Design of an UWB antenna to enhance bandwidth for S, C, and X bands Applications.

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By

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Certification

This is to certify that the thesis entitled, "**DESIGN OF AN UWB ANTENNA TO ENHANCE BANDWIDTH FOR S, C, AND X BANDS APPLICATIONS**" submitted by **RAYHAN MASUD** in partial fulfillment of the requirements for the award of Bachelor of Science Degree in ELECTRICAL AND ELECTRONIC ENGINEERING at the Daffodil International university, Ashulia is an authentic work carried out by him under my supervision and guidance. To the best of my/our knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

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LIST OF ABBREVIATIONS

UWB	Ultra-Wideband
RMPA	Rectangular Microstrip Patch Antenna
MPA	Microstrip Patch Antenna
GHz	Giga Hertz
IE3D	Moment of Method Based EM Simulator
EM	Electro-Magnetic
GPS	Global Positioning System
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
RF	Radio Frequency
VSWR	Voltage Standing Wave Ratio
R&R	Rose and Robbins
GSSI	Geophysical Survey System Inc
S/N	Signal power/Noise power
FCC	Federal Communications Commission
ITU	International Telecommunication Union
PCB	Printed Circuit Board
MP	Microstrip patch
WiMAX	Worldwide Interoperability for Microwave Access
RFID	Radio Frequency Identification
MIMO	Multiple-Input Multiple-Output
MHz	Mega Hertz
GPR	Ground Penetrating Radars
MSS	Mobile Satellite Service

NASA	National Aeronautics and Space Administration
BSS	Broadcast Satellite Service
2D	Two Dimensional
3D	Three Dimensional
Dg	Directivity Gain
Rp	Radiation intensity for Particular angle of antenna
Ra	Average Radiation intensity
Bw	Bandwidth
Fu	Upper Frequency
Fl	Lower Frequency
Fc	Center Frequency
RL	Return Loss

LIST OF SYMBOLS

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

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Design of an UWB antenna to enhance bandwidth for S, C, and X bands Applications.

Abstract

In this paper, the proposed Ultra-Wideband RMPA is designed by introducing a new formation of modified and combined U and H shape slots in patch and two rectangular slots in ground plane in order to attain a wideband working frequencies. This Ultra-Wideband patch antenna operates between the frequency ranges of 1.92 GHz to 11.256 GHz with S11 below -10 dB which covers almost entire three different frequency bands of S (2-4GHz), C (4-8GHz) and X (8-12GHz) frequency band respectively with standard efficiency. The proposed antenna design is simulated on Zeland IE3D simulation software using Rogers RT/duroid 5880 substrate with dielectric constant of 2.2 and thickness of 1.5 mm. The total size of the proposed antenna is 42×40 mm^2 and indicates worthy bandwidth of 80 MHz, 4 GHz, 4 GHz and 3.256 GHz (total 9.336 GHz) at L-band, S-band, C-band and X-band respectively. The proposed antenna resonates at 2.06 GHz, 3.36 GHz, 3.98 GHz, 5.208 GHz, 6.84 GHz, 8.66 GHz and 9.72 GHz concession UWB operation which can be used for satellite communication and radio navigation applications at low power. The same design has also been analysed by using CST Studio Suite to exhilarate the performance of the proposed antenna. The performance consideration and exploration of two separate simulation software, it can be terminated that the proposed antenna would be a superb postulant for UWB band satellite application.

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CHAPTER 1

OVERVIEW

1.1 Introduction

Wireless communication is the fastest growing portion and most vibrant technological field in the communication industry. The first communication between humans was by sound through voice. With the expectation for slightly more distance communication came, optical methods such as smoke signals, flags and flashing mirrors were used. These optical communication has been a part of human life and is continuously evolving. Latter, in the recent modern history, the electromagnetic (EM) band spectrum, outside the perceptible region has been engaged for communication through the use of radio. Modern wireless communication i.e. using radio waves and electrical signals for communication has been around us for more than a century. Without using any link/connection like cables or wires, wireless communication is a method of transmitting message from one point to other. The communication method can be wireless or wired and the nexus used for communication can be guided or unguided. Co-axial cables and Optical Fiber cables are used for wired cables. On the other hand, there is no compulsory physical medium in wireless communication but information propagates through space. However, space only complies for signal transmission without any guidance, where the medium used in wireless communication is called unguided medium. With the favor of wireless communication, the transmitter and receiver can be installed anywhere between few meters (remote control) to few thousand kilometers (satellite communication). Which gives us pleasure, unique sense of mobility and revolutionized way to do great things. Many new applications, including mobile phones, GPS receivers, remote controls, Bluetooth, Wi-Fi, wireless sensor networks, automated car and factories, and smart homes are emerging for research where antenna is an indispensable and vivid material in wireless communication system. An antenna is an array of conductors or an electrical element that's connected to the receiver or transmitter by propagating electromagnetic energy from the space circumambient it, in order to set up a wireless connection between two or more apparatuses. Antennas can transmit and receive radio waves in a certain direction or in all horizontal directions equally.

The radiation pattern, gain and efficiency are the basic terms of antenna's performance. In majority of the circumstance the performance characteristics of the antenna rely on the substrate material and its physical parameters. An electromagnetic wave consists of both electric and magnetic fields in the form of time varying sinusoidal waves, where they are oscillating perpendicular to each other and the heading of propagation of the EM wave is moreover perpendicular to both these fields. EM spectrum has been passed out ubiquitously for all types of EM wavelengths and frequencies where antennas can conduct according to the applications of wireless communication system such as wireless local area network (WLAN) connection, satellite and mobile phones etc. [18]. Materially micro-strip component consists of a field of metallization fulcrum above the ground plane, known as micro-strip patch. The mounting component is known as substrate material which is placed between the ground plane and the patch. The working frequency picking out for particular antennas in part of deciding the material that can be used to generate the antenna. The micro-strip antenna can be fabricated with Arlon Cu (lossy), flex, RT duriod, ceramic, steel plate, or some wire material. In recent years, using lithographic technique or by monolithic integrated circuit technique we can fabricate amplifiers, phase shifters and other essential devices by automated process. Nowadays antenna performance can be elevated by designing antenna with meta-material. However, antenna is perhaps the most observed part of radio frequency (RF) design. The range and performance of an RF link are critically dependent upon the antenna [23]. In the telecommunication field, researchers has given priority to antenna miniaturization and multifunctional system with designing much better antenna gains and wide bandwidth. For this purpose, the desire for ultra wide bandwidth is increasing day by day, based on antenna design it can operate at various radio frequency (RF). Designing micro-strip patch antenna (MPA) using different techniques opens the possibility of increasing the antenna characteristic such as antenna efficiency, gain, VSWR, directivity and larger bandwidth.

1.2 Background

Ultra wideband is a radio technology that can use a very low energy level for short range, high bandwidth communications over a massive part of the RF spectrum. It is also known as ultra wideband, ultra-wide band, UWB and ultraband. However UWB has conventional application such as target sensor data collection, non-cooperative radar imaging, precision locating and

tracking applications [27]. To produce EM waves, Heinrich Hertz used a spark discharge for his experiment in 1893. In the early 1960s the prosperity of the sampling oscilloscope and the similar techniques for generating sub-nanosecond baseband pulses sped up the improvement of UWB. Impulse measurement techniques were used to characterize the transient behavior of certain microwave networks [1]. The development of UWB RF signals initiated after 1960's with the pioneering contributions of Harmuth at Catholic University of America. The Harmuth books and published papers, 1969-1984, placed in the public domain the basic design for UWB transmitters and receivers. At nearly the same time and independently, the Rose and Robbins (R&R) patents, 1972-1987, pioneered the use of UWB signals in a number of application areas, including communications and radar and also using coding schemes. Paul Van Etten's experimental testing of UWB rader systems evolved in the development of system design and antenna concepts (Van Etten, 1977). In 1974 Morey designed a UWB radar system for penetrating the ground, which was to become a commercial success at Geophysical Survey Systems Inc. (GSSI). Other subsurface UWB radar designs followed (Moffat and Puskar, 1976). The methods of data encoding in UWB communications systems were introduced decades ago. Essentially, an UWB communications system trades pulse shortness (gaining a high signal/symbol rate) in exchange for two other variables bandwidth (which becomes wider) and S/N (which is reduced). Greater bandwidth use needs FCC (Federal Communications Commission) approval and a lower S/N requires signal averaging, which then lowers the signal/symbol rate and thus the channel capacity (data rate). Lowering the signal/symbol rate, plus the fact that the symbol/signal of a UWB system has an informational value no higher than 1 bit, defeats the aim, if the aim is to achieve high capacity or high data rate. There is no escape from these trades. As in the case of more conventional communications systems, the UWB wireless system designer must balance trade-offs among high bandwidth efficiency, low transmission peak power, low complexity, flexibility in supporting multiple rates and reliable performance as expressed in bit error rates [25]. The International Telecommunication Union (ITU) undertakes the work on UWB was made in 2002 to study the consistency between UWB and other communication services. Actually, ITU is an impartial, international body or a group where governments and the private sector work together on issues relevant to telecommunication networks [1]. There is several significant advantages in UWB to design microstrip patch antenna.

After the evolution of the printed circuit board (PCB) technology in the 1970s, Howell and Munson developed the first practical microstrip patch antenna, which opens widespread area

of research all over the world [sir]. Because of low profile planar configuration of MP antennas can be easily made conformal to host plane. That's why it has the wide arena of application for the civilian and military application such as mobile phone, Wi-Fi, Wi-Max, television, radio frequency identification (RFID), multiple-input multiple-output (MIMO) systems, satellite communication, global positioning system (GPS), vehicle collision avoidance system, surveillance systems, radar systems, remote sensing, missile guidance, biological application like biological imaging, and so on and still the work is going on the microstrip antennas for finding new applications of it by having more integration [23]. In [6], the author explain that modern UWB antennas have to estimate for several concern: low cost and small size, matching properties, minimum reactive power and hence resonance and the printed antenna is very popular for UWB.

1.3 Literature Review

Since many years, there is a progressive demand of microstrip patch antenna (MPA) for their small and brief shape, slender weight, cost utility, low profile, get at able to fabricate and install in numerous portable devices, robust, size flexibility, variety of polarization, spontaneously mountable on vehicles or missiles and usage in hand seized apparatus etc. For this purposes, researchers have pulled a great attention on this field [16-17, 23].

In February 2002, the Federal Communication Commission (FCC) delivered a reform (Part 15) that decides the regulations of Ultra-Wideband (UWB) transmission and reception. Under this deliverance any signal having a bandwidth greater than 500 MHz is reckoned as an UWB signal. From an antenna viewpoint, the UWB concept covers today three major types of applications [1]: i) Applications such as Ground Penetrating Radars (GPR, 1MHz to 10 GHz), ii) Multi-narrowband applications such as signal intelligence and detection, iii) Modern UWB operating in a 3.1 to 10.6 GHz frequency band. There are several uses of UWB antennas such as military tools, high speed mobile communications, in-car sensor network communication, automotive localization and tracking with high spatial resolution, emergency services and recently on consumer electronics and communications [4]. The difference between UWB and narrow band antennas is that narrowband wireless transmission technology are used in broadcasting on different frequencies with narrow bandwidth whereas UWB propagates signals

across a particular comprehensive range of frequencies. The main key of UWB systems is high data rates, improved impedance matching, multipath immunity, low radiation loss, low fabrication cost, ranging and communication at the same time and stable radiation pattern, and compact size [1-4]. UWB also has some disadvantages like low gain, larger dimension, the complexity and time-varying behaviour of pulse-shaping, and narrow band interference; among them narrowband interference is one of the prime challenges. As narrow bandwidth is one of the major drawback for this type of antenna, there have been applied various techniques to overcome this problem such as modifying the patch's shape, introducing parasitic components like co-planar or stack configuration, and increasing the substrate thickness. There have several method of improving or modifying patch's shape by cutting slots includes designing an E-shaped patch antennas [19, 23], or a U-slot patch antenna [20-21], inverse Z-shaped patch and our proposed new designed antenna patch. In [19], authors claim that microstrip patch antenna gives bandwidth up to 30%, when they cut a U-slot shape on their antenna patch. By thinking that we cut down two U-slots shape on our proposed antenna patch. Besides, we have got more low return loss by cutting two U shaped slots on parallel both ground and substrate layer.

An ultra-wideband and triple band Antennas for satellite applications at Wi-max, WLAN and downlink of X-band has been proposed in [11] with 32x26 mm^2 dimension. The ultra-wideband antenna consists of an inverted T-shaped stub and two C-shaped parasitic slots which provides a wide bandwidth from 2.8 to 11.8GHz. The C-shaped slots and a pair of rectangular split-ring close to the feed lone and patch has been introduced to obtain the triple band frequency response covering Wi-max (3.3-3.6GHz) band, WLAN (5.05-5.90GHz) band, and downlink of X-band (7.25-7.75) respectively with voltage standing wave ratio of less than 2 (VSWR<2). In [14] a coplanar compact monopole UWB Antenna using inverted U shaped parasitic patch has been proposed with dimensions of 1228.8 mm^3 exhibits wide band from 2.9795 to 11.2GHz for VSWR is less than or equal to 2 and the Antenna gain was 3.38dB. However, there are many different radio frequencies which are actually developed for several communication purpose such as the frequency range of L-band is 1 to 2 GHz and this antenna has been designed for Mobile satellite service (MSS). Consequently, S-band (2-4 GHz) (used for MSS, NASA, deep space research), C-band (4-8 GHz) (used for FSS), X-band (8-12.5 GHz) (used for FSS military, terrestrial earth exploration, and meteorological satellites), Ku-band (12.5-18 GHz) (used for FSS, broadcast satellite service (BSS)), K-band (18-26.5 GHz) (used for BSS, FSS) and Ka-band (26.5-40 GHz) (used for FSS).

In this paper, we concentrated on modern UWB communication technology and used a different shape to improve bandwidth, and enhance gain. The main objective of this designed is to compare the base design in [9] to transmit very low power in order to acquire high data rate without confusing other surrounding wireless communication systems, to obtain higher bandwidth. The designed antenna with a compact sized rectangular shape achieved more bandwidth.

1.4 Aim and Objectives

The major aim of this research is to achieve better performance of MPA characteristic under UWB applications. The objectives are provided below.

- Design a MPA with larger bandwidth
- Enhance antenna gain and efficiency
- To reduce antenna return loss

1.5 Methodology

All the improvement in performance of MPA have been done under UWB applications. Insertion of three U-shape slots in patch and two reverse U-shape slots in ground leads us to get adequate improved result. Fundamental procedures have been stated step by step to achieve our desirable objectives.

Step 1: To design a simple rectangular microstrip antenna (RMA) with basic structure by defining its length (L) and width (W).

Step 2: To increase the bandwidth, modified and combined U and H shape slots has been used.

Step 3: To compare antenna characteristics in between recent UWB antennas.

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

Step 5: Optimizing the lengths and widths of the patch using slots for better results.

Step 6: Modifying the ground plane using two rectangular slots for better results.

1.6 Thesis Organization

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

Chapter 2 explains brief literature studies of UWB microstrip antenna in order to get its basic fundamentals. It also discusses the relevant literatures on designing wideband microstrip patch antenna using slot.

Chapter 3: describes the design procedure of Ultra wideband high gain Microstrip patch antenna using line feeding technique. To increase the gain of the proposed antenna array configuration has been introduced.

Chapter 4: includes comparison between return loss graphs, bandwidth for all individual antennas, average and vector current distribution, 2D and 3D radiation patterns for the proposed single patch antenna using Zeland IE3D software. A brief comparative study also has been made between proposed antenna and other previously designed antennas in terms of various antenna parameters.

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

CHAPTER 2

LITERATURE STUDIES

2.1 Antenna Parameters:

Antenna is a way of converting the guided waves present in a waveguide, feeder cable or transmission line into radiating waves travelling in free space, or vice versa. To understand the strengths and weaknesses of a design, antennas have different kinds of parameters and dependent on one another. However, there are several important antenna parameters that should be considered when choosing an antenna for any particular application such as:

- Radiation Pattern
- Directivity
- Power Gain
- Bandwidth
- Return Loss
- VSWR
- Polarization

2.1.1 Radiation pattern:

The radiation only occurs, when coming current through fed line in the patch feel sudden discontinuity. But when feel continuity in patch there is no radiation occurs in the patch.

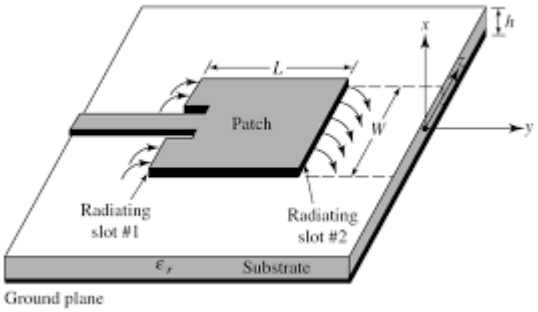

Figure 2.1(a) Radiation in microstrip antenna

Due to changing flow of current in conduction wire the radiation of antenna occurs. Mainly radiation of antenna abide by two ways which are given below.

1. By changing of velocity, acceleration and/or de-acceleration the current in a conductor, the current will produced a flow making the antenna radiate. If there is no motion of flow or if the flow of current is uniform, the straight conductor will not radiate.

2. If we bend the wire, even with uniform velocity, the curve along the wire will create an acceleration in the current flow and the wire will therefore radiate [23].

Due to attach a sinusoidal voltage source through the transmission line, electric field is produced. As a result Electric force line is also produced in it, which are the tangential the electric field line .Then the electric force line are forced the free electron of the conductor and thereby creating flow of current. Due to change of electric field, electromagnetic wave are also produced there. When the electromagnetic waves are within the transmission line, the antenna is sustained due to the charges from the voltage source, but as soon as they enter the free space they create closed loop because of the nature of physics.

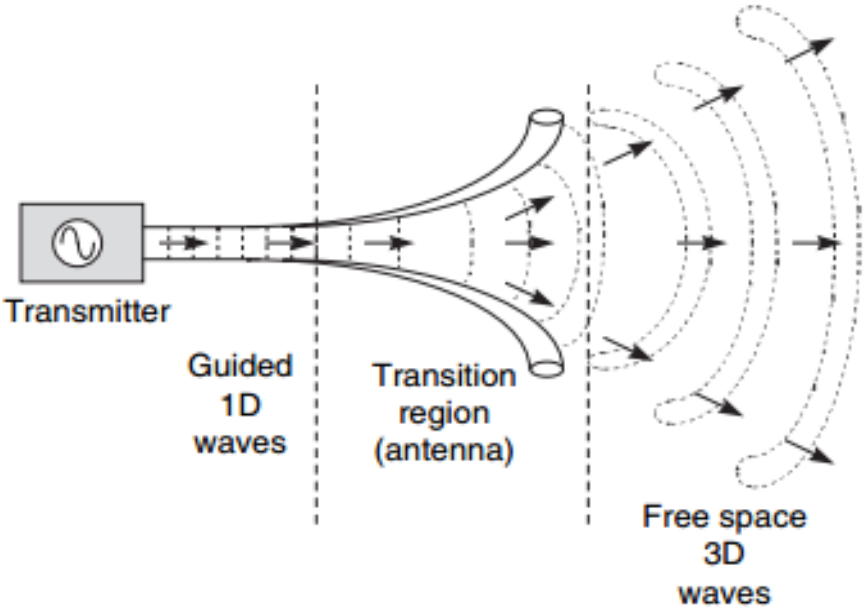

Figure 2.1(b) Antenna Radiation flow

2.1.2 Antenna Field Regions:

The whole process is performed by the combination of source, transmission line, and wave propagation in free space. When the electromagnetic wave come from antenna to free space, then the radiated electromagnetic wave crosses the near field and far field as demonstrated in the following figure.

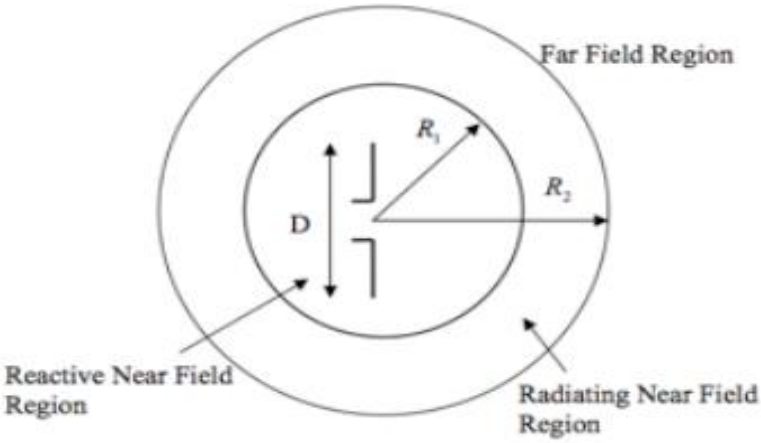

Figure 2.1(c) Field Regions

From the above **Figure 2.1(c)** the fields surrounding an antenna are divided into three main regions:

- Reactive Near Field
- Radiating Near Field
- Far Field

Both reactive and radiating near field are covers from R1 = 0 to R1 =$\frac{\lambda}{2\pi}$ or 0.159 x λ, while the radiating near field covers the remainder from R2 = $\frac{\lambda}{2\pi}$ to R2 = λ. The near field is calculated by using the equation of λ=$\frac{c}{f}$. In where λ is the far distance, c is the value of light velocity and f is the frequency.

The far field region is the most significant region as for determining the antenna radiation pattern and most of the other parameters. The range of far field is from 2λ to infinity. The whole range is called transmission zone. The transmission zone has both parameters near field and far field. It is calculated by using the equation =2C/f. In where 2λ is the far field parameters, and f and c respectively frequency and velocity of light.

2.1.3 Directivity:

The directivity D of an antenna, a function of direction is defined by the radiation intensity of antenna in direction to the main radiation intensity in all directions.
A directive antenna is another antenna which radiates differently at different angle. The ratio between radiation intensity of an antenna at a particular angle and average radiation intensity in all direction is known as Directive gain. If directive gain is express as 'Dg', radiation intensity for particular angle of antenna Express as 'Rp' and average radiation intensity express as 'Ra' then the mathematical Expression can be written as the following equation.

$$Dg=Rp/Ra$$

2.1.4 Power Gain:

The gain G, or simply the gain, of an antenna is the directivity of an antenna taking into consideration the antenna efficiency. It can be said that directivity of an antenna is the ideal case and gain is the real case. So, if it can be ensured that all the input powers to an antenna will be radiated, then gain and directivity will be same. As in practical case, there will always be losses associated with antennas; gain is always lesser than directivity.

$$\text{Antenna Gain} = \text{Antenna Efficiency power} \times \text{Directivity}$$

2.1.5 Bandwidth:

Generally bandwidth is the distance between minimum frequencies and maximum frequencies within the performance of antenna. Only impedance bandwidth is fixed. There are other important bandwidth definitions as well such as: polarization bandwidth, directivity bandwidth, and affectivity bandwidth, where the last two, if often combined, are defined as gain bandwidth. Impedance bandwidth depends upon the large number of parameters such as dielectric materials and size of ground plane.

If the symbolic expression for Bandwidth is Bw, upper frequency Fu, lower frequency is Fl and center frequency is Fc then the desire equation of Bandwidth can be written as follow.

$Bw = Fu/Fl$ [for broad bandwidth]

$Bw(\%) = \{(Fu-Fl)*100\}/Fc$ [for narrow Bandwidth]

2.1.6 Matching and Reflection:

During sending power from source to antenna, if most of the power is absorbed by antenna and negligible power is reflect back this can be ensure matched transmission line with antenna. When load impedance is not 100% match then most of the power reflect back. As a result source could be damage. The reflection can be measured by following equation.

Reflection coefficient, Γ= (Zl-Zs)/(Zl+Zs)

The reflection coefficient is a complex number (a+jb). If the imaginary part is 0, then if:
Γ = -1, the line is short-circuited (maximum negative reflection, phase shift of 180° or Π).
Γ = 0, the line is perfectly matched (no reflection).
Γ = 1, the line is open-circuited (maximum positive reflection).

As the reflection coefficient is complex and it change with changing frequency. The reflection coefficient can be expressed graphically by using smith chart like as **Figure 2.1(d)**.

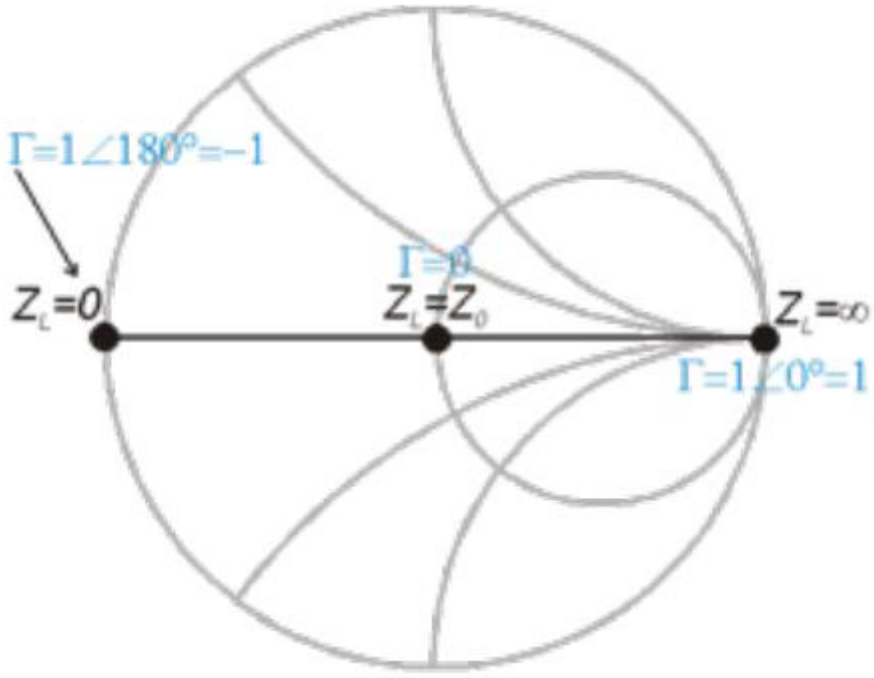

Figure 2.1(d) Smith Chart

2.1.7 Return Loss / S11 Parameters:

Due to impedance mismatch most of the sending power from source is reflected in the transmission line. It also called as Return loss. It can be written as following equation.

$$RL = -20 \log 10|\Gamma|$$

The Return loss also states as S11 of the s-parameters. Every Transmission lines have S-parameters also called as "Scattering parameters" which refers to RF's voltage out versus voltage in and are measured in dB unit. S-parameters are a complex number but they mostly refer to the magnitude to know how much loss or gain you get.

