are as of now continued either C-band or Ku-band with the uplink and downlink utilizing distinctive transporter frequencies. C-Band is most regularly utilized for satellite interchanges, climate anticipating radars, vehicle following, fire location radars and is utilized for most VSAT frameworks on yachts and ships today because of the blockage in C band. Numerous explores fusing C band have been going on as of late, examined in the writing survey, yet they are not covering the full C band.

Gain of a fix receiving wire diminishes with decline in radio wire size. Thusly, the size decrease, 7 with gain and data transmission improvement is turning out to be significant plan contemplations for most useful utilizations of microstrip receiving wires for remote correspondence. As of late numerous advances are as of now made to defeat above issues. Procedures like expanding the tallness of the substrate, stacking distinctive radio wire components, cutting openings in fix, the utilization of low permittivity substrate, electromagnetic band hole constructions, and Metamaterials have been proposed to moderate low transfer speed issue. In any case, Rectangular E molded Microstrip fix receiving wire has gotten one of the main stream in radio wire reproduction and planning plan since it can show better wideband and multiband attributes. To expand the addition of radio wire substrate with low dielectric steady, fragmentary expulsion of substrate, High permittivity dielectric superstrate, stacked design, exhibit setup, etc. can be utilized.

The reason for this research is to plan a radio wire that will show wideband qualities with upgraded acquire covering full C band (4-8 GHz). Upgraded transfer speed and gain inside one radio wire working in C band will make the gadgets appropriate as it will cover practically all capacities inside the C band.

Zeland IE3D simulation software has been decided to be utilized to plan and reenact the receiving wire on account of its straightforwardness and exactness as expressed by past scientists.

1 . 5 Aim and Objectives

The point of this exploration is to accomplish better execution of the MPA attributes under Ku band. The goals are featured beneath.

- Design a microstrip fix receiving wire with improved transfer speed
- Gain improvement of the planned receiving wire
- To diminish antenna, return loss

1 . 6 Methodology

Every one of the upgrades in execution of MPA have been done under Ku band recurrence space. Inclusion of two kinds of spaces in MPA drives us to get satisfactory improved outcome. Major strategies have been expressed bit by bit to accomplish our attractive targets.

Stage 1: Designing a basic rectangular microstrip fix radio wire with fundamental construction by characterizing its length (L) and width (W).

Stage 2: Using E shape in the antenna to expand the transfer speed.

Stage 3: Modifying and Optimizing the widths and lengths of the E shape for better outcomes.

Stage 4 To examination the exhibition of all planned radio wire separately in term of receiving wire trademark particularly receiving wire acquire, radio wire return misfortune and radio wire transfer speed.

Stage 5: Optimizing the widths and lengths of the spaces for better outcomes.

Stage 6: Comparing the proposed antenna boundaries with late writing.

1.7 Thesis Organization

This postulation is separated into 5 fundamental parts and the reference segment.

Chapter 1 examines about the presentation, writing survey, issue explanation, destinations and extent of the proposition.

Chapter 2 clarifies brief writing investigations of the microstrip antenna to get its essential things. It likewise examines the pertinent writings on planning wideband microstrip fix radio wire utilizing space.

Chapter 3 portrays the plan method of wideband high increase Microstrip fix radio wire utilizing coaxial taking care of strategy. A progression of radio wire design with improvement has been examined in this part. To expand the addition of the proposed radio wire cluster design has been presented.

Chapter 4 incorporates correlation between CST studio and Zeland IE3D, return misfortune charts, transmission capacity for every individual antenna, normal and vector current circulation, 2D and 3D radiation designs for the proposed single fix radio wire. Gain of the different exhibit arrangements has additionally been thought about in this section. The reenactment is finished utilizing CST studio Zeland IE3D of rectangular microstrip fix radio wire. A short relative investigation likewise has been made between proposed antenna and other recently planned radio wires regarding different antenna boundaries.

At last, Chapter 5 gives a finish of the work and degree for future work contemplations.

CHAPTER 2

Literature Studies

2.1 Antenna Parameters:

Antenna can be characterized as a transducer that changes over electrical energy into electromagnetic energy and the other way around. To decide if the plan of a gadget is positive or negative, there ought to be some quantifiable properties of that gadget that can be estimated against standard qualities. Receiving wires additionally have various types of boundaries to assist one with understanding the qualities and shortcomings of a plan. The boundaries of a radio wire are of various types and ward on each other. Thusly, at whatever point a radio wire is planned, one needs to ensure that every one of the boundaries are enhanced. For instance, if a plan of an omnidirectional radio wire is finished with reflection co-proficient of more noteworthy than - 6dB, at that point that omnidirectional example is of no worth, as the receiving wire won't transmit. Significant boundaries associated with this proposal will be talked about in a nutshell in this part.

2.1.1 Antenna Field Regions:

Albeit not a receiving wire boundary without anyone else, information on radio wire field districts is critical to comprehend after how much separation from the radio wire does the receiving wire really emanate. The fields encompassing a receiving wire are isolated into 3 standard locales:

- Reactive Near Field
- Radiating Near Field or Fresnel Region
- Far Field or Fraunhofer Region

The far field locale is the most significant, as this decides the receiving wire's radiation example and a large portion of different boundaries. Additionally, receiving wires are utilized to impart remotely from significant distances, so this is the locale of activity for most radio wires.

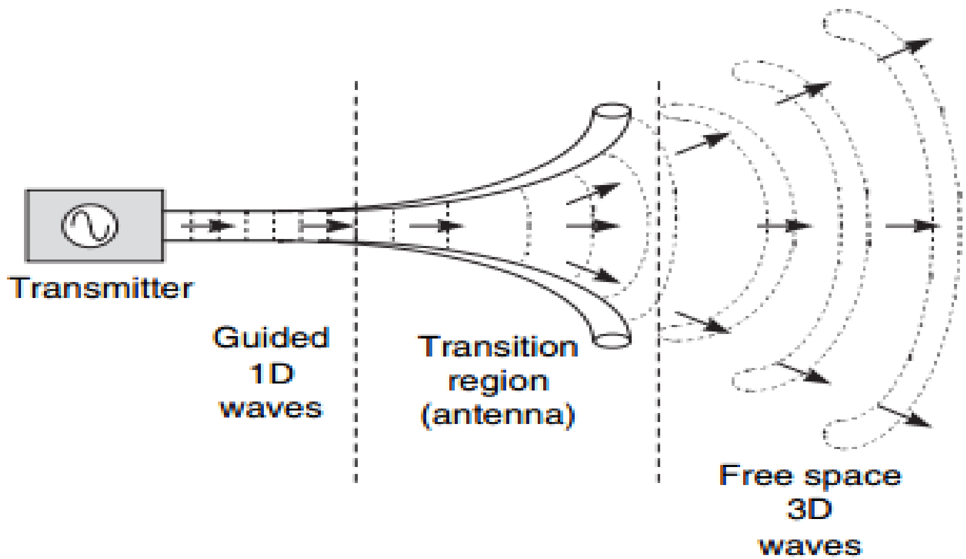


Figure 2.1.1 Antenna

Antennas have two field parts in Electric and Magnetic field conditions. These are named as radiative fields and responsive fields. In the responsive field parts, by and large there is a distance 'r' in the denominator of the condition which is of the request for two or higher than two. There is a distance part in the radiative segment additionally having 'r' of the primary request. Therefore, as distance builds, the responsive segment of the field kicks the bucket however radiative segment remains, which passes on at a far more prominent distance than receptive fields. As the responsive field is more noteworthy in the close to handle locale, there isn't a lot of radiation accessible. Yet, this distance is excessively little for us to encounter, of the request for R< λ (Wavelength at the working recurrence), which is in mm and cm levels at microwave frequencies. Accordingly, at whatever point any boundary of a radio wire is examined, it is really talked about in the far field area as radiation just exists there, except if it is indicated that it is done in the close to handle locale.

2.1.2 Radiation Pattern:

Radiation example of a receiving wire is a graphical portrayal of radiation force of a radio wire as for space co-ordinates, ordinarily in a round co-ordinate framework. In light of radiation design, radio wires are portrayed as directional or omnidirectional. At the point when a radio wire transmits similarly along the azimuthal point yet changes concerning height point sinusoidally, the receiving wire is called omnidirectional one. Then again, if a receiving wire emanates with higher directivity at a specific point regarding different points, the radio wire is supposed to be directional. The directionality of a radio wire is communicated with a term called directivity. Radiation example can be appeared as a 3D plot, 2D plot or a Polar plot. 2D and Polar plots are fundamental for logical purposes. We can see graphically the example at which the radio wire is transmitting in various ways from these figures.

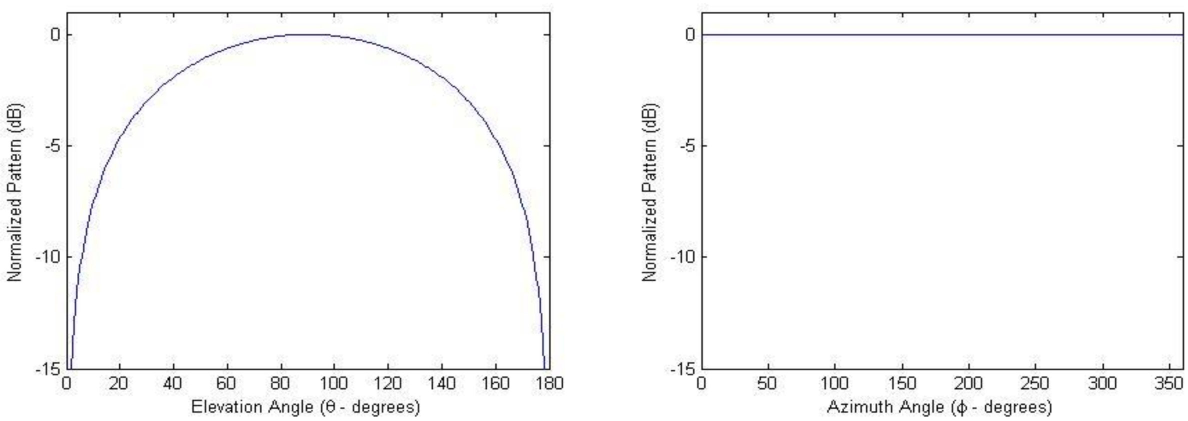


Fig 2.1.2 2D plot of an omnidirectional antenna

2.1.3 Directive Gain:

A directive antenna radiates differently at different angles. The ratio of radiation intensity of an antenna at a particular angle with respect to average radiation intensity of that antenna in all directions is called its directive gain at that angle. It is normally expressed in 'dBI'.

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

2.1.4 Directivity:

A directional antenna always has an angle of radiation where radiation intensity is higher than all other directions. The directive gain of a directional antenna at the direction of its maximum radiation is called directivity of the antenna.

2.1.5 Antenna Efficiency:

An antenna is always associated with at least two kinds of losses. One is due to mismatch of impedance between feed line and antenna and due to mismatch of impedance between antenna and free space. Another is due to losses associated with antenna because of its being a conductor. As a result, whole of the input power will not be radiated by the antenna. The ratio between the output power and input power of an antenna is called its efficiency.

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

2.1.6 Antenna Gain:

Antenna gain is the directivity of a radio wire mulling over the receiving wire productivity. It tends to be said that directivity of a radio wire is the ideal case and gain is the genuine case. Along these lines, in the event that it tends to be guaranteed that every one of the information forces to a radio wire will be emanated, at that point gain and directivity will be same. As in useful case, there will consistently be misfortunes related with radio wires; acquire is consistently lesser than directivity.

$$Antenna\ Gain = Antenna\ Efficiency\ \times Directivity$$

2.1.7 Voltage Standing Wave Ratio:

As it is unimaginable to completely coordinate with the impedance among radio wire and generator, there will consistently be some impedance crisscross. This impedance jumble will constrain a portion of the sign to be reflected back from the radio wire towards the generator. The forward wave to receiving wire and this reflected wave from the radio wire are generally inside the waveguide. These two voltages together structure a 'Standing Wave' inside the waveguide. This wave has a most extreme and a base. The ratio between the maximum and minimum voltage inside the waveguide is called Voltage Standing Wave Ratio (VSWR).

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

The base worth of VSWR is 1 which is when there is no crisscross among generator and radio wire. It addresses 100% emanated wave and 0% reflected wave. Ordinarily, VSWR of 2 is acknowledged as a decent match as it addresses roughly 10% of reflected force.

2.1.8 Return Loss / S11 Parameter:

Return loss is another boundary to pass on the data of impedance confound. Despite the fact that it gives a similar data like VSWR, it is the most famous boundary to depict impedance bungle and reverberation in radio wire writings. Reflection co-efficient is the ratio of reflected power to incident power. It is calculated by the following equation:

$$Reflection\ Co - efficient, \tau = \frac{z_A - z_o}{z_A + z_o}$$

Where, z_A = Antenna impedance

z_o = Transmission Line impedance

When there is a finished match between receiving wire impedance and line impedance, reflection co-proficient is zero addressing no reflection. Return loss is the value of reflection co-efficient in decibel. The relationship between Reflection Co-efficient and VSWR is:

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

A similar information can be acquired about VSWR and Return misfortune from Table 2.1. Return misfortune is given by the accompanying condition in dB. The short sign ensures that the worth of return misfortune remains a positive worth to consent to the IEEE definition. Minus value of the return loss is called s11 parameter.

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

2.1.9 Input Impedance (up to spin)

Input impedance is the impedance introduced by a receiving wire at its terminals or the proportion of the voltage to current at a couple of terminals. On the off chance that the information impedance of the transmission line and radio wire are coordinated, most extreme force move will be accomplished. In the event that isn't coordinated with it will cause decrease on in general framework effectiveness. This is on the grounds that reflected wave is produced at the receiving wire terminal and it will go back towards the energy source.

For this boundary, the input impedance should coordinate with the qualities impedance of transmission line to accomplish most extreme energy move between transmission line and fix. On the off chance that the information impedance not matches to one another, reflected wave will be created at radio wire terminal and travel back towards the fuel source. Impression of energy brings about a decrease in the general framework productivity. On the off chance that the receiving wire is utilized to communicate or get energy, at that point just this misfortune effectiveness will be happened

2.1.10 Antenna Bandwidth:

An antenna has various types of data transmissions relying upon various types of boundaries. There is a scope of frequencies where return misfortune is not exactly - 10dB that will be called s11 boundary transmission capacity. In the event that there is a scope of frequencies where radiation design stays true to form, that will be radiation design transmission capacity. However, in the event that there is a scope of recurrence, where all the antenna boundaries are inside satisfactory reach, is called antenna bandwidth

2.2 Introduction of Microstrip Patch Antenna

Microstrip antennas are quite possibly the most broadly utilized kinds of antennas in the microwave recurrence reach, and they are regularly utilized in the millimeter-wave recurrence range also [1, 2, 3]. (Beneath roughly 1 GHz, the size of a microstrip radio wire is normally too enormous to ever be down to earth, and different sorts of antennas, for example, wire radio wires overwhelm). Likewise called fix antennas, microstrip fix radio wires comprise of a metallic fix of metal that is on top of a grounded dielectric substrate of thickness h, with relative permittivity and penetrability εr and μr as demonstrated in Figure 2.1 (typically $\mu r = 1$). The metallic fix might be of different shapes, with rectangular and roundabout being the most widely recognized.

Microstrip antennas are alluring because of their light weight, comparability and ease. These antennas can be incorporated with printed strip-line feed organizations and dynamic gadgets. This is a moderately new space of radio wire designing. The radiation properties of miniature strip structures have been known since the mid 1950's. The use of this sort of radio wires began in mid1970's. when conformal antennas were needed for rockets. Rectangular and roundabout miniature strip full fixes have been utilized widely in an assortment of cluster arrangements. A significant contributing element for late advances of microstrip radio wires is the current transformation in electronic circuit scaling down achieved by improvements in enormous scope mix. As ordinary antennas are frequently massive and expensive piece of an electronic framework, miniature strip radio wires dependent on photolithographic innovation are viewed as a designing leap forward. [13]

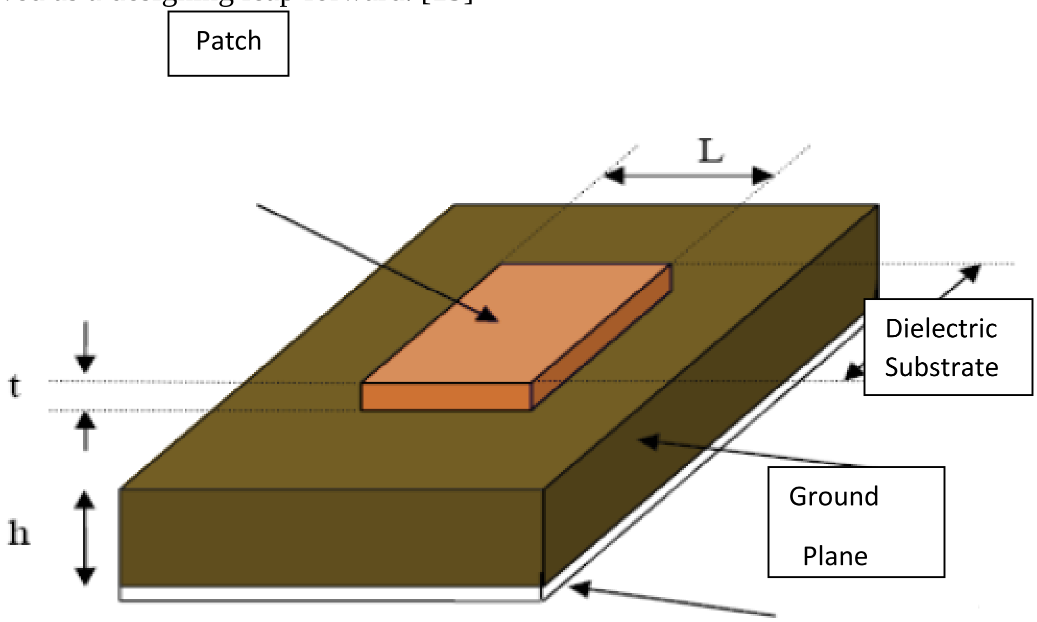


Figure 2.2 Patch antenna

In its most basic structure, a Microstrip Patch antenna comprises of a transmitting patch on one side of a dielectric substrate which has a ground plane on the opposite side as demonstrated in Figure 2.1. The fix is for the most part made of directing material like copper or gold and can take any conceivable shape. The transmitting patch and the feed lines are generally photograph carved on the dielectric substrate.

To improve on investigation and execution expectation, the fix is for the most part square, rectangular, roundabout, three-sided, and circular or some other normal shape as demonstrated in Figure 2.14. For a rectangular fix, the length L of the fix is normally, where is the free-space frequency. The fix is chosen to be exceptionally slight with the end goal that (where t is the fix thickness). The tallness h of the dielectric substrate is normally. The dielectric steady of the substrate ( ) is regularly in the reach.

