

Coplanar Waveguide Fed UWB Antenna with Dual Band Notch Characteristics

*Thesis submitted in partial fulfillment of the requirements for the award of
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Master of Engineering
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ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by
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DECLARATION

I, Malay, hereby certify that the work which is being presented in this thesis entitled "To Study and Implement Coplaner Waveguide Fed UWB Antenna with Dual Band Notch Characteristics" by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Electronics and Communication Engineering from Thapar University (Deemed University), Patiala, is an authentic record of my own work carried out under the supervision of "Mr.H.K.S.Randhawa".

The matter presented in this thesis has not been submitted in any other University / Institute for the award of any other degree.

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

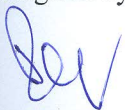
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Abstract

UWB System (3.1 to 10.6 GHz) has become a highly competitive topic in both academy and industry communities of telecommunication. To minimize the potential interferences between the UWB System and the narrowband System, a compact CPW-fed planer UWB antenna with dual bands at WLAN/WiMAX frequencies is to design and analysed.

The dual Band-notched operations are achieved by etching two nested C-shaped slots in the rectangular metal radiating patch. It is found that by adjusting the total length of the C-shaped slot to be approximately half-wavelength of the desired notched frequency, a destructive interference can take place, causing the antenna nonresponsive at that frequency. It is easy to tune the notch centre frequency with the change in total length of the C-shaped slot.

Single slot is to be etched for single band rejection by etching two nested C shaped slots in the patch dual band-rejection filtering properties in the WLAN/WiMAX bands (3.5 to 5.5 GHz) can be achieved. This antenna is to be simulated using EM software is expected to give wide impedance bandwidth, stable radiation pattern and constant gain.

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List of Abbreviations

UWB	Ultra Wideband
CPW	Coplanar Waveguide
WLAN	Wireless Local Area Network
WiMAX	Worldwide Interoperability Microwave Access
VSWR	Voltage Standing Wave Ratio
S_{11}	Return loss
L	Physical length of the antenna
γ	Propagation constant of the transmission line
Z_0	Characteristic impedance
Q	Quality factor
W	Width of the antenna
ϵ_{eff}	Effective dielectric constant
BW	Bandwidth of the antenna
h	Thickness of the substrate

CHAPTER ONE

INTRODUCTION

1.1 OBJECTIVE AND GOAL

The objective of the project is to design and fabricate an antenna that transmits or receives UWB signals. An antenna is a transducer between a guided wave propagating in a transmission line, and an electromagnetic wave propagating in an unbounded medium, like air. All wireless systems have a transmitting antenna and a receiving antenna. The transmitting antenna is the antenna that obtains the signal from the source. The receiving antenna is the antenna that outputs the desired signal to a receiver. Antennas are used for many applications; one of the more recognizable applications is radio. The receiving antenna on a car collects the signal from the radio station and outputs the signal into the receiver. Music can now be heard in the car. Over the designated bandwidth of UWB system (3.1-10.6 GHz), there are some other existing narrowband services that already occupy frequencies in the UWB band, such as wireless local-area network (WLAN) IEEE802.11a operating in the 5–6 GHz band. Besides the WLAN, in some Europe and Asian countries, WiMAX service from 3.3 to 3.6 GHz also operates in the UWB band.

So the main goal of the project is to design an antenna that is used for UWB applications with dual notched frequency bands both in 3.3–3.6 GHz and 5–6 GHz to minimize the potential interferences between UWB system and narrowband systems.

1.2 MOTIVATION FOR THE USE OF ULTRA-WIDEBAND

As a consequence of increasing demand the issue of rational use sharing and protection of the radio spectrum is becoming very important. So consequence of the limited radio spectrum is the development of new technologies to increase the efficient use. Ultra Wide Band (UWB) systems having wide bandwidth with low power spectral density and it is true that this increases efficiently the utilization of the radio frequencies. UWB technology is based on the use of very narrow baseband pulses in the order of nanoseconds. These pulses result in spectral components covering a very wide bandwidth in the frequency domain. The impulsive nature of UWB emissions and the resultant spectral characteristics have caused concerns about the compatibility of these signals with existing radio systems.

For communication applications high data rates are possible due to the large number of pulses that can be created in short time duration. Due to its low power spectral density, UWB can be

used in military applications that require low probability of detection. Other common uses of UWB are in radar and imaging technologies, where the ability to resolve multipath delay is in the nanosecond range, allowing for finer resolution whether it be from a target or from an image. After recognizing the potential advantages of UWB, FCC developed a report to allow UWB as a communications and imaging technology. A UWB definition was created as a signal with a fractional bandwidth greater than 0.2 or which occupies more than 500 MHz of spectrum. The fractional bandwidth is defined as

$$2 \cdot (f_H - f_L) / (f_H + f_L)$$

Where f_H and f_L are the upper and lower frequencies respectively measured at -10 dB below the peak emission point. To allow government and industry to conduct UWB testing, frequency spectrum from 3.1 GHz to 10.6 GHz was allocated for communications use below specified power levels while imaging was limited to below 960MHz as seen in Fig. 1.1 below.

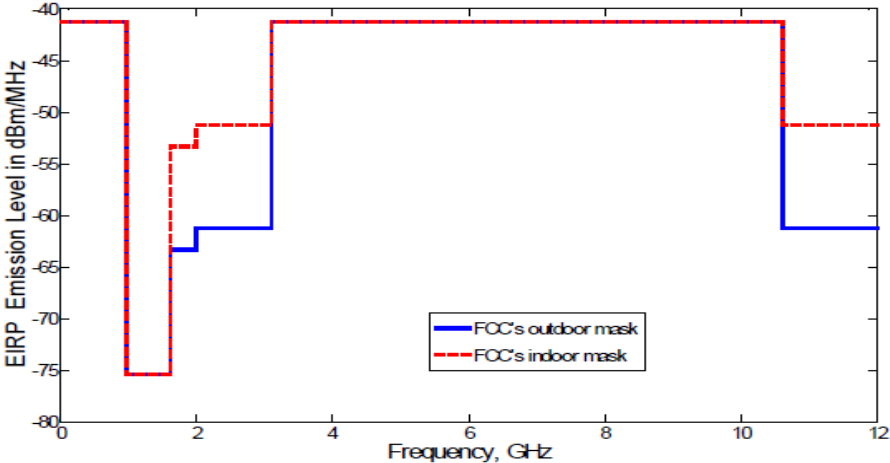


Fig. 1.1: FCC Spectral Mask for UWB Indoor and outdoor Communication Systems

Although the FCC has regulated spectrum and power levels for UWB, there is currently no standard for industry to follow. Discussions have developed on the use of two standards specifically, multiband orthogonal frequency division multiplexing (OFDM) and direct sequence spread spectrum (DS-SS) which is based on impulse radio technology.

Each of these schemes OFDM and DS-SS has their advantages in a communications system although OFDM is currently a more popular technology. Impulse radio has many advantages over OFDM, with its ability to penetrate through materials and resolve multipath with path length differences on the order of a foot or less. Impulse radio also allows for lower power consumption with a low duty cycle, making it very beneficial in low probability of detection applications. Numerous multiple access techniques such as time-hopping and direct sequence

are commonly applied to impulse radio, giving it the ability to service many users in a network. There are three primary drawbacks to current implementations of impulse radio, namely lack of high data rates, lack of long communication range and analog components are necessary to construct the system.

1.3 IMPORTANCE OF UWB ANTENNA AND PROJECT OVERVIEW

Ultra Wide Band, a wireless communications technology that can currently transmit data at speeds between 40 to 60 Mbps and eventually up to 1 Gbps. UWB transmits ultra-low power radio signals with very short electrical pulses, often in the ps range, across all frequencies at once. UWB receivers must translate these short bursts of noise into data by listening for a familiar pulse sequence sent by the transmitter.

Secondly, UWB systems operate at extremely low power transmission levels. By dividing the power of the signal across a huge frequency spectrum, the effect upon any frequency is below the acceptable noise floor.

For example, 1 watt of power spread across 1 GHz of spectrum results in only 1 nano watt of power into each Hertz band of frequency. Thus, UWB signals do not cause significant interference to other wireless systems.

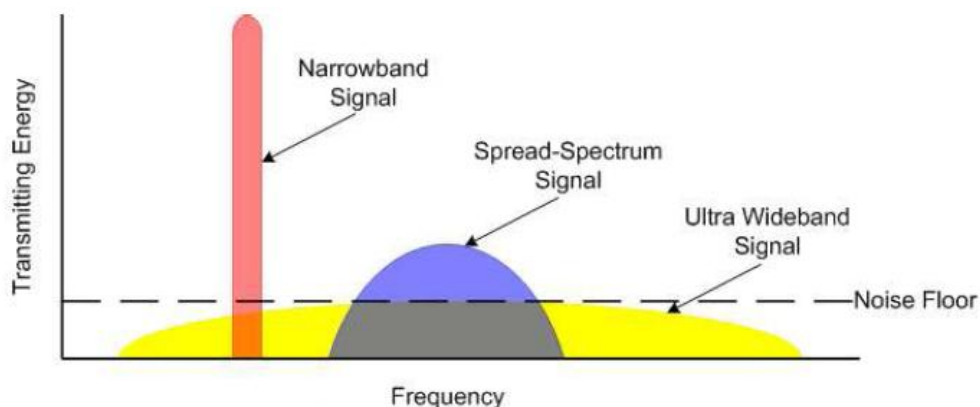


Fig. 1.2: Ultra wideband communications spread transmitting energy across a wide spectrum of frequency.

After the FCC approved for commercial use of ultra wideband in 2002, the feasible design and implementation of UWB system has become a highly competitive topic in both academy and industry communities of telecommunications. In particular, as a key component of the UWB system, an extremely broadband antenna will be launched in the frequency range from 3.1–10.6 GHz, which has attracted significant research power in the recent years. Challenges of the feasible UWB antenna design include the UWB performances of the impedance matching and

radiation stability, the compact appearance of the antenna size and the low manufacturing cost for consumer electronics applications.