2.1.8 Voltage Standing Wave Ratio (VSWR):

This is another way that determines how much mismatch impedance occurs. By calculating VSWR it can be realized that how much mismatch impedance occurs in transmission line. VSWR is the ratio between maximum voltage and minimum voltage.

If maximum voltage and minimum voltage is Mx=1+ ρ and Mm=1- ρ respectively (where ρ is the magnitude of coefficient). Then mathematically it can be represent as VSWR=Mx/Mm.

The minimum value of VSWR is 1 which is when there is no mismatch between generator and antenna. It represents 100% radiated wave and 0% reflected wave. Normally, VSWR of 2 is accepted as a good match as it represents approximately 10% of reflected power.

2.1.9 Antenna Efficiency:

When sending power could not be equal to output power of any system then loss will be occurs in the system. Similarly, Antenna also have two losses. One is due to mismatch of impedance

with antenna and free space. Another is due to not radiated input power for being a conducting material of antenna. An Antenna efficiency is the ratio between output power and input power. Mathematically can be expressed as the flowing equation.

$$\text{Antenna Efficiency} = \frac{\text{Output power}}{\text{Input power}} * 100\%$$

2.2 Transmission line:

The measuring unit of impedance of transmission line is ohms and symbolic expression of this impedance characteristic is Z_0. According to the application of micro-strip patch antenna, the different value of impedance is used such as in coaxial cable of transmission line in which the value of impedance is used 50 ohms for most of antenna application, the value of impedance 75 ohms is used for satellite communication or very high frequency application and 100 ohm and 300 ohm is also used for radio communication.

As any impedance is the combination of resistance and inductance, the transmission line impedance also have resistance and inductance. Because of every transmission line is not ideal that's why loss will be occurs on it. If R, L, C, and G are the resistance, inductance, capacitance and conductance respectively then the circuit of the transmission line will be like following figure.

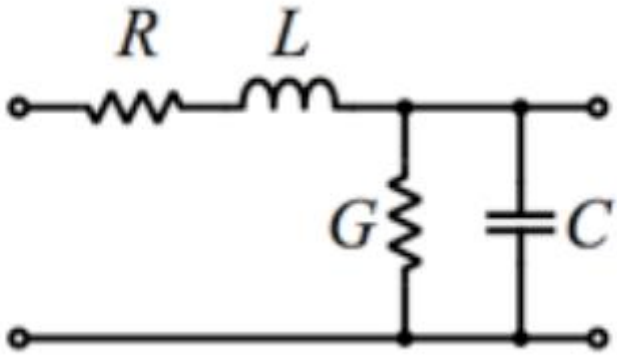

Figure 2.2 Equivalent circuit

To calculate the value of impedance also have an equation which is known as Telegrapher equation. The equation is given below.

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

2.3 Introduction of Microstrip Patch Antenna

A microstrip antenna consists of Patch, Dielectric material and Ground. Patch is a conducting material which is placed on one side of dielectric material and other side of dielectric material connected to the ground of conducting material to the patch as like as the **Figure 2.3**.

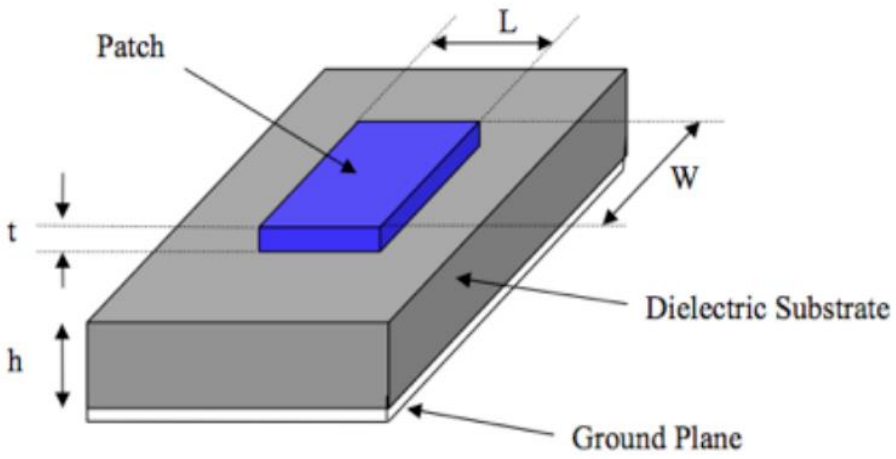

Figure 2.3 Patch antenna

2.3.1 Pros and Cons of Microstrip Patch Antenna

Now a days a microstrip patch antennas are becoming more and more popular because of having various facilities. Some of their principal advantages discussed by [26] are given below:

- Light weight
- Low fabrication cost
- Mechanically robust when mounted on rigid surfaces
- Can be easily integrated with microwave integrated circuits (MICs)
- Supports both, linear as well as circular polarization

On the other hand, mirostrip antennas also have some disadvantages compared to conventional antennas. Some of their major drawbacks discussed by [26] are given below:

- Low gain
- Low efficiency
- Narrow bandwidth
- Low power handling capacity
- Surface wave excitation

2.4 Feeding technique

Antenna feeding actually excitation of patch .There are different ways to feed the antenna. It is obvious that one cannot have merely a patch and transmit power through it without actually delivering the power to the patch and vice versa by receiving. Although there are different ways to feed among them microstrip feed line method and coaxial feed line method is the most uses method.

2.4.1 Microstrip line

The feed line to the patch antenna is in its origin a transmission line and is therefore often referred to as the transmission line feed. The feed line width is smaller than the patch and is etched directly to the edge of the patch so that power is transferred from the source through a coaxial cable, into the feed line and then to the patch. The purpose of the feed line is to match the impedance from the patch without any additional matching component, because the feed line is a patch itself it can cause radiation interfering with the patch which will decrease the bandwidth of the antenna.

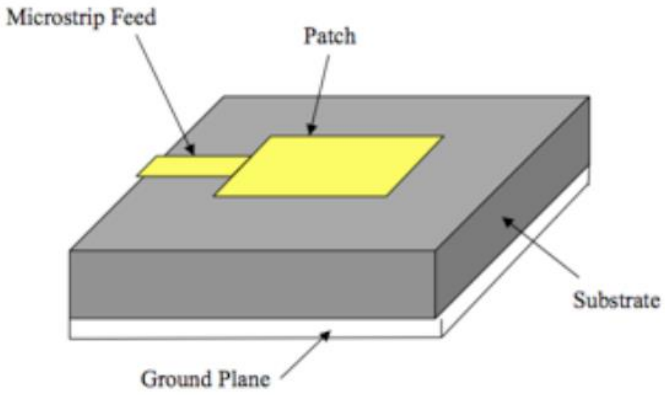

Figure 2.4.1 Microstrip Line Feed

2.4.2 Coaxial Feed Line

The coaxial feed (also referred to as a probe feed) is a very common way to feed the antenna. As seen from above figure the coaxial connector is inserted at the ground plane where the inner conductor extends through the dielectric substrate and is soldered on to the patch. The advantages of this kind of feed are it's lower radiation and the fact that it can be placed anywhere to match the impedance of the patch (though a calculation of the x, y plan of the patch). The disadvantage is that it provides a narrow bandwidth and is it is difficult to drill though the substrate. With a fragile dielectric substrate you might end up damaging the

substrate or the inner connector might not perfectly fit the drilled hole and thereby create power loss to air conductivity. Another problem is that with a thick substrate the inner coaxial conductor has to be longer leading to higher input inductivity which creates matching problems.

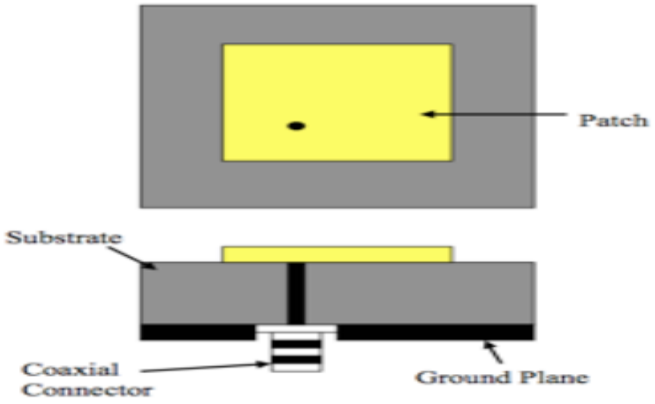

Figure 2.4.2 Probe Feed Patch Antenna

CHAPTER 3

DESIGN OF THE PROPOSED PATCH ANTENNA

The primary focus of this thesis is to design a microstrip patch antenna having enhanced bandwidth, standard gain and return loss for UWB in S, C and X band region. In this chapter antenna designs are shown in chronological order where gradual antenna performance enhancements are observed from rectangular microstrip patch antenna to proposed single patch antenna.

To design the proposed antenna Zeland IE3D simulation software has been used. All the antennas are unique and have the ability to operate for UWB application in S, C and X band region.

3.1 Basic Parameters

Three ordinary parameters are provided below for designing all the antennas consequently.

- The frequency of operation: UWB (S, C and X) frequency domain has been selected for MPAs operation.

- Dielectric constant: Rogers RT/duroid substrate with dielectric constant of 2.2 has been selected as dielectric material for MPAs.

- ❖ Height of substrate: MPAs are very impenetrable devices so for fundamental configuration of MPA standard thickness has been selected as 1.5 mm.

3.2 Substrate Selection

The first significant step in designing an antenna is to choose an accurate substrate with low substrate permittivity and loss tangent for better bandwidth and gain. The substrate of MPA is most important requirement for the mechanical support of the antenna and which may also affect the electrical performance of the antenna.

Table 3.1: Commonly used materials

SL.No	Substrate Material	Dielectric constant **εr**	Loss tangent **tanδ**
1	Arlon Cu (lossy) Normal	2.33	0.0013
2	Arlon AD250 (lossy) normal	2.5	0.0018
3	FR-4 (lossy)	4.3	0.025
4	RT/duroid 5880	2.2	0.0009
5	RT/duroid 5870	2.33	0.0012
6	RT/duroid 6010.2LM	10.7	0.0023
7	RT/duroid 6002 PR	2.90	0.0020
8	RT/duroid RO4050B	3.66	0.0037
9	RT/duroid RO4003C	3.55	0.0027
10	Epoxy/glass (FR-4)	4.4	0.01
11	TLC-32	3.2	0.003
12	HT-2	4.3	0.0033

An appropriate choice of substrate permittivity diminishes the amount of surface wave losses, copper losses and cost which improves the antenna performance particularly, radiation efficiency and impedance bandwidth.

Selection of appropriate substrate thickness (h) is also an important obligation in MPA design. Moreover, a designer needs to know the effect of changing substrate thickness for selecting

proper substrate thickness [22]. A mechanically strong thicker substrate will increase bandwidth, radiated power and minimize the copper loss. Whereas, the lower the permittivity the higher the antenna gain [23]. Therefore, a dielectric constant of 2.2 and substrate thickness of 1.5 (h=1.5) used for this analysis. RT/duroid has lower dielectric constant than FR4 dielectric constant and increases the bandwidth because bandwidth is inversely proportional to dielectric constant or permittivity and further RT/duroid gives maximum radiation due to its low dielectric constant.

3.3 Fundamental Formulas of MPA

The radiation depends on the antenna width and length. Not only radiation but also resonant frequency depends on the width of antenna. The width of antenna is directly proportional to power radiation, bandwidth of antenna, and radiation efficiency and inversely proportional to resonant resistance. To determine micro-strip patch antenna's length by given equation.

$$L = \frac{\mathrm{c}}{2\mathrm{fr}\sqrt{\varepsilon_\mathrm{r}}} \tag{3.1}$$

Where speed of light is denoted by c, resonant frequency fr and dielectric constant εr.

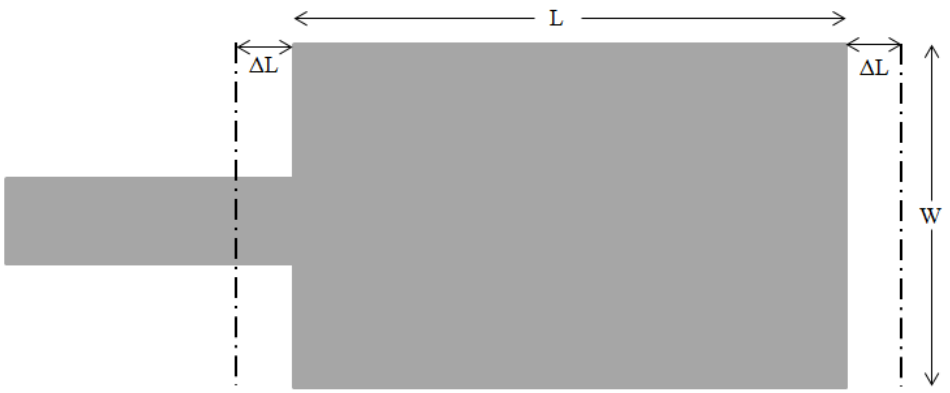

Figure 3.3(a) Microstrip Patch Antenna Dimension

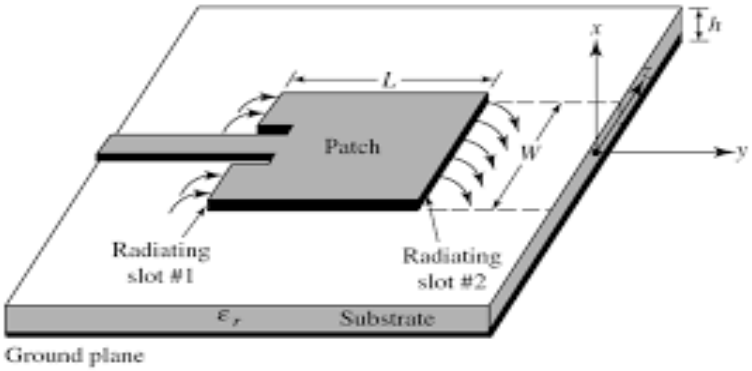

Figure 3.3(b) Radiation flow from patch to ground

For efficient radiation, width of patch is given by:

$$W = \frac{v_0}{2 f_r \sqrt{\frac{2}{\varepsilon_r + 1}}} \tag{3.2}$$

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

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}} \tag{3.3}$$

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

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

Now the actual length of patch can be expressed by

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

Where, length extension is as follows [22].

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

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

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

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

3.4 Mensuration and Design Procedure of Proposed Antenna

The mensuration, dimensions, structure and design view of UWB micro strip patch antenna using modified and combined U and H shaped patch with two rectangular slots in the ground plane are presented in the following section.

3.4.1 Mensuration of Proposed Antenna

The dimension and structure of the top view and the back view of the proposed UWB micro-strip antenna are illustrated in **Figure 3.4(a)** and **Figure 3.4(b)** respectively. RT/duroid 5880 is used as substrate material which have dielectric constant of 2.2 with thickness of 1.5mm. The ground plane is rectangular shape with two rectangular slots and radiating element or patch is of modified and combined U and H shaped whose dimensions are illustrated in **figure 3.1**. The 50 Ohm. Feed line and the patch are united on the same side of dielectric substrate and the ground plane is placed on the other side.

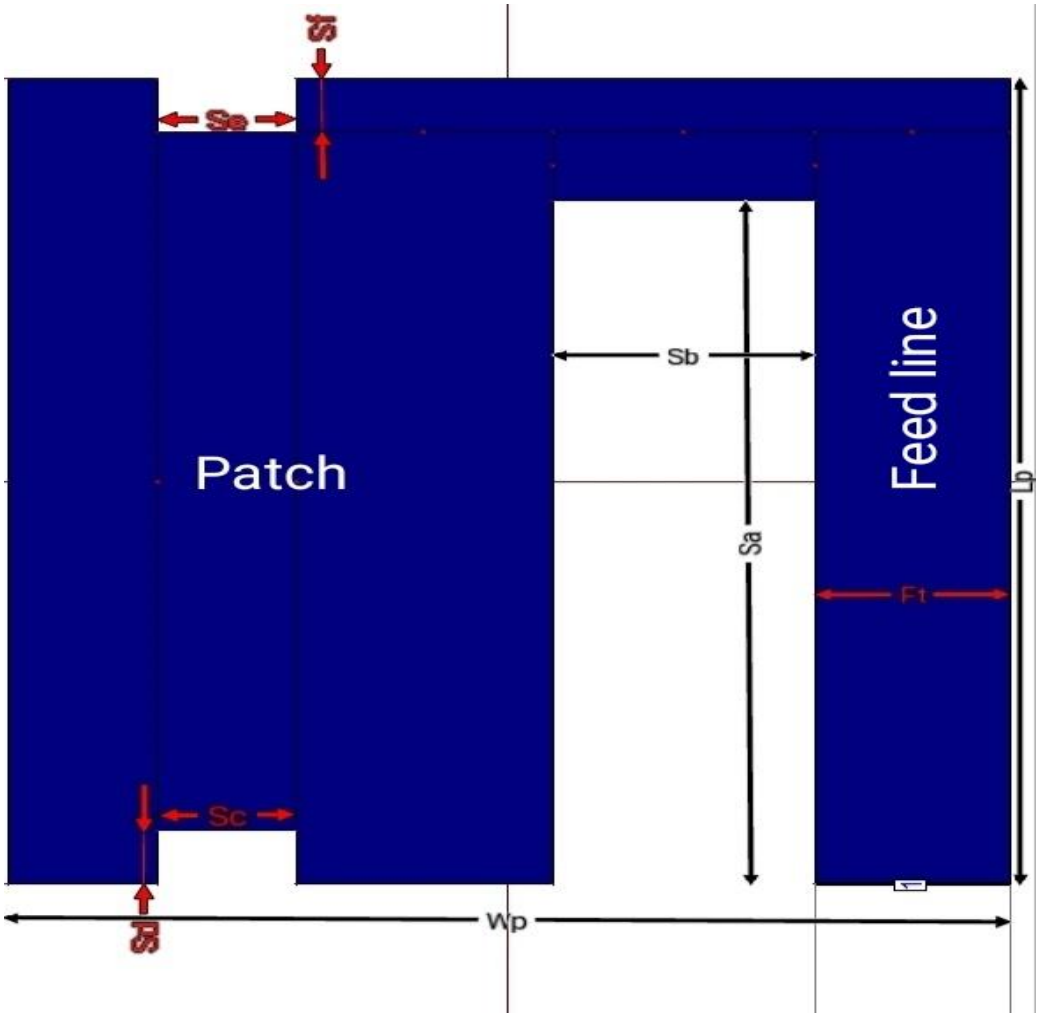

Figure 3.4 (a) Top view of the antenna with modified and combined U and H shaped patch.

Table 3.2 Dimension description of the micro-strip patch with rectangular slots

Dimensions/Parameter	Description	Values
Length of patch	Lp	30mm
Width of patch	Wp	28.5mm
Length of U slot	Sa	25.5mm
Width of U slot	Sb	7.5mm
Other two rectangular slots are parallel	Sc=Se Sd=Sf	4mm 2mm
Feed line width	Ft	4.5mm

The desired antenna with the top view is exhibited with complete dimensions in Table 3.2 above. The total width of the radiator is 28.5 mm which includes patch and feed line.

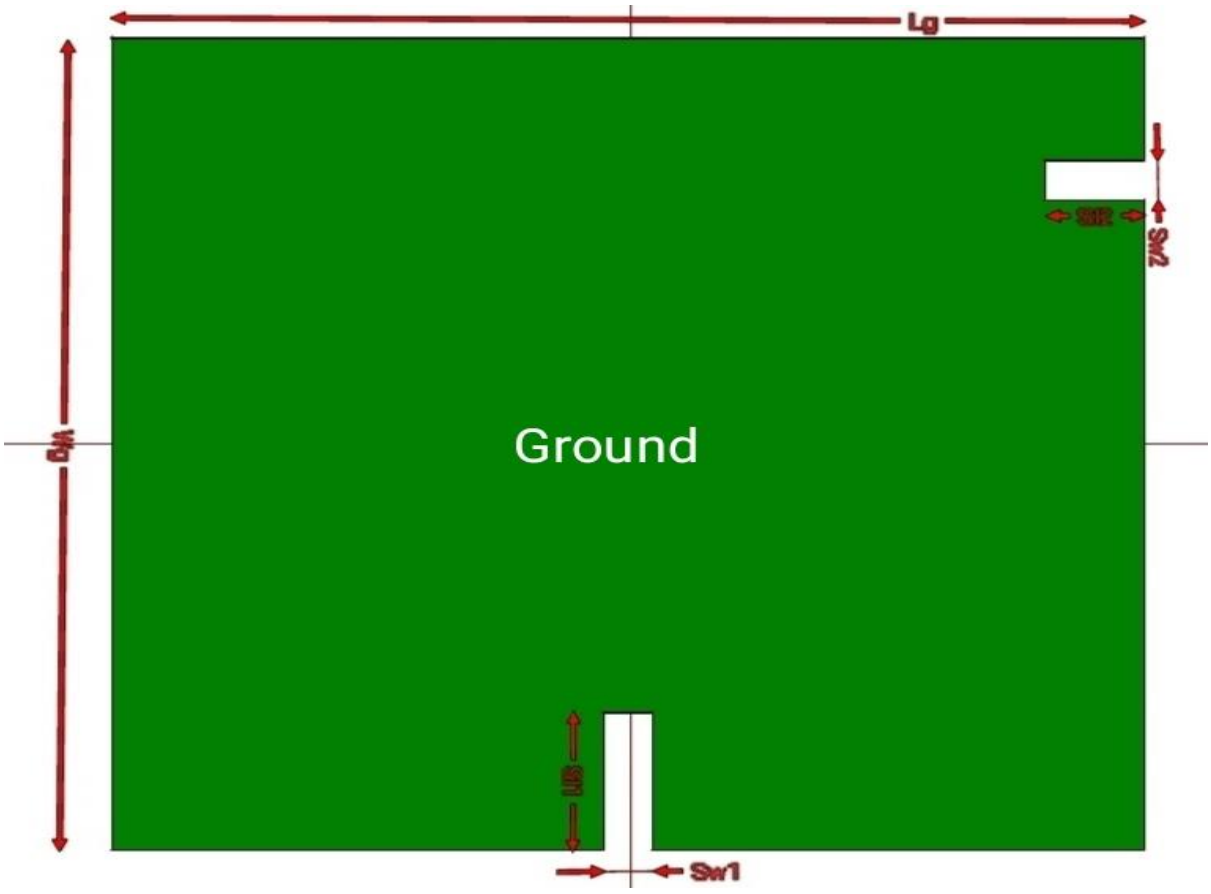

Figure 3.4 (b) Back view of the proposed antenna with two rectangular slots

Table 3.3 Dimension description of the ground plane with rectangular slots

Dimensions/Parameter	Description	Values
Length of ground	Lg	42mm
Width of ground	Wg	40mm
Length and width of rectangular slots in ground plane	Sl1 Sw1 Sl2 Sw2	6.75mm 2mm 4mm 2mm

The desired antenna from the back side has been demonstrated in the **Table 3.3** above. The back side contains the ground of length 42 mm and width 40 mm. Then the substrate is in between the ground and the patch where the ground plane and the patch is made up of conducting material. On the other hand, the dielectric substrate is predominantly used for intercepting the patch from the plane of ground of micro-strip antenna.

3.4.2 Design Procedure of Proposed Antenna

The following **Table 3.4** demonstrates the various specifications of the proposed UWB micro-strip antenna. The resonance frequencies of the designed patch antenna with modified and combined U and H shaped are 2.06GHz, 3.36GHz, 3.98GHz, 5.21GHz, 6.84GHz, 8.66GHz, and 9.72GHz. To improve the bandwidth and resonance frequencies, the rectangular slots are used. The substrate used in the antenna is RT/duroid 5880 with dielectric constant of 2.2 and thickness of 1.5mm. The micro-strip feed line is used to feed the patch. Table 3.3 demonstrates the several parameters, their description and values.

Table 3.4 Specification for the designed antenna

Parameters	Description	Value
Resonant Frequency, f_0	f1, f2, f3, f4, f5, f6, and f7 (Proposed Antenna)	2.06GHz, 3.36GHz, 3.98GHz, 5.21GHz, 6.84GHz, 8.66GHz, and 9.72GHz
Substrate Material	sub mat.	RT/duroid 5880
Dielectric Constant of substrate material	ε_r	2.2
Thickness of substrate	t_s	1.5mm
Dielectric Loss tangent	$\tan\delta$	0.0009
Feeding Technique	Micro strip feed	

3.5 Design and Optimization of RMPA

Design and result of simulation are presented in this volume for the single band MPA. The following **figure 3.5 (a)** illustrates the first step of designing RMPA with U shaped slot. Then the following **figure 3.5 (b)** illustrates the return loss of designing first step of U shaped slot in the patch using IE3D simulator.