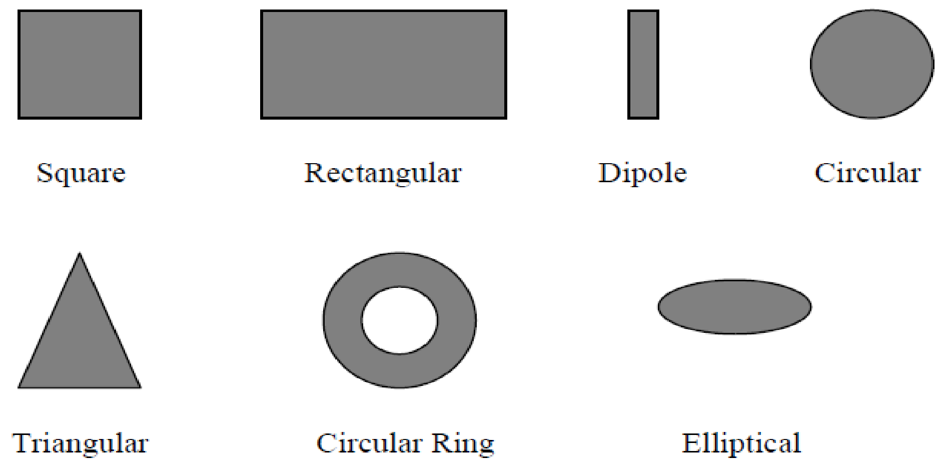


Figure 2.2.1: Different shapes of Patch elements

Microstrip fix antennas transmit fundamentally due to the bordering fields between the fix edge and the ground plane. For great radio wire execution, a thick dielectric substrate having a low dielectric steady is alluring since this gives better proficiency, bigger transfer speed and better radiation [5]. Be that as it may, such a design prompts a bigger receiving wire size. To plan a reduced Microstrip fix radio wire, substrates with higher dielectric constants should be utilized which are less effective and result in smaller transfer speed. Thus a compromise should be acknowledged between the radio wire measurements and antenna execution.

2.2.1 Advantages and Disadvantages

Microstrip fix radio wires are expanding in prominence for use in remote applications because of their position of safety structure. Consequently, they are amazingly viable for installed radio wires in handheld remote gadgets like mobile phones, pagers and so forth The telemetry and correspondence radio wires on rockets should be meager and conformal and are regularly as Microstrip fix antennas. Another territory where they have been utilized effectively is in Satellite correspondence.

A portion of their chief benefits talked about by [9] are given beneath:

- Light weight and low volume.
- Low profile planar design which can be effectively made conformal to have surface.
- Low creation cost, thus can be fabricated in enormous amounts.
- Supports both, direct just as round polarization.
- Can be handily incorporated with microwave coordinated circuits (MICs).
- Capable of double and triple recurrence tasks.
- Mechanically powerful when mounted on unbending surfaces.

Microstrip fix radio wires experience the ill effects of more disadvantages when contrasted with traditional antennas. A portion of their significant weaknesses examined by [9] and Garg et al [10] are given beneath:

- Narrow data transmission
- Low proficiency
- Low Gain
- Extraneous radiation from feeds and intersections
- Poor end fire radiator aside from tightened space radio wires
- Low force dealing with limit.
- Surface wave excitation

Microstrip fix receiving wires have an extremely high radio wire quality factor (Q). It addresses the misfortunes related with the receiving wire where a huge Q prompts thin data transfer capacity and low proficiency. Q can be diminished by expanding the thickness of the dielectric substrate. Be that as it may, as the thickness builds, an expanding part of the complete force conveyed by the source goes into a surface wave. This surface wave commitment can be considered an undesirable force misfortune since it is eventually dissipated at the dielectric twists and causes debasement of the radio wire qualities. Different issues, for example, lower gain and lower power dealing with limit can be overwhelmed by utilizing an exhibit design for the components.

2.3 Basic ‘Principles of Operation'

The figure shows a fix antenna in its fundamental structure a level plate over a ground plane The middle conveyor of a persuade fills in as the feed test to couple electromagnetic energy in or potentially out of the fix. The electric field conveyance of a rectangular fix energized in its essential mode is likewise shown

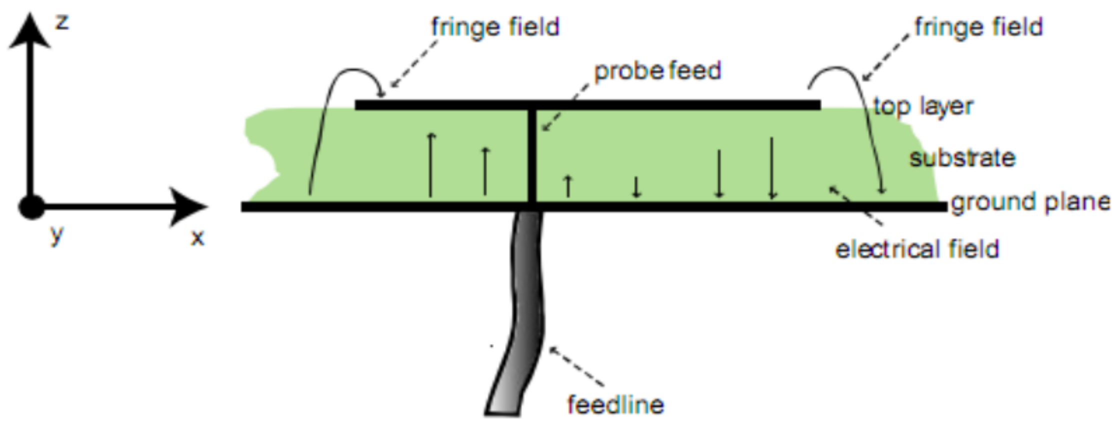


Figure 2.3 A Side view!of Microstrip Patch Antenna

The electric field is zero at the focal point of the fix, maximum(positive) at one side, and least (negative) on the contrary side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal.

2.4 Feeding Technique

MPA has different strategies for taking care of methods. As these radio wires having dielectric substrate on one side and the transmitting component on the other. These feed methods are being put as two distinct classifications reaching and non-reaching. Reaching feed procedure is the one where the force is being taken care of straightforwardly to transmitting patch through the associating component for example through the microstrip line. Non-reaching strategy is the one where an electromagnetic attractive coupling is done to move the force between the microstrip line and the emanating patch. Despite the fact that there are numerous new strategies for feed methods the most well-known or ordinarily utilized procedures are the microstrip line, coaxial test, opening coupling and closeness coupling.

.

2.4.1 Microstrip Line

The microstrip feed line is associated straightforwardly to the edge of the fix antenna. This feed understanding has the advantage is that it very well may be carved on a similar substrate, so the absolute construction stays planar.

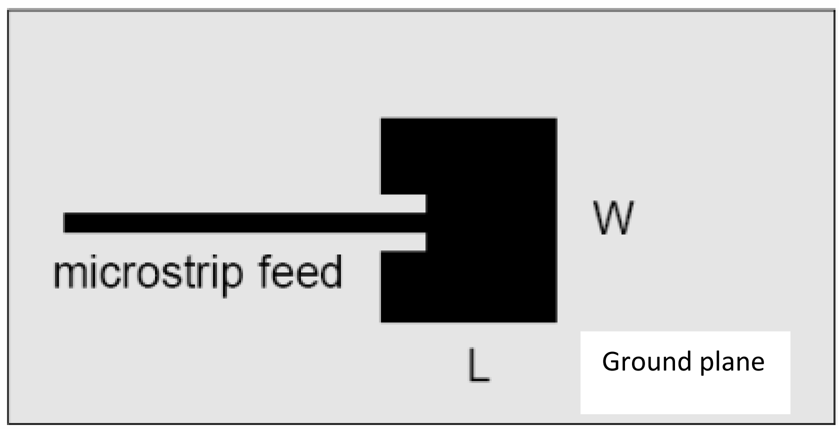


Figure 2.4.1 Microstrip line feed.

As outlined in Figure 2.3, it is typically of a lot more modest width contrasted with the fix, easy to match and simple to create by controlling the inset position [29].

2.4.2 Coaxial Feed

Coaxial-line feed or test feed, is a natural strategy utilized for taking care of microstrip fix receiving wires this days, where the interior conduit of the coaxial is reached out through the dielectric and joined to the radiation fix radio wire, albeit the external channel is associated with the ground plane, as found in Figure 2.4. The significant advantage of this feed is that it very well may be putted at any ideal area inside the fix to coordinate with it is input impedance of the fix. It is additionally simple to manufacture, and it has low false radiation. The drawbacks are that it additionally has limited transfer speed and is more-hard to demonstrate [28].

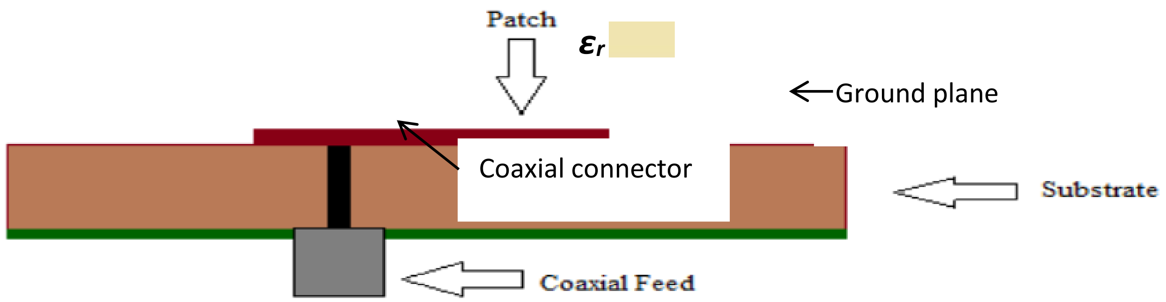


Figure 2.4.2 Probe-fed patch antenna.

2.4.3 Aperture-Coupled Feed

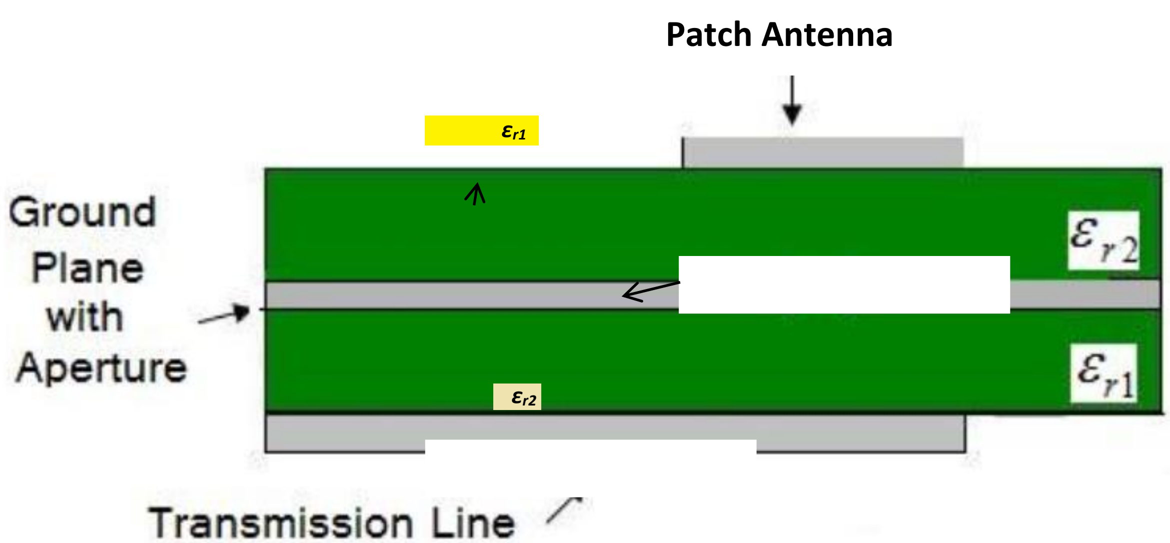


Figure 1.4.3 Aperture-Coupled Feed

The opening coupled design is extremely mainstream taking care of setup in microstrip fix antennas, comprises of two substrates isolated by a ground plane. Also, the lower substrate can see on the base side. There is a microstrip feed line whose energy is connected to the fix during an opening on the ground plane isolating, the two substrates for this plan as demonstrated in Figure 2.5. A high dielectric material is utilized for the base substrate and a thick low dielectric steady material for the top substrate. The ground plane between the substrates additionally disengages the feed from the emanating component and limits the impedance of fake radiation for design arrangement and polarization immaculateness. The drawback of this taking care of method is that it is difficult to manufacture and it has a thin band. Then again, it is to some degree simpler to show and has a moderate false radiation [28].

2.4.4 Proximity Coupled Feed

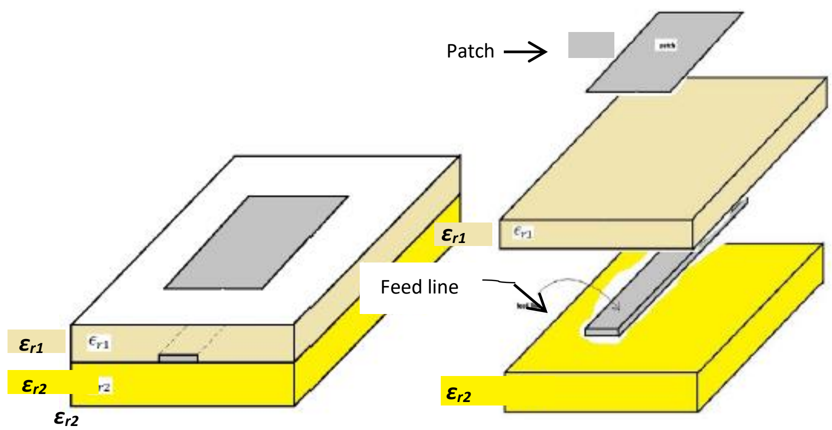


Figure 2.4.4 Proximity Coupled Feed

This sort of taking care of procedure is perceived as electromagnetic coupling. The taking care of line is putted between the ground plane and the fix, which is isolated by two dielectric media as demonstrated in Figure 2.6. Energy is moved through the electromagnetic coupling between the fix and the taking care of line. The upsides of this taking care of design incorporate the end of deceptive feed-network radiation; and the increment in the data transmission because of the increment in the general substrate thickness. The primary burdens of this taking care of method are that it is hard to be created in light of the two layers should have been adjusted appropriately [28].

Subsequent to choosing the fix measurements L and W for the given substrate, the feed point must be resolved to accomplish a decent impedance match between the generator impedance and information impedance of the fix component. The adjustment of feed area brings about an adjustment of the info impedance and subsequently gives a basic strategy to impedance coordinating. The feed point is chosen to such an extent that the information obstruction Rin is equivalent to the feed line impedance, typically taken to be 50ohm.

2.5 Feed Point Location

Subsequent to choosing the fix measurements L and W for the given substrate, the feed point must be resolved to accomplish a decent impedance match between the generator impedance and info impedance of the fix component. The adjustment of feed area brings about an adjustment of the information impedance and consequently gives a straightforward strategy to impedance coordinating. The feed point is chosen with the end goal that the information opposition Rin is equivalent to the feed line impedance, normally taken to be 50 ohm.

2.5.1 Polarization

The polarization of a rectangular fix antenna is straight and coordinated along the reverberating measurement, when worked in the predominant mode. Enormous transmission capacity fix antennas may work in the higher request mode too. The radiation example and polarization for these modes can be not the same as the prevailing mode. Another hotspot for cross-polarization is the bordering field along the no emanating edges. These fields are arranged 90 degrees regarding the field at the emanating edges. Their commitment to the radiation fields in the E and H planes is zero. Nonetheless, in the inter cardinal planes, even the ideal, single mode fix will transmit cross-captivated fields. The cross-polarization level increments with substrate thickness. Polarization of the radio wire can be changed precisely or electronically. For the electronic tuning, PIN diodes or varactor diodes can be utilized. Polarization variety utilized in portable interchanges to represent the decrease in signal strength because of blurring [18].

Table 2.2 Comparison between Different Feeding Techniques

Characteristics	**Microstrip Line feed**	**Coaxial Feed**	**Aperture coupled Feed**	**Proximity coupled Feed**
Deceptive feed radiation	More	More	Less	Minimum

Reliability	Better	Poor because of patching	Good	Good
Simplicity of manufacture	Easy	Patching and penetrating required	Arrangement required	Arrangement required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

2.6 E Shape Microstrip Patch Antenna

From past conversation it has been noticed that MPA has a great deal of extraordinary benefits just as significant disadvantages particularly slender transmission capacity and low force gain of radio wire qualities. Numerous analysts and RF engineers all throughout the planet have been analyzing and exploring for additional improvement of MPA. As of late numerous advances have been now made to defeat some of prime downsides. The substrate permittivity (εr) and thickness of the MPA influences the resounding transmission capacity and gain, changing them in appropriate extents may prompt accomplish alluring radio wire attributes [14]. Like-wise it has been seen that the data transfer capacity of MPA can be improved by utilizing air as substrate [15], expanding the substrate stature, including parasitic patches component in co-planer or stack arrangement. In [16], a gap coupled MPA has been appeared with parasitic patches stacked on the highest point of the primary fix. Managing spaces off from the metallic patches have become an exceptionally mainstream approach to build data transfer capacity of single fix antennas. The openings can be any unique shape on the patches. Different sorts of alphabetic opened radio wires have been seen in [17-19], for example, U-space fix antenna, V-opening patch antenna, C-space fix radio wire. In [20] it was shown that altering the U-space to a diminished V-opening can improve antenna transfer speed. Adjusting the primary shape and size of emanating patch into various mathematical or in sequential order shape additionally turned into another appealing route for antenna trademark improvement since it can keep a solitary layer structure and give slim profile.

Among them E molded fix is famous and much adequate for the less difficult development. The E molded fix is framed by removing the two equal openings from the limit edge of RMPA. Figure 2.7 addresses the same circuit of fundamental RMPA where thunderous recurrence is dictated by

L1 and C1. The impedance of arrangement LC circuit is zero and greatest force will be move at working recurrence. The worth of info obstruction of antenna can be fluctuated by changing the area of feed point to such an extent that it coordinates with the trademark impedance of the coaxial link; for the most part, input impedance is match at 50 ohms.