It is noted that the UWB antenna design remains to be the main challenge in the progress of UWB technology. This is primarily attributed to the fact that antennas act as a band pass filter and limit the transmission bandwidth. It is claimed that, as a rule of thumb, antennas with a bandwidth such that the ratio of the maximum to minimum frequency is more than two are not easy to build practically. A UWB signal spanning the frequency range 1 GHz to 10 GHz has a ratio of 10 and therefore an antenna providing this bandwidth is very difficult to construct.

From a compatibility point of view it would be useful to have information on the radiation patterns associated with UWB antennas. Little information on this was found in the references obtained, although the specific topic was not pursued in its own right. In many of the compatibility studies it is either assumed that the UWB devices radiate omni directionally or that their maximum radiated power is directed towards the receiver.

Over the designated bandwidth of UWB system, there are some other existing narrowband services that already occupy frequencies in the UWB band, such as WLAN IEEE 802.11a and HIPERLAN/2 operating in the 5–6 GHz band. Besides the WLAN, in some Europe and Asia countries, WiMAX service from 3.3 to 3.6 GHz also operates in the UWB band. In some applications, UWB antenna uses filters to suppress dispensable bands. However, the uses of filters indeed increase the complexity of the UWB system and lead to increase in cost. It is desirable to design the UWB antenna with dual notched frequency bands both in 3.3–3.6 GHz and 5–6 GHz to minimize the potential interferences between UWB system and narrowband systems.

In this project a compact planar ultra wideband antenna with 3.4/5.5 GHz dual band-notched characteristics is investigated. The antenna consists of a beveled rectangular metal patch and a 50 Ω CPW transmission line. By etching two nested C-shaped slots in the patch, band-rejected filtering properties in the WiMAX/WLAN bands has been achieved. The proposed antenna has been successfully designed and simulated. The simulated VSWR is in good agreement with the measured VSWR. The simulated result also shows stable radiation patterns and constant gain.

CHAPTER TWO

ULTRA WIDE BAND TECHNOLOGY

2.1 ULTRA WIDE BAND

Wireless communication technology has changed our lives during the past two decades. In countless homes and offices, the cordless phones free us from the short leash of handset cords. Cell phones give us even more freedom such that we can communicate with each other at any time and in any place. Wireless local area network (WLAN) technology provides us easy access to the internet without suffering of unsightly and expensive cable.

As we know UWB technology has been used in the areas of radar, sensing and military communications during the past 20 years. A substantial surge of research interest has occurred since February 2002, when the FCC issued a ruling that UWB could be used for data communications as well as for radar and safety applications. Since then, UWB technology has been rapidly advancing as a promising high data rate wireless communication technology for various applications.

Ultra Wide Band is a radio technology based on the generation of very short Pulses of electromagnetic energy. These pulses, being short in the time domain, give rise to spectral components covering a very wide bandwidth in the frequency domain, hence the term Ultra Wide Band. It is claimed that the spectral components fall within existing regulations designed to control the unwanted emissions associated with conventional radio technologies and therefore should cause no problem to existing radio services.

2.1.1 UWB Advantages

Power Consumption

The Federal Communications Commission power requirement for UWB systems is -41.3dBm/MHz (75nW/MHz). Such a power restriction allows UWB systems to live below the noise floor of a typical narrowband receiver and enables UWB signals to coexist with current radio services with minimum interference. UWB radio offers short-range communication that uses 1/1000 of the power required for equivalent conventional transmission methods. Low battery power consumption is a constraint for many wireless communication systems,

especially in the transmission devices. Furthermore, since UWB signals use such low powers, they are less harmful to human.

High Security

Because of their low average transmission power, UWB communications systems have an inherent immunity to detection and interception. UWB pulses are time-modulated with codes unique to each transmitter and receiver. The time modulation of extremely narrow pulses will add security to UWB transmissions, because detecting Pico-second pulses without knowing when they will arrive is next to impossible. Such security is a critical need for military operations.

Resistance to Interference

Unlike the well-defined narrowband frequency spectrum, the UWB spectrum covers a vast range of frequencies. UWB signals then, are relatively resistant to intentional and unintentional jamming, because it is almost impossible to jam every frequency in the UWB spectrum at once. Thus, even though some of the frequencies are jammed, there will still be a range of frequencies that remain signal coding. UWB provides less interference than narrowband radio designs. Because of their low power spectrum density, unlicensed UWB radios will cause no interference to other radio systems operating in dedicated bands.

High Performance in Multipath Channels

The phenomenon known as multipath interference is unavoidable in many wireless communications channels. When signals are transmitted between transmitter and receiver, they scatter; reflect from objects and surfaces along the path. At the receiver end, the receiver sees the superposition of delayed versions of the original signal. When signals are continuous-waves or sinusoidal waveforms, these 'replicas' may cancel the original signal due to the phase difference of the signals. UWB communication uses pulse waveforms and they tend not to overlap in time because of the extreme narrowness of the pulse. Because the transmission duration of a UWB pulse is shorter than a nanosecond in most cases, the reflected pulse has a small window of opportunity to collide with a line-of-sight (LOS) pulse and cause signal degradation.

Strong Penetration Ability

Unlike narrowband technologies, UWB systems can penetrate effectively through different materials. The low frequencies included in the broad range of the UWB frequency spectrum have long wavelengths, which allow UWB signals to penetrate a variety of materials, such as

walls. This property makes UWB technology viable for through-the-wall communications and ground penetrating radar. This is a great advantage for sealed space and body implant wireless communication.

2.2 ANTENNA REQUIREMENTS AND SPECIFICATIONS FOR UWB APPLICATIONS

To understand the challenges faced when designing antennas it is necessary to provide some background information on some of the key parameters and performance metrics. There are many antenna types with differing geometry but there are certain fundamental parameters that can be used to describe all of them.

2.2.1 Fundamental Antenna Parameters

The most fundamental antenna parameters are:

1. Impedance Bandwidth
2. Radiation pattern
3. Directivity
4. Efficiency
5. Gain
6. Polarisation

All of the parameters mentioned above are necessary to fully characterise an antenna, and to establish whether the antenna is optimised for its purpose.

2.2.1.1 Impedance Bandwidth

The term ‘impedance bandwidth’ is used to describe the bandwidth over which the antenna has acceptable losses due to mismatch. The impedance bandwidth can be measured by the characterisation of both the Voltage Standing Wave Ratio (VSWR) and Return Loss (RL) at the frequency band of interest. Both VSWR and RL are dependent on the reflection coefficient (Γ). Γ is defined as the ratio of the amplitude of the reflected voltage wave (V_0^-) normalised to the amplitude of the incident voltage wave (V_0^+) at a load. Γ can also be defined by using other field or circuit quantities and is defined by the following equation.

$$\Gamma = \frac{V_0^-}{V_0^+} \quad 2.1$$

$$\text{VSWR} = \frac{Z_L}{Z_0} \quad \text{OR} \quad \frac{1+\Gamma}{1-\Gamma} \quad 2.2$$

$$\text{RL} = -20 \text{ Log } \Gamma \quad 2.3$$

The maximum acceptable mismatch for an antenna is normally 10% of the incident signal. For the reflection coefficient, this equates to $\Gamma = 0.3162$. For the impedance bandwidth $1 < \text{VSWR} < 2$, and for Return Loss its value must be greater than 10 dB or $S_{11} < -10$ dB.

2.2.1.2 Radiation pattern

An antenna radiation pattern is defined in the IEEE Standard Definitions of Terms as:

A mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarisation. Primarily, when measuring the radiation pattern, the property of most interest is the energy radiated relative to the antennas position. This is usually measured using spherical coordinates.