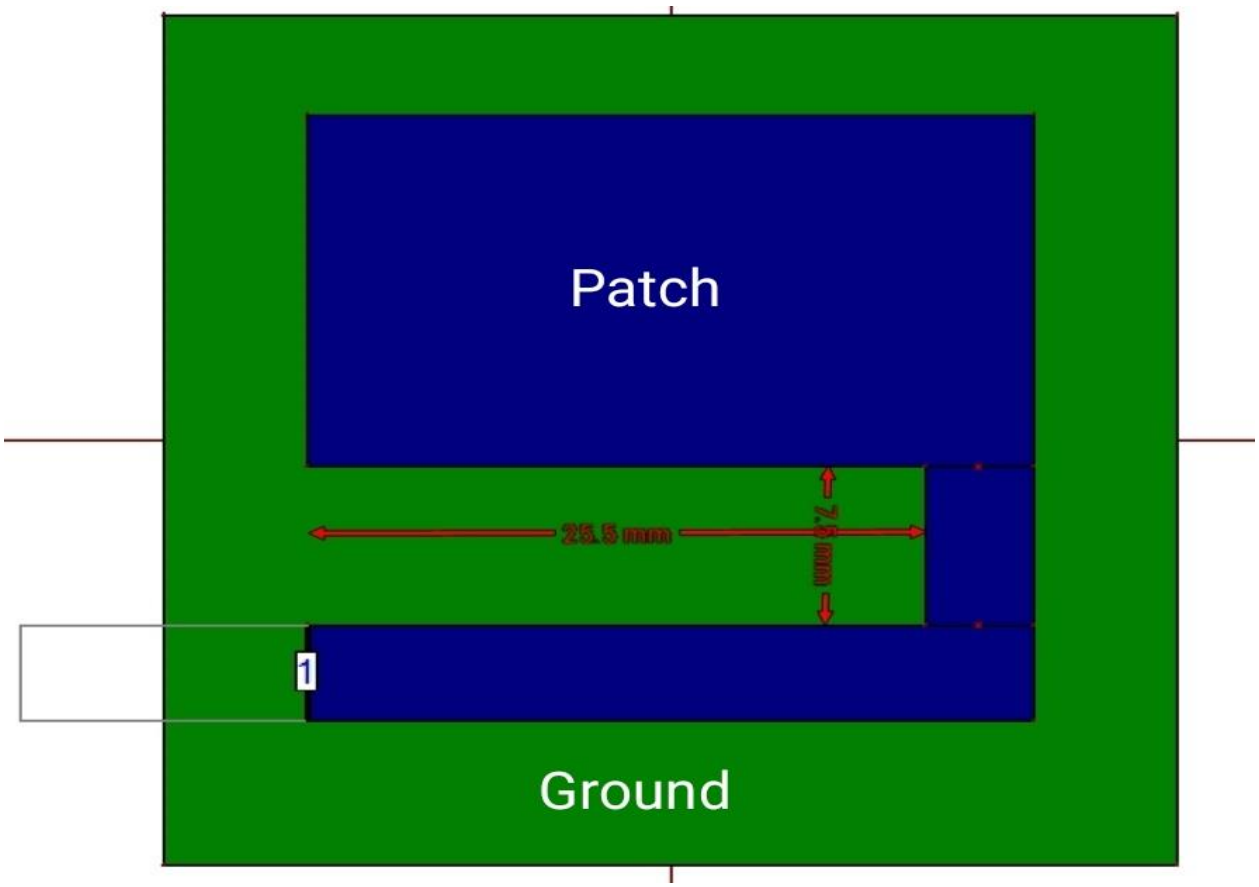

Figure 3.5 (a) Geometry with U shape of MPA after 1st Optimization

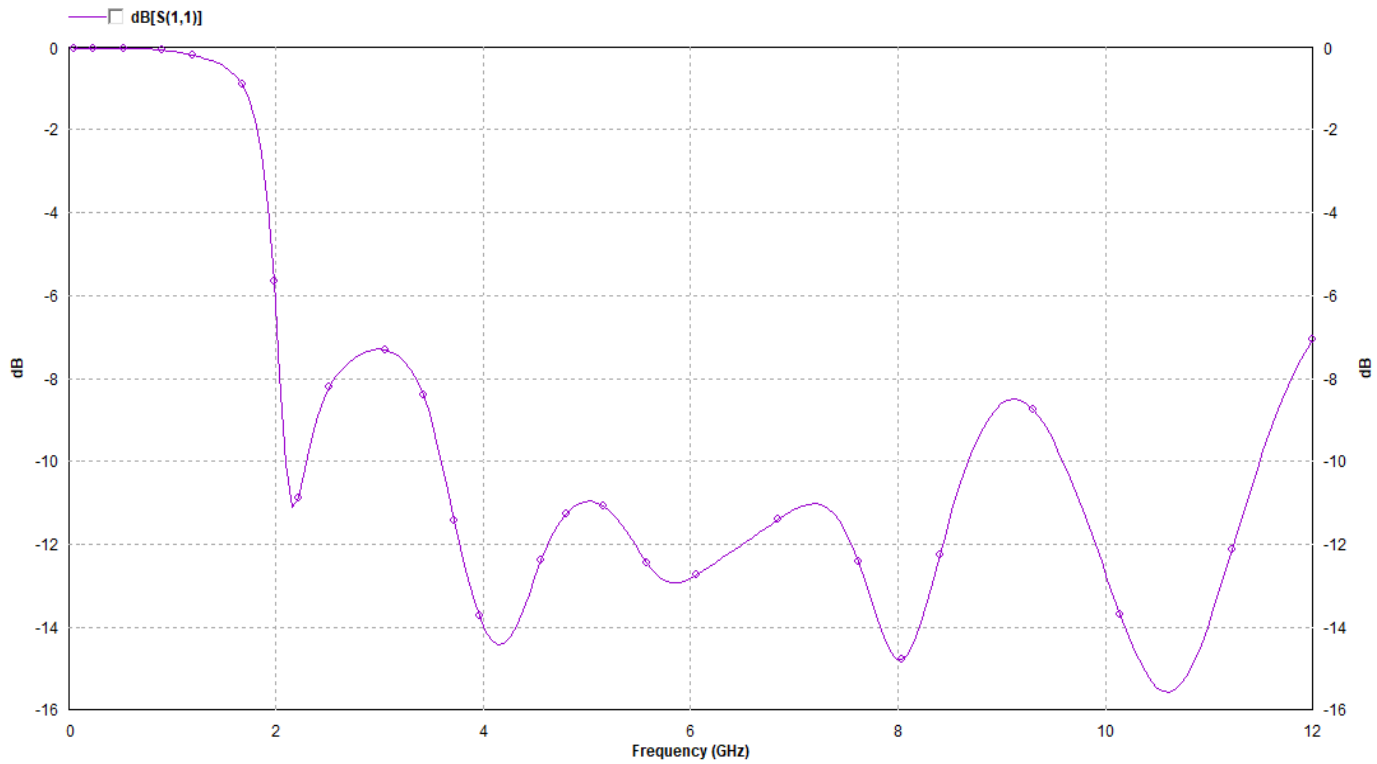

Figure 3.5 (b) Return loss with respect to position after 1st Optimization

Figure 3.5 (a) is allowed to be optimized as U-shape slot with length 25.5 mm and width 7.5 mm. In this section S-parameters are provided in **Figure 3.5 (b)** above. Combining two rectangular slots as H shape in the patch is demonstrated in the next optimization. After 2nd optimization of the proposed antenna is given following **Figure 3.5 (c)** as Geometry and **Figure 3.5 (d)** as return loss of it. Length (4mm) and width (2mm) of two rectangular slots are same and parallel face to each other for making H shape.

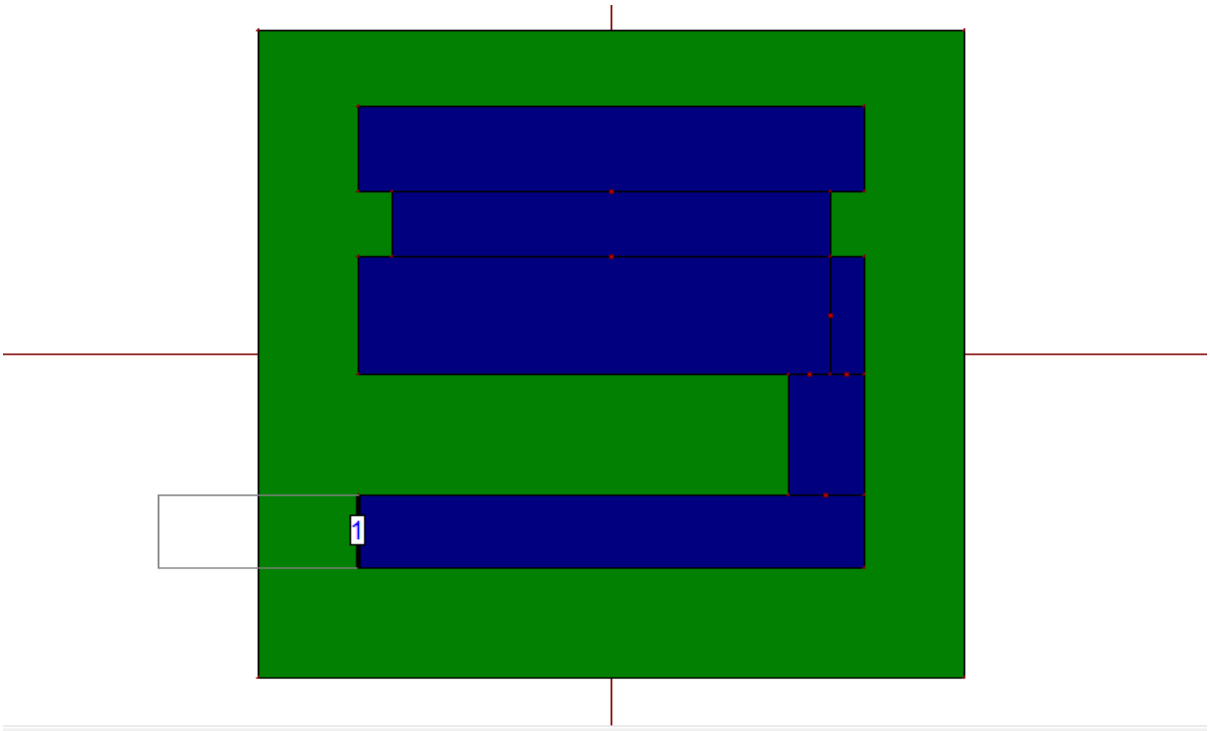

Figure 3.5 (c) Geometry with modified and combined U and H shape after 2nd optimization

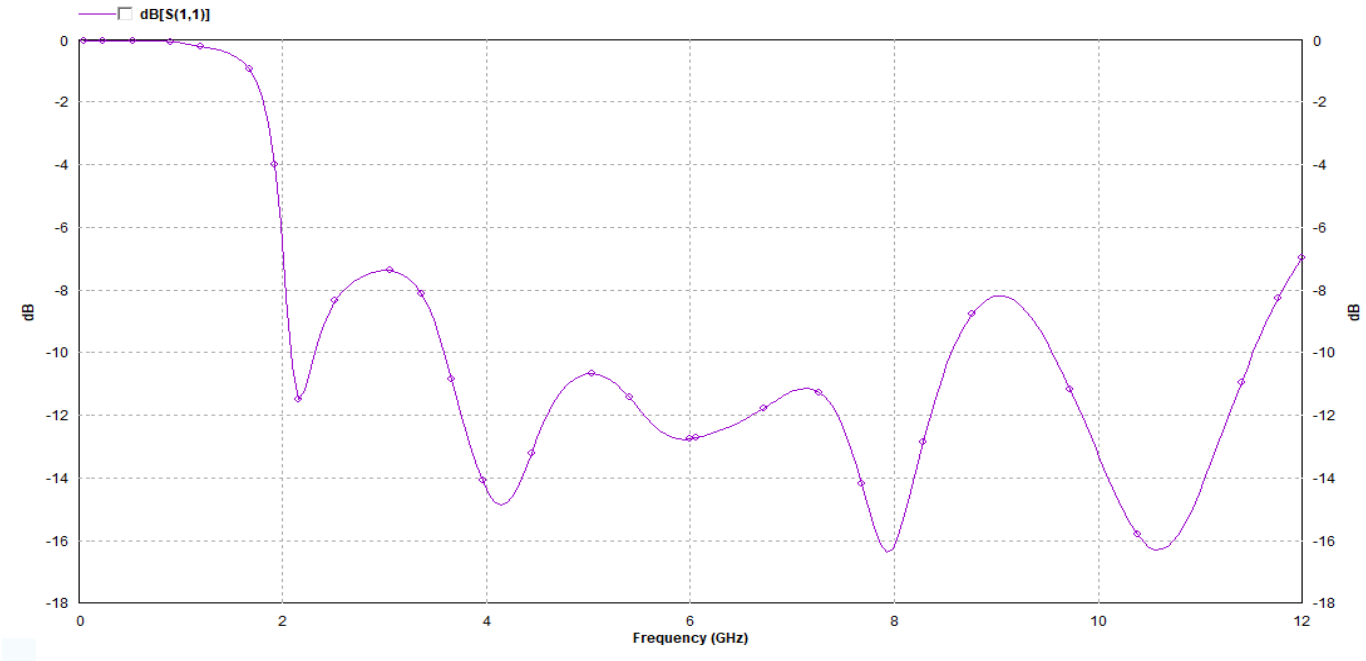

Figure 3.5 (d) Return loss with respect to position after 2nd Optimization

The final design of the optimized MPA is illustrated in **Figure 3.5(e)** with two rectangular slots in ground plane. Final value of S-parameter plot for return loss is given in **Figure 3.5(f).**

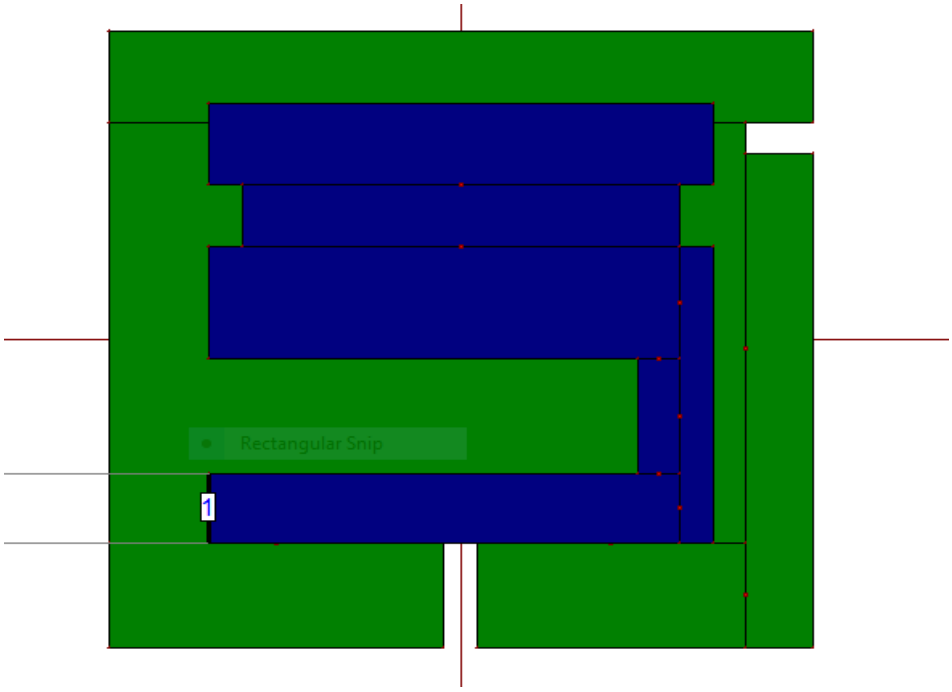

Figure 3.5(e) Final design of the optimized MPA

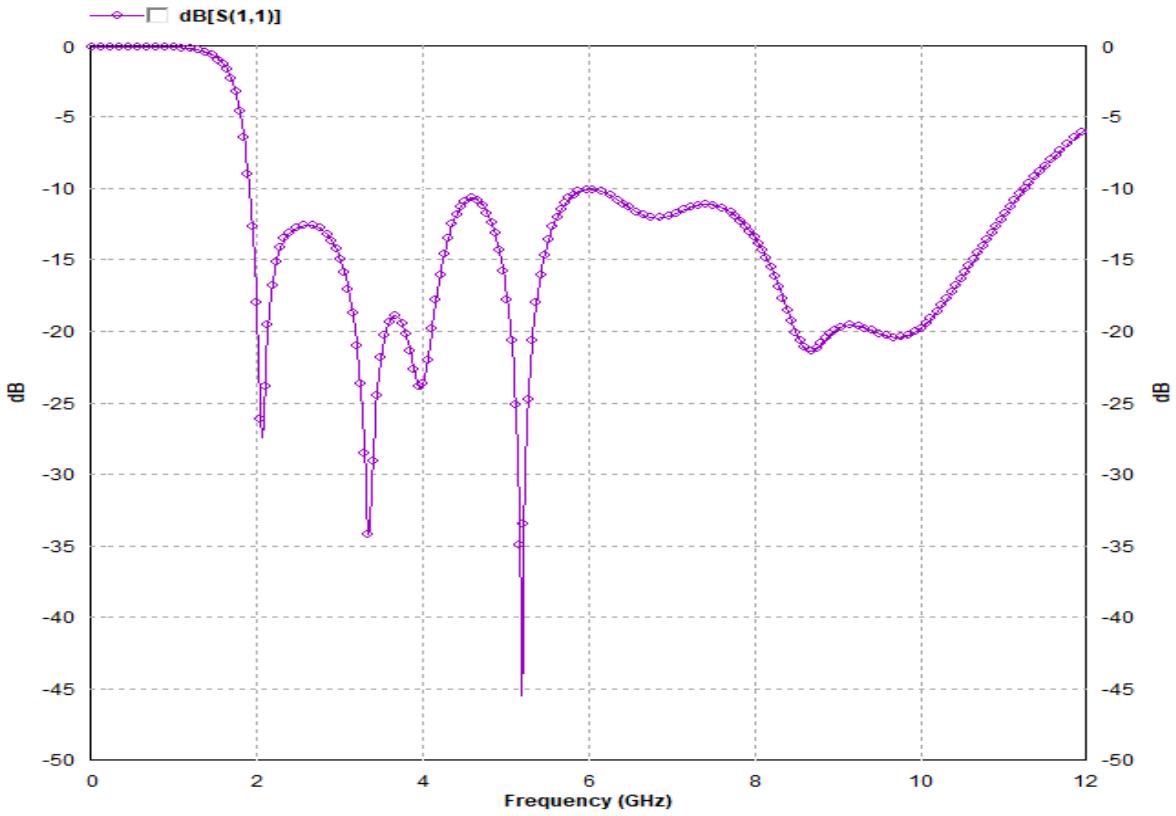

Figure 3.5(f) Optimization goal graph for Return loss v/s frequency

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Results and Discussion of the Proposed Antenna using IE3D Zeland

In the previous chapter a vivid simulation has been performed to design the desire antenna for the frequency range of 1.92-11.256 GHz. As a result we have found an antenna having an area 42x40 mm^2 with six different notch band. The resonant frequencies are 2.06GHz, 3.36GHz, 3.98GHz, 5.21GHz, 6.84GHz, 8.66GHz and 9.72GHz with lower than -10dB return loss, -27.5dB, -34dB, -24dB, -45.5dB, -12dB, -21.5dB and -20.5dB respectively. In the proposed antenna slot cutting technique has been assigned for better antenna characteristics. Modified and combined U and H shape slots are imposed in this patch antenna to increase the bandwidth. The proposed antenna has bandwidth of 9.35 GHz and it can cover 100% of S, C and X band frequency range, it means antenna has the ability of UWB application.

All the antennas are explored by the performance analysis under the IE3D simulator. We should examine our antenna operation in each of the standards by our antennas bandwidth, return loss, average current distribution, vector current distribution, 2D, 3D radiation patterns of gain and directivity for a frequency in each bands. The current distribution provides us an insight into the antenna structure by showing the density and the direction of current movement inside the patch at different frequencies. It also gives us how different part of the antenna behaves for different operating frequencies. 2D and 3D radiation pattern demonstrates us how antenna radiates its output signal. 2D radiation profile provides information about the gain and polarization of E-H fields where as 3D radiation patterns can illustrate the directivity and emission style. If all the distribution and pattern at all operating frequencies are found satisfactory only then we can proceed to future works with this simulated model [24].

4.1.1 Average Current distribution

Average current distribution demonstrates average intensity of the current in terms of colour representation on the patch at each location. It can be noticed from the average current distribution which is radiating and which is non-radiating side. However, the simulation results observed antenna at six different frequencies f = 2.06GHz, 3.36GHz, 3.98GHz, 5.21GHz, 6.84GHz, 8.66GHz and 9.72GHz with 10 cells per wavelength for better precision and it illustrates the average current distribution over the antenna surface [26].