At the point when the pair of the openings is managed off from RMPA, a changed comparable circuit has been appeared in Figure (b) where second thunderous recurrence is controlled by L2 and C2. Two equal openings bother the surface current way on the fix and present neighborhood inductive impact which energizes the second resounding recurrence. The info impedance of the recieving wire can be addressing by given condition after examination the circuit organization. At two arrangement full frequencies the fanciful piece of the information impedance is zero. At the point when the two arrangement full frequencies are excessively far separated, the reactance of the recieving wire at the midland recurrence might be too high and the reflection coefficient at the radio wire info might be unsuitable and the two arrangement thunderous frequencies are set excessively close to one another, the equal resounding mode may influence the general recurrence reaction and the reflection coefficient close to every one of the arrangement full frequencies might be debased. The amplitudes of flows around the spaces in the E formed MPA are diverse at low full frequencies and high resounding which serves to degree the data transmission and influences the fundamental working recurrence. At the high recurrence, the amplitudes of the flows around the openings are practically equivalent to conventional fix which implies the impact of the spaces are not huge. Nonetheless, the fix width is less influenced by the spaces in deciding the high full recurrence. At the low recurrence, the amplitudes of the flows around the spaces are more noteworthy than those at high recurrence. The openings

gather the flows and this impact delivers an inductance. Because of this extra inductance impact, it resounds at a low recurrence. For this component E molded MPA can accomplish multiband just as wide transmission capacity receiving wire trademark [21-22].

As of late broad examination works on E formed MPA have been going on around the world at various recurrence band range particularly in L band, S band and C band. Nonetheless, for E formed MPA there are very little of study have been made under C band recurrence area. The C band is a bit of the electromagnetic range in the microwave scope of frequencies which is utilized for satellite interchanges, especially for satellite backhauls from far off areas back to a telecom company's studio for altering and broad casting. [27-28]

The setup of the ESPA is appeared in Fig. A test, which might be an expansion of the inward conductor of a coaxial feedline, takes care of the fix. The hole between the fix and the ground plane might be filled, completely or mostly, with a froth material, for mechanical solidness. The boundaries that portray the radio wire are the fix length and width (L, W), the stature of the fix H , the length of the center wing(Ls) , the widths of the wings (W1,W2)and the area of the coaxial test (L0) . The even E-formed fix radio wire has two thunderous frequencies: the middle wing resounds at a higher recurrence and the two side wings reverberate at a lower recurrence. [10]

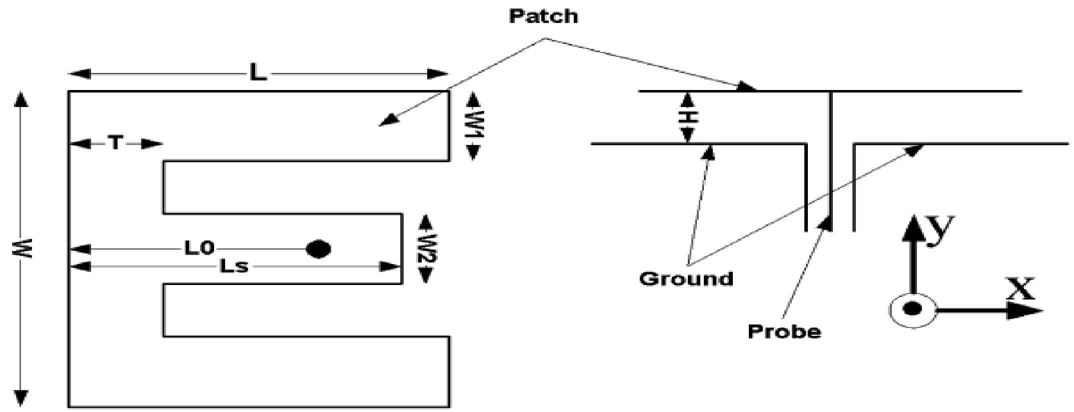


Figure: 2.6 2E Shape Microstrip Patch Antenna

The E-molded fix radio wire. At the point when two equal spaces are consolidated into the receiving wire fix, the transmission capacity increments above 30%. Contrasted with the U-opening microstrip fix receiving wire, the E-molded fix radio wire is easier in development By just changing the length, width, and position of the spaces, one can get acceptable exhibitions. [11]. The E-molded fix likewise gives wideband attributes and the data transfer capacity is additionally expanded to 44.9%. [12]. A microstrip receiving wire, when planned with the conditions accessible in reading material, reverberates just in one recurrence with an exceptionally limited data transmission. There is nobody set up technique to make the MPAs multiband. Presently a-days, as innovation is propelling, we are having various offices accessible in various frequencies that are should have been gotten by a similar electronic device. As receiving wire is the segment that gets electromagnetic wave, resounding at three frequencies will require three separate MPAs in a similar gadget which will take a lot of room of the gadget hardware. In this period of scaling down of gadgets, such radio wires are not invited. Subsequently, investigates have been progressing on creating MPAs with reverberation in numerous recurrence groups. By a long shot, the most well-known strategy for fusing more than one recurrence groups in a MPA has been cutting openings in the MPA. Various sizes and shapes are intended to consolidate the extra groups. A double band radio wire for WLAN tasks has been created by cutting spaces of various sizes at various places of MPA in [13]. Antennas with U-shape, E-shape, L shape and so on openings were likewise planned in various written works [14] [15] [16].

CHPATER 3

DESIGN OF THE PROPOSED PATCH ANTENNA

In writing survey, it has been seen that the radio wires, working in C band locale, transmission capacity and gain are reliably poor in same receiving wire. Thus, the essential focal point of this proposition is to plan a microstrip fix receiving wire having upgraded data transfer capacity and gain in C band. In this section radio wire plans are appeared in sequential request where steady upgrade of transmission capacity of the receiving wire execution are seen from rectangular microstrip fix receiving wire to proposed single fix receiving wire.

To plan the ideal receiving wires Zeland IE3D reenactment programming has been utilized. Every one of the radio wires are remarkable and can work for C band application.

3.1 Basic Parameters

Three general boundaries are given beneath for planning every one of the radio wires as needs be.

- The frequency operation: C band recurrence space has been chosen for MPAs activity.
- Dielectric consistent: RT/druid substrate with dielectric steady of 2.2 has been chosen as dielectric material for MPAs.
- Height of substrate: Generally, MPAs are exceptionally conservative gadgets so for essential arrangement of MPA standard thickness has been chosen as 5 mm.

3.2 Substrate Selection

Substrate permittivity and misfortune digression are two most significant boundaries to consider when planning patch antennas. The most genuine disadvantages of microstrip fix radio wire are its limited transfer speed and low increase. In this manner, an appropriate decision of substrate permittivity decreases the measure of surface wave misfortunes and accordingly improves the radio wire execution particularly, impedance data transfer capacity and radiation proficiency. A thicker substrate, other than being precisely solid, will build the transmitted force, decrease director misfortune and improve impedance transmission capacity. In any case, it will likewise build the weight, dielectric misfortune, surface wave misfortune and superfluous radiation from the test feed. A low dielectric consistent for the substrate will expand the bordering field at the fix fringe. Therefore, the emanated force of the radio wire will be likewise expanded. In this way, a dielectric steady of under 2.55 ($\varepsilon r < 2.55$) is favored except if a more modest fix size is wanted. A high substrate misfortune digression builds the dielectric loss of the radio wire and diminishes the receiving wire effectiveness.

The most regularly utilized dielectric substrate materials to print fix receiving wires have a permittivity going from around 2 to 10 contingents upon the application. The lower the permittivity the higher the radio wires acquire. This is because of that for higher permittivity substrate voyaging wave eases back down as it goes through the receiving wire. Additionally, expanding substrate permittivity makes emanated energy bob on different occasions and builds energy dissemination in the dielectric material [32].

3.3 Microstrip Patch Antenna Dimension

Fix width minorly affects the resounding recurrence and radiation example of the receiving wire. Be that as it may, it influences the info obstruction and data transfer capacity to a bigger degree. A greater fix width builds the force emanated and accordingly gives a diminished full opposition, expanded data transfer capacity, and expanded radiation effectiveness. A requirement against a bigger fix width is the age of grinding flaps in radio wire exhibits. It has been proposed that the length to width proportion of the way needs to lie in the scope of one and two (1 < L/W < 2) to get a decent radiation effectiveness. The fix length decides the full recurrence, and is a basic boundary in the plan, in view of the inalienable tight transmission capacity of the fix. The microstrip fix length (L) can be approximated as,

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

Where c, f_r and ε_r represents speed of light in free space, resonant frequency and dielectric constant of the substrate respectively.

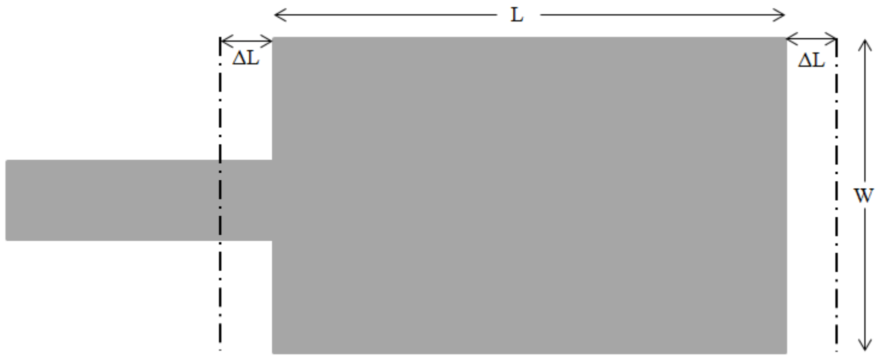


Figure3.3(a) 3Microstrip Patch Antenna Dimension

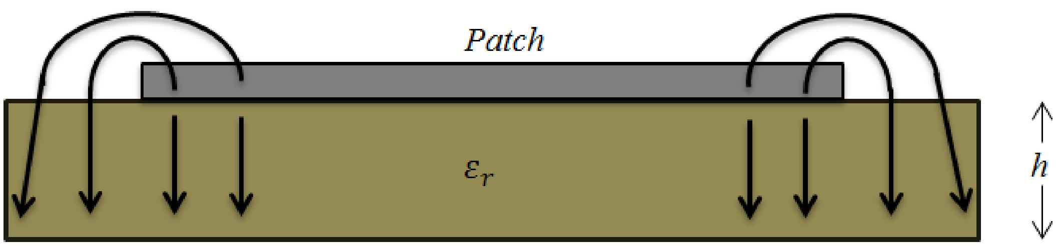


Figure3.3(b) Microstrip Patch Antenna Dimension

Practically speaking, the fields are not kept to the fix. A small amount of the fields lies outside the actual components of the fix (L×W) as demonstrated in figure 3.1. This is known as the fringing field. The impact of the bordering field along the fix width, W can be incorporated through the viable dielectric consistent ε, reff for a microstrip line of width W, on the given substrate.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}} \qquad (3.2)$$

Where *h* is height of dielectric substrate. The effect of the fringing field along the patch length *L* can be described in terms of an additional line length on either ends of the patch length as [29]

$$\frac{\Delta L_{eff}}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{3.3}$$

The effective length is given by –

$$L_{eff} = \left(L + 2\Delta L_{eff}\right) \tag{3.4}$$

The resonant frequency is expressed as –

$$f_r = \frac{c}{2L_{eff}\sqrt{\varepsilon_{eff}}} \tag{3.5}$$

For efficient radiation the width *W* is given by –

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{3.6}$$

For real contemplations, it is fundamental to have a limited ground plane. Comparative outcomes for limited and endless ground plane can be acquired if the size of the ground plane is more prominent than the fix measurements by roughly multiple times the substrate thickness all around the outskirts. Thus, for this plan, the ground plane measurements given as [30]-

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

$$W_g = 6h + W \tag{3.8}$$

3.4 Design of RMPA

Design and result of simulation are given in this part for the single band MPA. Return misfortune is the essential boundary of a radio wire to check the activity of an antenna at the ideal band. It very well may be seen that the planned radio wire resounds at 6GHz with a most extreme return loss of - 12.75dB. Albeit the qualities are extricated from conditions, it is seen that the return misfortune esteem isn't in a good level despite the fact that it is reverberating at the ideal frequency.

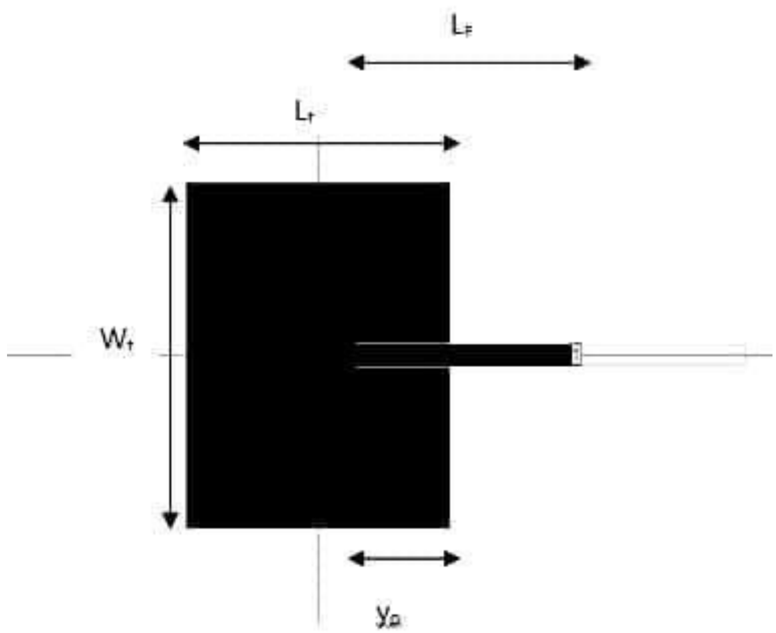


Figure 3.4(a) Design of the Single Band RMPA

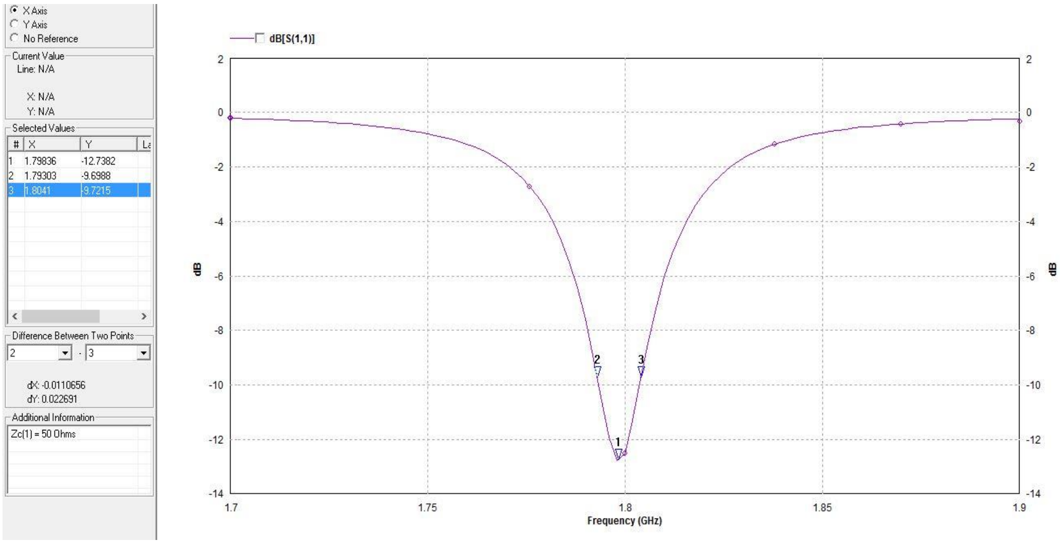


Figure 3.4(b) Return Loss of the un optimized single band MPA

As expressed before radio wire measurements have been discovered utilizing exact articulations from [8]. To keep the plan basic the boundaries are gathered together to the closest whole numbers. So the radio wire measurements are W = 34 mm, L = 19 mm and substrate Dielectric Constant, εr = 2.2 and H = 5 mm. Presently a solitary antenna with these measurements is planned and reenacted utilizing IE3D.

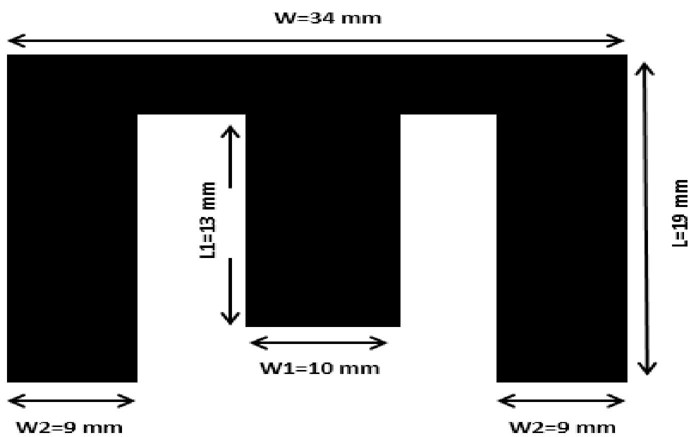


Figure 3.4(c): Basic structure of MPA.

The feeding technique and location of the feeding point provides antenna to operate in C band region. As referenced before, RT/druid substrate with dielectric consistent of 2.2 has been utilized as dielectric material, the element of the ground plane of length and width likewise removed from condition 3.7 and 3.8 individually. The RMPA is energized by test taking care of method at position of x0 pivot at 0 and Y hub at - 9 where least return misfortune have been found. Detail boundaries given in Table 3.1.