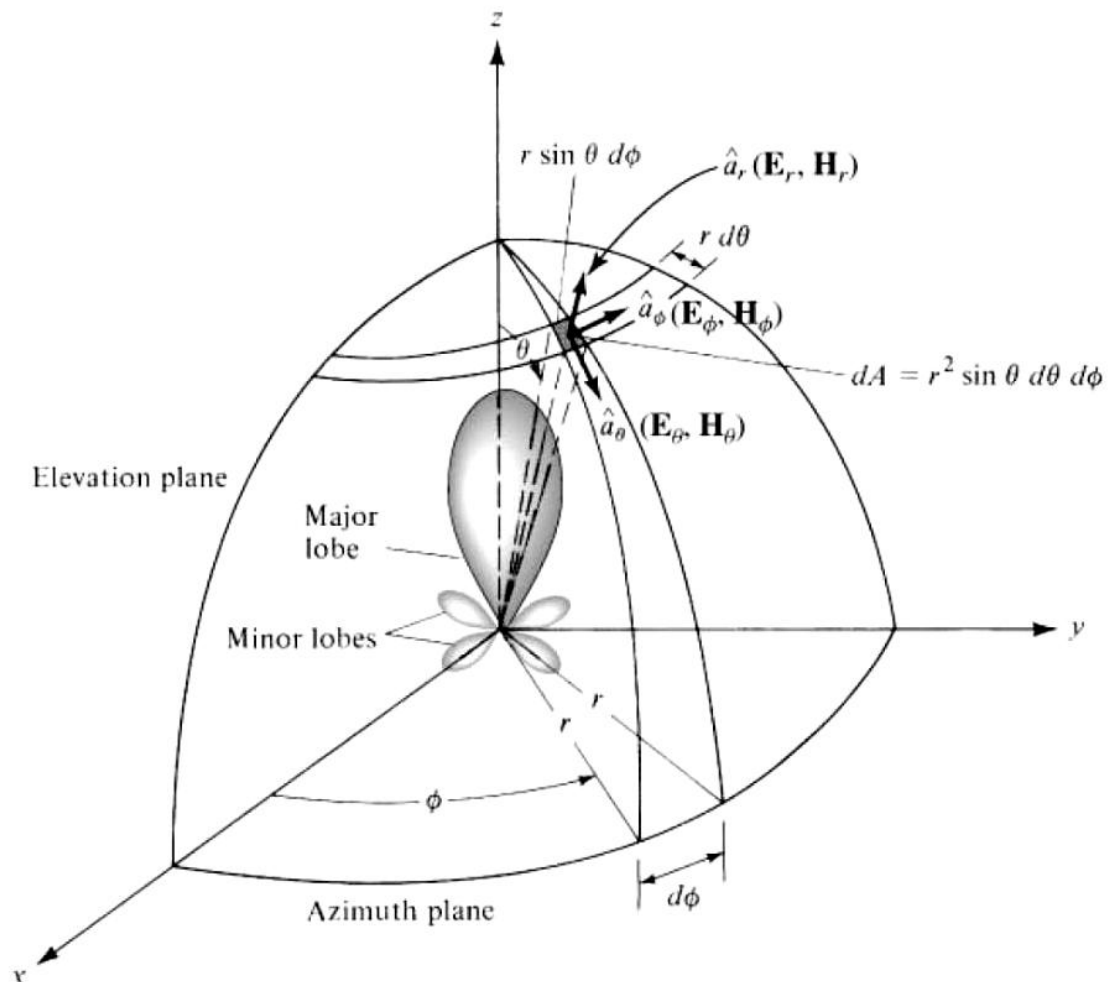


Fig. 2.1: Coordinate system, for antenna analysis

The antenna under test is placed at the origin and is rotated through $\phi = 0^\circ - 360^\circ$ and $\theta = 0^\circ - 180^\circ$ while the power is measured in the far-field. As shown in Fig. 2.1 the x-z plane is

considered the elevation plane. This is normally aligned with the electric field vector and is called the E-plane. The x-y plane is normally aligned with the magnetic field vector and is termed the H-plane.

2.2.1.3 Directivity

The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all the directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π . If the direction is not specified, the direction of the maximum radiation intensity is implied.

Essentially, this means that the directivity of an antenna is the ratio of the radiation intensity in a given direction over that of an isotropic source. This can be written as:

$$D = U/U_0 \quad 2.4$$

$$= 4\pi U/P_{\text{rad}} \quad 2.5$$

Where,

U = radiation intensity (W/unit solid angle)

U_0 = radiation intensity of an isotropic source (W/unit solid angle)

P_{rad} = total radiated power (W)

If the antenna is to radiate in all directions (isotropic radiator) then its directivity would be unity. As an isotropic radiator cannot be realised practically, the most comparable antenna is a short dipole, which has a directivity of 1.5. Any other antenna will have a higher directivity than 1.5, which means their patterns are more focused in a particular direction.

2.2.1.4 Antenna Efficiency

Like other microwave components, antennas can suffer from losses. The total antenna efficiency takes into account the losses at the input terminals, and within the structure of the antenna itself.

The mismatch or reflection efficiency (η_r) is directly related to the return loss and can be defined as:

$$\eta_r = 1 - |\Gamma|^2 \quad 2.6$$

The radiation efficiency (η) is a measure of how much power is lost in the antenna due to conductor and dielectric losses. These losses reduce the radiation in any given direction and can be expressed as:

$$\eta = P_{\text{rad}}/P_{\text{in}} \quad 2.7$$

2.2.1.5 Gain

The ratio of the intensity in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically, the radiation intensity corresponding to the isotropically radiated power is equal to the power accepted by the antenna divided by 4π . This can be expressed as;

$$G = 4\pi U(\phi, \theta) / P_{in} \quad 2.8$$

Unless specified, it is assumed that the antenna is receiving a signal in the direction of maximum gain. It is also common for the gain to be expressed in decibels and referenced to an isotropic source ($G = 1$), as shown;

$$G (\text{dB}_i) = 10 \text{ Log } (G/1) \quad 2.9$$

2.2.1.6 Polarisation

The property of an electromagnetic wave describing the time-varying direction and relative magnitude of the electric-field vector; specifically, the Fig. traced as a function of time by the extremity of the vector at a fixed location in space, and the sense in which it is traced, as observed along the direction of propagation.

Polarisation is the curve traced by the tip of the electric field vector viewed in the direction of propagation. Fig. 2.2 shows a typical trace as a function of time.

The polarisation of the wave may be linear, circular, or elliptical. The instantaneous electric field of a plane wave travelling in the negative z direction may be written as:

$$E(z, t) = E_x(z, t) \hat{x} + E_y(z, t) \hat{y} \quad 2.10$$

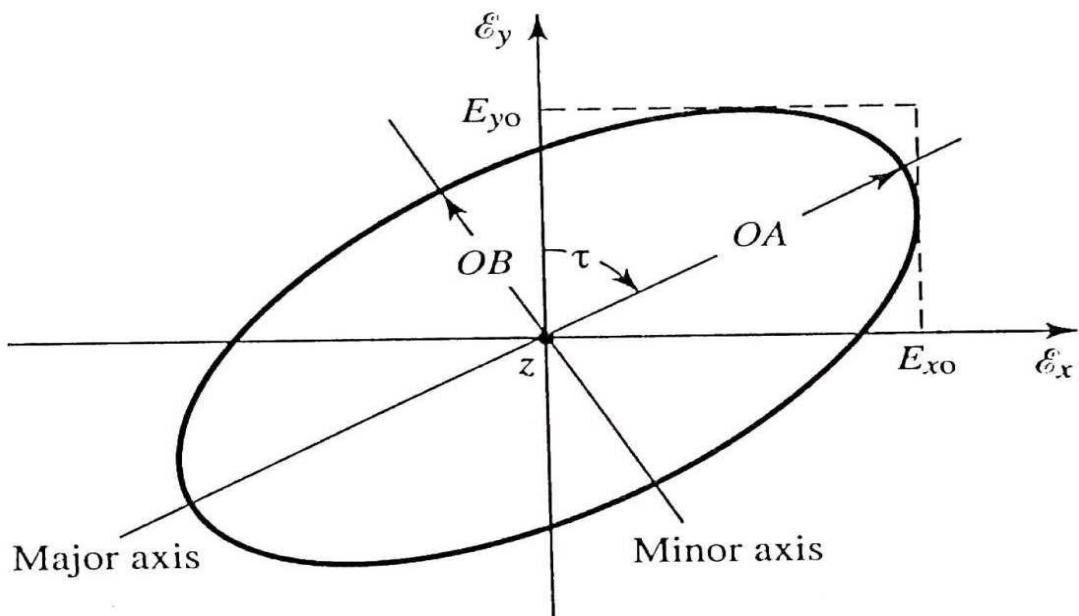
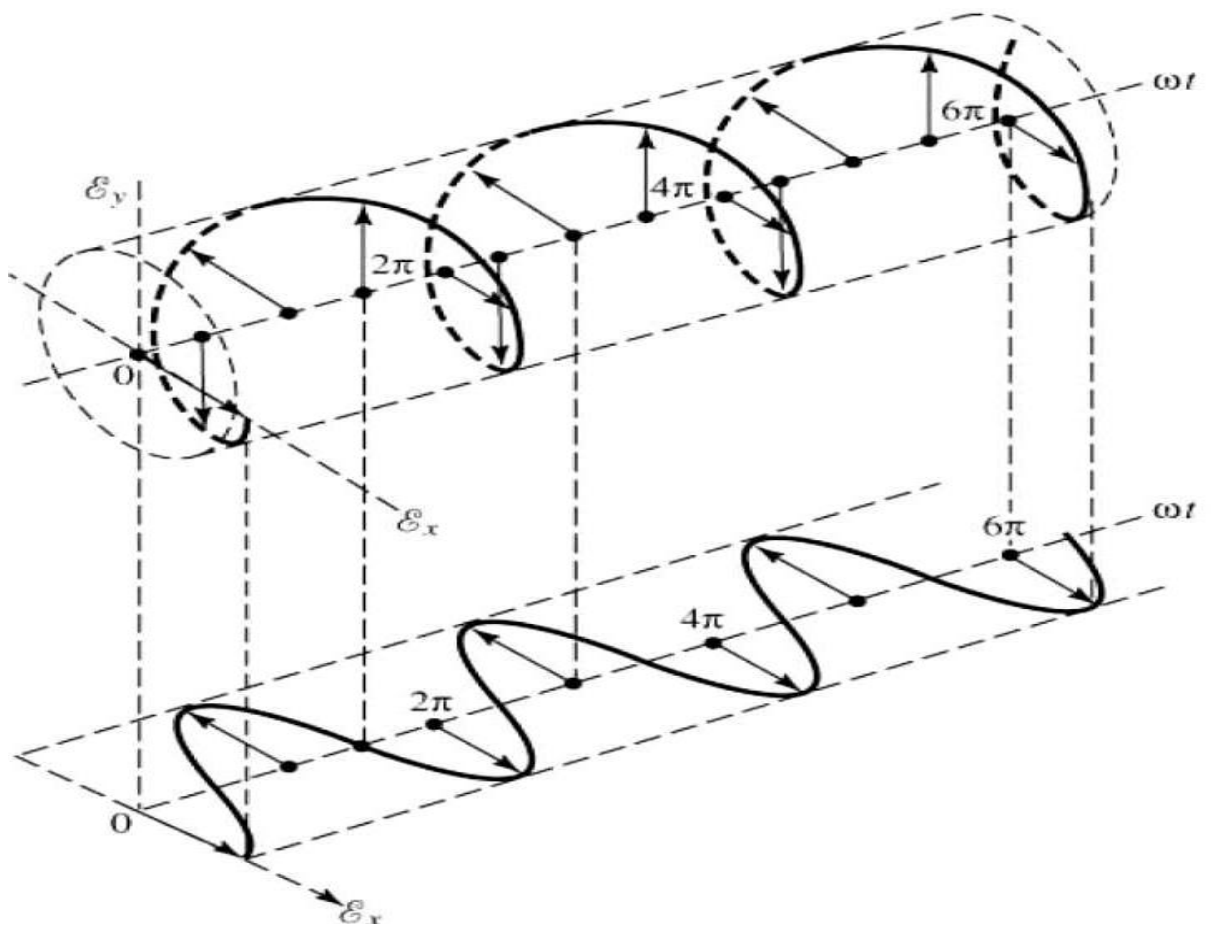


Fig. 2.2: Rotation of a plane electromagnetic wave and its polarisation ellipse at $z = 0$ as a function of time.