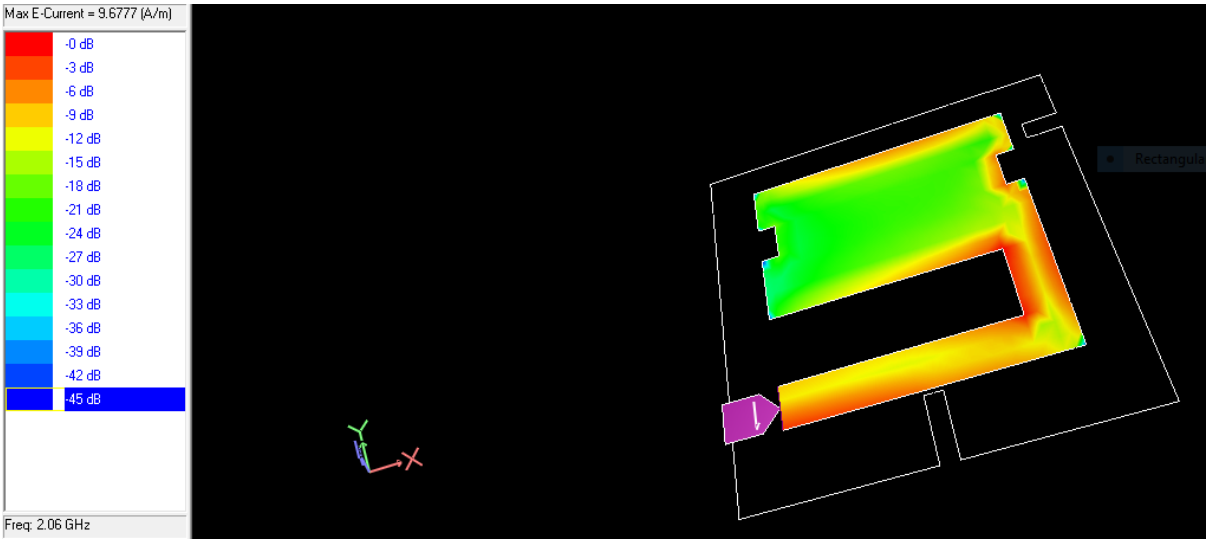

Figure 4.1(a) Average current distribution of proposed antenna at 2.06 GHz

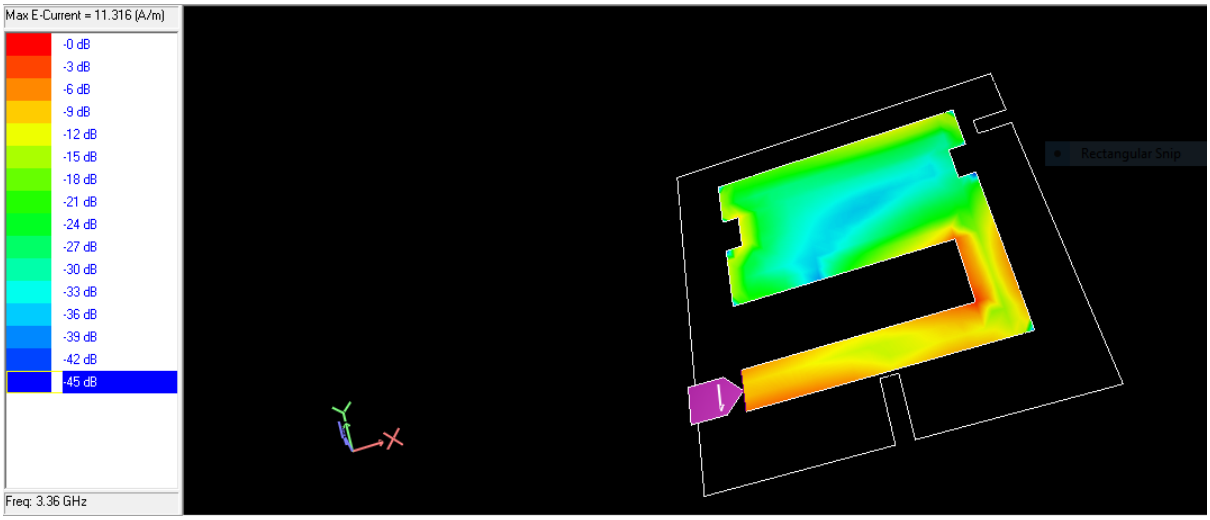

Figure 4.1(b) Average current distribution of proposed antenna at 3.36 GHz

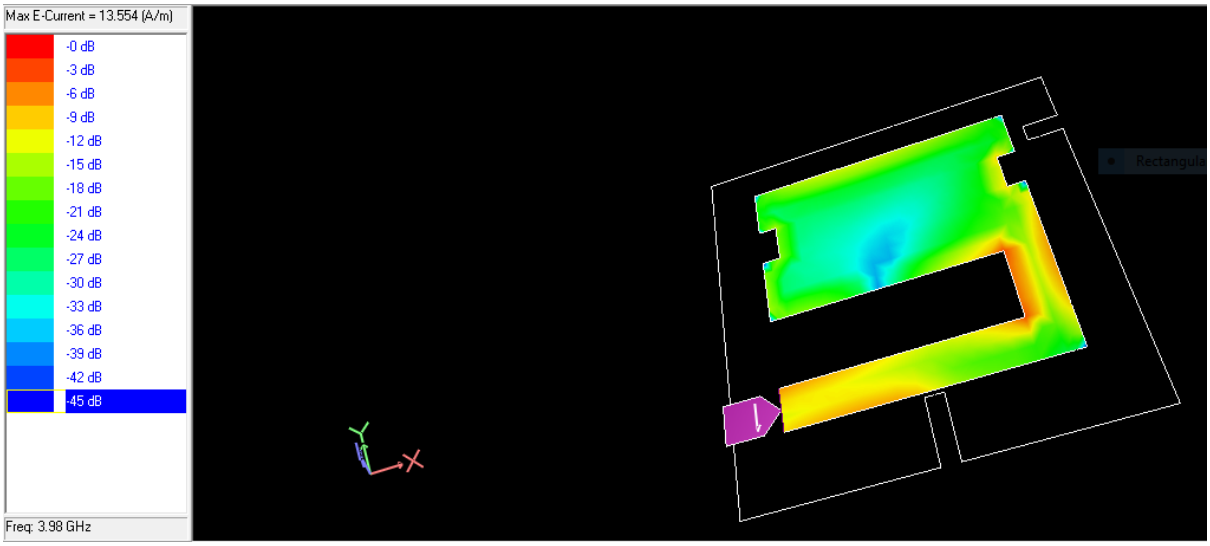

Figure 4.1(c) Average current distribution of proposed antenna at 3.98 GHz

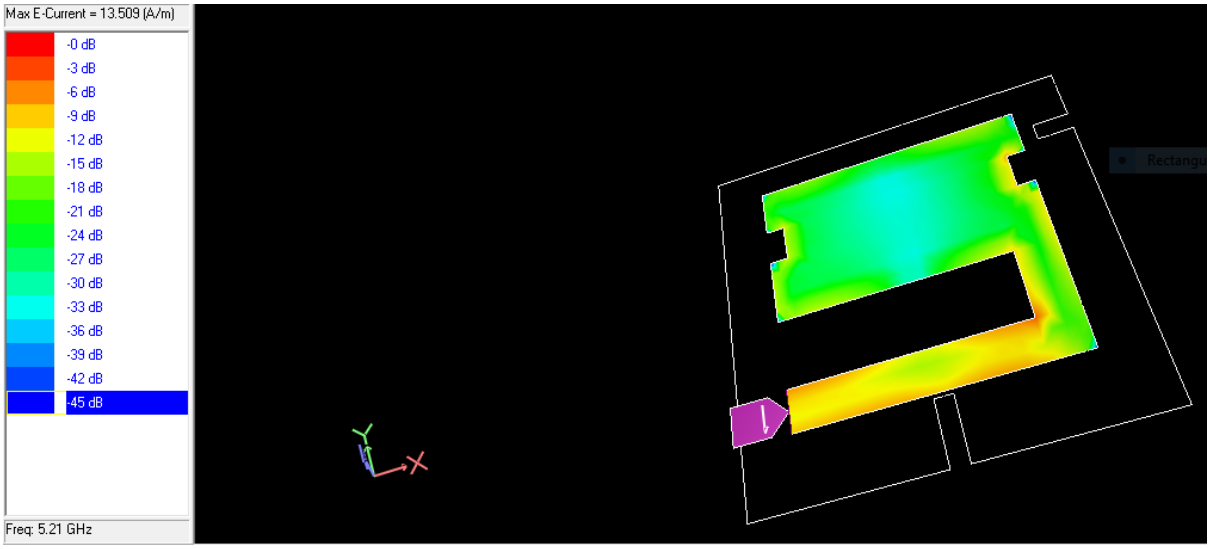

Figure 4.1(d) Average current distribution of proposed antenna at 5.21 GHz

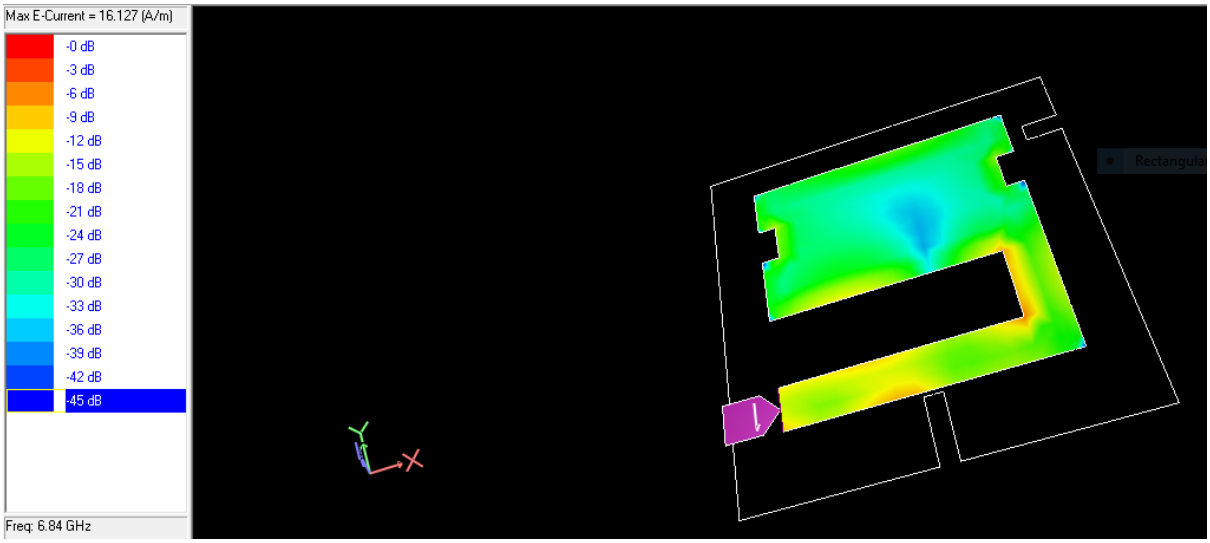

Figure 4.1(e) Average current distribution of proposed antenna at 6.84 GHz

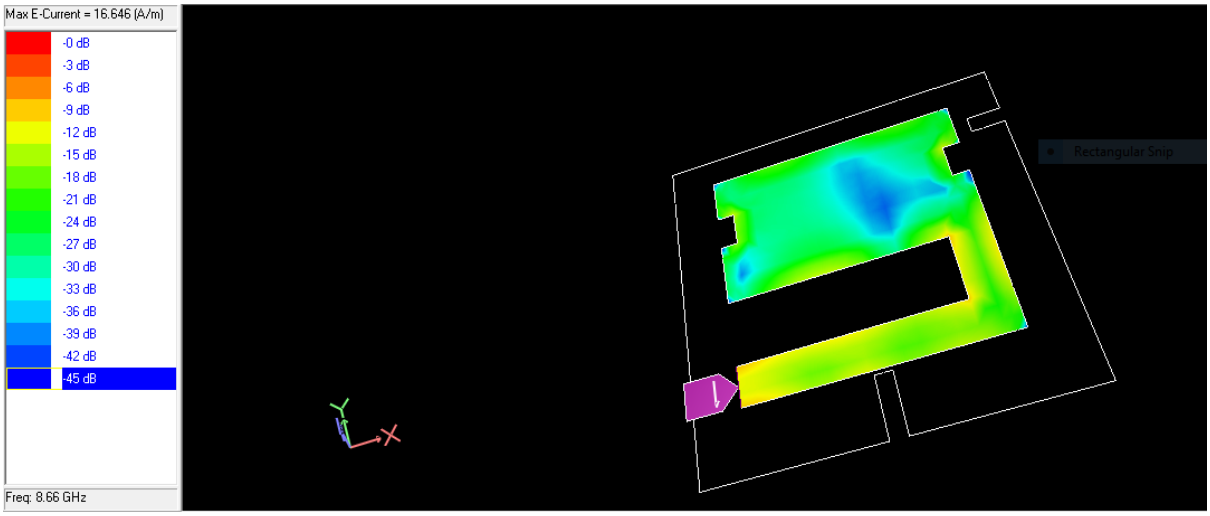

Figure 4.1(f) Average current distribution of proposed antenna at 8.66 GHz

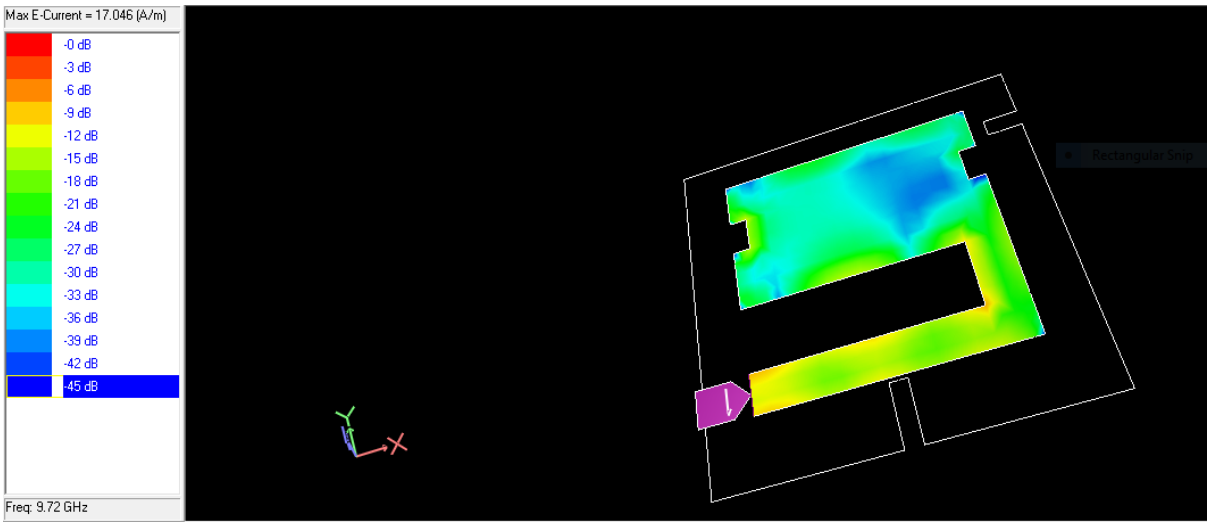

Figure 4.1(g) Average current distribution of proposed antenna at 9.72 GHz

4.1.2 Vector Current Distribution

Vector current distribution demonstrates how the current is distributed and how the current flows in the surface of the antenna. It also supports us to determine the polarization of the antenna and the density of current at different frequencies. For same frequencies we will now compare the current vector distribution on the surface of patch to understand the frequency response better [24].