Table 3.1 Design dimensions of RMPA

Parameters	Optimized Dimensions (mm)
L_1	13
W_1	10
Ls	13.8
W_2	9

H	5
(x_0,y_0)	(0 ,-9)

Return loss of the designed antenna express us a resounding condition at 4.9 GHz. This is because of the oddity in the articulations utilized in the computation. Those articulations were improved for E shape fix radio wire for lower recurrence band of 2-3 GHz band. In spite of the fact that reverberation recurrence of this radio wire isn't what we want, however as a beginning reference point this antenna is sufficient for parametric investigation to improve the antenna into our ideal recurrence band of 4.0 GHz to 8.0GHz

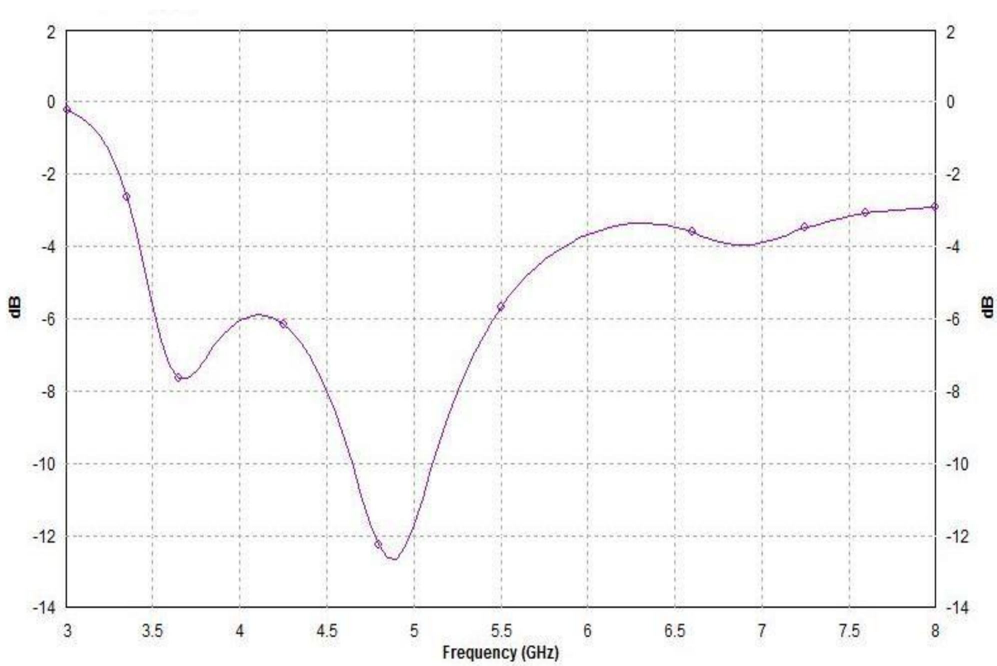


Figure 3.4(d): Return loss of the primary antenna

3.5 Optimization

The antenna improvement comprises of a first phase of experimentation where I distinguish how the various boundaries impact the radio wire's conduct. As a first commonsense technique, it very well may be demonstrated that, to situate a thunderous recurrence in an alternate operational frequency. To apply an enhancement procedure, it requires choosing the upsides of the various boundaries or elements. [32]

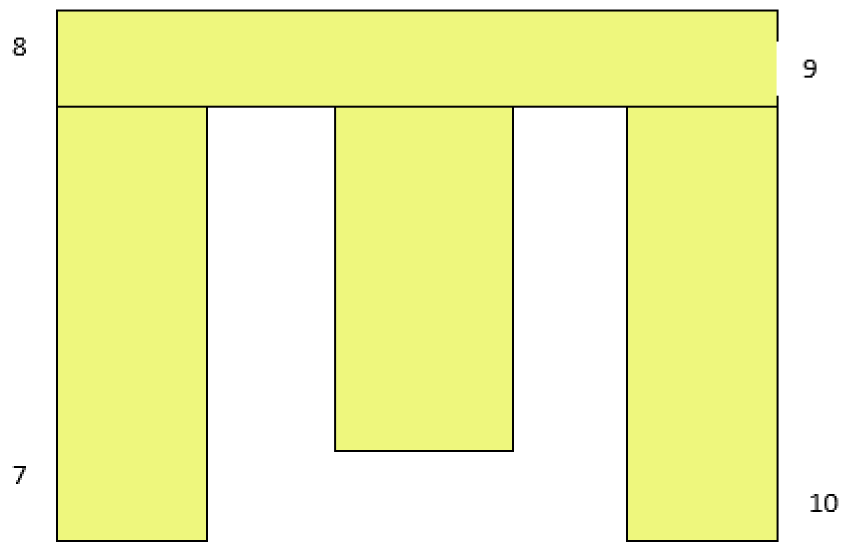


Figure 3.5(a) The patch and its vertices to be defined as optimization variables

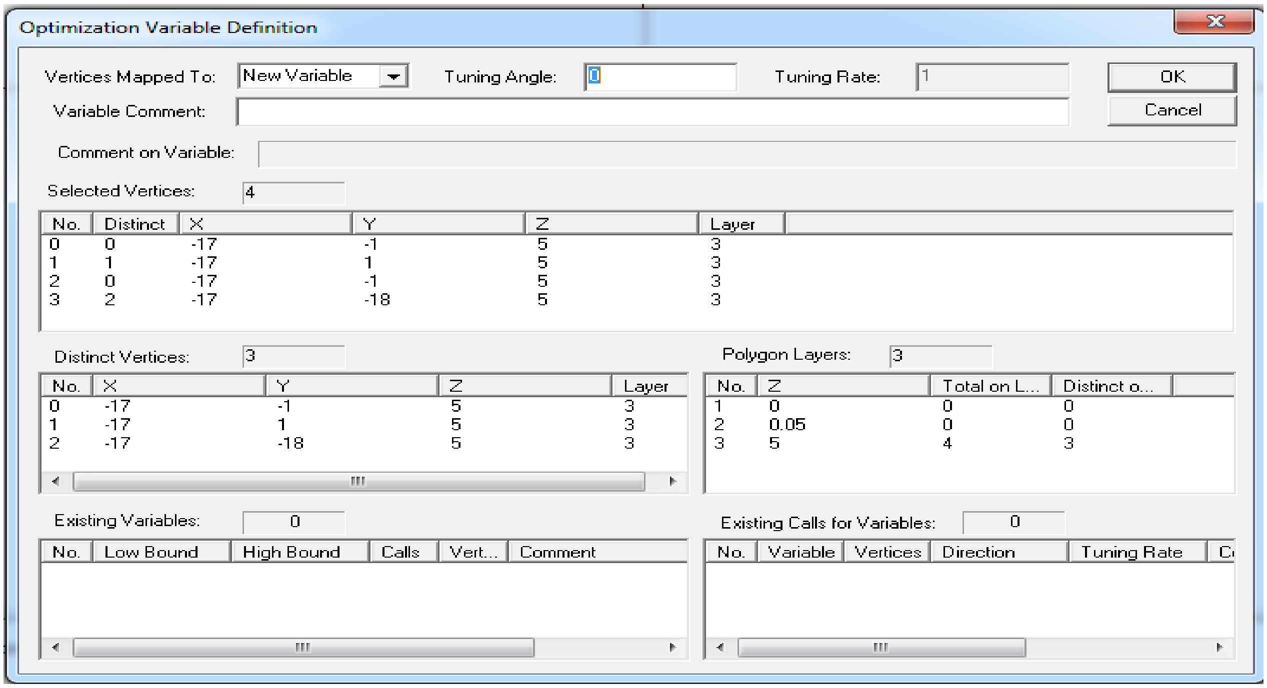


Figure 3.5(b) The Optimization Variable Definition dialog for the Optim->Variable for Selected Objects

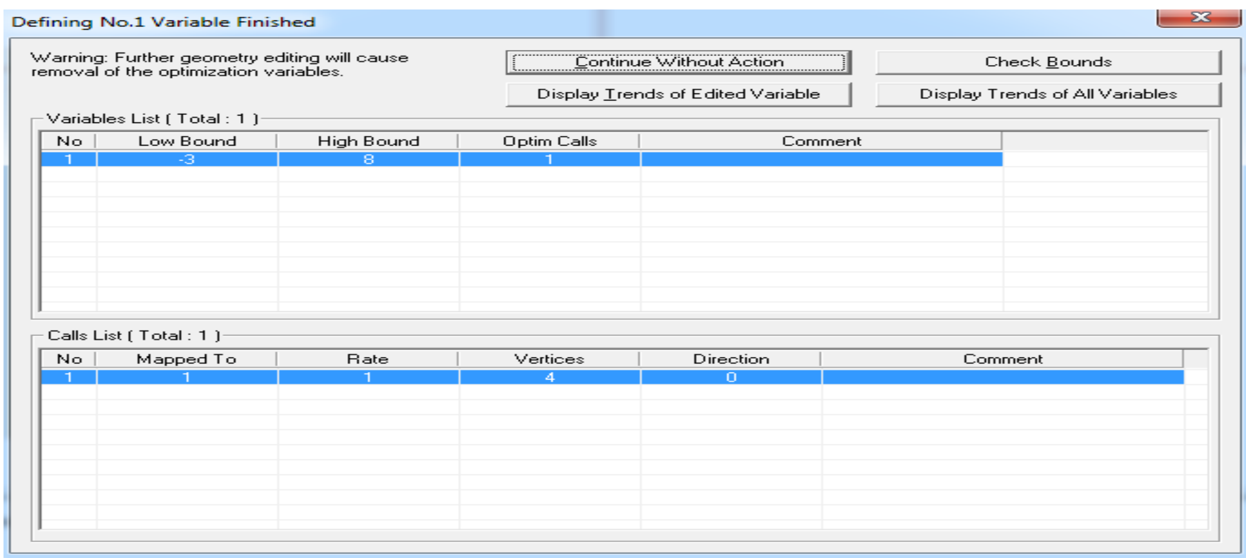


Figure 3.5(c) The Defining No.1 Variable Finished dialog

Traditional search and streamlining techniques show various challenges when confronted with complex issues. The significant trouble emerges when one calculation is applied to take care of various issues. This is on the grounds that every traditional strategy is intended to tackle just a specific class of issues productively. Hence, these strategies don't have the broadness to tackle various kinds of issues regularly looked by creators and professionals. In addition, the greater part of the traditional techniques doesn’t have the worldwide viewpoint and regularly get merged to a locally ideal arrangement.

Among the different techniques portrayed, there wasn't a very remarkable hypothesis or condition that was proposed to discover an improved math for the receiving wire. Distinctive discretionary shapes were proposed with lengths and widths continually fluctuating. E-shape fix receiving wire planners attempted to think of certain conditions. As the issue directs, an experimentation or advancement calculation is the best thing to discover the ideal answer for MPAs.

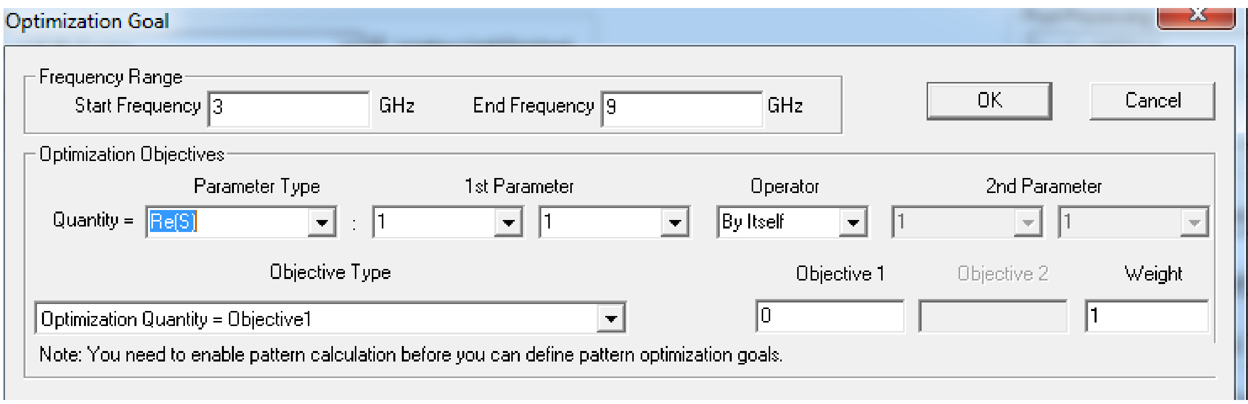


Figure 3.5(d) the Optimization Goal dialog.

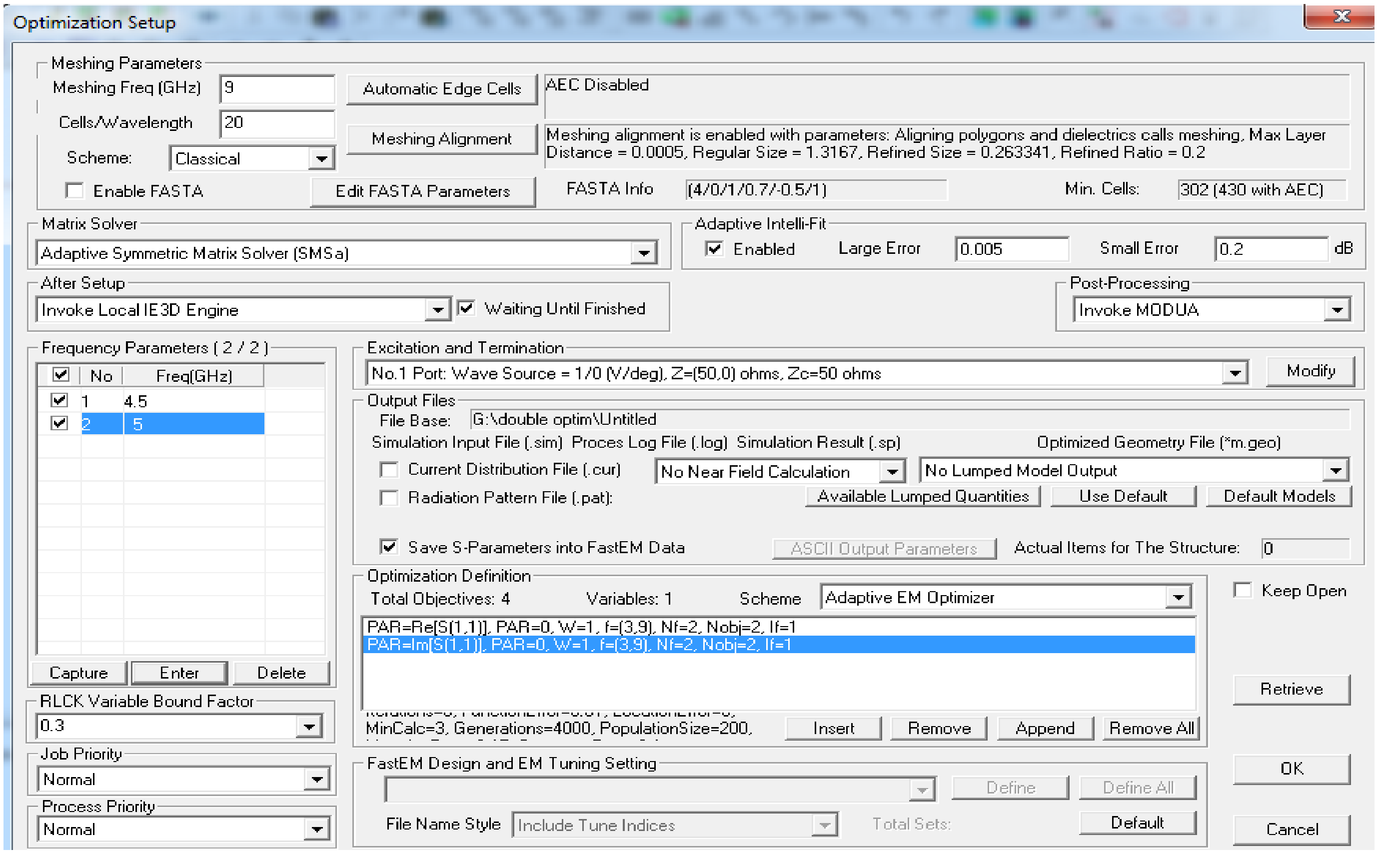


Figure 3.5(e)) The Optimization Definition dialog after the goals are defined.

Benefits of various strategies over the others are that it is not difficult to configuration, doesn't need any additional component to be joined in the gadget and it makes the space of the gadget minimal. A hypothesis of quarter wave monopole was introduced in one of the works where the opening was cut in the edge so it joined with the free space can go about as a monopole [15].

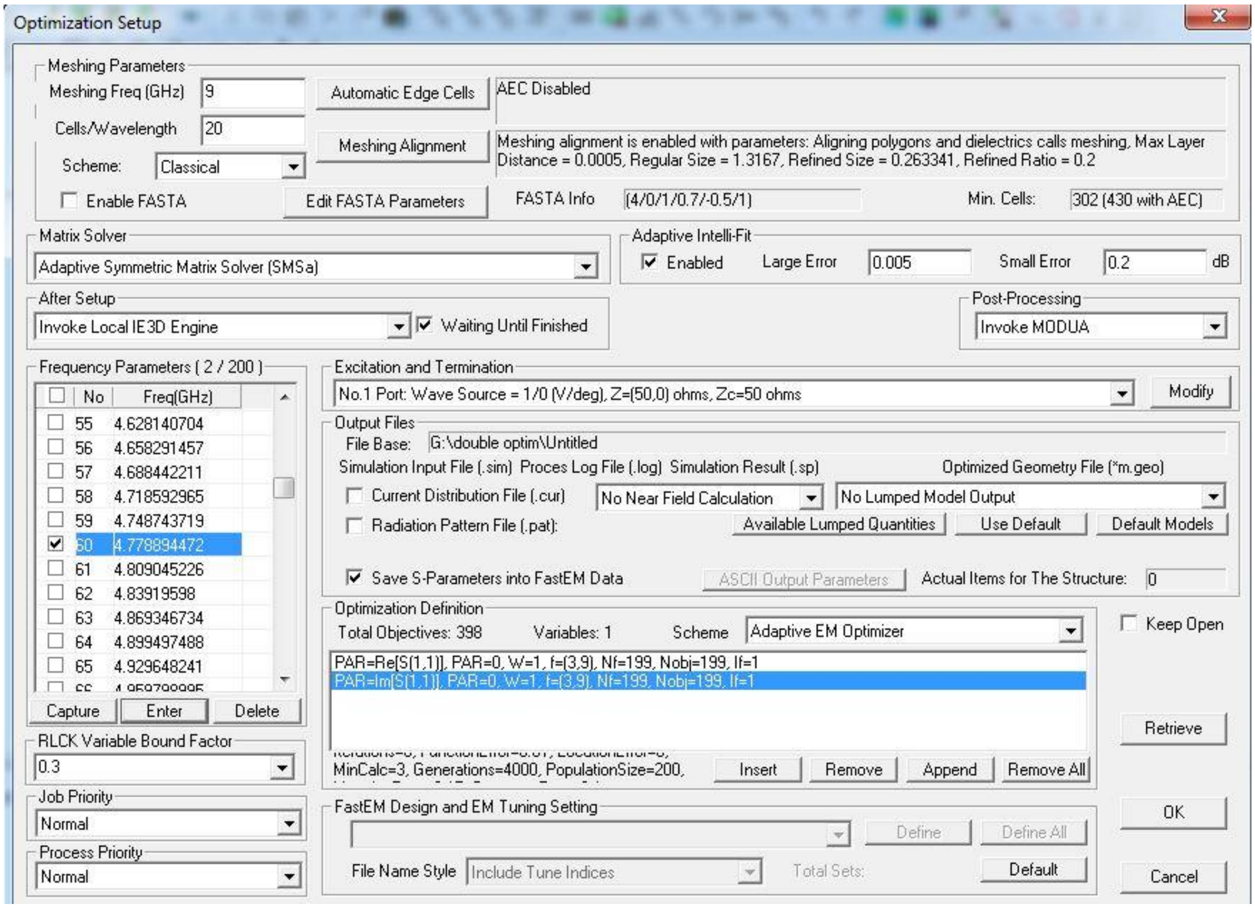


Figure 3.5(f) The Simulation Setup dialog

To apply a headway framework, its necessary's picking the assessments of the assorted boundaries or factors. It additionally requires a wellness capacity to ascertain the wellness of various arrangements and achieve the ideal outcome. Objective of this paper is to accomplish want transmission capacity from the radio wire and the wellness work is grown in like manner. By utilizing above conditions and procedures and got the accompanying E shape MPA(ESMPA) from which is un advanced toward the start. With this standard, the length that the radio wire should have to accomplish the normal thunderous recurrence can be determined given the non-wanted current upsides of the antenna's length and operational recurrence. Following the means taken in "First optimization", a few boundary mixes were taken a stab at, applying the before referenced standard as a rule to put the thunderous frequencies in their ideal spot alongside a compromise between the other plan esteems.