The instantaneous components are related to their complex counterparts by:

$$E_x(z, t) = E_y \cos(\omega t + \beta z + \theta_x) \quad 2.11$$

and

$$E_y(z, t) = E_x \cos(\omega t + \beta z + \theta_y) \quad 2.12$$

Where E_x and E_y are the maximum magnitudes and θ_x and θ_y are the phase angles of the x and y components respectively, ω is the angular frequency and β is the propagation constant.

2.3 COPLANAR WAVEGUIDE (CPW) TECHNOLOGY

2.3.1 Introduction

The CPW proposed by C. P. Wen in 1969 consisted of a dielectric substrate with conductors on the top surface. The conductors formed a centre strip separated by a narrow gap from two ground planes on either side. The dimensions of the centre strip, the gap, the thickness and permittivity of the dielectric substrate determined the effective dielectric constant, characteristic impedance and the attenuation of the line. This basic structure known as conventional CPW.

A conventional CPW on a dielectric substrate consists of a centre strip conductor with semi-infinite ground planes on either side as shown in Fig. 2.1. This structure supports a quasi-TEM mode of propagation. The CPW offers several advantages over conventional micro strip line: First, it simplifies fabrication: second, it facilitates easy shunt as well as series surface mounting of active and passive devices. Third it eliminates the need for wrap around and via holes and fourth, it reduces radiation loss. Furthermore the characteristic impedance is determined by the ratio of a/b , so size reduction is possible without limit, the only penalty being higher losses. In addition a ground plane exists between any two adjacent lines; hence cross talk effects between adjacent lines are very weak. As a result, CPW circuits can be made denser than conventional micro strip circuits. These, as well as several other advantages, make CPW ideally suited for MIC as well as MMIC applications.

Major advantages gained in manufacturing are, first, CPW lends itself to the use of automatic pick-and-place and bond assembly equipments for surface mount component placement and interconnection of components respectively.

2.3.2 Performance of CPW

The quasi-TEM mode of propagation on a CPW has low dispersion and hence it offers the potential to construct wide band circuits and components. In CPW amplifier circuits, by eliminating via holes and its associated parasitic source inductance, the gain can be enhanced.

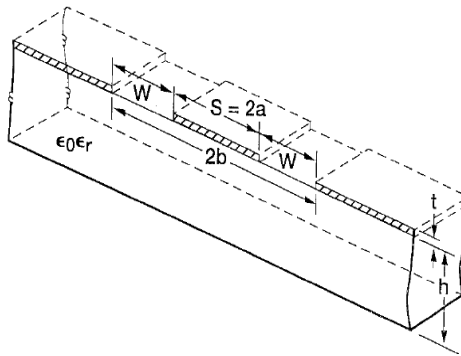


Fig. 2.3: Schematic of a coplanar waveguide (CPW) on a dielectric substrate of finite thickness.

2.3.3 Types of CPW

- 1- Conventional CPW
- 2- Conductor backed CPW
- 3- Micro machined CPW

In a conventional CPW, the ground planes are of semi-infinite extent on either side. However, in a practical circuit the ground planes are made of finite extent. The conductor-backed CPW has an additional ground plane at the bottom surface of the substrate. This lower ground plane not only provides mechanical support to the substrate but also acts as a heat sink for circuits with active devices. A conductor backed CPW is shown in Fig. 2.2. The micro machined CPWs are of two types, namely, the micro shield line and the CPW suspended by a silicon dioxide membrane above a micro machined groove.

These lines are illustrated in Figs. 2.3 and 2.4 respectively. The advantages of the micro shield line are its extremely wide bandwidth, minimal dispersion and zero dielectric loss. The advantage of the later CPW is that it is compatible with commercial CMOS foundry process and hence, is capable of monolithically integrating CMOS devices and circuits.

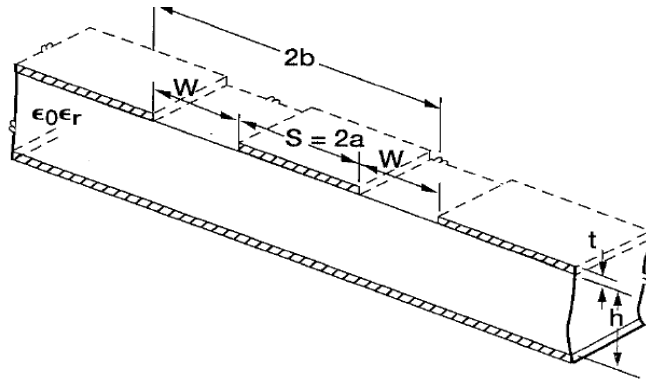


Fig. 2.4: Schematic of a conductor-backed coplanar waveguide (CBCPW).

2.3.4 Typical Applications of CPW

Micro-electromechanical Systems (MEMS) Metal Membrane Capacitive Switches

The rapid progress made in the area of semiconductor wafer processing has led to the successful development of MEMS based microwave circuits. In a CPW the conductors are located on the top surface of a substrate which makes it ideally suited for fabricating metal membrane, capacitive, shunt-type switches. CPW MEMS shunt switches with good insertion loss characteristics, reasonable switching voltages, fast switching speed, and excellent linearity have recently been demonstrated. These switches offer the potential to build new generation of low-loss high-linearity microwave circuits for phased array antennas and communication systems.

Thin Film High-Temperature Superconducting /Ferroelectric Tuneable Circuits and Components

Recent advances made in the area of thin film deposition techniques, such as sputtering, chemical vapour deposition, and etching technologies, have resulted in the application of high temperature superconducting (HTS) materials to microwave circuits. The HTS circuits have low microwave surface resistance over a wide range of frequencies. As a result signal propagation takes place along these transmission lines with negligible amount of attenuation.

Furthermore the advantage of using CPW is that only one surface of the substrate needs to be coated with HTS material before pattern. Recently HTS low-pass and band-stop CPW filters have been demonstrated.

In addition by incorporating ferroelectric materials with HTS materials such as, low-loss, voltage-tuneable MMICs with reduced length scales can be constructed. These MMICs have potential applications in phased array antenna systems and frequency agile communications

systems. Recently voltage tuneable CPW phase shifters, mixers and filters have been demonstrated.

Photonic Band gap Structures

When an electromagnetic wave propagates along a conductor backed CPW some considerable amount of energy leakage takes place. The energy that leaks, propagates along the transverse directions away from the line, and excites a parallel plate mode between the CPW top and bottom ground planes. The parasitic parallel plate mode is the leading cause for crosstalk between adjacent circuits. The cross talk can be suppressed by constructing a photonic band gap lattice on the CPW top ground planes as demonstrated.

Printed Antennas

A radiating element is constructed from a conventional CPW by widening the centre strip conductor to form a rectangular or square patch. This patch produces a single-lobe, linearly polarized pattern directed normal to the plane of the conductors. The advantage gained over conventional micro strip patch antenna is lower cross polarized radiation from the feed. A conductor backed CPW with a series gap in the centre strip conductor is used to couple power to a patch through an aperture in the common ground plane. This design offers the flexibility of inserting semiconductor devices in the series gap of the feed for controlling the coupling

The micro strip patch antennas have a lot of merits such as low-cost, low-profile, conformability, and ease of manufacture, which make them very attractive. The primary barrier to implementing these antennas in many applications, however, is their limited bandwidth only on the order of a few percent for a typical patch radiator. Because of this fact, much work has been devoted to increasing the bandwidth of micro strip patches. A straightforward method is to use a thick substrate with a low dielectric constant for the antenna. Another technique which can be implemented in the aperture coupled configuration is to use a near-resonance aperture in combination with the thick antennas substrate or multilayer substrates to achieve wide frequency band. But the common aperture coupled structure where the slot in the ground plane is fed via a micro strip line on an additional substrate layer which complicates the antenna design. Coplanar waveguides have been suggested as an alternate to micro strip-line for feeding the micro strip antenna and they have been used increasingly in the design of millimetre-wave micro strip antennas.

However, there haven't been yet any special papers which systematically analyze feed characteristics of the coplanar waveguide with coupling slots. Although the coplanar waveguide with a C-shape slot has been studied in some papers, the effects of feeding structure dimensions on the antenna performance are not presented concretely. In this project, the

feeding performance of coplanar waveguides with dual-C and single C-shape are studied respectively.

2.4 KEY REQUIREMENTS FOR UWB ANTENNAS

The key requirements that should be considered are as follows:

1. All of the parameters described above i.e. pattern, gain efficiency etc. must be considered when designing any type of antenna that is part of a RF-front end. However, UWB antennas have additional design challenges. For example, as the name suggests, the antenna must operate over a large bandwidth when compared to narrowband antennas. The bandwidth is specified by the FCC is 3.1 to 10.6 GHz; hence the antenna must achieve an impedance bandwidth of 7.5 GHz.
2. Another important requirement is group delay. Group delay is defined as the rate of change of the total phase shift, θ , with respect to the angular frequency, ω , as shown in Equation 2.13.

$$\text{Group delay} = d(\Theta)/d(\omega) \quad 2.13$$

If the phase is linear throughout the bandwidth then the group delay is constant throughout the bandwidth. Group delay can then be used as an indicator to show how well a pulse will be transmitted with consideration of distortion and dispersion. Normally, group delay is not considered in narrowband antenna design because linear phase is normally quite easy to achieve over a narrow band. Generally, if the group delay is in the tens of nano-seconds range, or less the performance is acceptable.