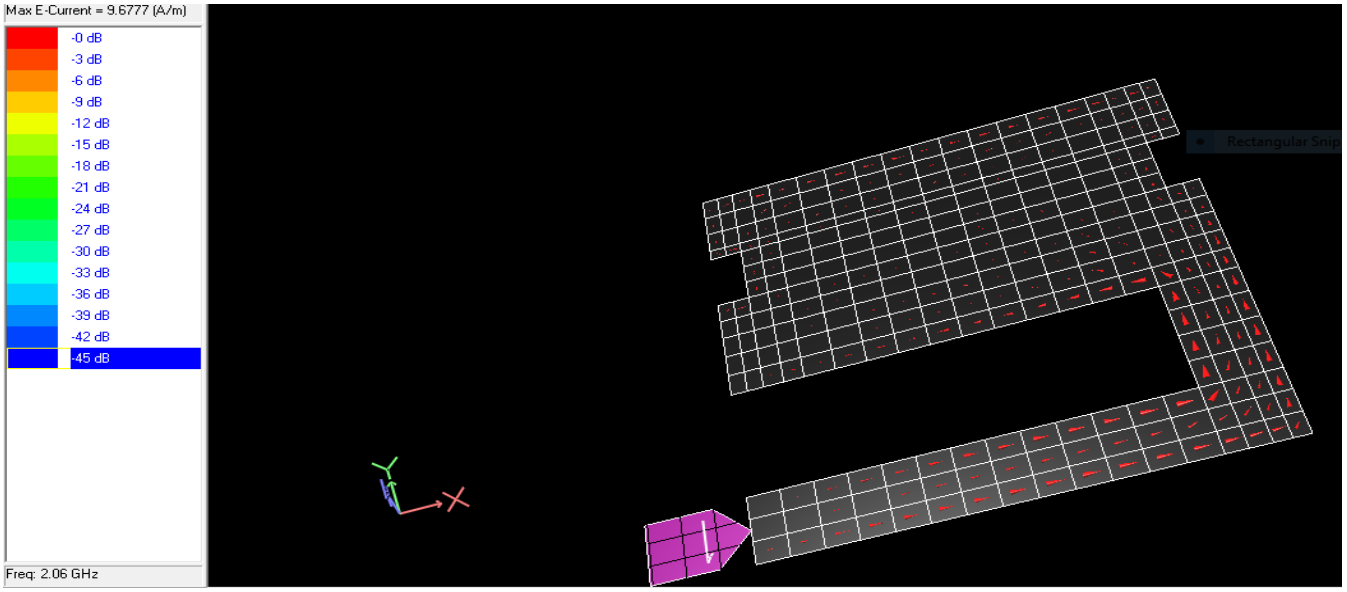

Figure 4.2(a) Vector current distribution of proposed antenna at 2.06 GHz

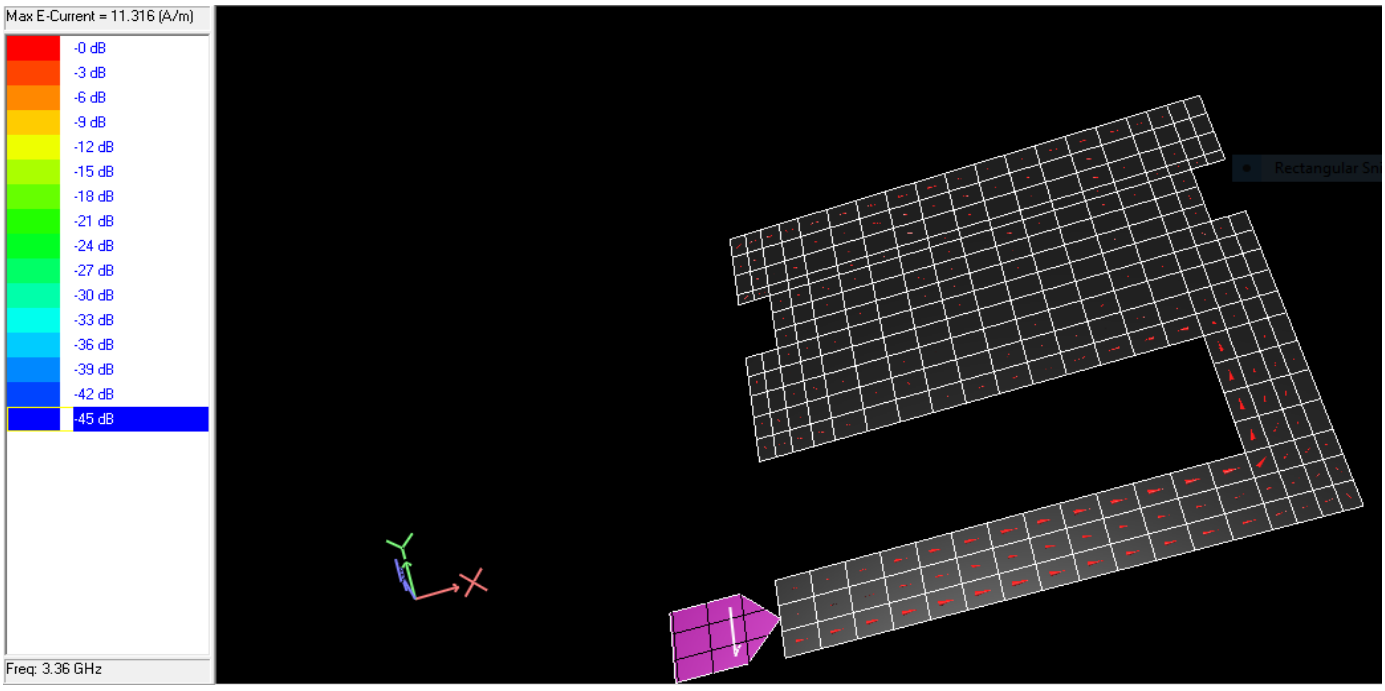

Figure 4.2(b) Vector current distribution of proposed antenna at 3.36 GHz

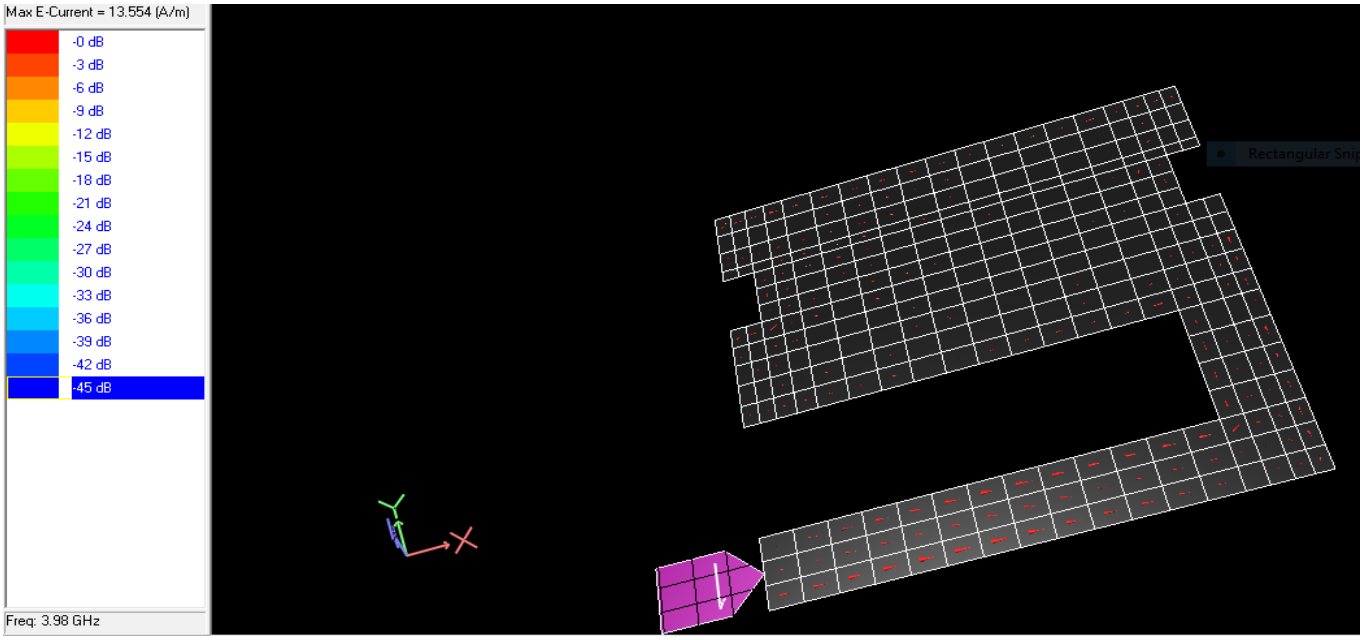

Figure 4.2(c) Vector current distribution of proposed antenna at 3.98 GHz

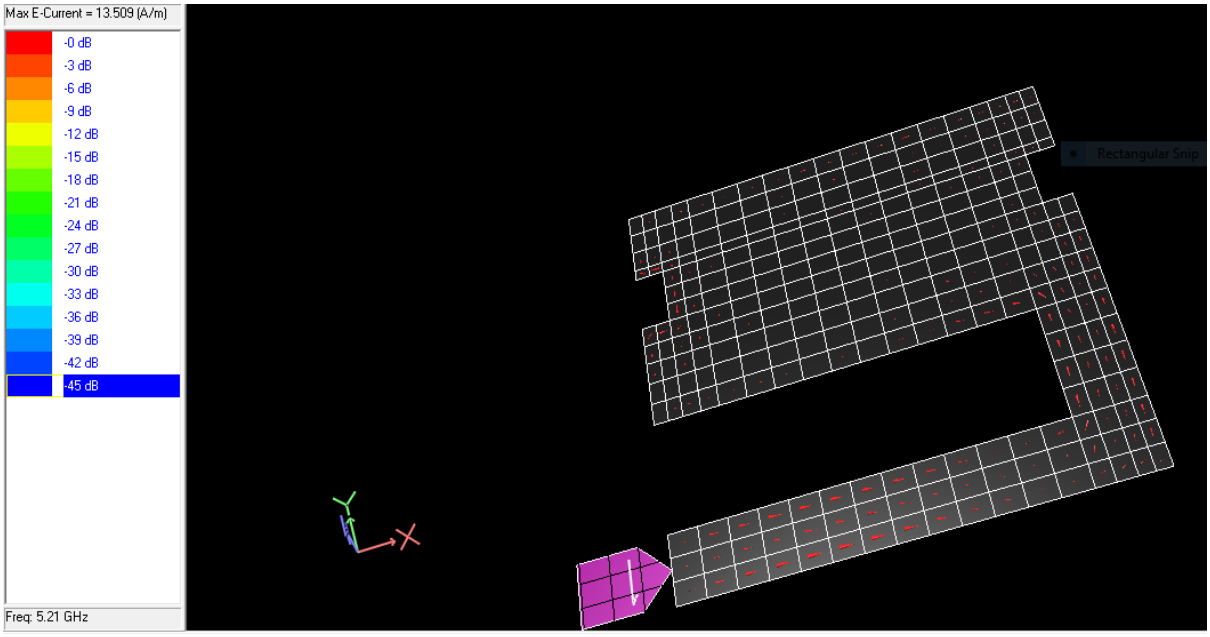

Figure 4.2(d) Vector current distribution of proposed antenna at 5.21 GHz

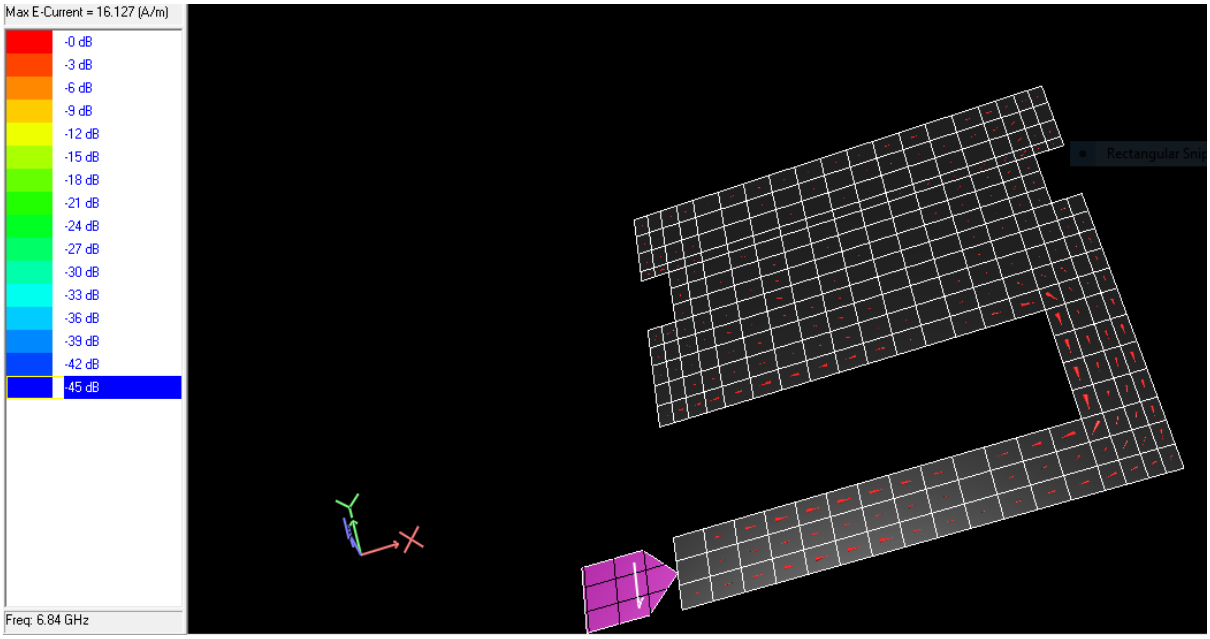

Figure 4.2(e) Vector current distribution of proposed antenna at 6.84 GHz

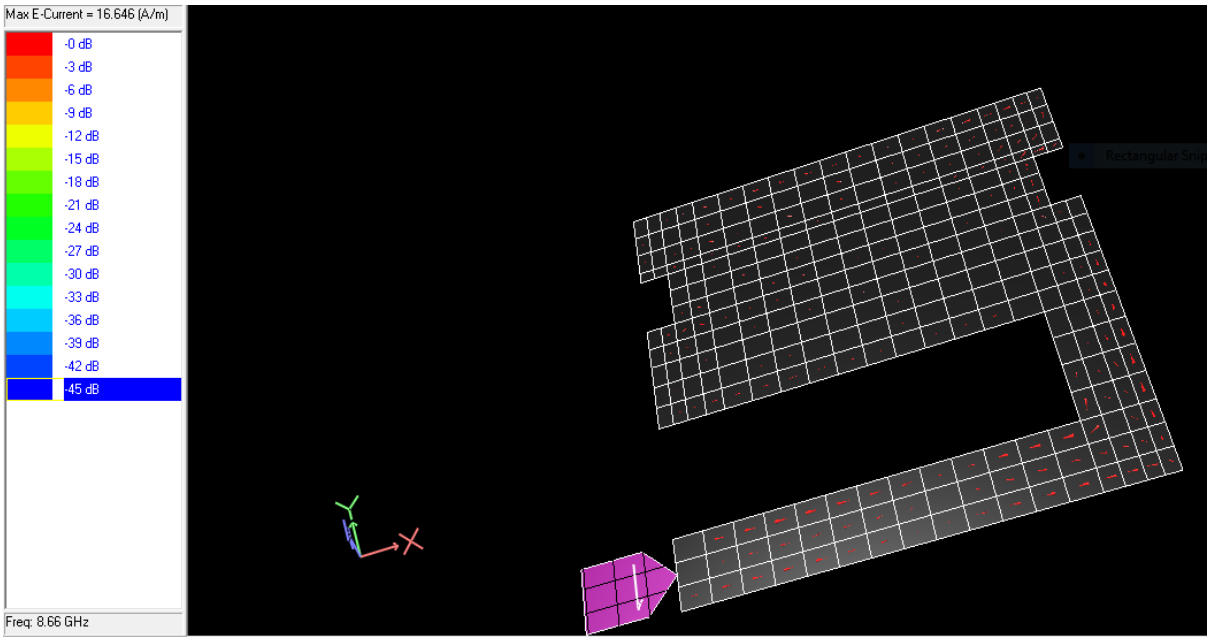

Figure 4.2(f) Vector current distribution of proposed antenna at 8.66 GHz

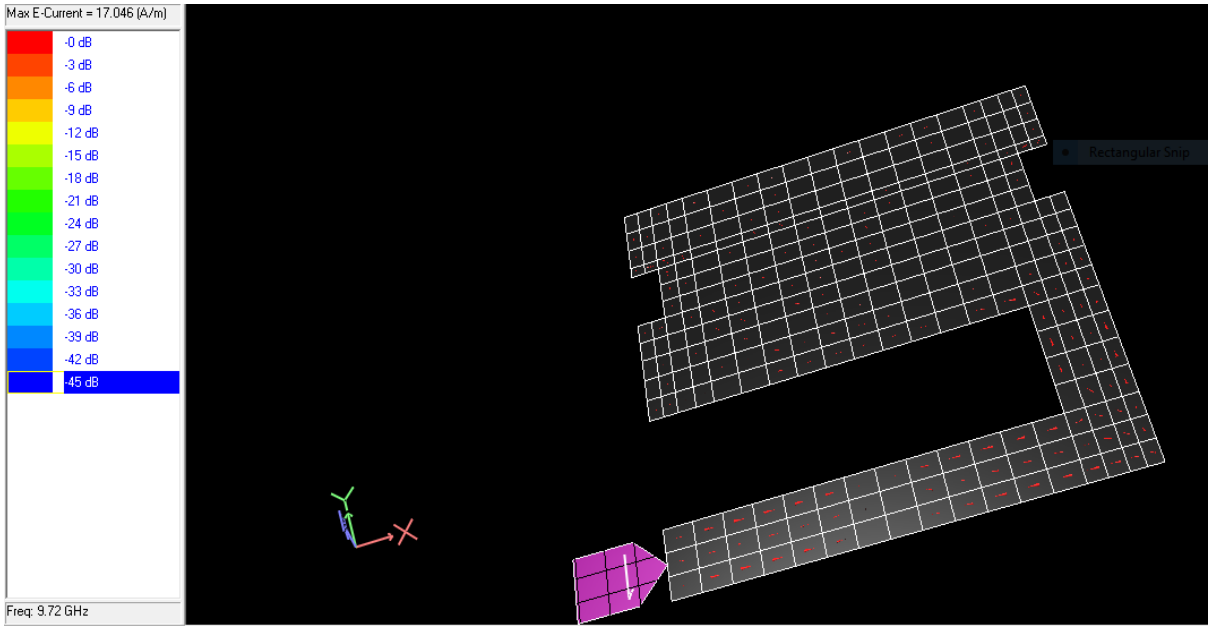

Figure 4.2(g) Vector current distribution of proposed antenna at 9.72 GHz

4.1.3 2D Radiation Pattern

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

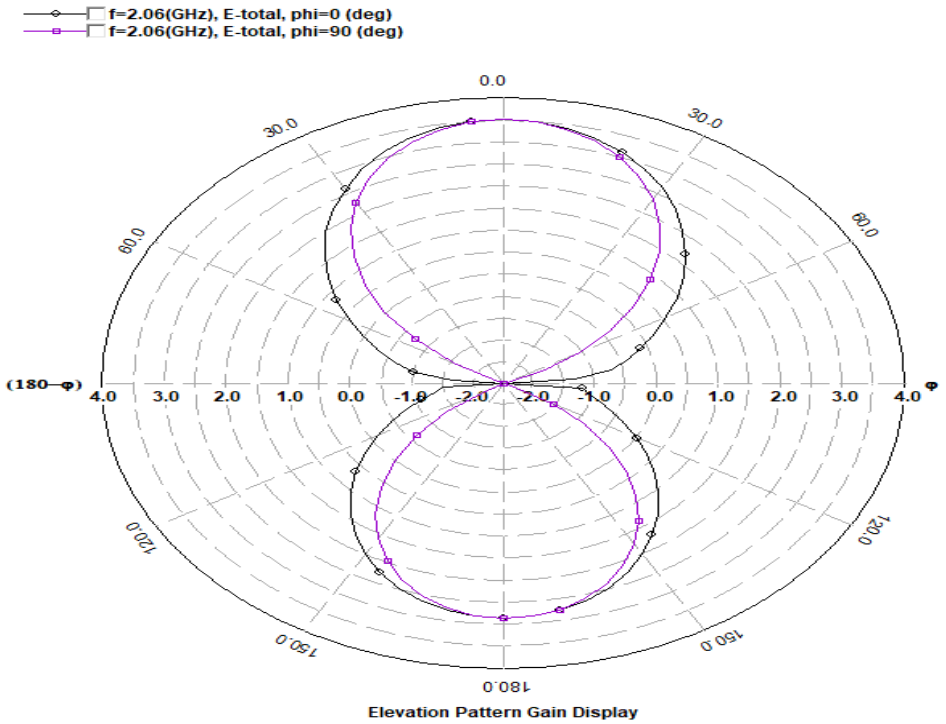

Figure 4.3(a) 2D radiation pattern of proposed antenna at 2.06 GHz

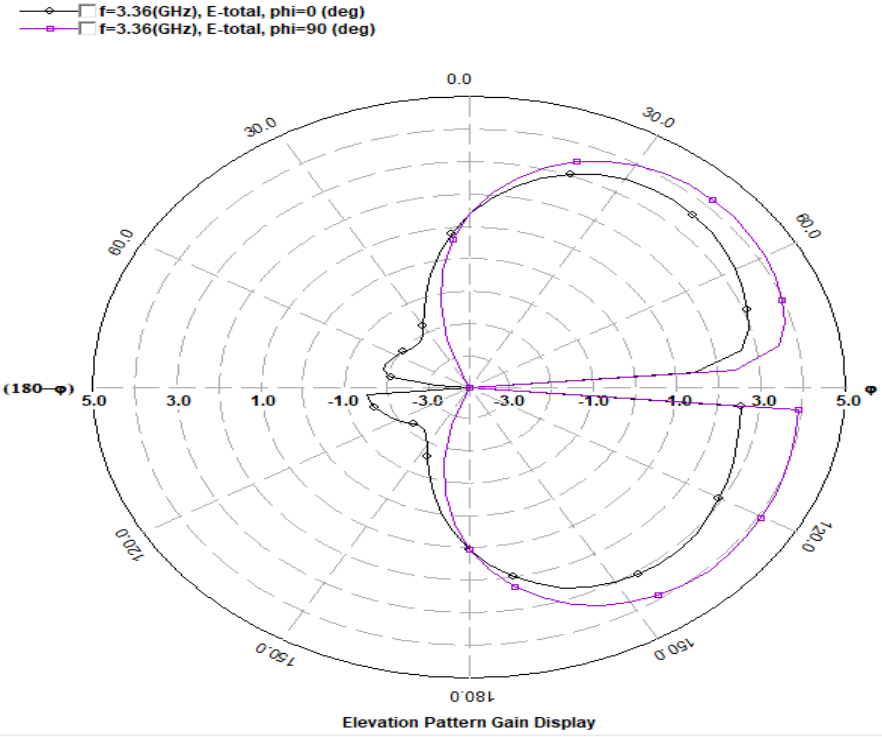

Figure 4.3(b) 2D radiation pattern of proposed antenna at 3.36 GHz

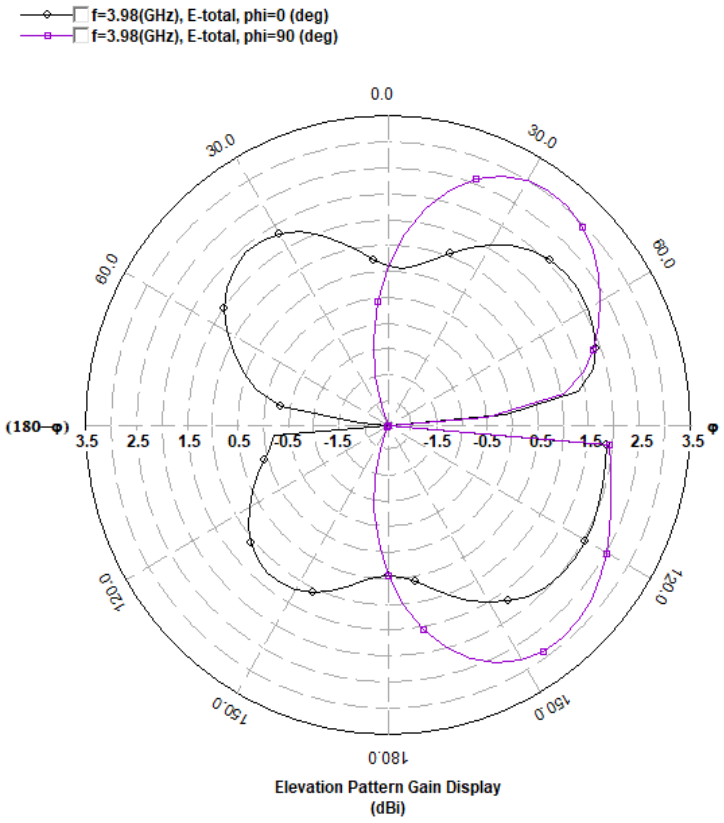

Figure 4.3(c) 2D radiation pattern of proposed antenna at 3.98 GHz

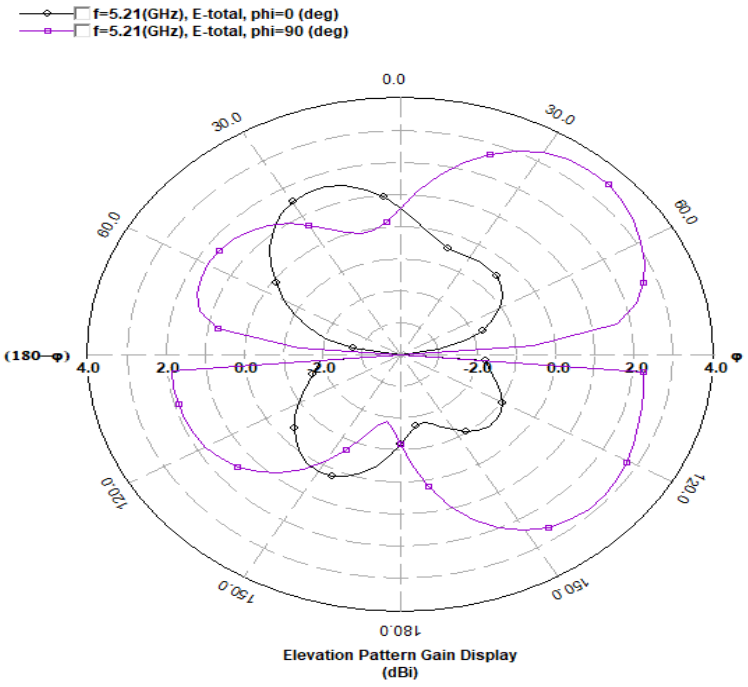

Figure 4.3(d) 2D radiation pattern of proposed antenna at 5.21 GHz

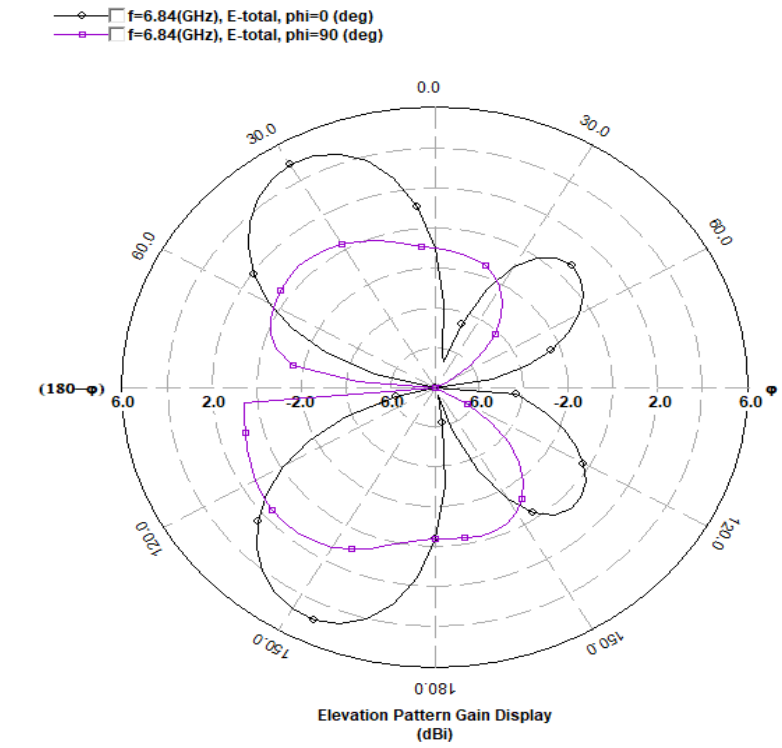

Figure 4.3(e) 2D radiation pattern of proposed antenna at 6.84 GHz

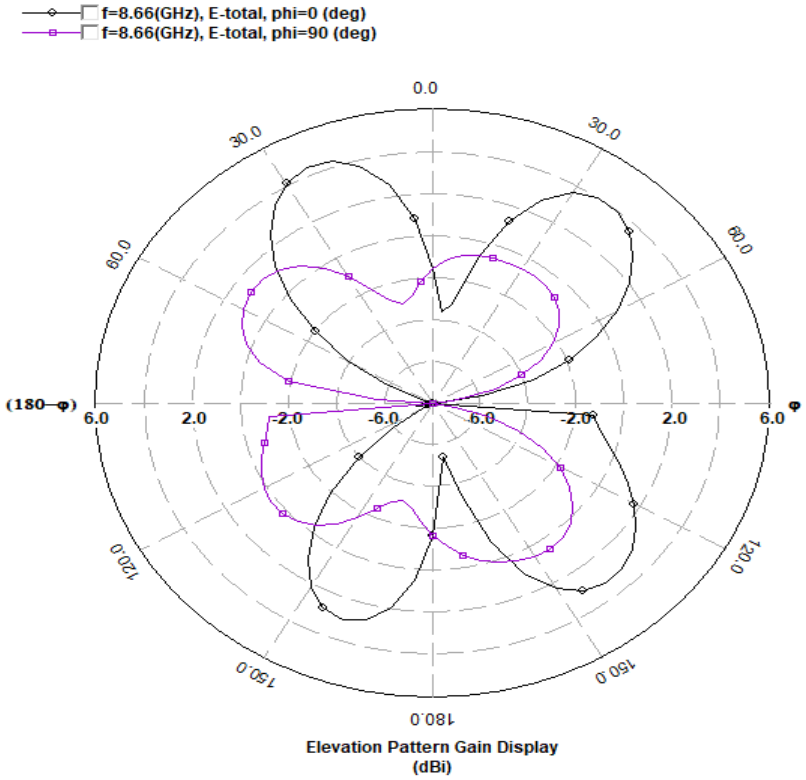

Figure 4.3(f) 2D radiation pattern of proposed antenna at 8.66 GHz

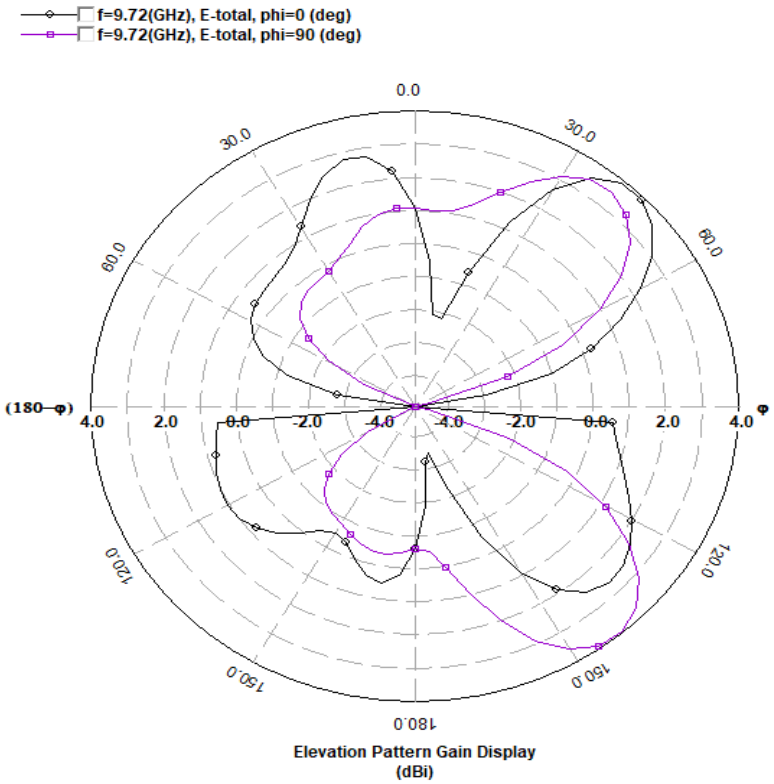

Figure 4.3(g) 2D radiation pattern of proposed antenna at 9.72 GHz

4.1.4 3D Radiation Pattern

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

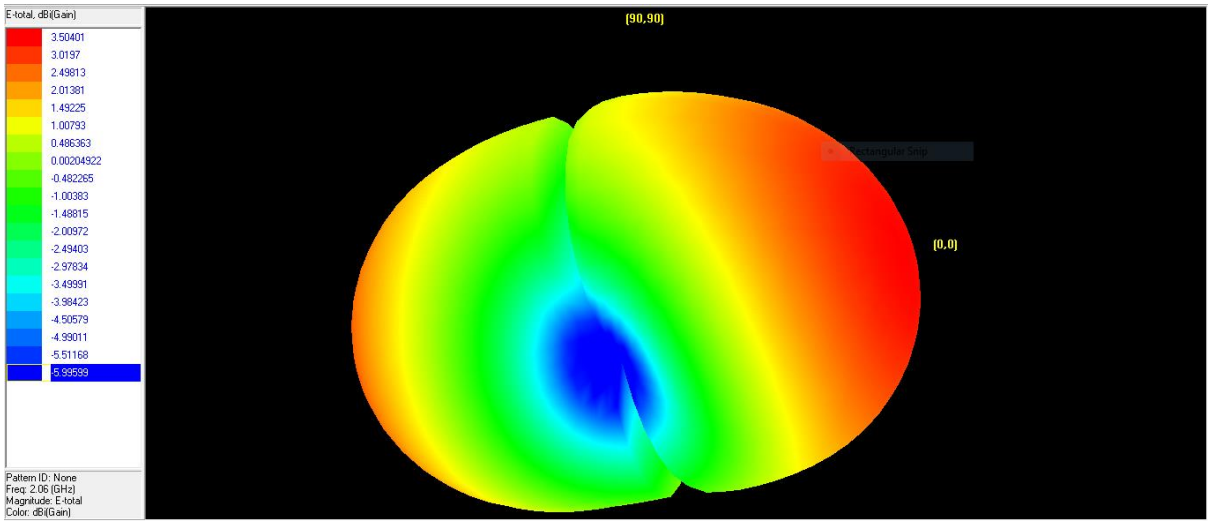

Figure 4.4(a) 3D radiation pattern at 2.06 GHz

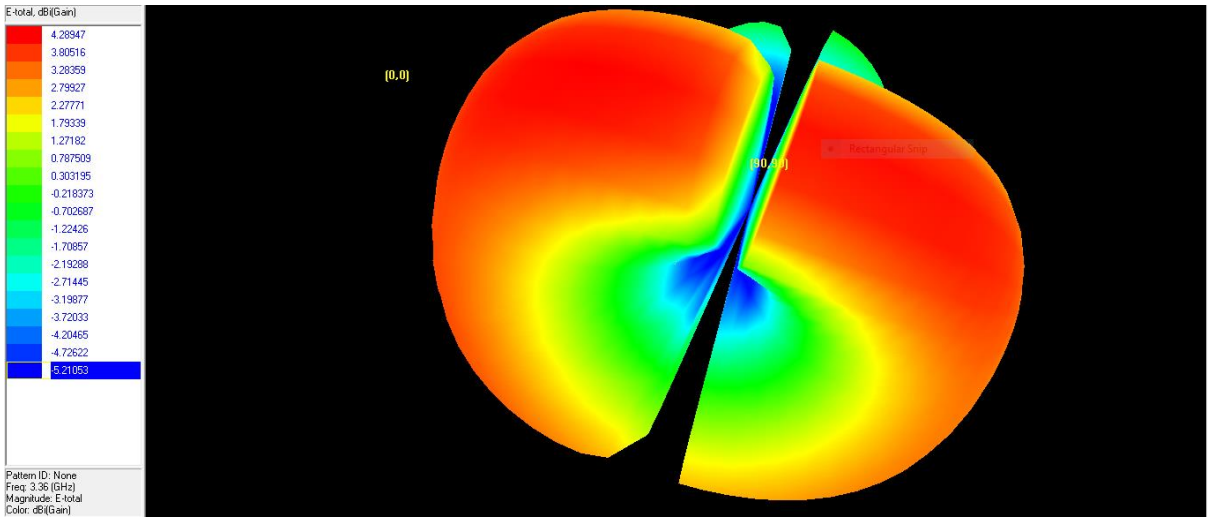

Figure 4.4(b) 3D radiation pattern at 3.36 GHz

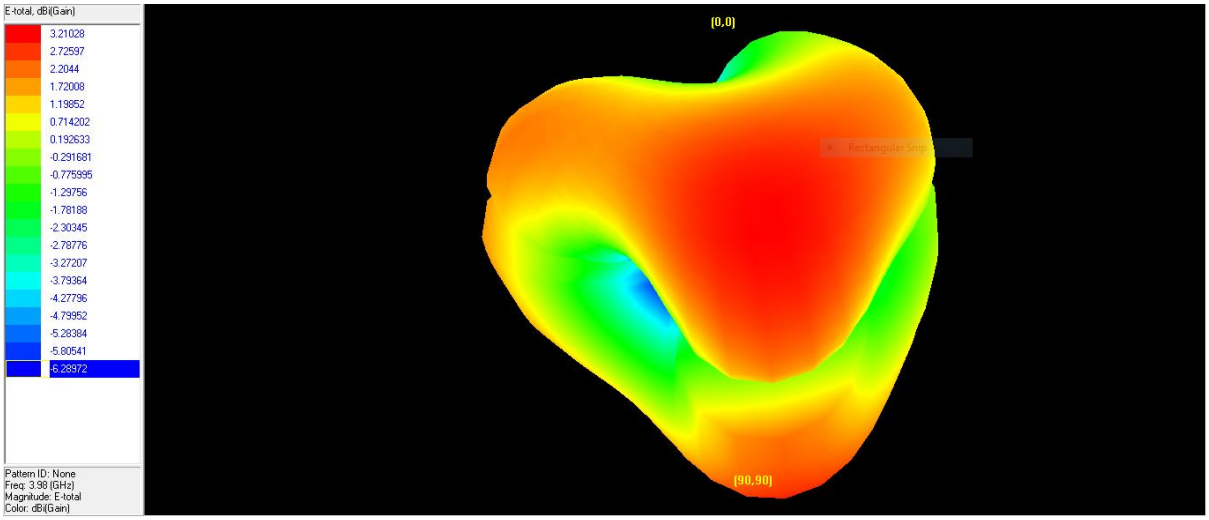

Figure 4.4(c) 3D radiation pattern at 3.98 GHz

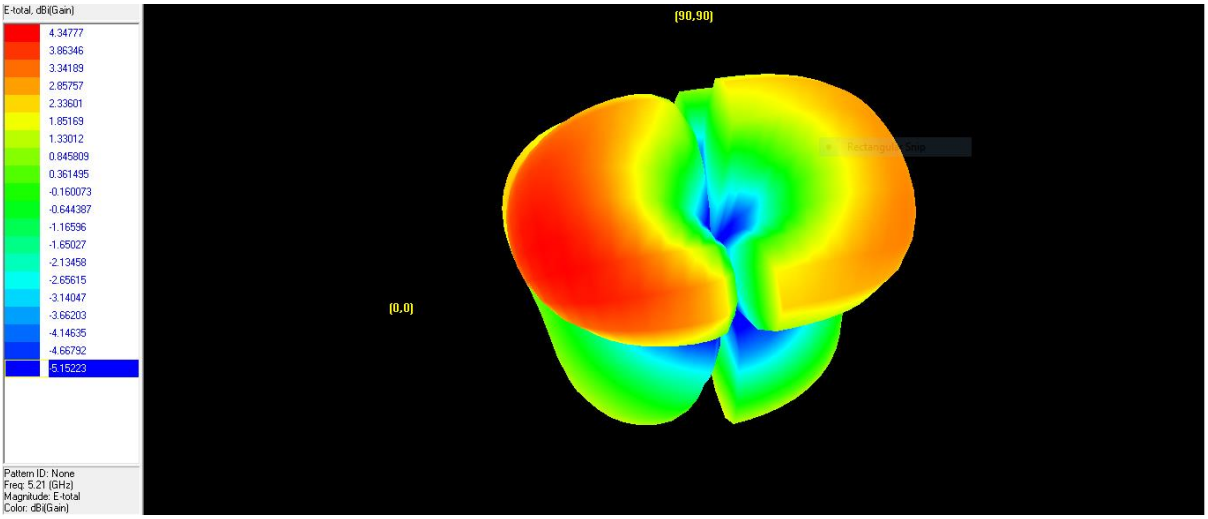

Figure 4.4(d) 3D radiation pattern at 5.21 GHz

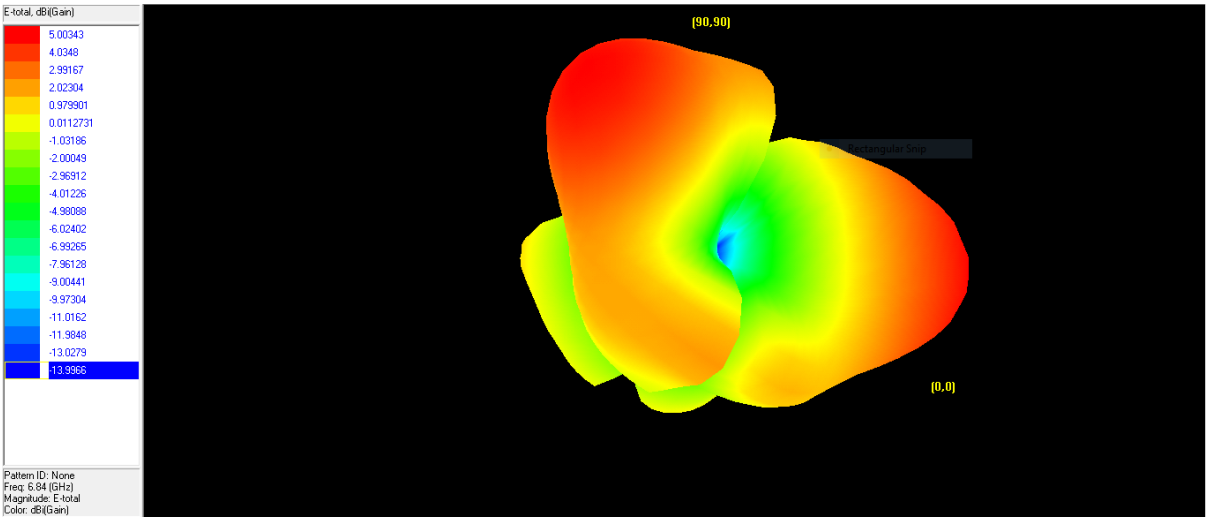

Figure 4.4(e) 3D radiation pattern at 6.84 GHz

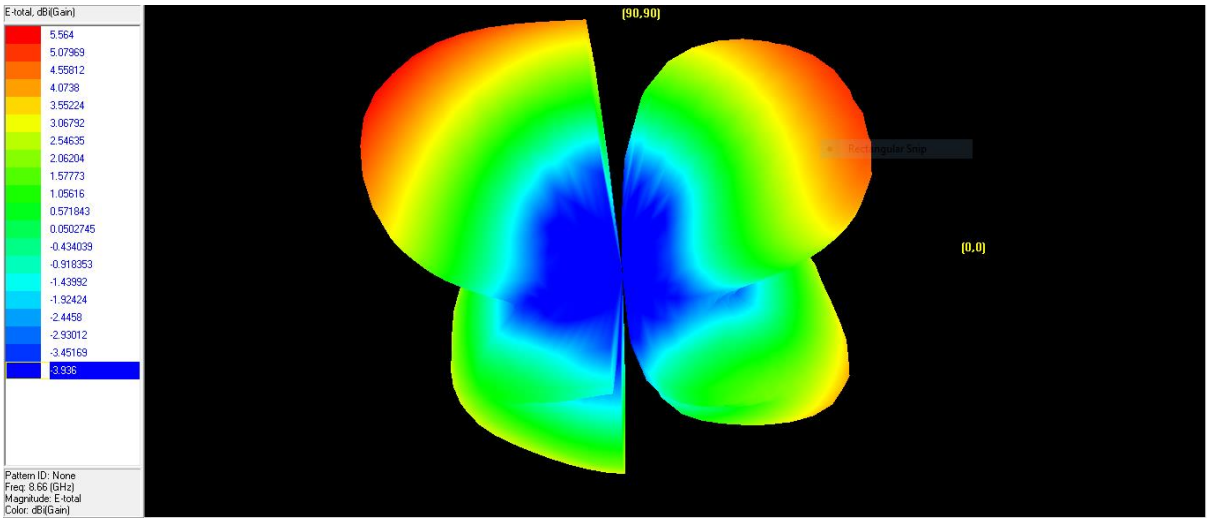

Figure 4.4(f) 3D radiation pattern at 8.66 GHz

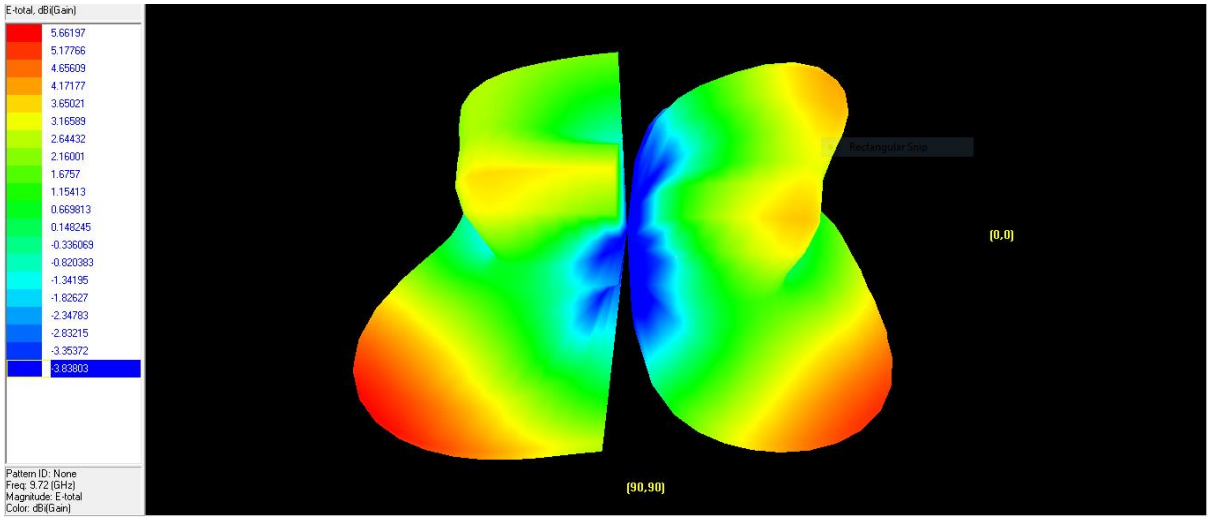

Figure 4.4(g) 3D radiation pattern at 9.72 GHz

The maximum gain and directivity of the proposed antenna are 8.1135 dBi and 8.431 dBi respectively.

Table 4.1: The results of proposed antenna after simulation.

Antenna Parameters	RMPA with modified and combined U and H shape						
Resonant Frequency (GHz)	2.064	3.36	3.984	5.208	6.84	8.664	9.72
Return Loss (dB)	-27.5	-34	-24	-45.5	-12	-21.5	-20.5
Bandwidth (GHz)	9.35294						
Gain (dBi)	6.12	7.003	6.151	6.956	8.25	8.143	8.126
Directivity (dBi)	6.296	7.047	6.178	7.011	8.531	8.173	8.189
Efficiency (%)	95.6	98.9	99.4	98.7	93.6	99.3	98.5

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

Parameters	References					Proposed Antenna
	4	12	14	16	9	
Substrate Height (mm)	0.8	1.525	1.6	1.6	1.4	1.5
Length (mm)	42	70	32	40	40.16	42
Width (mm)	24	90	24	40	42.56	40
Band Width	7.8 GHz	7.5 GHz	8.1 GHz	Max. 2.82 GHz	7.5 GHz	9.35 GHz
Return Loss	N/A	-30 dB	-30 dB	-40 dB	-35	-45.5 dB
Gain (dBi)	3.5	3.5	3.38	Max. 5.9	N/A	8.25024
Directivity	Low	Low	N/A	N/A	N/A	8.531

CHAPTER 5

CONCLUSION & FUTURE WORKS

5.1 Major Contribution of the Thesis

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