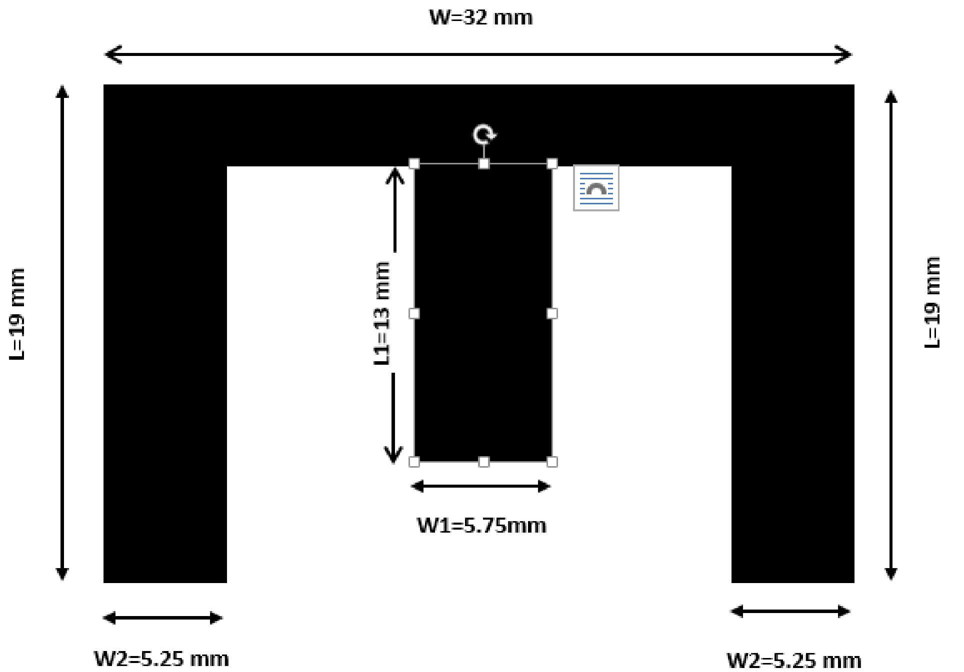


Figure 3.5(g) After 1st Optimization

The width W2 was permitted to fluctuate from - 5mm to +5 mm and W1was permitted to differ from - 3mm to +3 the areas of the shapes were permitted to be changed by 3mm on one or the other side. After first advancement, improved transfer speed.

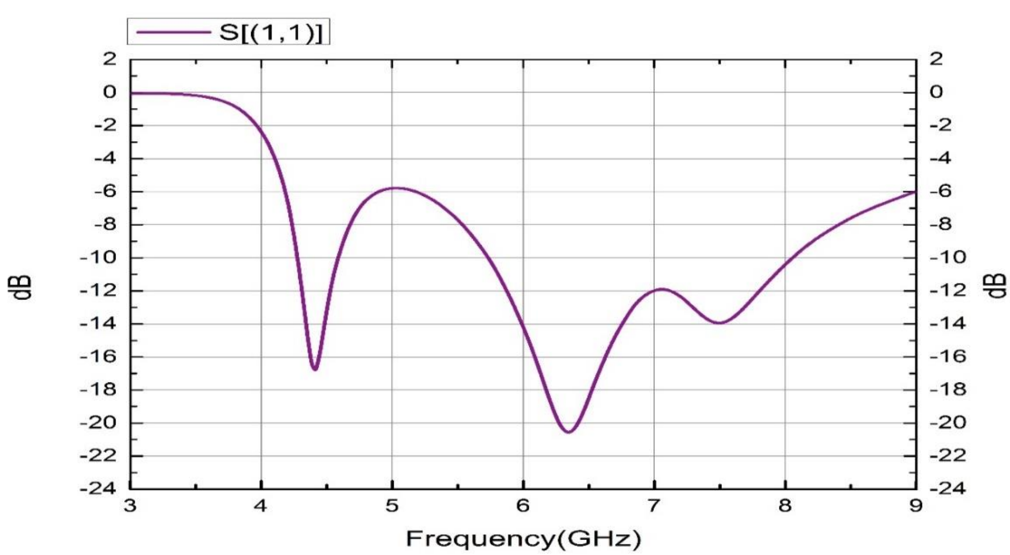


Figure 3.5(h) Return loss with respect to position After 1st Optimization

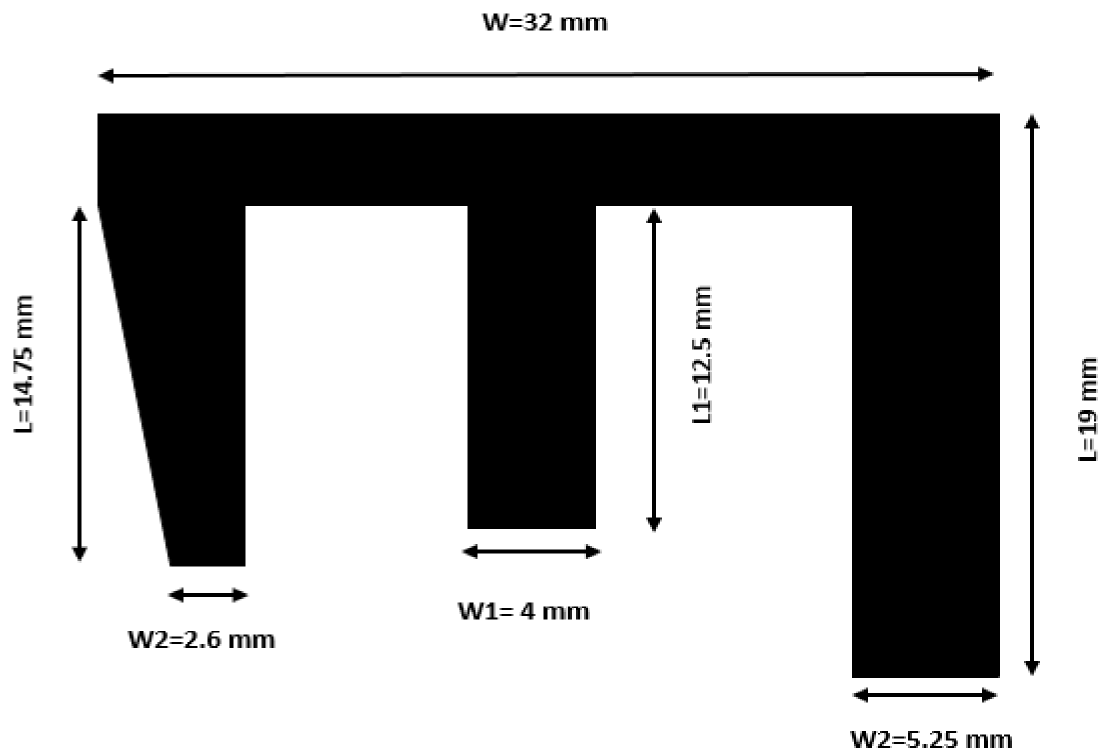


Figure 3.5 (i) Geometry with E shape after 2nd optimization MPA

Fig 3.5 (I) is permitted to be upgraded as it was recommended in the past subsection. The width W2 is permitted to differ from 5mm to - 5mm and the tuning point is around 1350 so the proposed radio wire was twisting the two sides. W2/is likewise upgraded from - 3mm to +3 mm with tuning point of 900. After second streamlining measurement of the proposed antenna is given after.

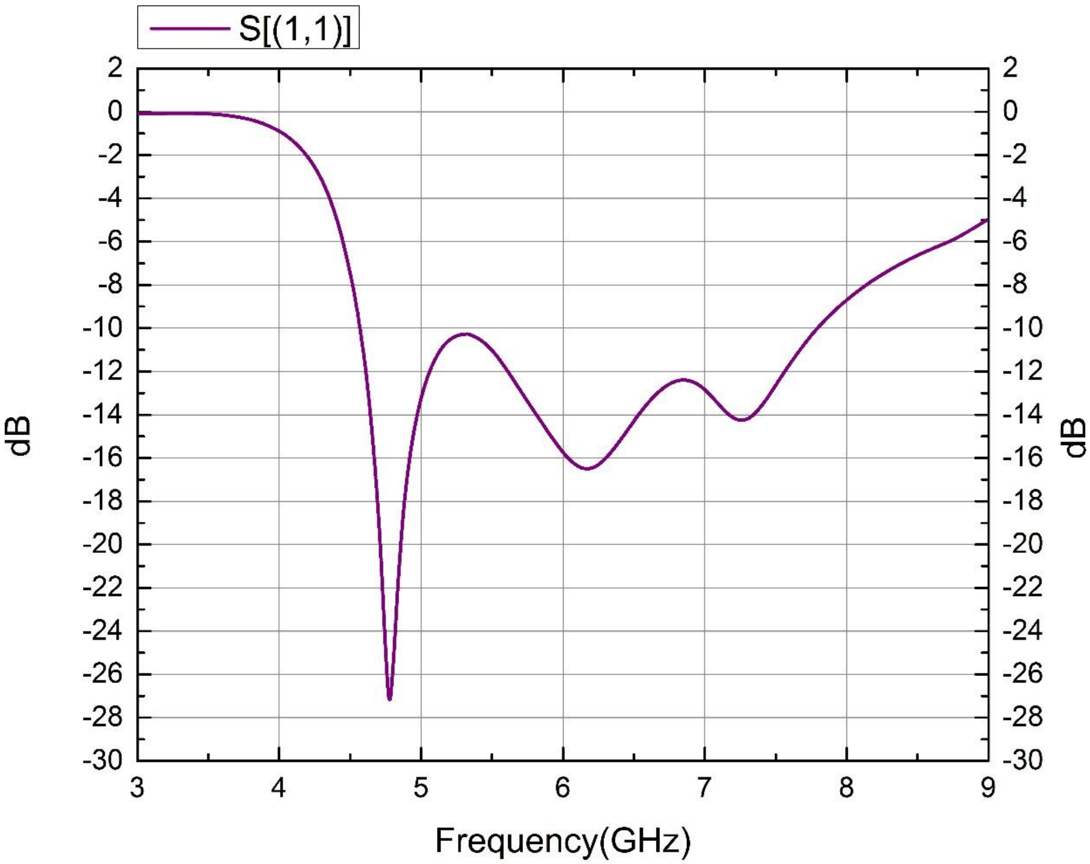


Figure 3.5(j) Return loss with respect to position After 2nd Optimization

The final design of the optimized MPA is shown in Fig 3.5(l). Final value of different parameters of the design is systematize below.

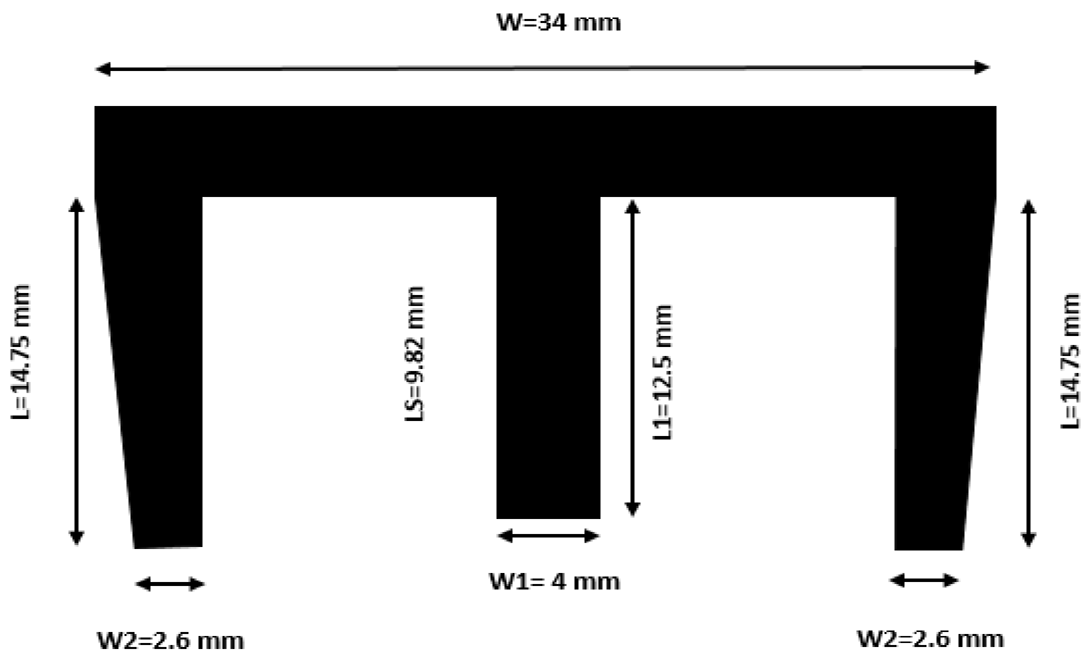


Figure 3.5(k) The final design of the optimized MPA

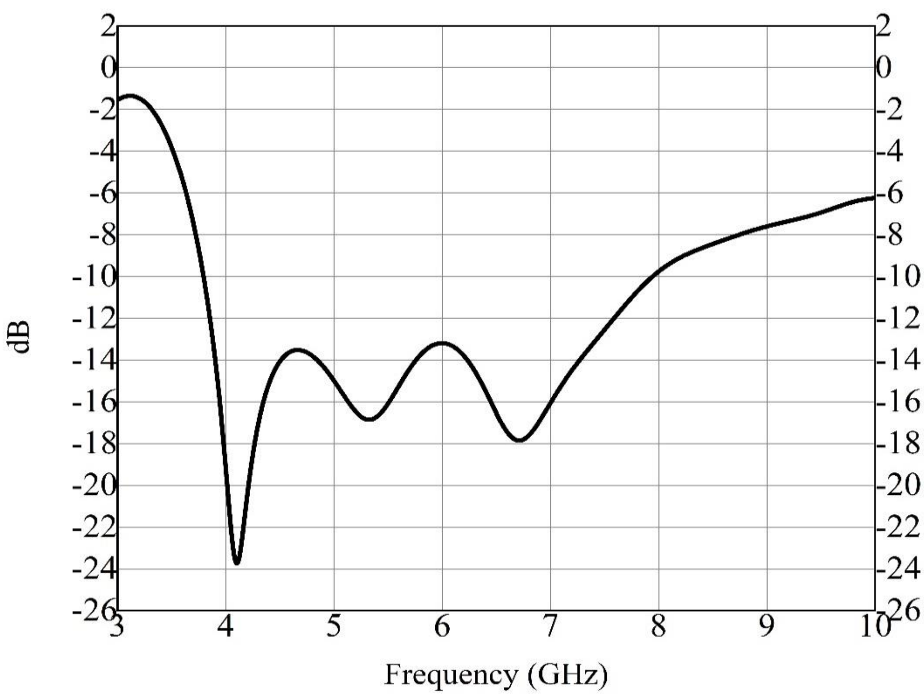


Figure 3.5(l) the Optimization Goal Graph

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Simulated Results of the Proposed Antenna using IE3D Zeland

To achieve the essential goal of the proposition serious reenactments have been done to track down the alluring upgraded antenna for C band activity. Four specific antennas and cluster arrangements have been planned where steady improvement in transmission capacity has been noticed. In the proposed antenna space cutting method has been forced for better radio wire attributes. The transmission capacity has been expanded dramatically because of the properties of spaces. The proposed antenna has data transfer capacity of 4.0 GHz and it can cover 100% of C band recurrence range, it implies antenna can uphold uplink and broadcasting satellite assistance just as communicating satellite, fixed microwave, digital TV hand-off, fixed-satellite (Earth-to-Space), earth investigation satellite, aeronautical radio-route and space research, standard recurrence and time signal satellite (earth-to-space), versatile satellite (earth-to-space), and radio stargazing.

The radio wire execution measurements like transfer speed, return misfortune, normal current appropriation, vector current circulation, 2D, 3D radiation examples of gain and directivity are mimicked utilizing IE3D test system. Similar execution measurements are likewise reproduced utilizing CST reproduction device for examination reason that will be talked about in the segment…

The current circulation represents the radio wire design and assists with understanding the thickness and course of the current development inside the fix at any frequencies. It likewise shows how extraordinary piece of the radio wire acts for various working frequencies. 2D and 3D radiation designs are graphical portrayal of the force transmitted by antenna as a component of the bearing away from the radio wire. 2D radiation alternative gives data primarily about radio wire gain and directivity gain of E-H fields regarding pivotal proportion, azimuth and rise for both polar and cartesian structure though 3D radiation design gives 3D rotatable perspective on antenna directivity and gain with discharge style. The simulations have been accomplished for proposed plan antennas at different thunderous frequencies which give better comprehension of radio wire boundaries.

4.1.1 Average Current Distribution

It tends to be seen from the normal current appropriation which is transmitting and which is non-emanating side. A radio wire typically resounds at a half frequency length. In a half frequency, in the event of patches and dipoles, current most extreme happens in the center and least proposals at the edges as the conductor closes. It very well may be seen that current is greatest (Yellowish) at the center of the transmitting side and is least at the edges of that side. For this, it very well may be perceived which side is transmitting or going about as length and which side is non-emanating or going about as width. As can be seen, there is no thickness of current in the non-transmitting side.