3. The radiation pattern is an extremely important requirement for UWB antennas. For wireless sensor network applications, it is desirable to have an Omni-directional pattern so orientation of the transmitter/receiver is not as important. As the antenna operates over a large bandwidth, its pattern at the low frequency cut-off (3.1 GHz) is different to that of the pattern at the higher frequency end (10.6 GHz), although good design can minimize this effect.
4. There are several other key requirements that are desirable for UWB antennas and are summarised below:

Compactness – Size is critical in terms of cost, as well as achieving the ultimate aim for this project.

Planar – Ease of integration into monolithic circuits.

Good VSWR (<2) – This is required across the whole band of operation so as to maintain good matching and efficient operation.

Constant Gain – This is desirable across the whole band of operation because the signal is transmitted instantaneously across the whole (or a large part) of the frequency band (3.1 – 10.6 GHz).

CHAPTER THREE

ANTENNA DESIGN

3.1 DESIGNS OF UWB ANTENNAS

For this project, we have four main parameters. Those parameters are the bandwidth, VSWR, gain, and the radiation pattern of the antenna. These parameters will help us understand if the antenna we are designing will be the optimal design for our application.

As we know the several design methods and structures have been reported. These UWB antennas with filtering property at the 5–6 GHz band have been proposed not only to mitigate the potential interferences but also to remove the requirement of an extra band stop filter in the system [9].

Recently, more and more band-notched UWB antenna designs have been proposed. J.Kim proposed a 5.2 GHz notched UWB antenna using slot-type SRR [10]. This UWB antenna fulfils all the critical requirements including high radiation efficiency, low profile, stable radiation patterns and constant gain. However, the input impedance is not well matched at the lowest frequencies (3.1–3.8 GHz). In addition, the notched frequency band from 5–5.3 GHz cannot successfully block out the whole WLAN bands. The potential interferences between the UWB and WLAN systems cannot be reduced to the minimum.

Yi-Cheng Lin have been discussed the design of three advanced band-notched 5–6 GHz UWB rectangular aperture antennas [8]. The antenna structure is simple and the aperture size is compact. Broad impedance bandwidth and stable radiation patterns are obtained, whereas the ground plane dimension is a bit large. In practice, when integrated with the system board of different ground plane size, the antenna might need a retuning for the optimized dimensions.

Wang-Sang also has proposed wideband planar monopole antennas with dual band-notched characteristics [11]. This technique is suitable for creating UWB antenna with narrow frequency notches or for creating multiband antennas. However, the antenna is not suitable for integration with compact systems, because its ground plane is very large and it is perpendicular to the radiator, which limits its applications in compact UWB systems. Furthermore, the bandwidth performance of the antenna is from 2 GHz to 6 GHz, which can not satisfy the demands of UWB system.

In [14] the authors propose a new ultra wide band antenna for UWB applications. The proposed antenna consists of a rectangular patch with two steps, a single slot on the patch and a partial ground plane but the gain is not constant.

3.2 CPW-FED UWB ANTENNA WITH DUAL BAND-NOTCH

Based on the background of the researches above, a simple and compact CPW-fed planar UWB antenna with dual band-notched characteristics in 3.4 GHz (3.3–3.8 GHz) and 5.5 GHz (5–6 GHz) is designed and tested. The dual band-notched operations are achieved by etching two nested C-shaped slots in the rectangular metal radiating patch. It is found that by adjusting the total length of the C-shaped slot to approximately half-wavelength of the desired notched frequency, a destructive interference can take place, causing the antenna nonresponsive at that frequency. It is easy to tune the notch centre frequency with the change in total length of slot.

This antenna yields an impedance bandwidth of 3.1–10.6 GHz with $VSWR \leq 2$, except the WiMAX band (3.3–3.8 GHz) and (5–6) GHz for HIPERLAN/2 WLAN systems. The stable radiation patterns and constant gain are also obtained.

The notch frequency is given by

$$f_{\text{notch}} = C / (2L\sqrt{\epsilon_{\text{eff}}}) \quad 3.1$$

Besides WLAN systems, WiMAX also operates in the UWB band. To minimize the potential interferences between UWB system and narrowband systems, in this project, a kind of dual band-notched design is presented to demonstrate the superior features. By etching two nested C-shaped slots in radiating patch, the required dual band-notched filtering properties both in 3.3–3.6 GHz band and 5–6 GHz band are achieved.

3.2.1 Design 1 using trapezium ground plane

Fig. 3.1 shows the geometry of the antenna without slot (antenna A1) which works in the frequency band (3.1-10.6GHz) of UWB without any frequency notch.

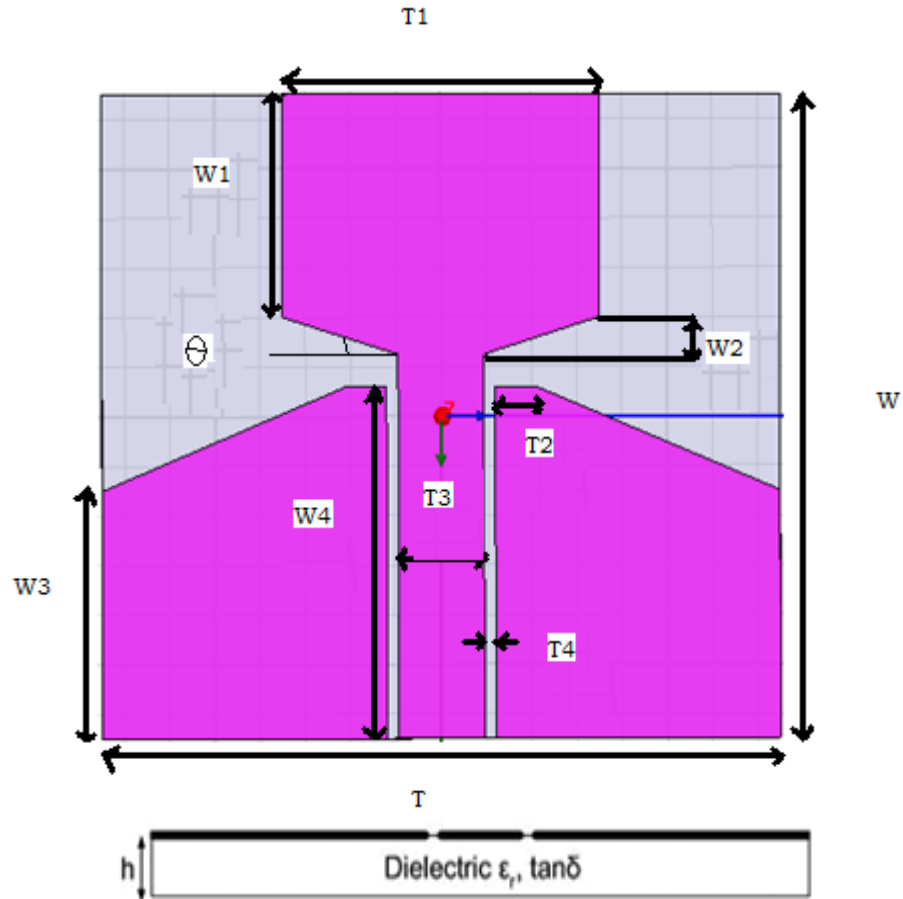


Fig. 3.1: Geometry and configuration of antenna without slot (antenna A1).

The optimize dimensional of the antenna are

T (Total length) =30mm

W (Total width) =26mm

T₁ (Patch length) =14mm

W₁ (Patch width) =9mm

T₂=1.8mm

W₂ (slop) =1.5mm

T₃ (Fed width) =3.8mm

W₃ (Ground plane height) =9.2mm

T₄(Gap) =0.5mm

W₄ (Ground plane height 2) =14.7mm

The antenna is fabricated on an h=1.6mm FR4 epoxy substrate with dielectric constant $\epsilon_r=4.4$ and loss tangent $\tan \delta =0.02$ and thickness h=1.6mm. As shown in the Fig. 3.1 a rectangle radiator is fed by a 50 CPW transmission line which is terminated with a sub miniature A (SMA) connector for measurement purpose. Since both the antenna and the feeding are implemented on the same plane, only one layer of substrate with single-sided metallization is used, and the manufacturing of the antenna is very easy and extremely low cost. Both the radiating patch and the ground plane are bevelled, which results in a smooth transition from one resonant mode to another and ensures good impedance match over a broad frequency range.

$$W = T = C/2 * f_L * \sqrt{\epsilon_{\text{reff}}} \quad 3.2$$

$$\epsilon_{\text{reff}} = (\epsilon_r + 1)/2$$

$$T_1 = W_1 = C/2 * f_r * \sqrt{\epsilon_{\text{reff}}} \quad 3.3$$

$$f_r = (f_H + f_L)/2$$

The width of the CPW-feed line is

$$T_3 \leq 120 * h * \pi / z_0 * \sqrt{\epsilon_r} \quad 3.4$$

For good accuracy of CPW

$$T_4/h \leq 0.5 \text{mm} \quad 3.5$$

The ground plane size is

$$W_4 = C/2 * f_r * \sqrt{\epsilon_r} \quad 3.6$$

To reduce the interferences from the IEEE802.11a and HIPERLAN/2 WLAN systems, the band-notched function is desirable in the UWB system. Fig.3.2 shows the geometry and dimensions of the UWB antenna with filtering property operating in the 5–6 GHz band (denoted as antenna A2). By etching a C-shaped slot in the rectangular radiating patch of antenna A1, a frequency band notch is created. Note that when the band-notched design applied to antenna A1, there is no retuning work required for the previously determined dimensions.