In this thesis, the narrow bandwidth and low gain problem for UWB patch antenna has been observed. The slot cutting method is applied in this proposed antenna which affects electromagnetic properties of host medium, therefore it has the working power to improve bandwidth and gain. This thesis narrates a successive improvement in antenna characteristic from a compact microstrip line fed UWB antenna designing process. The bandwidth of the proposed antenna is capitally raised by modified and combined U and H shape patch and further improvement is performed by inserting two rectangular slots in ground plane and changing the substrate material. The dimension of patch and ground is 30 × 28.5 mm^2 and 42 × 40 mm^2 respectively with substrate height of 1.5 mm. The proposed patch antenna covers full S, C, and X band with six resonant frequencies at 2.06GHz, 3.36GHz, 3.98GHz, 5.21GHz, 6.84GHz, 8.66GHz and 9.72GHz. The reflection coefficient or return loss at these frequencies are -27.5dB, -34dB, -24dB, -45.5dB, -12dB, -21.5dB and -20.5dB respectively and VSWR is less than 2 for the whole UWB antenna. Maximum gain and directivity of the structure are 8.1135 dBi and 8.431 dBi respectively.

All these optimization have performed using Zeland's IE3D electromagnetic simulation software. A comparative study with existing literature has been given to understand the effects of various parameters between each other in term of bandwidth, gain, directivity, return loss and size. The consequences of the results are appeased and inspiring. The proposed antenna can be used in several wireless application.

5.2 Future Scope of Work

In this thesis, we explored rectangular patch antenna and the outcome of modified and combined U and H shape and rectangular slots to improve the bandwidth. For all the wireless communication system, UWB antenna is required compact small size. Therefore, in near future researchers would be over excited to discover new techniques to minimize the size of UWB microstrip antenna and fabrication of this antenna can be performed to overlook real time representation of the antenna and measured results will be compared with simulated results. Further prosperity can be acquired by using arrays, changing antenna shape, the dielectric of the substrate and the feeding techniques of microstrip patch antenna like probe feed.

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APPENDIX

ANTENNA SIMULATION IN IE3D

Step by step procedure to design our desire patch antenna with modified and combined U and H shape patch and two rectangular slots in ground plane is discussed here with corresponding screenshots.

1. Run Zeland Program Manager and click on MGRID ( ).

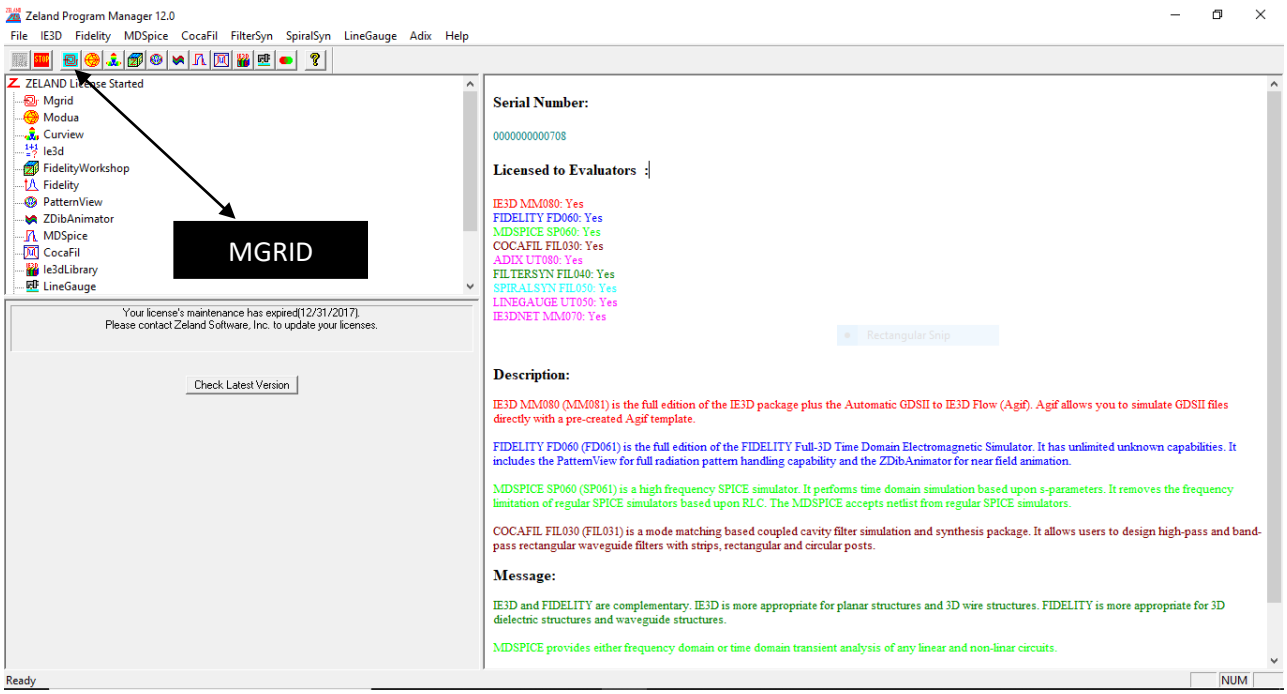

Figure A-1: Zeland Program Manager

2. After opening the MGRID window. Click the new button as shown below ( ).

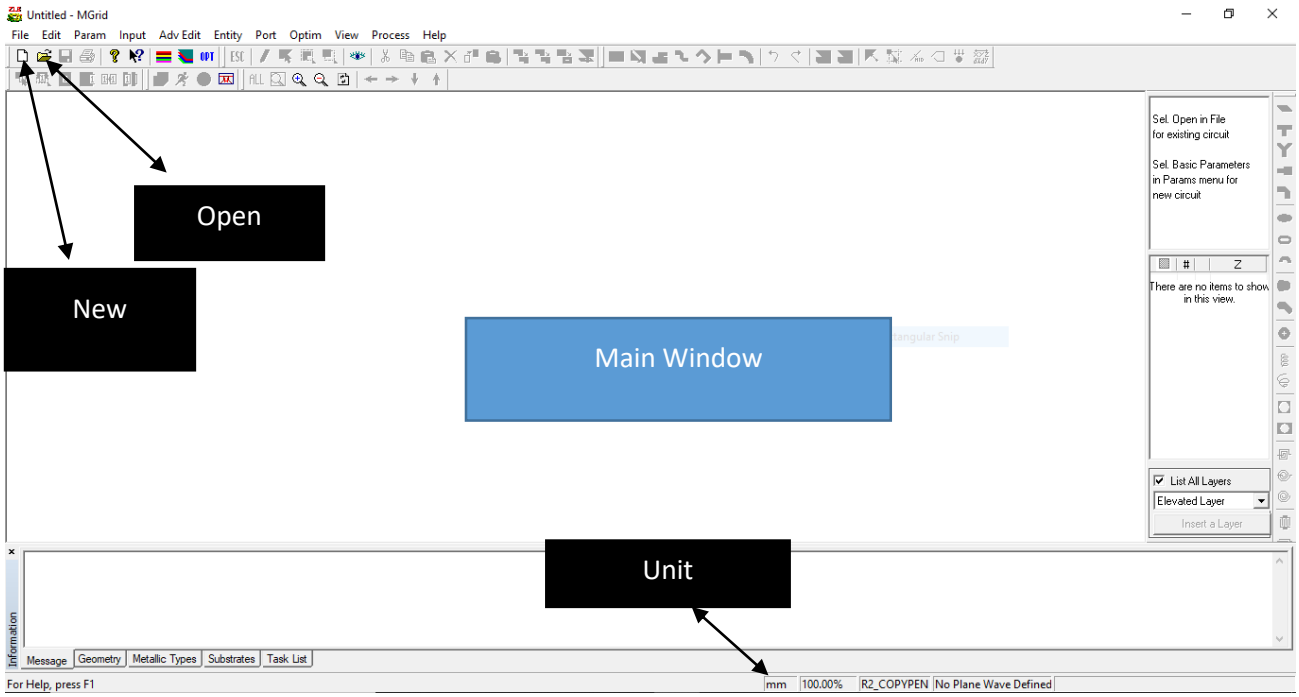

Figure A-2: MGRID window

3. Here, the basic parameter definition window will be pops up. In this windows fundamental parameters of the simulation can be identified by users such as dielectric constant of different layers, the units and layout dimensions. In "Substrate Layer" section two layers are automatically defined. At Z=0, the program automatically places an infinite ground plane (Note the material conductivity at Z=0) and the second layer is defined at infinity with the dielectric constant of 1.

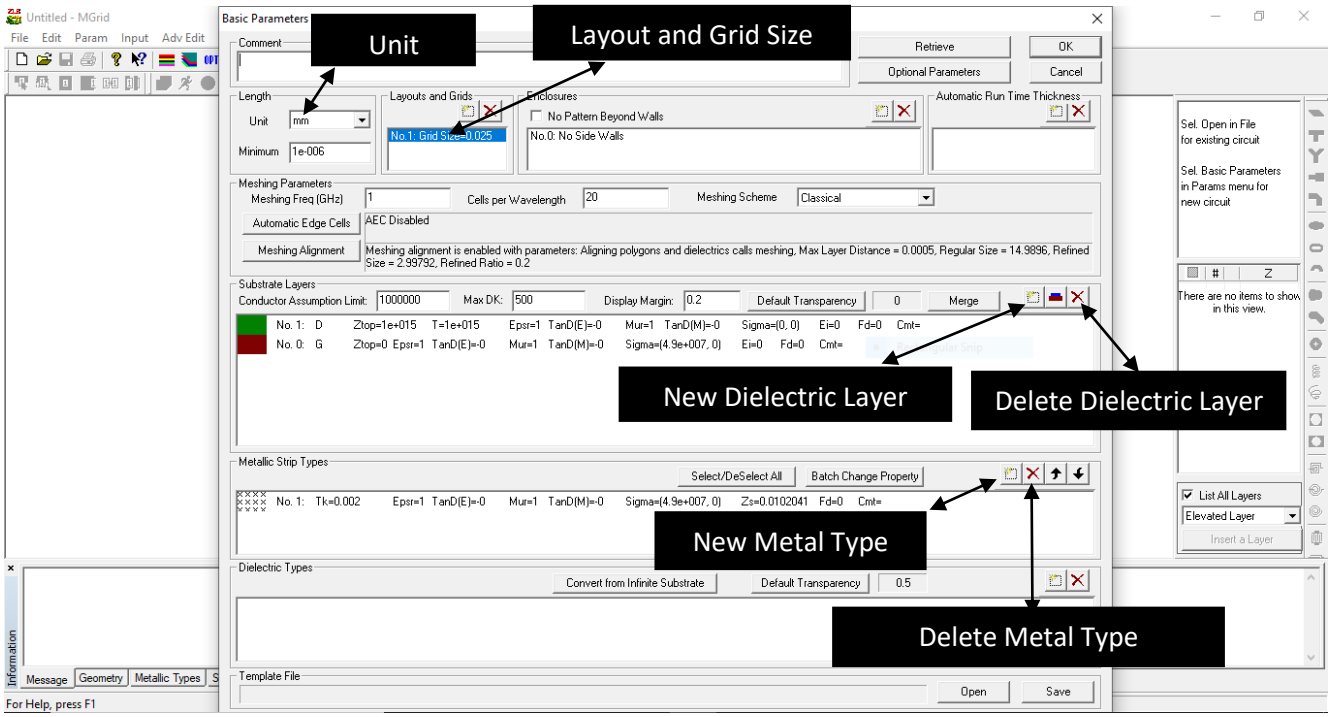

Figure A-3: Basic Parameter

4. Now, click on "New Dielectric Layer" button ( ). Then enter the fundamental parameters as input (Top surface=1.5; Dielectric Constant=2.2; Loss Tangent=0.0009) in this window which is given below. Then, click OK.

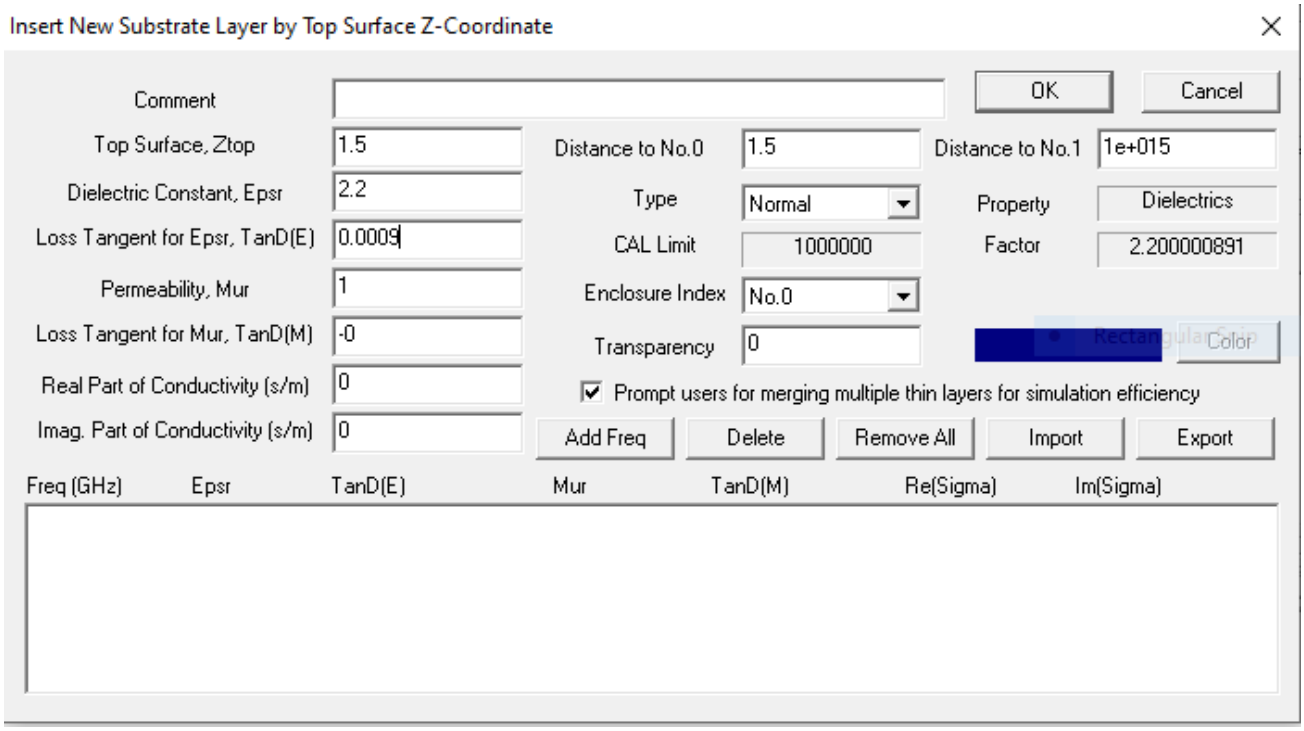

Figure A-4: New Substrate Layer Dialog Box

5. Click OK again to go back to MGRID window. In Menu bar click Entity>Rectangle or Click ( ). Rectangle window will be pops up. Now, enter length 42, width 40, Z-coordinate 0 (Ground plane) and click OK. To see the whole structure clearly click ALL button (

).