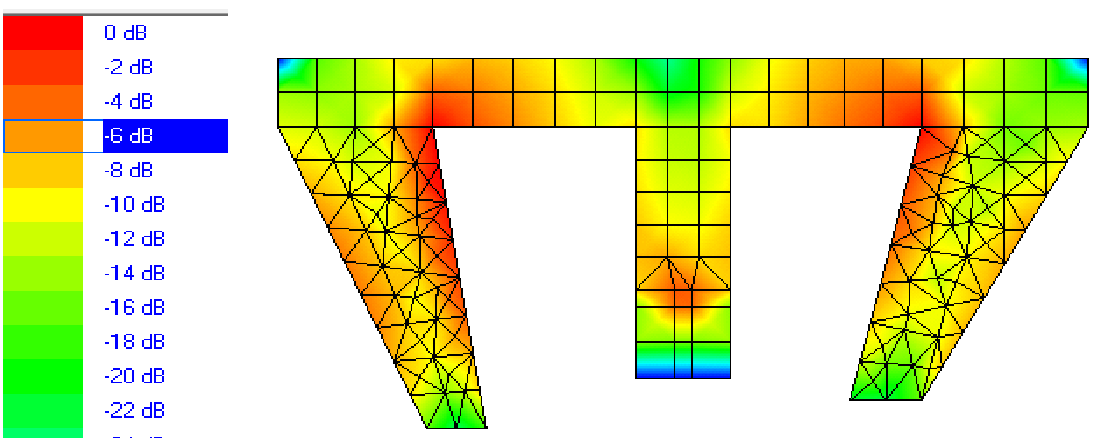


Figure 4.1(a): Average current distribution of proposed antenna at 4.10 GHz

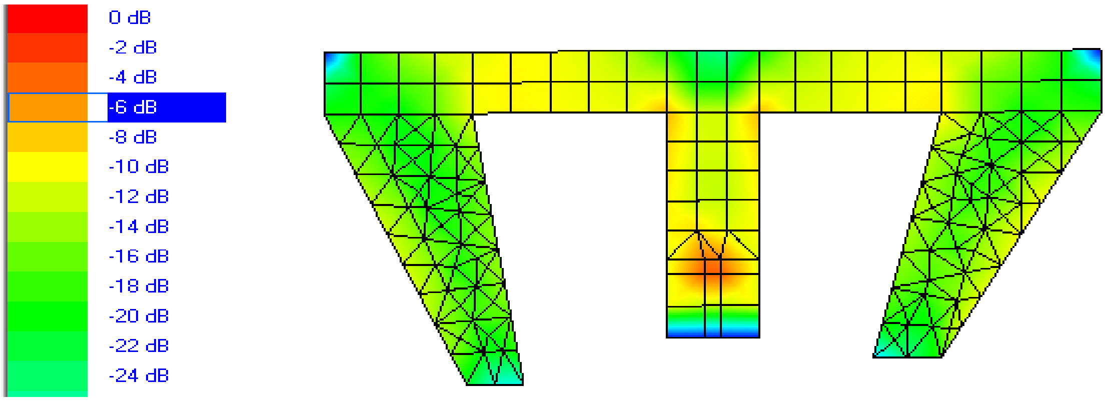


Figure 4.1(b): Average current distribution of proposed antenna at 5.3 GHz

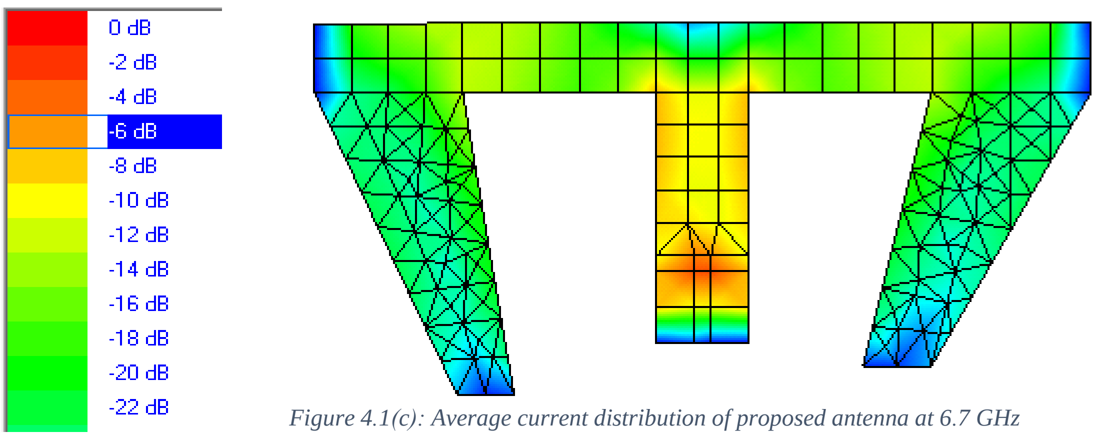


Figure 4.1(c): Average current distribution of proposed antenna at 6.7 GHz

The normal current thickness on the outside of the relative multitude of radio wires is appeared in above Figure at 4.10 GHz, 5.3 GHz and 6.7 GHz. In these figures red shadings shows the most extreme current thickness and blue tones is for the base current thickness inside the fix of the RMPA.

4.1.2 Vector Current Distribution

Vector current appropriation shows how the current is circulated and how the current streams in the outside of the radio wire. It assists us with deciding the polarization of the antenna. It tends to be seen from the figure that current follows a direct way in the surface which compares to a straight polarization of the antenna. Once more, the circulation shows that the antenna has top current in the length of the radio wire and littlest at the edges.

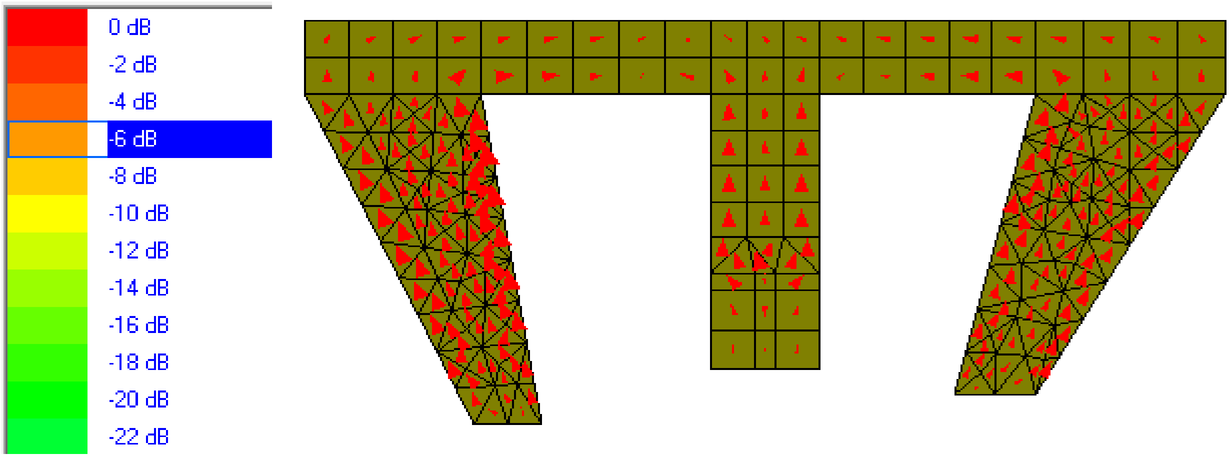


Figure 4.2(a) Vector current distribution of proposed antenna at 4.1 GHz

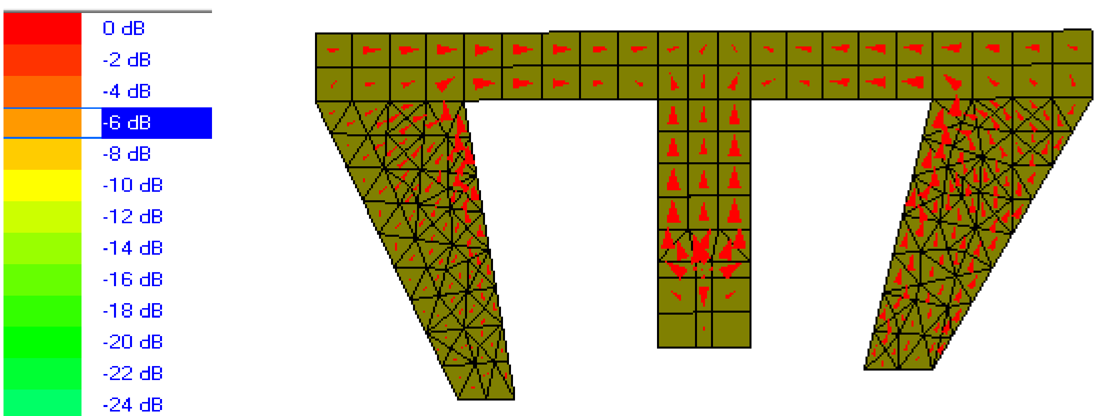


Figure 4.2: (b)Vector current distribution of proposed antenna at 5.3 GHz

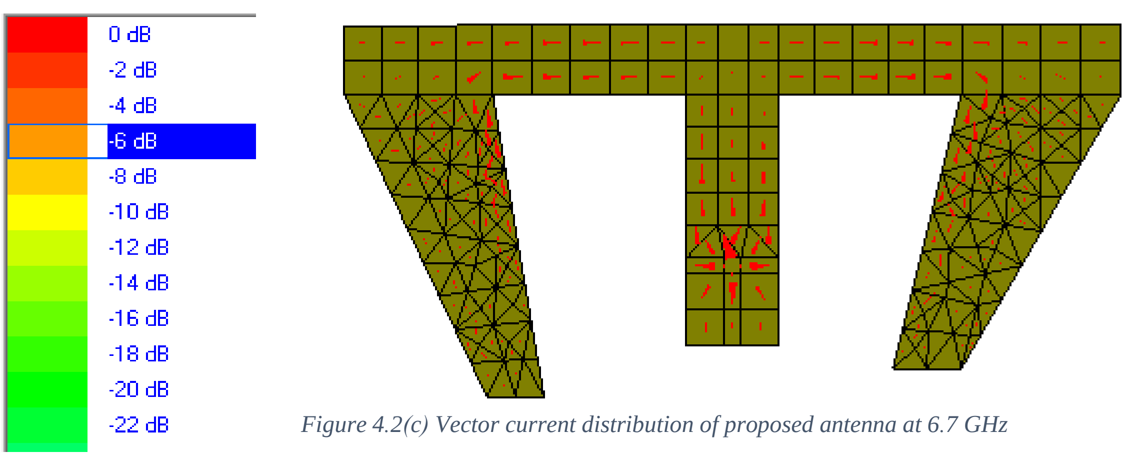
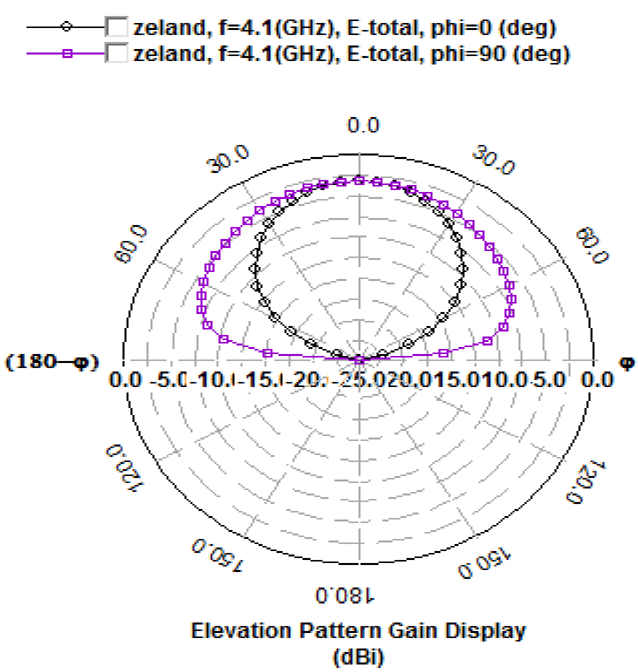


Figure 4.2(c) Vector current distribution of proposed antenna at 6.7 GHz

Vector current appropriation of the current over the outside of all the fix antennas are appeared in Figure 4.2 (a) to 4.2 (c) at three full frequencies. The size of the vectors shows the size of the current thickness at a particular area at a particular time. For first and third thunderous recurrence the current thickness is a lot higher inside and outside edges of the E shape and for second one current thickness is a lot higher at the top and lower part of the rectangular spaces.

4.1.3 2D Radiation Pattern

2D radiation design assists with seeing how the radio wire is really transmitting in 3D. As it is hard to show 3D example on a 2D surface, 2D radiation design is the thing that is utilized for insightful purposes. Fig 4.3 shows the 2D polar plot of the planned radio wire at 6 GHz. The antenna emanates bi directionally as for azimuth point. That is to say, on the off chance that it emanates with significant shaft width at 0 degree and 180-degree azimuth point, it won't transmit at 90 degrees and 270 degrees. Cross polarization was additionally checked as it was directly spellbound and there was not all that much. As for rise point, the example has its top at 0 degree. It doesn't transmit under and just emanates upwards (inverse to ground plane).



(a)

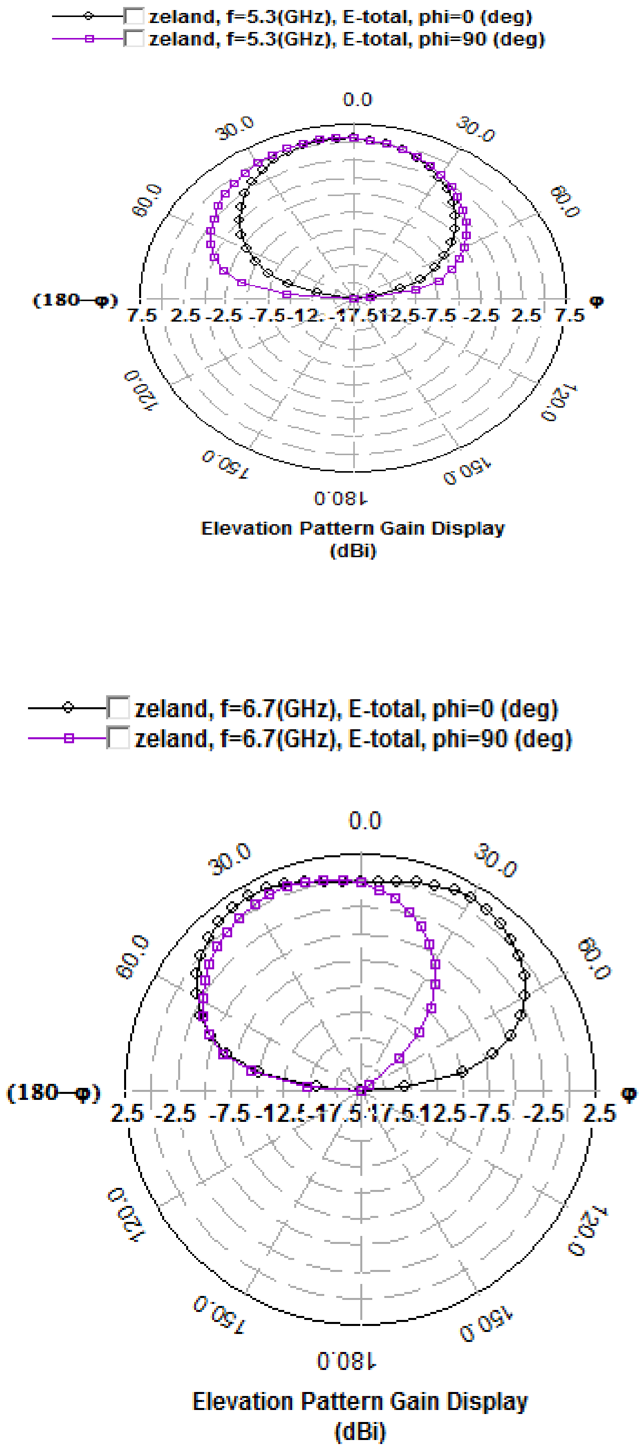
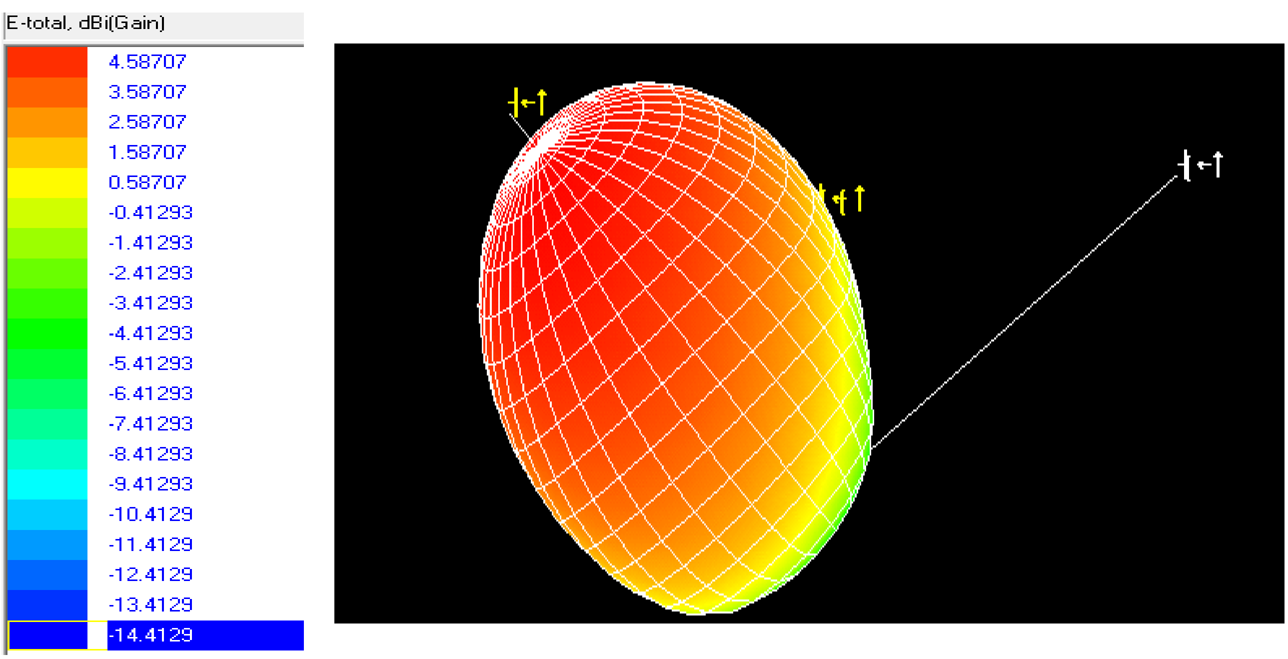


Figure 4.3 2D radiation pattern of proposed antenna at (a) 4.10 GHz (b) 5.30 GHz and (c) 6.70 GHz

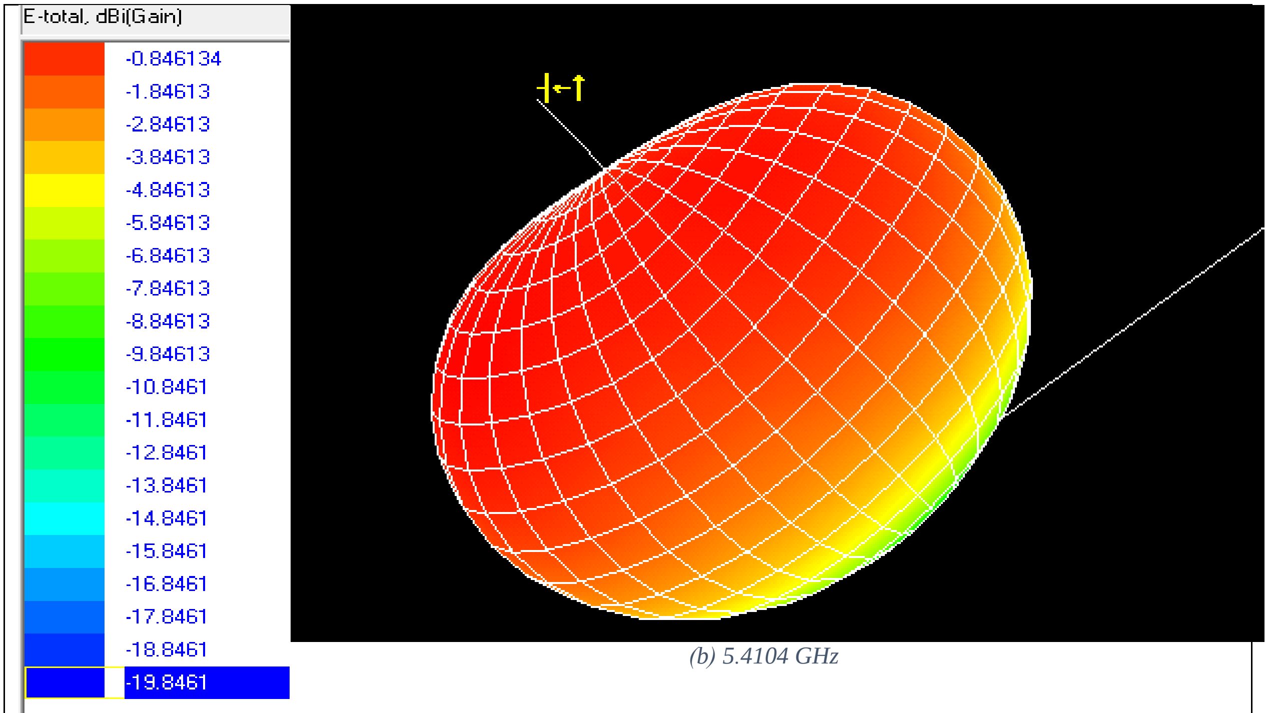
A decent antenna ought to keep up its radiation design all through the recurrence range that it covers. 2D radiation design for the proposed antenna at various thunderous 49 frequencies are appeared in Figure 4.3. As MPA emanates typical to its fix surface, the rise design for φ = 0 and φ = 90 degrees would be significant. The greatest increase of the proposed antenna is 6 dBi.