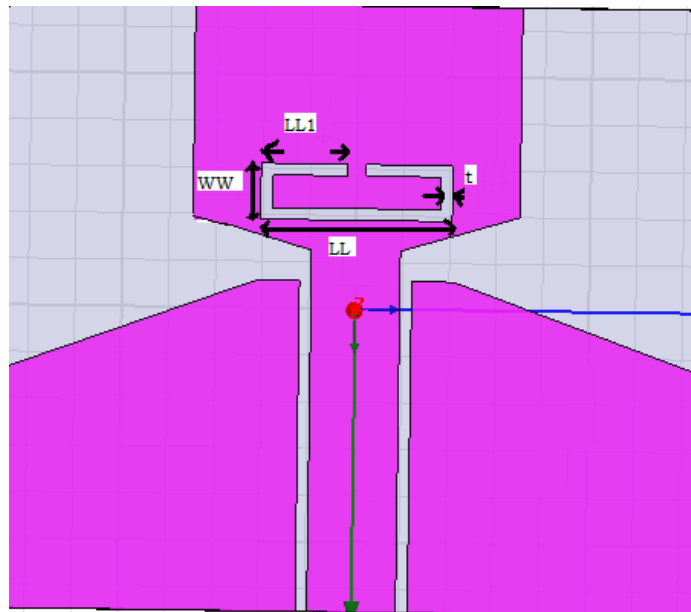


Fig.3.2: Geometry and configuration of antenna with single slot (antenna A2).

Generally, the design concept of the notch function is to adjust the total length of the C-shaped slot to be approximately half-wavelength at the desired notched frequency, which makes the input impedance singular. The current distribution flows around the C-shaped slot. In this case, destructive interference for the excited surface currents in the antenna will occur, which causes the antenna to be nonresponsive at that frequency of 5.5 GHz. The impedance nearby the feed-point changes acutely making large reflection at the desired notched frequency.

The notch frequency given the dimensions of the band-notched feature can be postulated as

$$L = \text{slot length (19.2mm)}$$

Where

$$LL_1 = 6\text{mm}$$

$$WW = 2.6\text{mm}$$

$$LL = 8\text{mm}$$

$$t = 0.5\text{mm}$$

Besides WLAN systems, WiMAX also operates in the UWB band. To minimize the potential interferences between UWB system and narrowband systems in this project, a kind of dual band-notched design is presented to demonstrate the superior features. By etching two nested C-shaped slots in antenna 1, the required dual band-notched filtering properties are achieved.

Fig. 3.3 shows the geometry of the dual band-notched UWB antenna (denoted as antenna A3) and the proposed C-shaped slots. The exterior C-shaped slot makes a notch band at 3.4 GHz and the interior C-shaped slot makes another one at 5.5 GHz, each of the total length of the C-shaped slots is obtained by using equation 3.1.

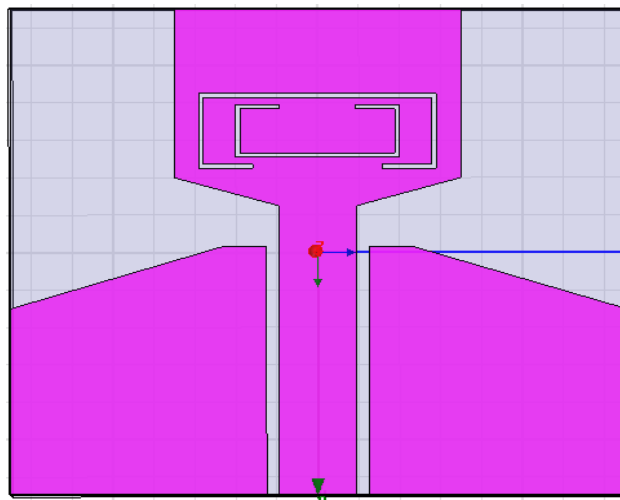


Fig. 3.3: Geometry and configuration of antenna with dual slot (antenna A3).

The length of the exterior C-shaped slot is

$$L2 = 24.8\text{mm}$$

$$t = 0.3\text{mm}$$

Where 't' is the thickness of the slot.

3.2.2 Design 2 using rectangular ground plane

As the ground plane size is small, a few leakage currents distribute along the external conductor of the SMA connector and may affect the radiation patterns. To tackle this problem, an optimized ground plane dimension is needed. It is a very interesting work to discuss the relationship between ground plane and radiation patterns.

So in this design we have done the optimization of design 1, in this case we replaced the trapezium ground plane in to rectangular ground plane ($W_3 = W_4 = 14.7\text{mm}$).

SIMULATION, FABRICATION AND MEASUREMENT

4.1 SIMULATION PROCESSES

The simulation processes flow chart is given below in Fig 4.1.

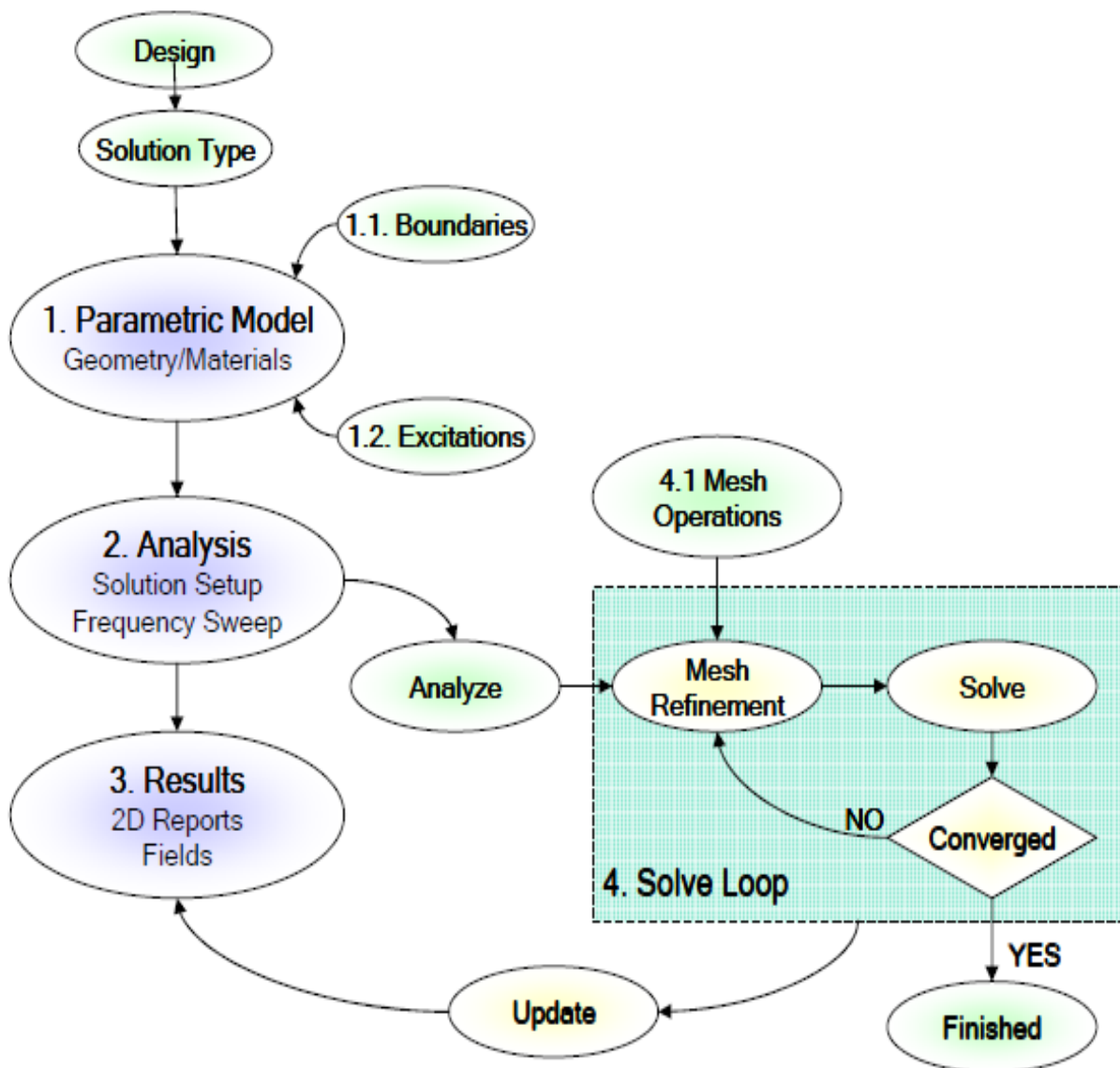


Fig.4.1: Flow chart of simulation processes

4.2 FABRICATION PROCESSES

For fabrication process Circuit CAM software is used. Circuit CAM provides the user with a sophisticated CAM station. It can control all production data, modify the design step, repeat the complete layout, perform different design rule checks and generate ground planes. With the help of this software the DXF file can easily interface with the fabrication machine. The main procedures are:

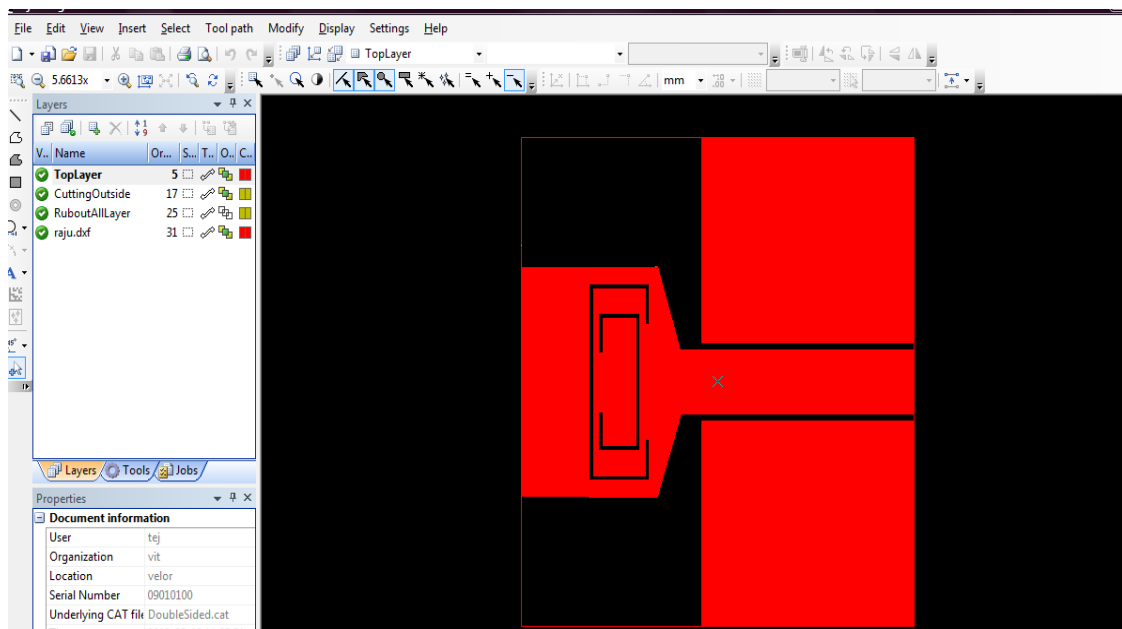
- 1-Importing of CAM files generated by PCB CAD systems
- 2-Verification and design checks of the imported data
- 3-Modifying the layout data for manufacturing purposes
- 4-Tool paths generation for NC machines from LPKF
- 5-Exporting of CAM files

1-Export file > auto CAD DXF file.