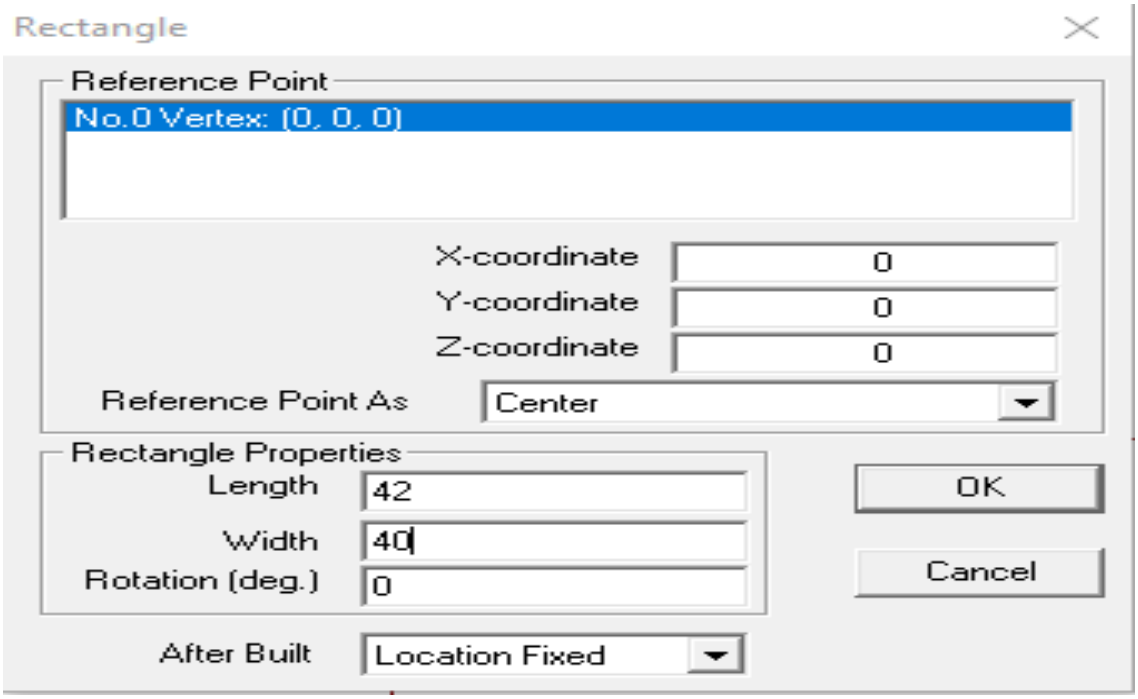

Figure A-5: Rectangle Dialog Box

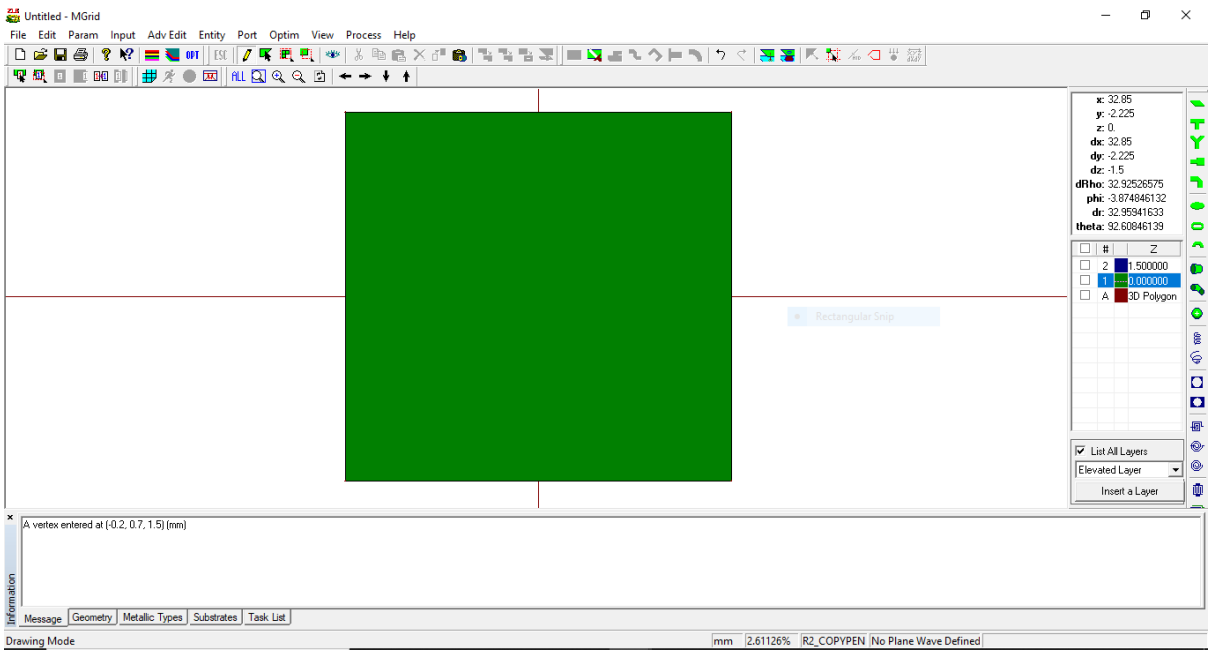

Figure A-6: Ground plane of antenna

6. In Menu bar again click Entity>Rectangle and when Rectangle window pops up, enter length 30, width 28.5, Z-coordinate 1.5 (Patch) and click OK. The main body has been created.

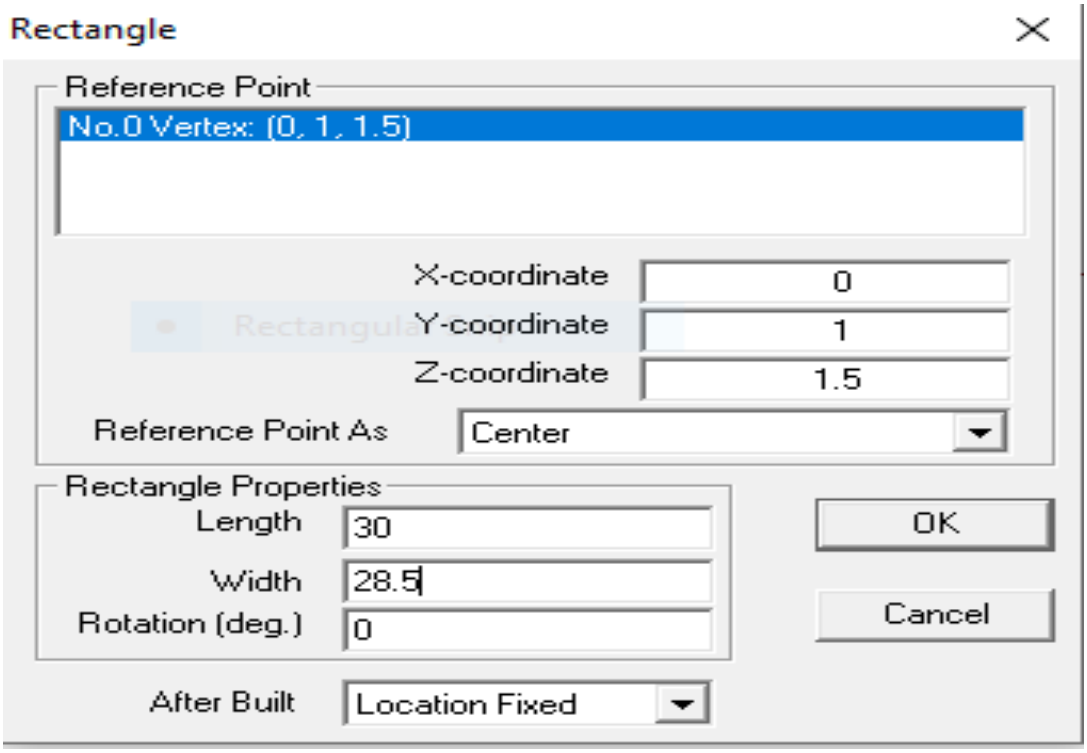

Figure A-7: Rectangle Dialog Box

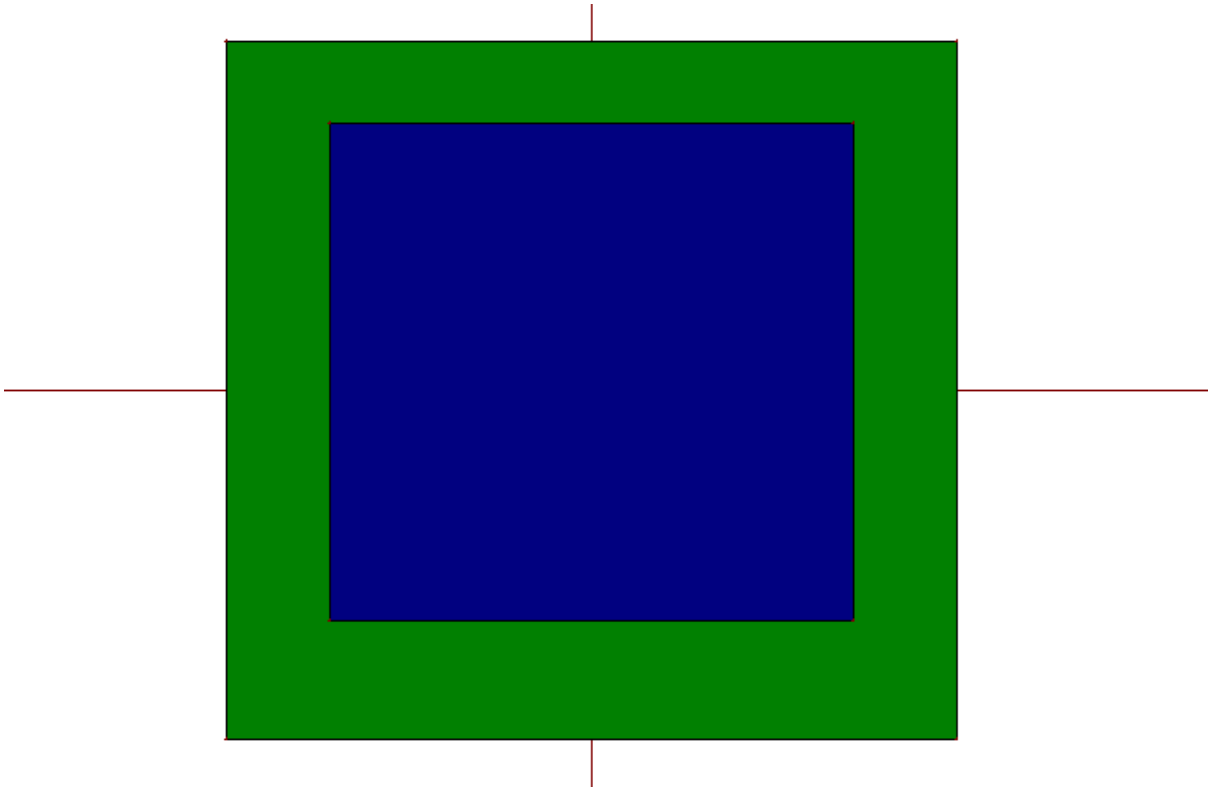

Figure A-8: Main body of antenna with patch

7. Click Adv Edit>Dig Rectangular Hole or press Alt+Shift+D. A new window will be pops up, enter Center X-coordinate 19, Center Y-coordinate 13, Center Z-coordinate 0 (for cutting a slot of ground plane), Rectangle Length 4 and Rectangle Width 3. Then click OK.

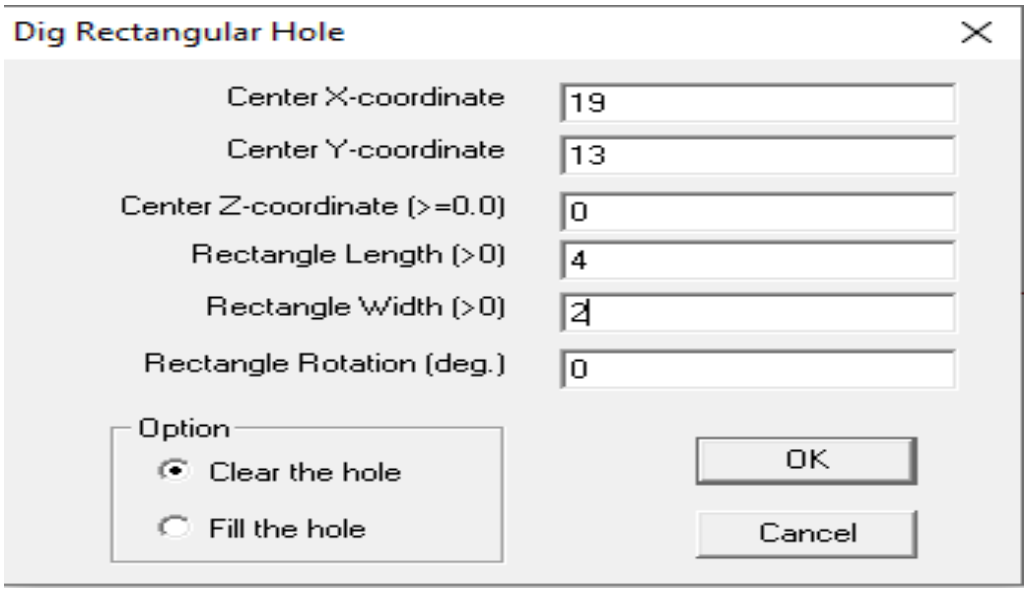

Figure A-9: Dig Rectangular Hole Dialog Box

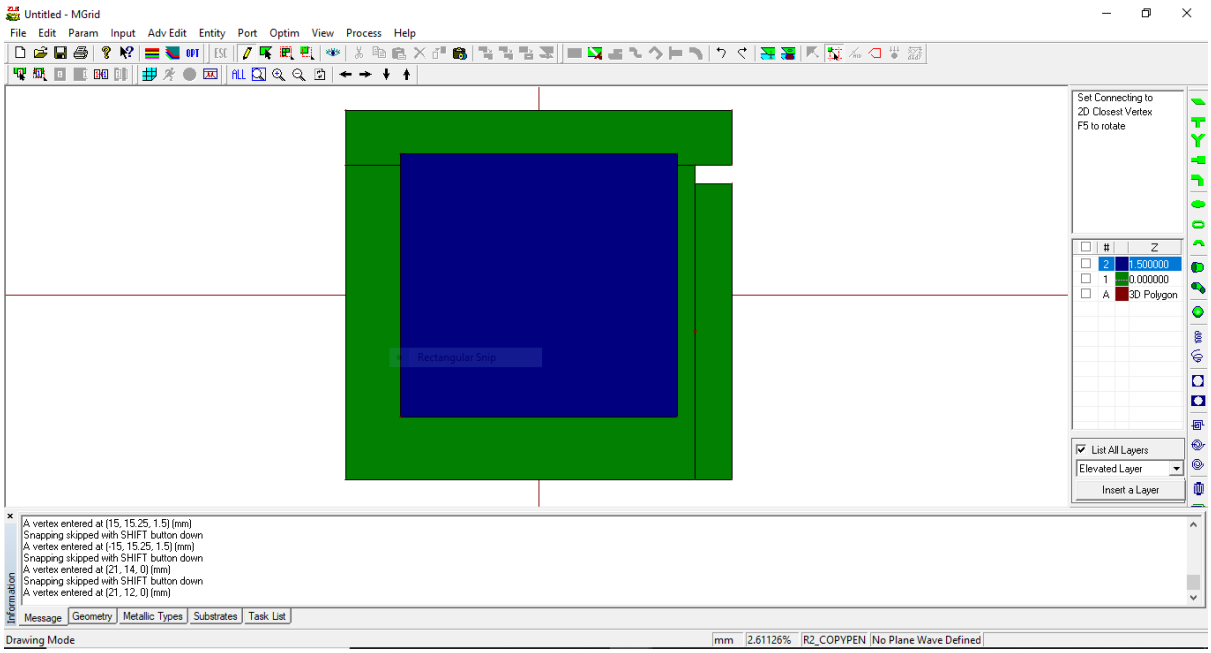

Figure A-10: Antenna Structure with slot1 in Ground

8. Click again Adv Edit>Dig Rectangular Hole or press Alt+Shift+D. New window pops up, enter Center X-coordinate 0, Center Y-coordinate -17, Center Z-coordinate 0 (for cutting a slot of ground plane), Rectangle Length 2 and Rectangle Width 7.5 and then click OK. Slot cutting technique has been completed for Ground plane.

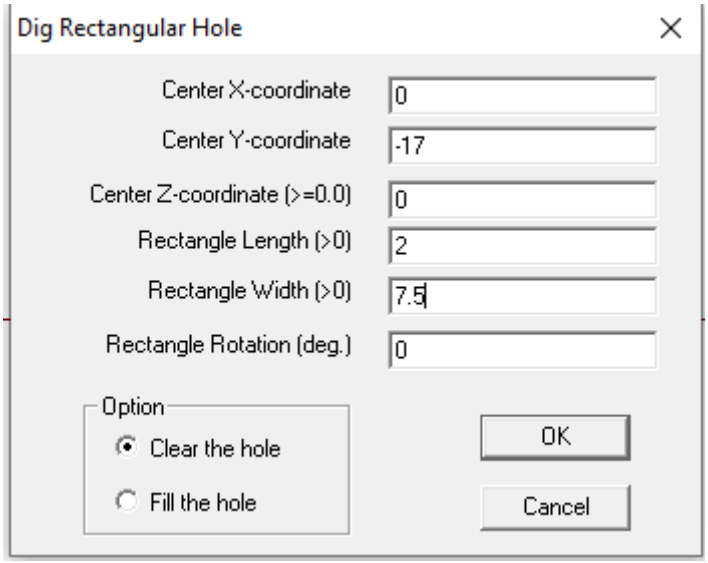

Figure A-11: Dig Rectangular Hole Dialog Box

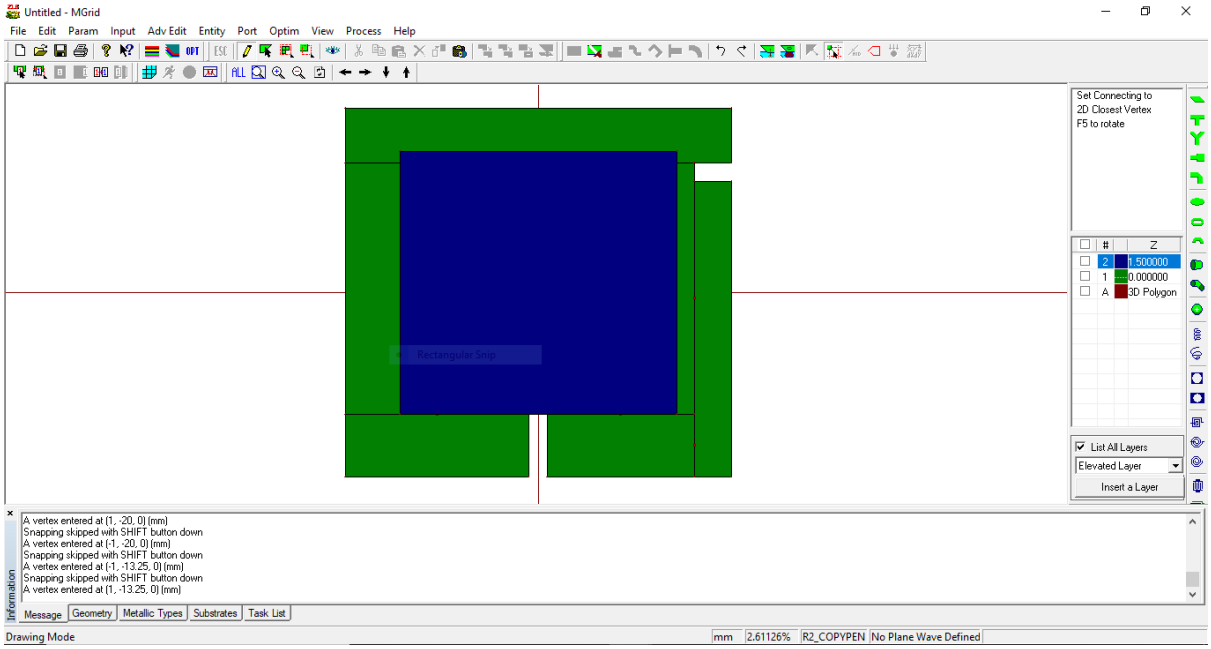

Figure A-12: Antenna Structure with slot2 in Ground

9. Now press Alt+Shift+D again. A new window pops up, enter Center X-coordinate 15, Center Y-coordinate 8, Center Z-coordinate 1.5 (for cutting a slot in the patch), Rectangle Length 4 and Rectangle Width 4. Then click OK.

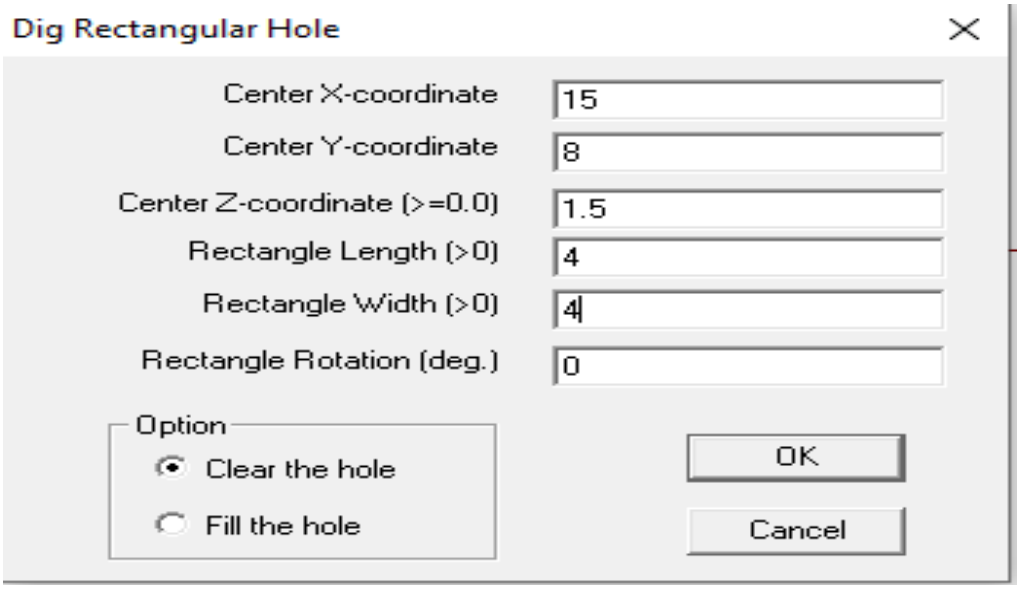

Figure A-13: Dig Rectangular Hole Dialog Box

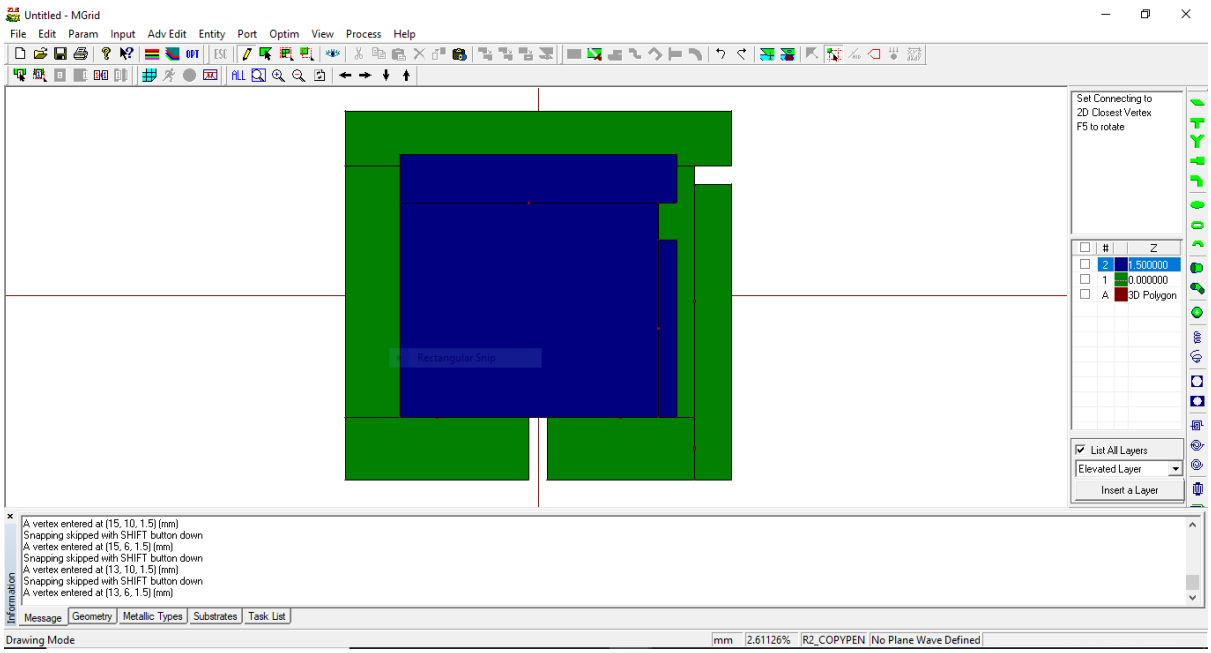

Figure A-14: Antenna Structure with slot1 in Patch

10. Moreover, now press Alt+Shift+D. New window pops up, enter Center X-coordinate -15, Center Y-coordinate 8, Center Z-coordinate 1.5 (for cutting a slot in the patch), Rectangle Length 4 and Rectangle Width 4 and then click OK.

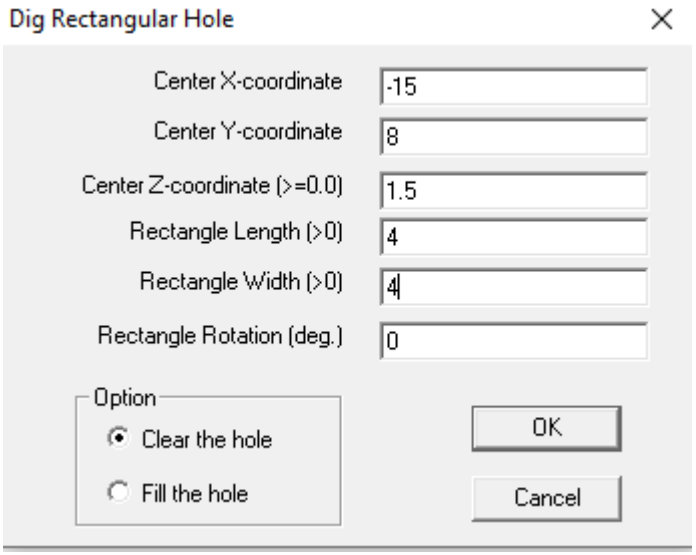

Figure A-15: Dig Rectangular Hole Dialog Box

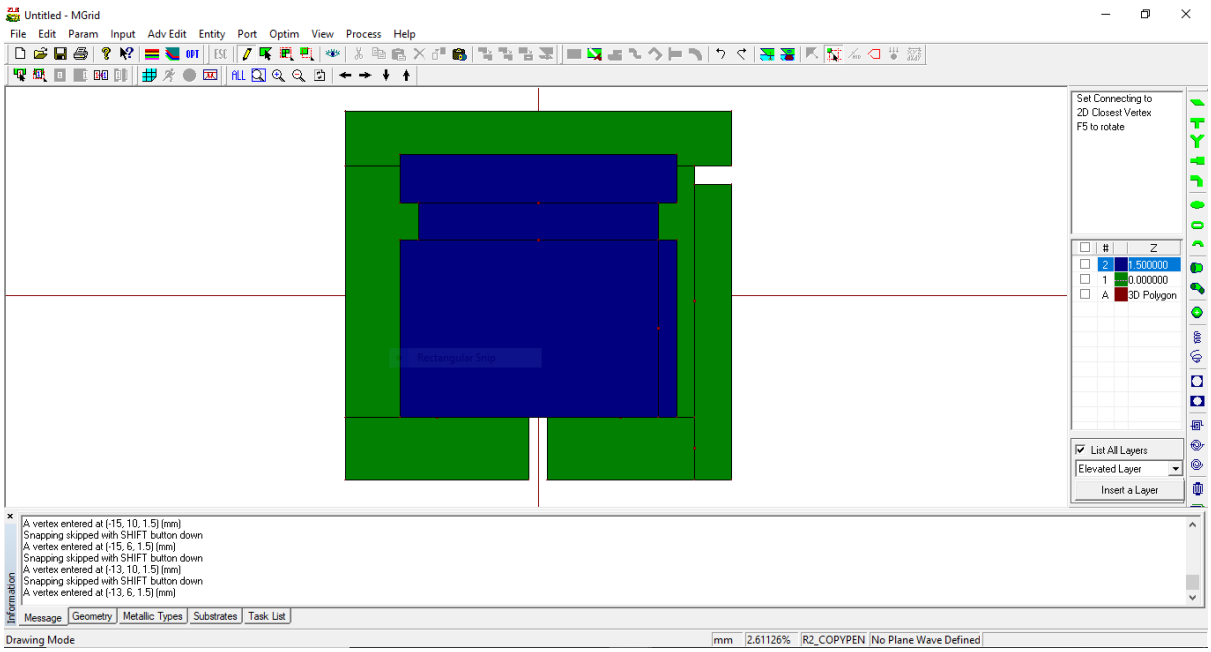

Figure A-16: Antenna Structure with slot2 in Patch

11. To create the final slot in the patch which also built a feed line. Press Alt+Shift+D. New window pops up, enter Center X-coordinate -2.25, Center Y-coordinate -5, Center Z-coordinate 1.5 (for cutting a slot in the patch), Rectangle Length 25.5 and Rectangle Width 7.5 and then click OK. Here, slot cutting technique has been completed for patch.