4.1.4 3D Radiation Pattern:

In spite of a lot can be gotten from the 3D radiation design, it has been remembered for the book to additionally explain the 2D examples. 3D radiation design portrays better comprehension of antenna power radiation course. Figure 4.13 shows genuine 3D radiation designs at three full frequencies of the proposed single component RMPA. They are the example in the genuine 3D space. The size of the example from the birthplace addresses how solid the field at a particular (theta, phi) angle.



(a) 4.1104 GHz


E-total, dBi(Gain)
-0.846134
-1.84613
-2.84613
-3.84613
-4.84613
-5.84613
-6.84613
-7.84613
-8.84613
-9.84613
-10.8461
-11.8461
-12.8461
-13.8461
-14.8461
-15.8461
-16.8461
-17.8461
-18.8461
-19.8461

(b) 5.4104 GHz

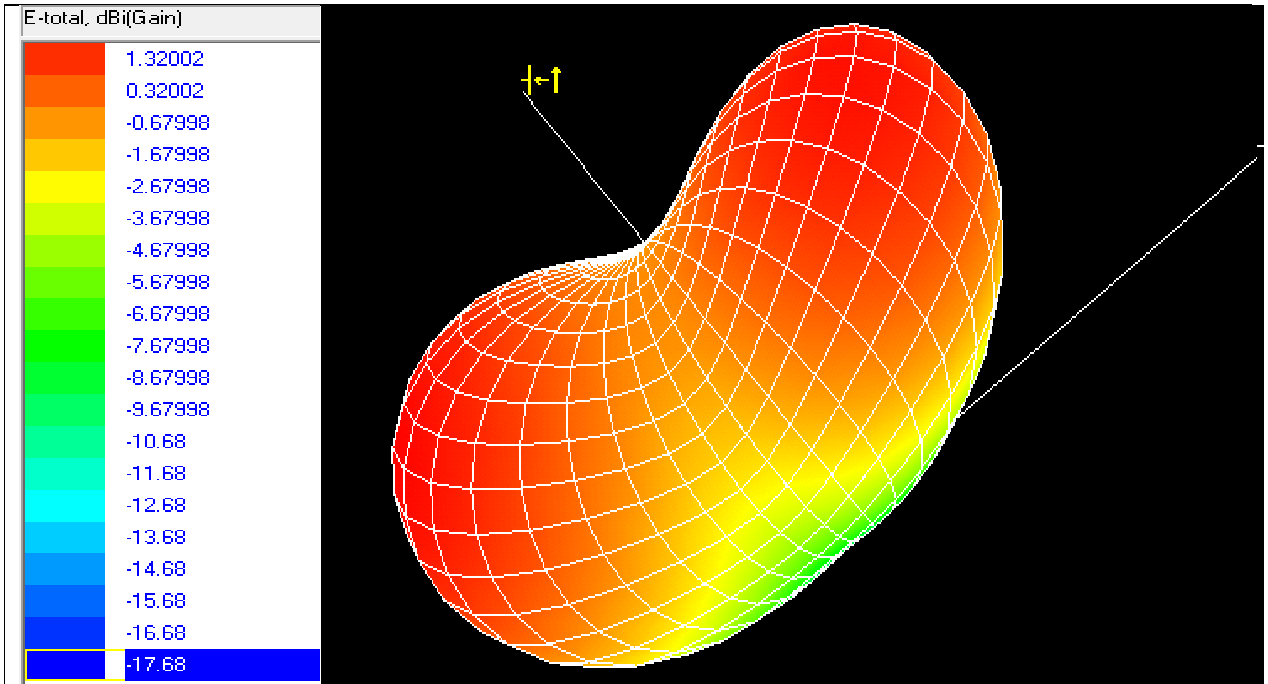


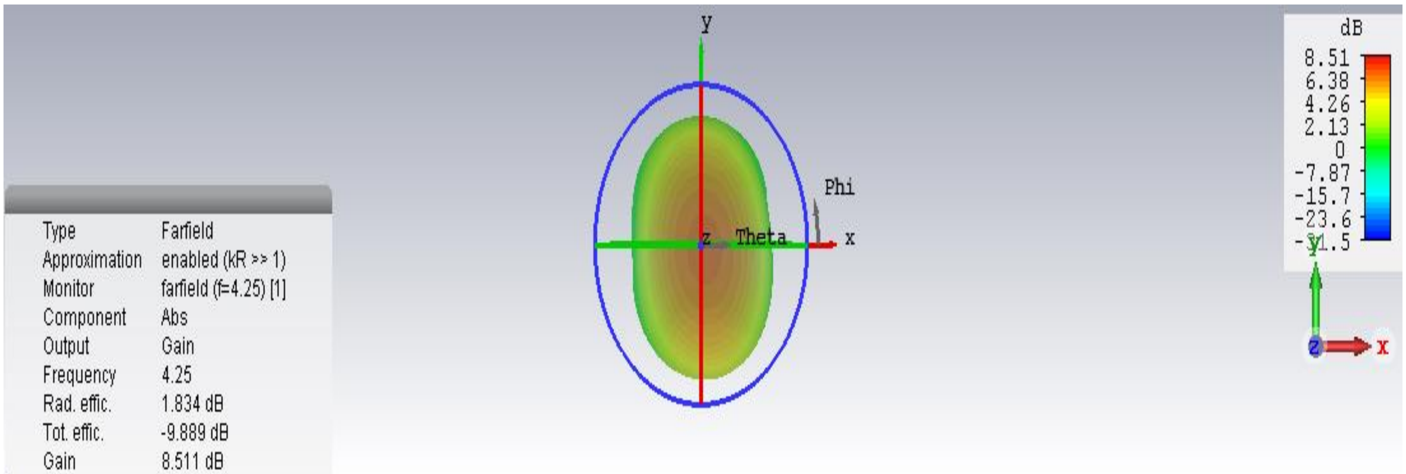
Figure 4.1.4 D radiation pattern of proposed antenna at (a) 4.10 GHz (b) 5.30 GHz and (c) 6.70 GHz

Directivity estimates the power density that, the radio wire emanates toward its most grounded outflow, versus the power density transmitted by an ideal isotropic radiator (which produces consistently every which way) emanating a similar complete force. 3D radiation profile of our radio wire for three thunderous frequencies is practically the equivalent demonstrating that this patch antenna gives a decent radiation example to the whole C band. The greatest directivity of the proposed radio antenna is 8.51 dBi.

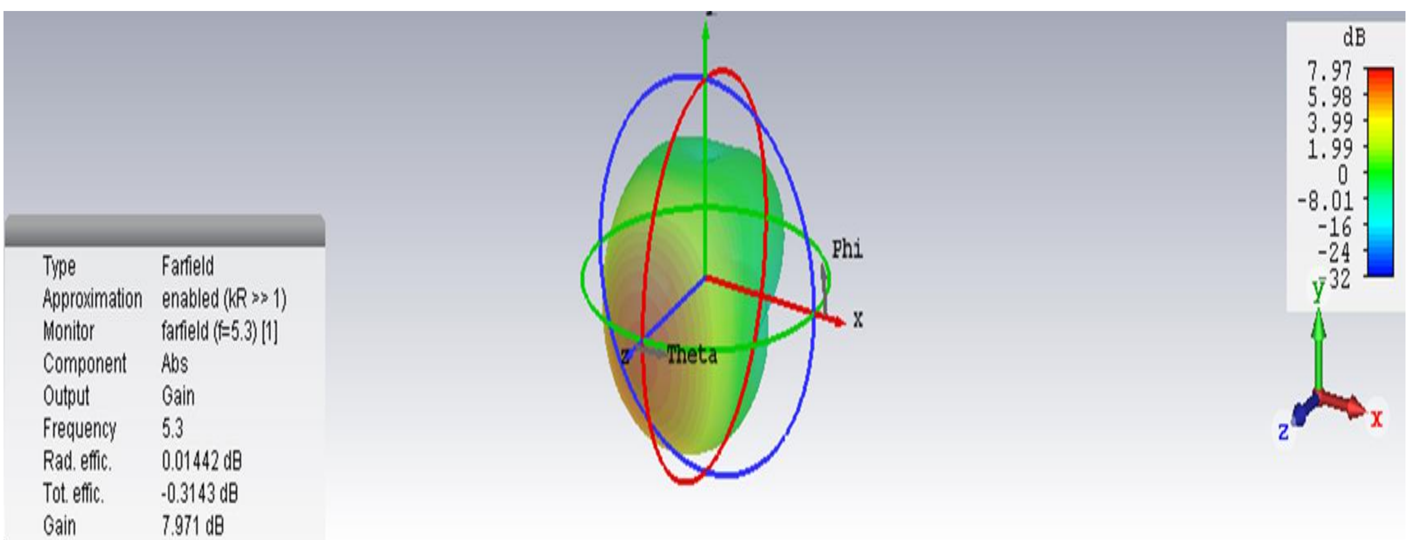
4.2 Simulated Results of the Proposed Antenna using CST Microwave Studio

4.2.1 Simulated Radiation Pattern

The 3D, 2D and polar radiation pattern of the proposed antenna are appeared in this segment. Figure 4.5 shows the 3 D radiation pattern while Figure 4.5 appears the 2 D radiation pattern at resonance frequencies 4.25 GHz, 5.3 GHz and 6.7 GHz respectively.



(a)



(b)

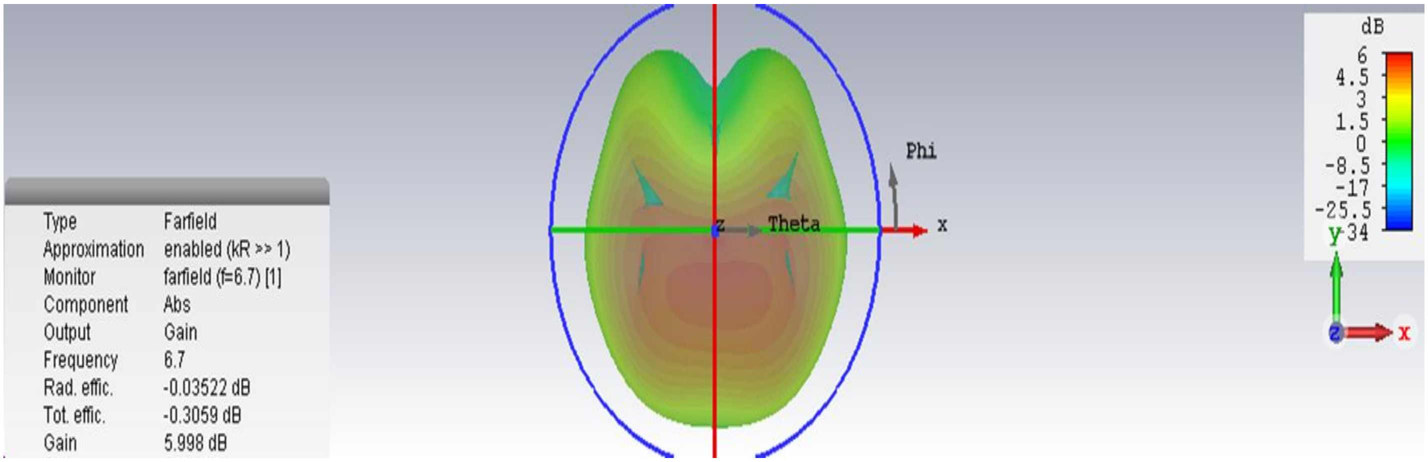
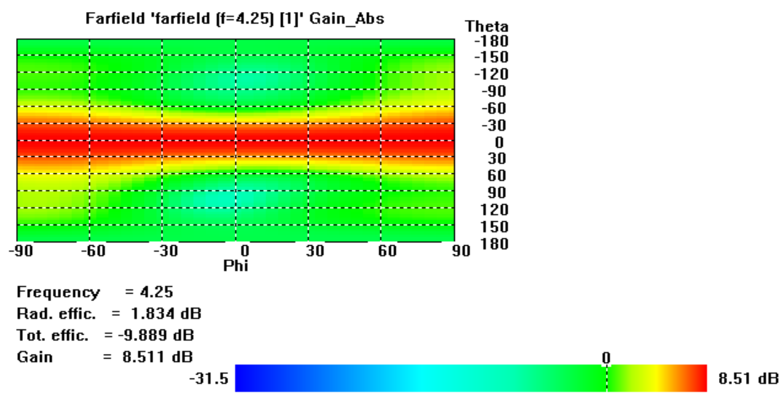
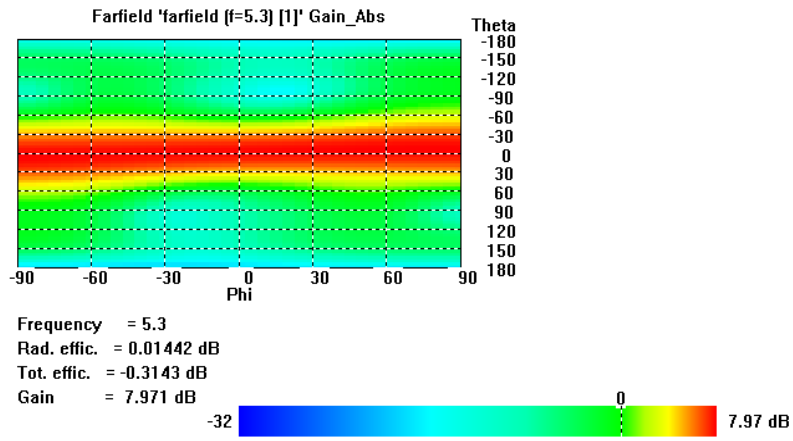


Figure:4.2 3D radiation pattern of proposed antenna at (a) 4.25 GHz (b) 5.3 GHz, & (c) 6.7 GHz.

(c)



(a)



(b)

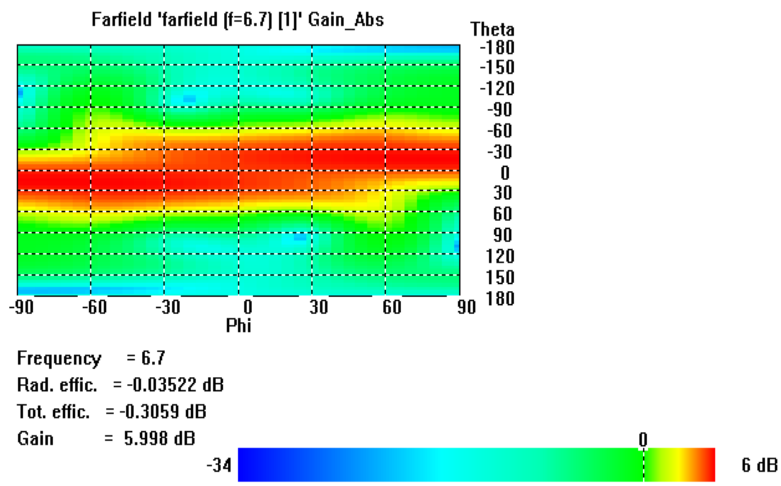
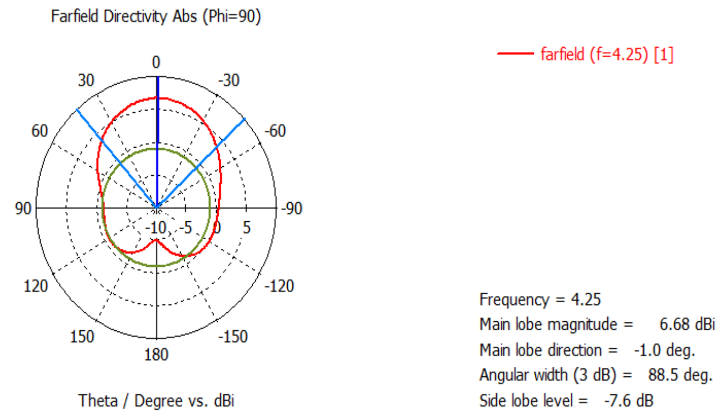


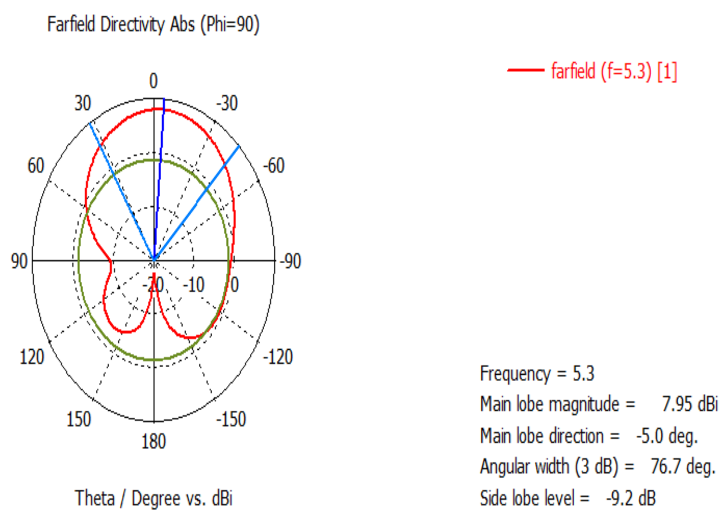
Figure4.3 2D radiation pattern of proposed antenna at (a) 4.25 GHz (b) 5.3 GHz, & (c) 6.7 GHz.