2- Open circuit CAM > file > import

Click ok.

The below Fig.4.2 shows the antenna configuration fabrication setup.



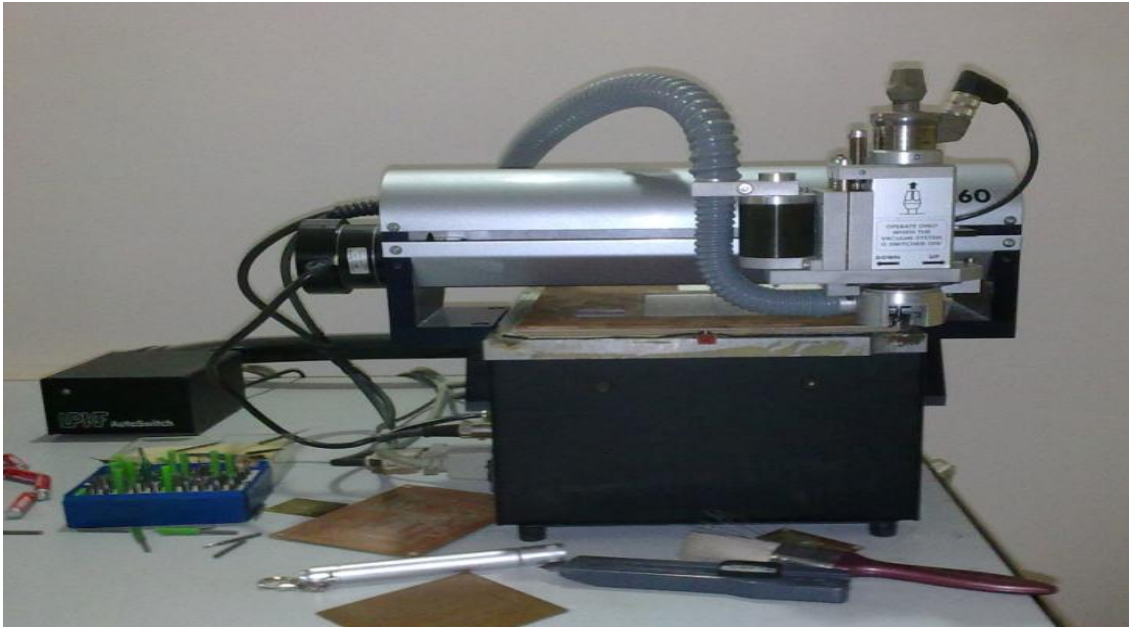


Fig.4.2: fabrication setup

The fabricated antenna shown in Fig.4.3.

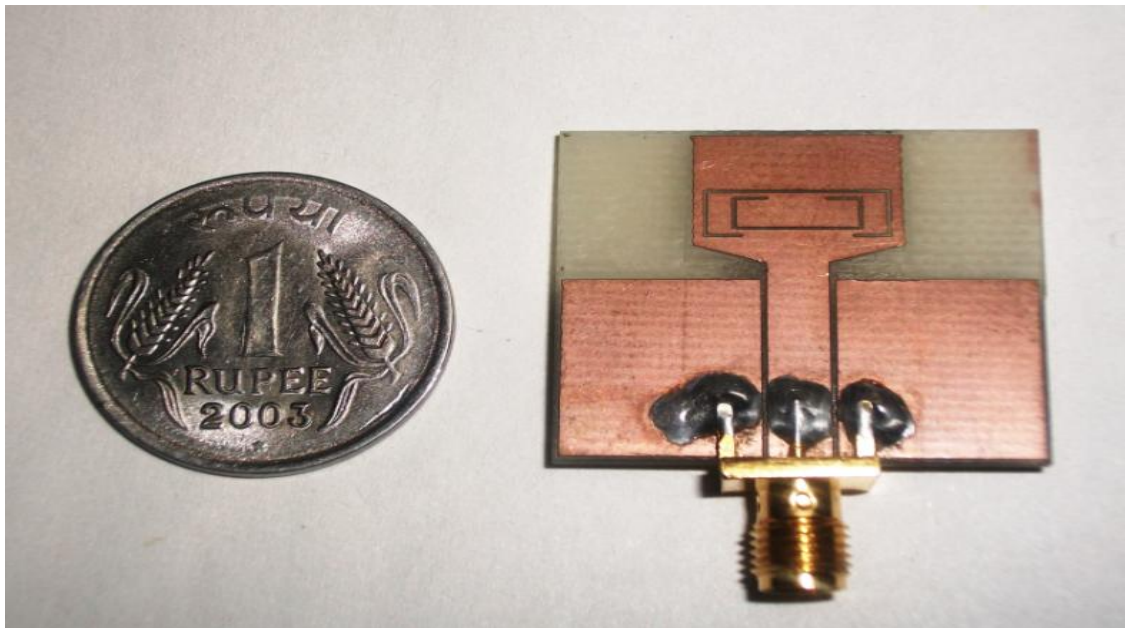


Fig.4.3: Photograph of fabricated antenna

4.3 MEASUREMENT

The fabricated antenna was testing N5230 Network analyser. Fig.4.4 shows the measurement setup of antenna.

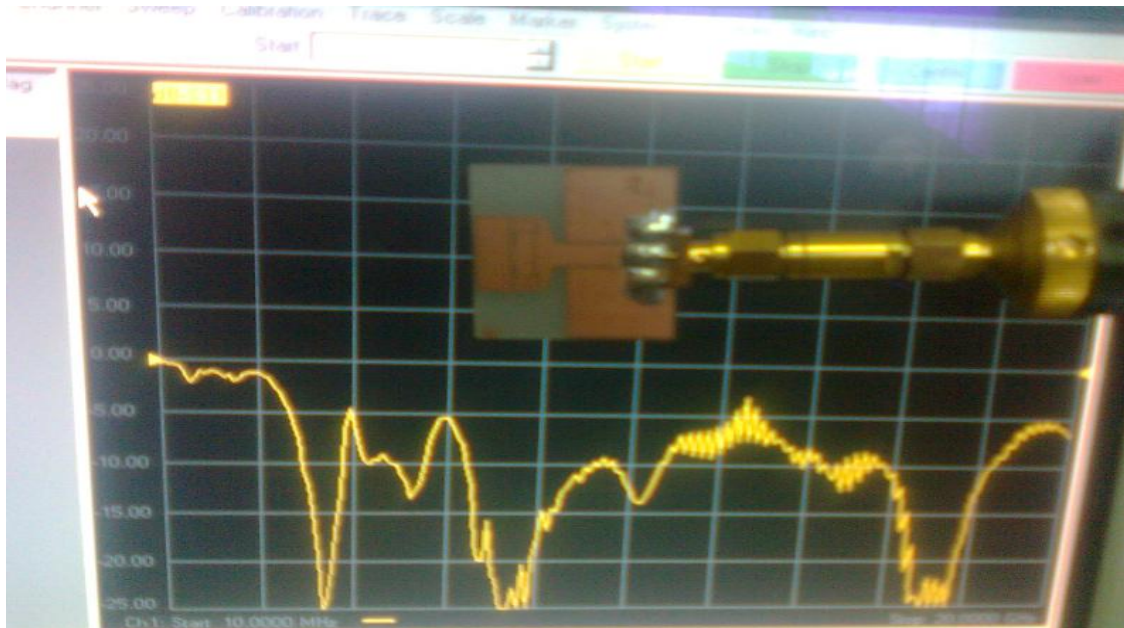


Fig.4.4: measurement setup

The VSWR measurement is shown in Fig. 4.5. Ultra wide bandwidth from 3.1 GHz to 10.6 GHz with two notch band is obtained.

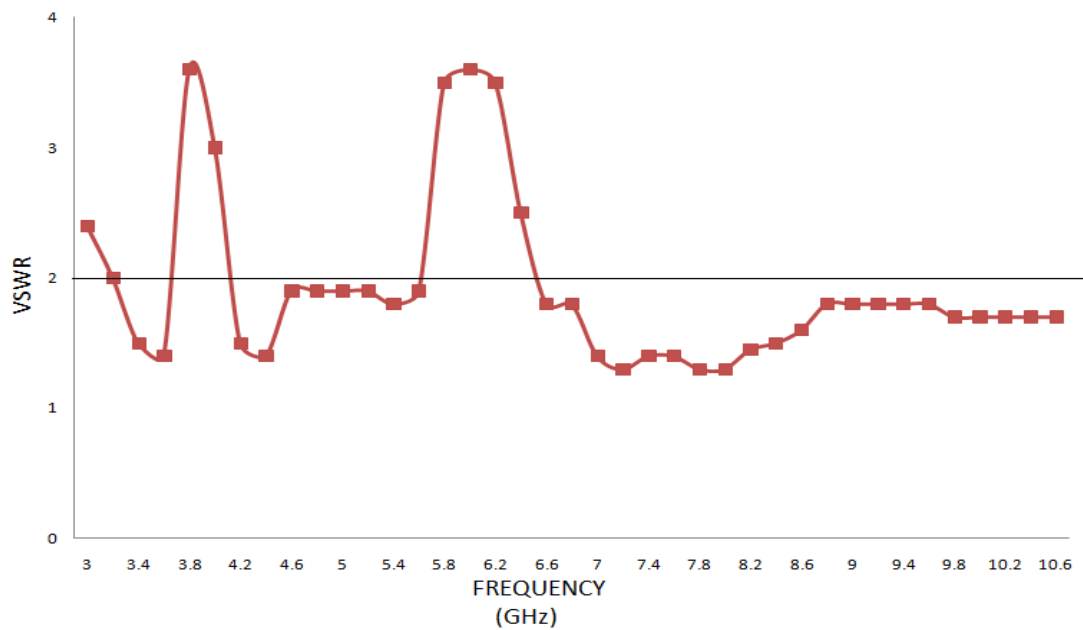


Fig.4.5: Measurement VSWR

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 ANTENNA A1

Fig. 5.1 shows the simulated VSWR of antenna A1. It is found that the input impedance of the antenna A1 is well matched as the bandwidth covers the entire UWB band (3.1–10.6 GHz) and goes beyond the required 10.6 GHz with (VSWR \leq 2). Fig. 5.2 presents the simulated gain for antenna A1. The antenna gain in the UWB band is about 2–5 dB_i.