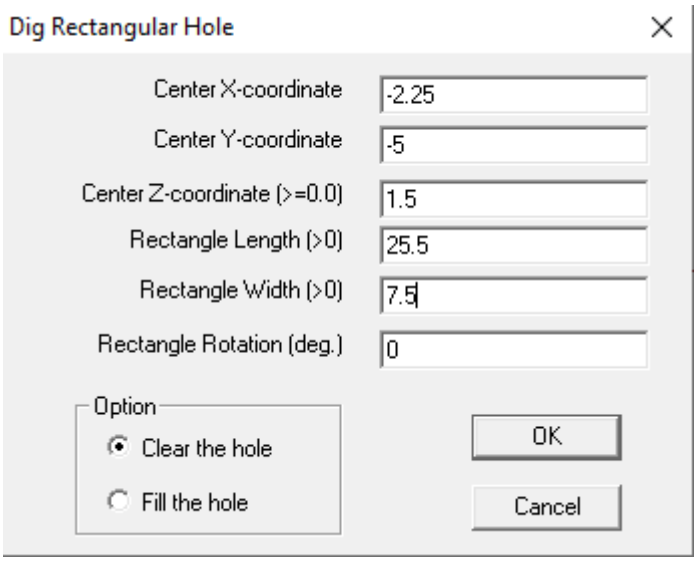

Figure A-17: Dig Rectangular Hole Dialog Box

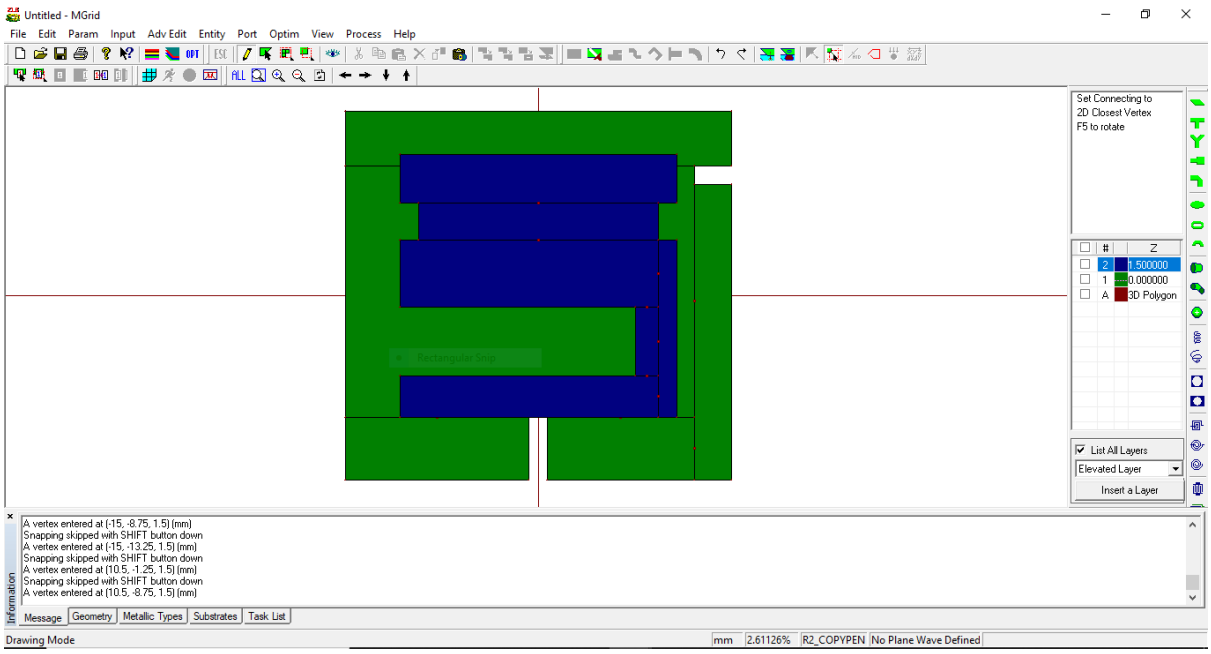

Figure A-18: Antenna Structure with slot3 in Patch

12. Next we need to connect the feed line to the antenna. Click Port>Define Port or press the "Define Port Button" ( ). The window shown in Figure pops up. Select "Advanced Extension" in the De-Embedding Scheme field. Leave the rest of the fields unchanged at this stage and click the Ok button. It seems that nothing has happened. However, we have entered the port definition mode. The next step is to move the mouse cursor to the left corner and lower edge of the feed line and click on it. It defines a port at that location. Now, press Esc key to exit this mode. The layout should look like the one shown in Figure. The antenna is ready for simulation.

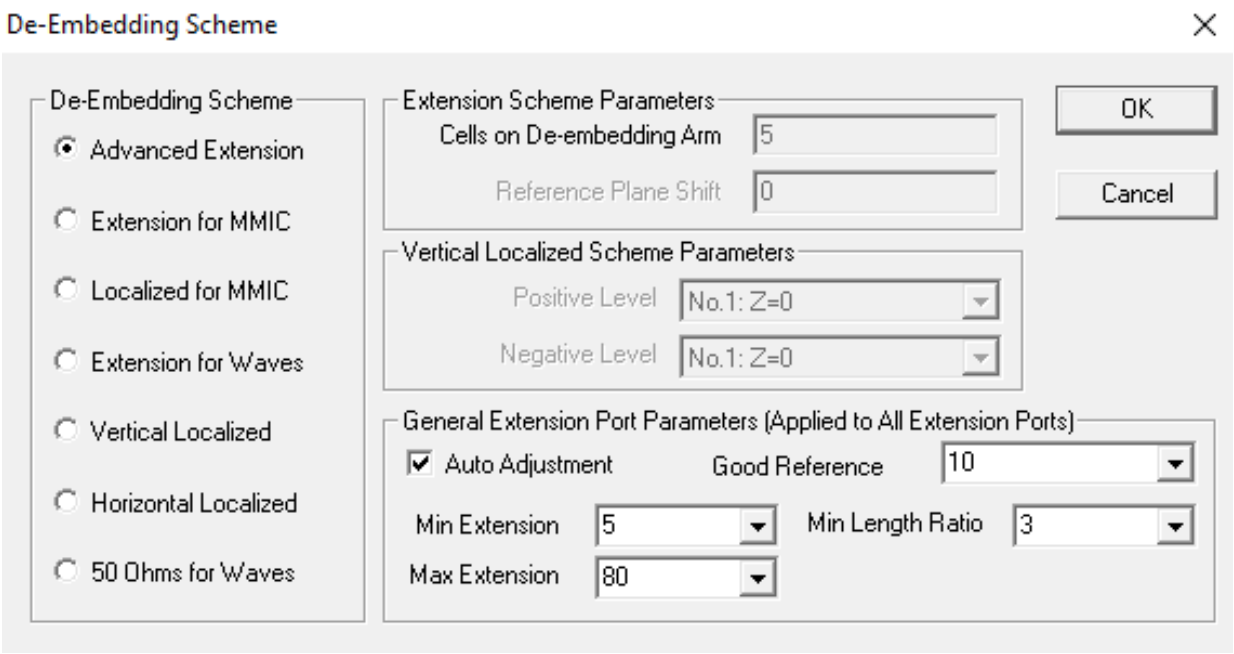

Figure A-19: Port selection Dialog Box

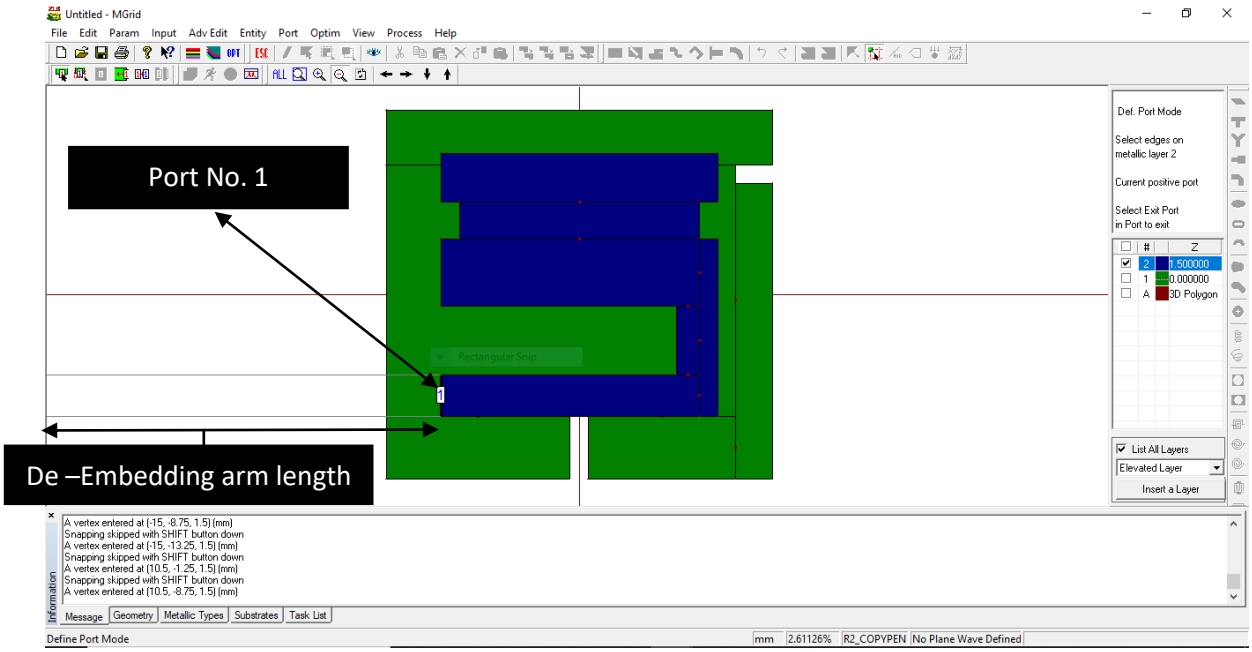

Figure A-20: Antanna Structure with microstrip line feed probe

13. Let us first mesh the structure before simulation. Actually, this mesh is used in the Method of Moment (MoM) calculation. Press the "Display Meshing" button ( ). The "Automatic Meshing Parameters" menu pops up which is shown in figure A-21.

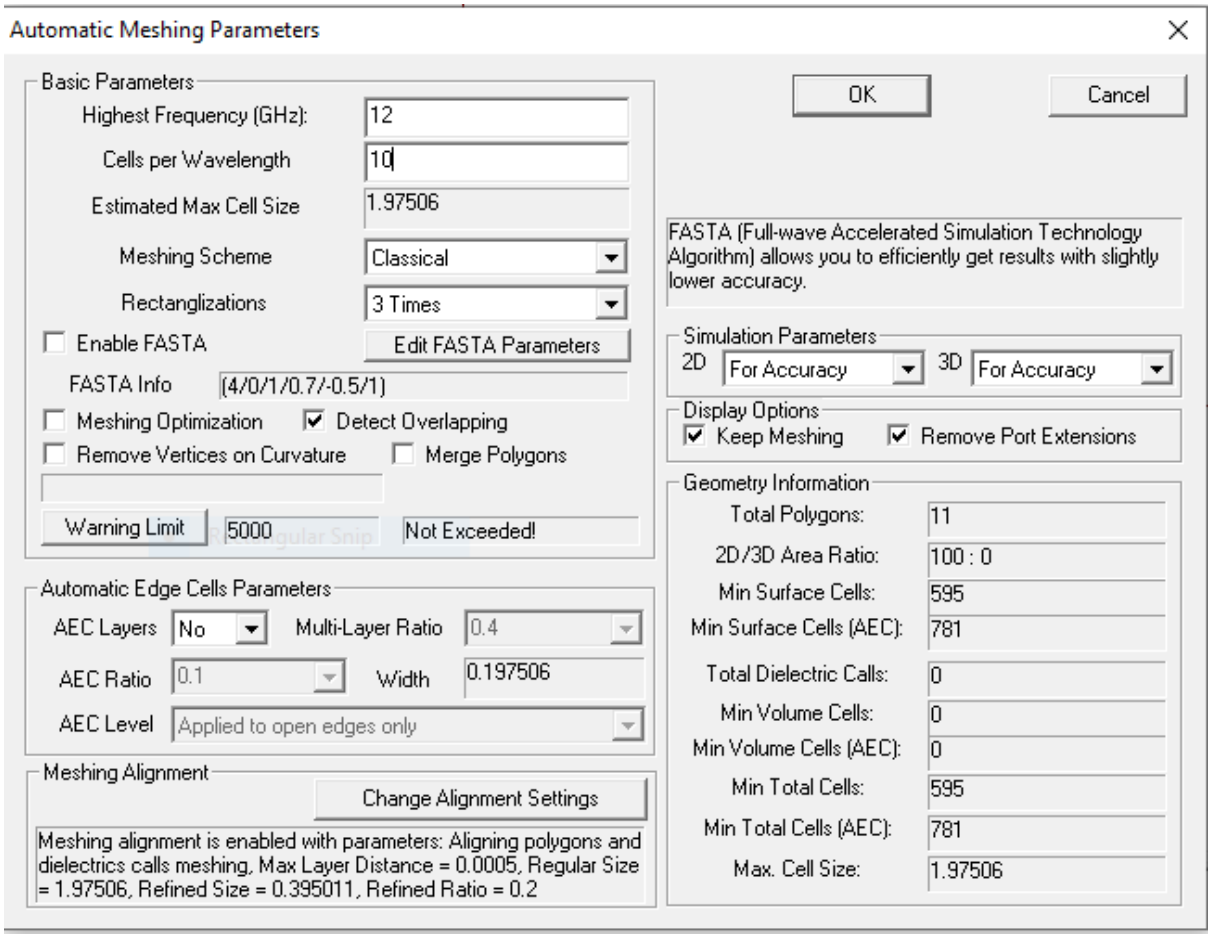

Figure A-21: Automatic Meshing Parameter dialog box

14. In this menu, you have to specify the highest frequency that the structure will be simulated at. Now, enter 12 in the "Highest Frequency" field. In this case, the operating frequency cover maximum X-band which end in 12 GHz. Therefore, choosing 12 GHz as the maximum frequency should be OK. Then, enter 10 in the "Cells per wavelength" field. The number of "cells per wavelength" determines the density of the mesh. Press Ok, a new window pops up that shows the statistics of the mesh, press continue and the structure will be meshed.

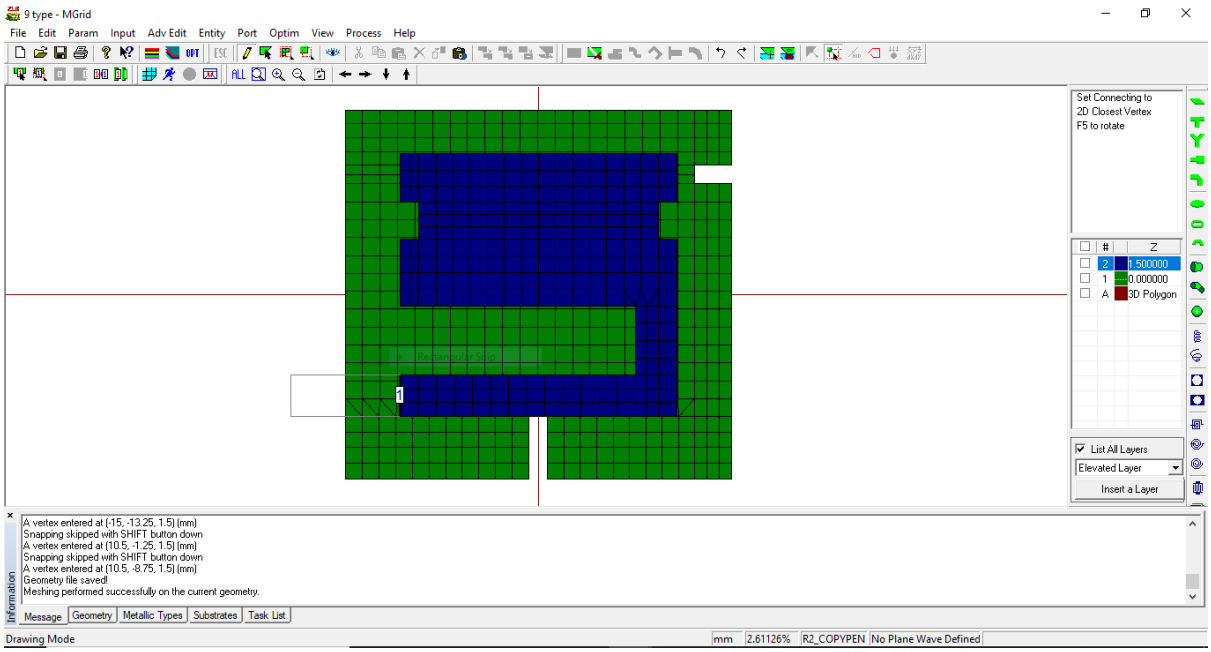

Figure A-22: Meshed Antenna for MoM calculation

15. Now it is time to simulate the structure. Press the "Run Simulation" button ( ). The simulation setup window pops up. Here we can specify the simulation frequency points as well as the basic parameters of the mesh. Click on Enter button in the Frequency parameters field. Enter 1 in the "Start Freq (GHz)" field, 12 at the "End Freq (GHz)" field, and 201 or 1000 in the "Number of Freq" field and click OK. The "Frequency Parameters" field is now filled with 201 or 1000 spaced frequency points between 1 GHz and 12 GHz range. Make sure that the "Adaptive Intelli-Fit" check box is checked as shown in Figure. It automatically selects a number of frequency points and simulates the structure at these particular points and interpolates the response based on the simulated points.

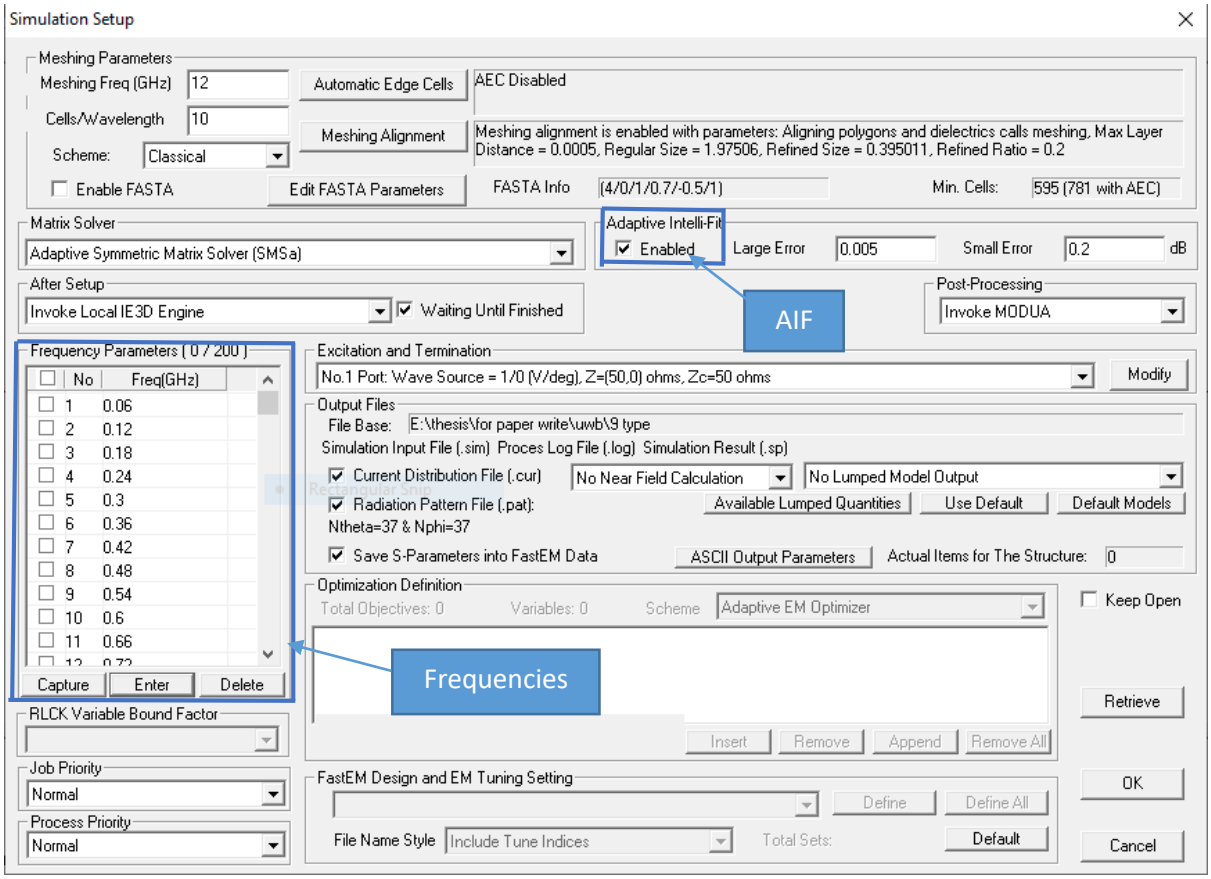

Figure A-23: Simulation Setup dialog box

16. Press Ok. The structure will be simulated. The simulation progress window demonstrates the progress of the simulation. After the simulation is completed, IE3D automatically invoked MODUA and illustrates S parameters of the simulated structure. From the Control Menu of MODUA the display graph can be defined. Display Parameter window pops up with many option. Any needed data can be chosen for display.

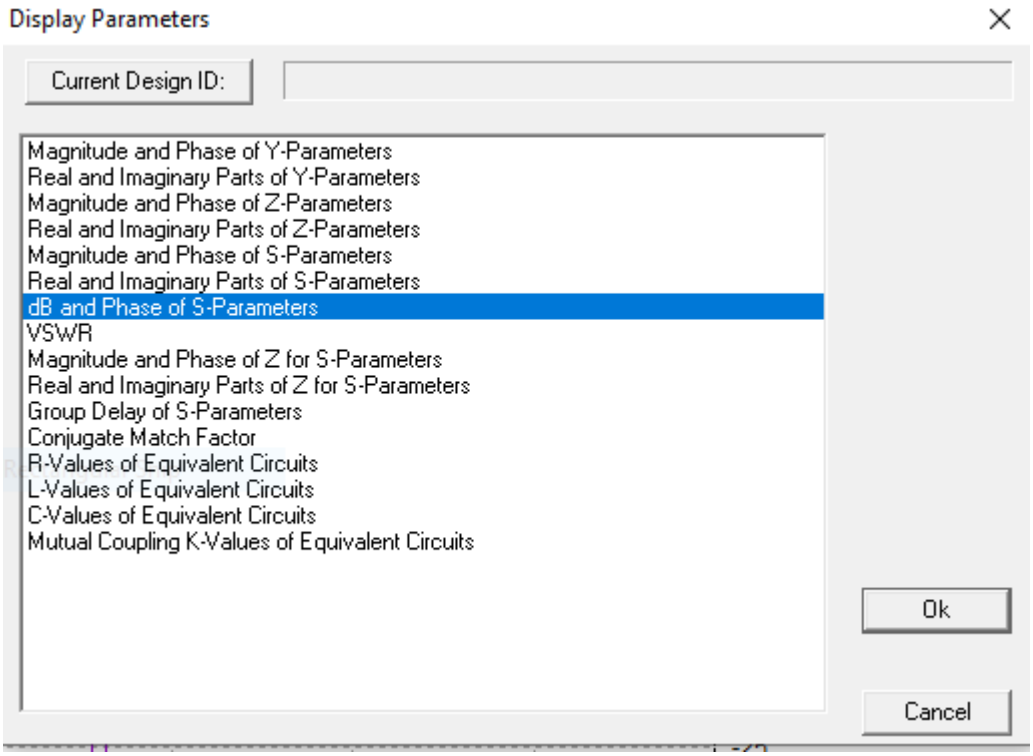

Figure A-24: Display Parameters