(c)

From 3D and 2D radiation design that are appeared in Figure 5 and Figure 6 the addition at reverberation recurrence 4.25 GHz is 8.511 dB, at reverberation recurrence 5.3 GHz is 7.971 dB and at reverberation at reverberation recurrence 6.7 GHz is 5.998 dB. The reenacted directivity at the three distinctive reverberation frequencies is 6.677 dBi, 7.957 dBi and 6.033 dBi individually.

The reenacted polar plot of the radiation example of the planned antenna is appeared in Figure 4.6 The Figure shows the 3 dB shaft width, side flap level (SLL) primary projection bearing and principal projection greatness. The 3 dB pillar width at the three diverse reverberation frequencies are 88.50, 76.70, and 72.30 separately.





(b)

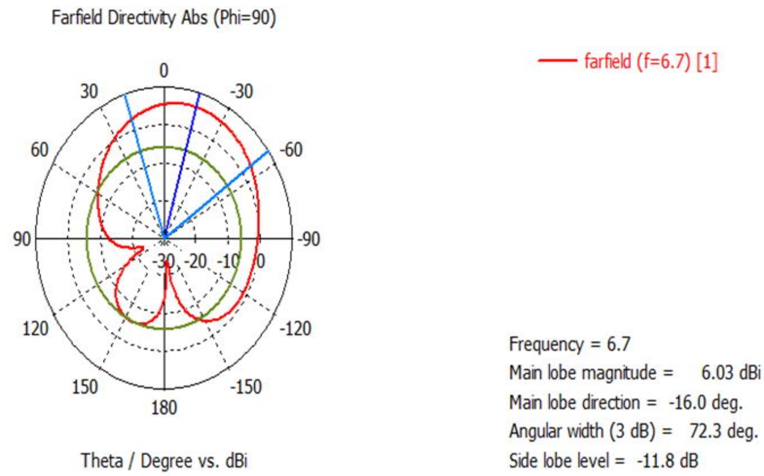


Figure4.7: Polar plot of the proposed antenna at (a) 4.25 GHz (b) 5.3 GHz, & (c) 6.7 GHz.

(c)

It is obvious that the SLL at frequency 4.25 GHz is - 7.6 dB, at reverberation recurrence 5.3 GHz is - 9.2 dB and at reverberation recurrence 6.7 GHz is - 11.8 db. The meaning of SLL is that the higher negative extent of SLL implies minimal measure of force emanates by the antenna side flap and greatest force of the radio wire is transmitted by the fundamental projection. In Figure 7 unmistakably at all the three that reverberation frequencies the SLL is above - 7 dB regrettable way that guarantees the proposed radio wire at these frequencies gives critical sum radiation toward principal flap.

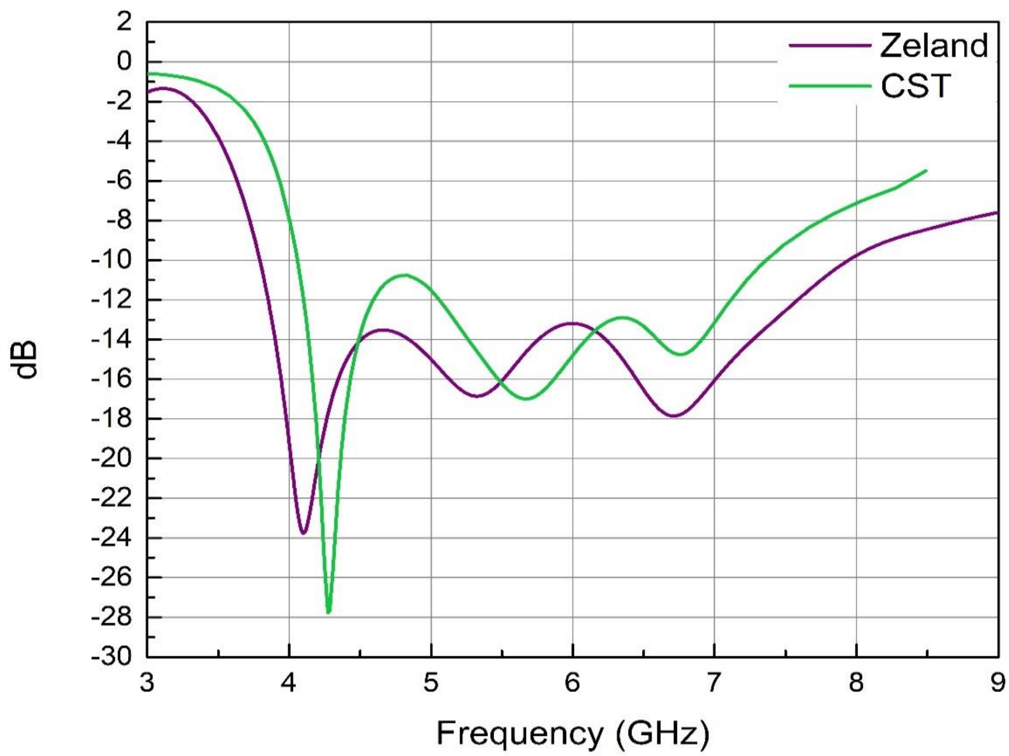


Figure 4.8: Comparative S-boundary of the proposed antenna utilizing CST and IE3D Zeland.

Relative investigation of the s-boundary (return loss) of the planned antenna utilizing CST and Zeland is appeared in Figure 8. The significance of s-boundary is that how radio wire impedance coordinated with the reference transmission line impedance. By and large, the antenna wire is reproduced considering reference impedance Z0 = 50 Ohm. At the point when the radio wire impedance entirely coordinated with the reference 50 ohm impedance then the less force is reflected from the antenna port and most extreme force is transmitted by the antenna toward principle flap. The bigger size of return misfortune regrettable way implies the antenna impedance is extensively coordinated with reference transmission line impedance. It ought to be referenced that generally - 10 dB return misfortune is significant for remote correspondence. The Figure 8 shows that the CST and IE3D both the test system gives return misfortune above - 10 dB at the recurrence going from 4 GHz to 8 GHz. This band of recurrence covers the utilization of C band in remote correspondence situations. It is likewise mentionable that the best yield misfortune inside the inclusion frequency band of the proposed radio wire at reverberation recurrence 4.25 GHz is - 28 dB and - 20 dB for CST and IE3D individually. The - 10 dB return misfortune transmission capacity at these three reverberation frequencies are 600 MHz (1.33% of resonance frequency) going from 4.10 GHz to 6.70 GHz, 1200 MHz (2.13% of reverberation recurrence) going from 5.0 GHz to 6.2 GHz, and 600 MHz (8.93% of resonance frequency) going from 6.4 GHz to 7.0 GHz.

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

Parameter	CST			IE3D Zeland		
Frequency in GHz	4.25	5.7	6.7	4.10	5.3	6.7
Bandwidth in MHz	600	1200	600	600	700	1000
Return Loss	-28	-17	-18	-24	-17	-15
Gain in dB	8.511	7.971	5.998	5.34	6.58	6.96
Directivity in dBi	8.64	8.074	6.50	7.800	8.61	7.821

TABLE II: Comparison between proposed design and references based on E shape C band

Parameters	**Reference**						**Proposed**
	8	**9**	**10**	**27**	**28**	**33**	
Band width	1.5 GHz	3.75 GHz	3.75 GHz	3.6 GHz	N/A	0.3 GHZ	4.0 GHz

Return Loss	-25 dB	-28 dB	-29 dB	-20 dB	-18 dB	-15 dB	- 28 dB
Width (mm)	32	70	34	25	146	21.7	34
Length (mm)	23.6	45	13	24	90	42	16.5
Substrate Height	3.5	1.6	3.4	0.8	1.6	5	5
Gain (dBi)	7.0	N/A	3.68	5.0	10.27	6.8	8.515
Directivity	Low	No Info	No Info	N/A	6.9	No Info	8.64

From the above clarification it is obvious that the proposed antenna appears preferable execution over others with transfer speed and gain qualities for satellite correspondence

CHAPTER 5
CONCLUSION & FUTURE WORKS

5.1 Major Contributions of the Thesis

Patch antennas are famous in view of their position of safety nature, light weight and low expenses. They have numerous benefits over ordinary radio wires. In any case, thin transmission capacity and low gain are the two significant issues.

In this proposition, the small data transfer capacity and low gain issue for a solitary band fix microstrip antenna has been considered. The strategy utilized to improve its transmission capacity is opening cutting. Space influences electromagnetic properties of host medium, so it has the ability to improve data transfer capacity and gain in antenna designing measure. This proposition addresses a steady improvement in radio wire trademark from RMPA to the proposed gain in antenna. Every one of the planned radio wires have been examined momentarily where every one of them work in Ku band recurrence range so they all have the limit with regards to propel satellite correspondence, broadcasting satellite and other energizing activities which are dispensed in this space. The data transmission of the proposed antenna is primarily expanded by forming E and further improvement is finished by embedding two rectangular openings and changing the substrate material. The element of the antenna is 34 × 15 mm2 with a substrate stature of 5 mm. The proposed single component fix radio wire covers full C band with three resounding frequencies at 5.0 GHz, 6.43 GHz and 7.58 GHz. The reflection coefficient or return misfortune at these frequencies are - 23.53 dB, - 17.21 dB and - 18.96 dB and the VSWR is under 2 for the entire C band. Greatest addition and directivity of the construction is 7.979 dBi and 7.989 dBi separately.

To check the outcome, I need to compare the outcome with two famous programming like CST studio and Zeland IE3D.The return misfortune is almost same and the addition is likewise comparable. The worth of VSWR differs somewhere in the range of 1 and 2. A near report with existing writing has been given to comprehend the impacts of different boundaries between one another in term of data transfer capacity, return misfortune, gain, directivity and size. The results of the outcomes are acceptable and empowering. The proposed exhibit radio wire shows promising and improvement in data transmission covering full C band and gain trademark contrast with different antennas. This proposed radio wire can be utilized in remote application under C band.

5.2 Future Scope of Work

In this research, we studied rectangular patch antenna and the impact of opening and rectangular slots to upgrade the bandwidth. The future work can include changing the antenna type (build in antenna shape and the dielectric of the substrate) and do additionally explore with other space structures. Impedance coordinating with organization might be utilized to improve the impedance data transfer capacity. Different strategies can likewise be utilized in future to configuration improved antennas which are as Follows:

- Split-Ring Resonator Structure (SRRS)
- Electromagnetic Band Gap Structure (EBG)
- Metamaterials

Other taking care of procedures of microstrip fix antenna like line taking care of can likewise be utilized in future to plan the equivalent microstrip fix antennas for better attributes. For future work, manufacture of these antennas should be possible to notice ongoing execution of the radio wires. The created of proposed antenna can be fabricate monetarily for C band applications all throughout the globe. Further upgrade in antenna trademark might be finished by utilizing other predominant procedures on proposed radio wire.

REFERENCES

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

[2] 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

[3] 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...

[4] Yang, F.; Xue-Xia Zhang; Xiaoning Ye; Rahmat-Samii, Y.; , "Wide-band E-shaped patch antennas for wireless communications," Antennas and Propagation, IEEE Transactions on , vol.49, no.7, pp.1094-1100, Jul2001

[5] Hadian, A. M., and H. R. Hassani. "Wideband rectangular microstrip patch antenna with U-slot." Antennas and Propagation, 2007. EuCAP 2007. The Second European Conference on. IET, 2007

[6] Vedaprabhu, B.; Vinoy, K.J.; , "A double U-slot patch antenna with dual wideband characteristics," Communications (NCC), 2010 National Conference on , vol., no., pp.1-4, 29-31 Jan. 2010

[7] Weigand, S.; Huff, G.H.; Pan, K.H.; Bernhard, J.T , "Analysis and design of broad-band single-layer rectangular U slot microstrip patch antennas," Antennas and Propagation, IEEE Transactions on , vol.51,no.3, pp. 457- 468, March 2003

[8] IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 52, NO. 12, DECEMBER 2004 3213 E-Shaped Patch Antennas for High-Speed Wireless Networks Yuehe Ge, Member, IEEE, Karu P. Esselle, Senior Member, IEEE, and Trevor S. Bird, Fellow, IEEE
[9] 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.
[10] Wang, B.-Z.; Xiao, S.; Wang, J.; , "Reconfigurable patch-antenna design for wideband wireless communication systems," Microwaves, Antennas & Propagation, IET , vol.1, no.2, pp.414-419, April 2007
[11] IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 49, NO. 7, JULY 2001 Wide-Band E-Shaped Patch Antennas for Wireless Communications Fan Yang, Student Member, IEEE, Xue-Xia Zhang, Xiaoning Ye, and Yahya Rahmat-Samii, Fellow, IEEE
[12] Probe Fed Stacked Patch Antenna for Wideband Applications M. A. Matin, B. S. Sharif, and C. C. Tsimenidis IEEE TRANSACTIONS ON ANTENNA S AND PROPAGATION, VOL. 55, NO. 8, AUGUST 2007
[13] Gourav Hans, “Design and operation of dual/triple band slotted Microstrip monopole antenna for wireless applications”. M.Sc. Thesis, Thapar University, 2014.
[14] B.T.P.Madhav, Prof.VGKM Pisipati, Dr.K.Sarat Kumar, P.Rakesh Kumar, K.Praveen Kumar, N.V.K.Ramesh and M.Ravi Kumar, “Substrate permittivity effects on the performance of the microstrip elliptical patch antenna,” in Journal of Emerging Trends in Computing and Information Sciences, Volume 2 No. 3, 2011
[15] Ayoub, A. F. A., “Analysis of rectangular micro-strip antennas with air substrates,” in Journal of Electromagnetic Waves and Applications, Vol. 17, No. 12, pp 1755–1766, 2003.
[16] D. M. Pozar, “Micro-strip antenna coupled to a micro-strip-line,” Electron. Lett., vol. 21, no. 2, pp. 49–50, Jan. 1985
[17] R. Chair, K. F. Lee, C. L. Mak, K. M. Luk and A. A. Kishk, “Miniature Wideband Half U-Slot and Half E-Shaped Patch Antennas,” IEEE Transactions on Antennas and Propagation, Vol. 53, no. 8, pp. 2645-2652, Aug. 2005
[18] M. Sanad, “Double C-patch antennas having different aperture shapes,” in Proc. IEEE AP-S Symp., Newport Beach, CA, pp. 2116–2119, June 1995.
[19] Lee, K. F., et al., “Experimental and simulation studies of the coaxially fed U-slot rectangular patch antenna,” in Proc. Inst. Elect. Eng. Microw. Antenna Propa., Vol. 144, 354-358, 1997
[20] Rafi, G. and L. Shafai, “Broadband micro-strip patch antenna with V-slot,” IEE Proc. Microw. Antenna Propag., Vol. 151, No. 5, 435–440, Oct. 2004
[21] Yang, F., X. X. Zhang, X. Ye, and Y. Rahmat-Samii, “Wide-band E-shaped patch antennas for wireless communications,” IEEE Trans. Antennas Propagat., Vol. 49, No. 7, 1094–1100, July 2001
[22] B.K, Ang and B.K Chung, “A wideband E shaped Microstrip Patch Antenna for 5-6 GHz Wireless Communications,” Progress In Electromagnetics Research, PIER 75, 397–407, 2007
[23] Gagandeep Kaur and Madhusudhan R Goud. Article: Slotted Rectangular Microstrip Antenna for Dual Band Operation.International Journal of Computer Applications 66(17):40-43, March 2013.
[24] J. Ghalibafan, A. R. Attari, and F. Hojjat-Kashani, "A new dual-band microstrip antenna with u-shaped slot,"Progress In Electromagnetics Research C, Vol. 12, 215-223, 2010.
[25] P. Salonen, Jaehoon Kim and Y. Rahmat-Samii, "Dual-band E-shaped patch wearable textile antenna," 2005 IEEE Antennas and Propagation Society International Symposium, 2005, pp. 466-469 Vol. 1A.
[26] A. Srivastava, Raghvendra Kumar Chaudhary, A. Biswas and M. Jaleel Akhtar, "Dual-band L-shaped SIW Slot antenna," Microwave and Photonics (ICMAP), 2013 International Conference on, Dhanbad, 2013, pp. 1-3
[27] Chen, Q., Zhang, H., Yang, L. C., Xue, B., & Zeng, Y. C. (2017). Compact microstrip-via-fed wideband circularly polarized antenna with monofilar spiral stub for C-band applications. International Journal of RF and Microwave Computer-Aided Engineering, 27(7).
[28] Kaushal, D., & Shanmuganantham, T. (2017). A Vinayak slotted rectangular microstrip patch antenna design for C-band applications. Microwave and Optical Technology Letters, 59(8), 1833-1837.
[29] Raj, R. K., Joseph, M., Aanandan, C. K., Vasudevan, K., & Mohanan, P. (2006). A new compact microstrip-fed dual-band coplanar antenna for WLAN applications. IEEE Transactions on Antennas and Propagation, 54(12), 3755-3762.

[30] Santosa, C. E., Sri Sumantyo, J. T., Urata, K., Chua, M. Y., Ito, K., & Gao, S. (2018). Development of a Low Profile Wide-Bandwidth Circularly Polarized Microstrip Antenna for C-Band Airborne CP-SAR Sensor. Progress In Electromagnetics Research, 81, 77-88.

[31] Paul, L. C., Akhter, M. S., Haque, M. A., Islam, M. R., Islam, M. F., & Rahman, M. M. (2017, December). Design and analysis of four elements E, H and combined EH shaped microstrip patch array antenna for wireless applications. In Electrical Information and Communication Technology (EICT), 2017 3rd International Conference on (pp. 1-6). IEEE.

[32] Islam, M. T., Misran, N., Take, T. C., & Moniruzzaman, M. (2009, August). Optimization of microstrip patch antenna using particle swarm optimization with curve fitting. In *Electrical Engineering and Informatics, 2009. ICEEI'09. International Conference on* (Vol. 2, pp. 711-714). IEEE.

[33] WANG, Y. Z., SU, D. L., XIAO, Y. X., & DING, K. J. (2006). Design of Broadband Square Microstrip Patch Antenna. *Journal of Microwaves*, S1.