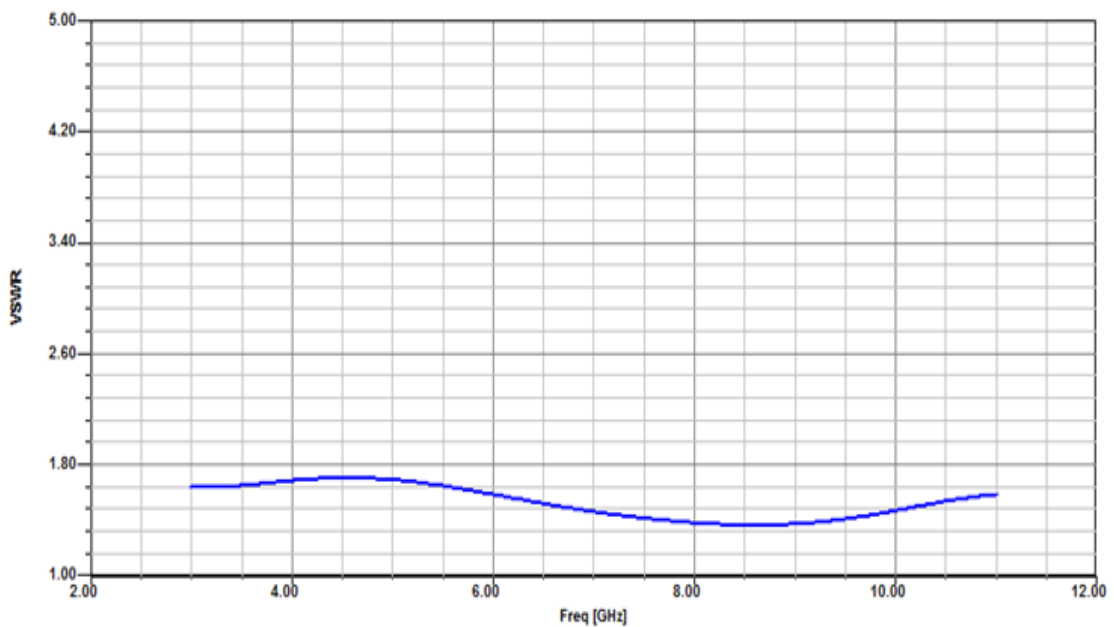


Fig. 5.1: Simulated VSWR of antenna A1 with optimal dimensions.

Group delay is another important requirement. Group delay is defined as the rate of change of the total phase shift θ , with respect to the angular frequency ω , as shown in Equation 5.1.

$$\text{Group delay} = d(\Theta)/d(\omega) \quad 5.1$$

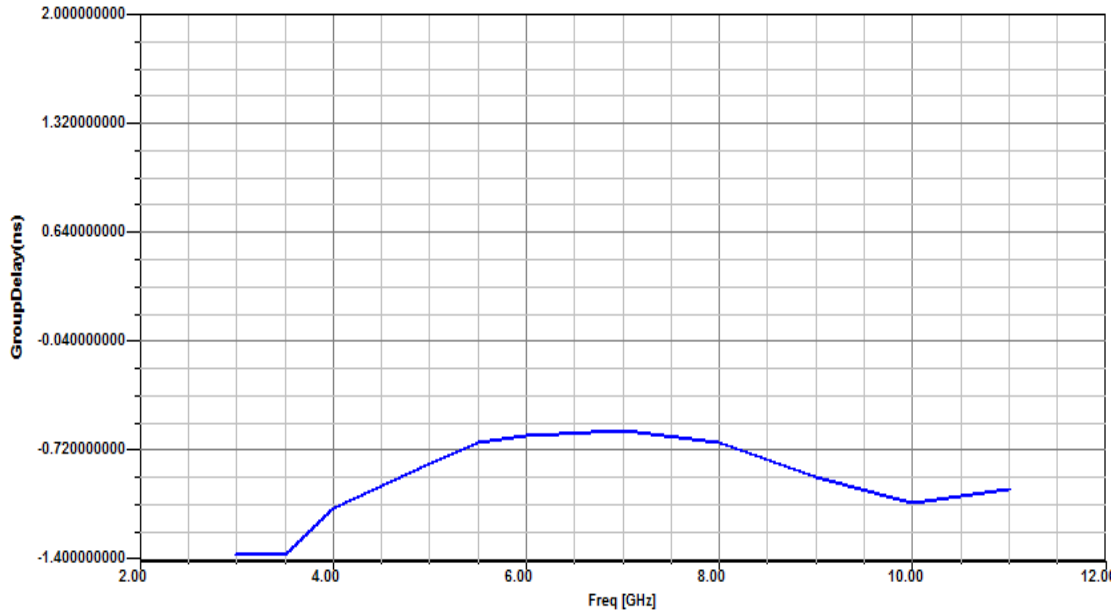


Fig. 5.2: Simulated group delay of antenna A1 with optimal dimensions.

If the phase is linear throughout the bandwidth then the group delay should be constant throughout the bandwidth. Group delay can then be used as an indicator to show how well a pulse will be transmitted without distortion and dispersion. Generally, if the group delay is in the tens of nano-seconds range or less the performance is acceptable.

Fig. 5.2 shows the group delay vs frequency, the variation in group delay is 0.70 ns. The radiation intensity corresponding to the isotropic ally radiated power is equal to the power accepted by the antenna divided by 4π . This can be expressed as;

$$G = 4\pi U(\phi, \Theta) / P_{in} \quad 5.2$$

Fig. 5.3 presents the simulated gain for antenna A1. The antenna gain in the UWB band is about 3.5–6 dB_i. The variation in gain in over all bandwidth is 2.5 dB_i.

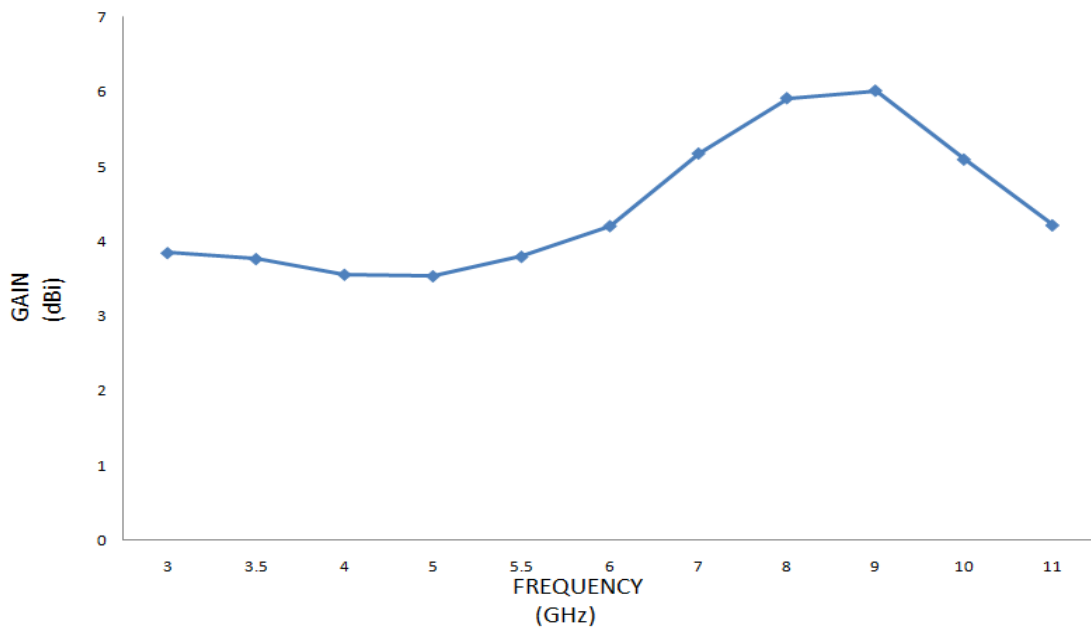


Fig. 5.3: Simulated gain of antenna A1.

It is assumed that the antenna is receiving a signal in the direction of maximum gain. It is also common for the gain to be expressed in decibels and referenced to an isotropic source ($G = 1$), as shown;

$$G \text{ (dBi)} = 10 \text{ Log} (G/1) \quad 5.4$$

5.2 ANTENNA A2

By etching a C-shaped slot in the rectangular radiating patch of antenna A1, a frequency band notch is created. Generally speaking, the design concept of the notch function is to adjust the total length of the C-shaped slot to be approximately half-wavelength at the desired notched frequency, which makes the input impedance singular. For other frequencies, the addition of the C-shaped slot filter has few effects.

Fig. 5.4 (antenna A2) shows the single band notch 5.15-6.02 GHz using single slot.

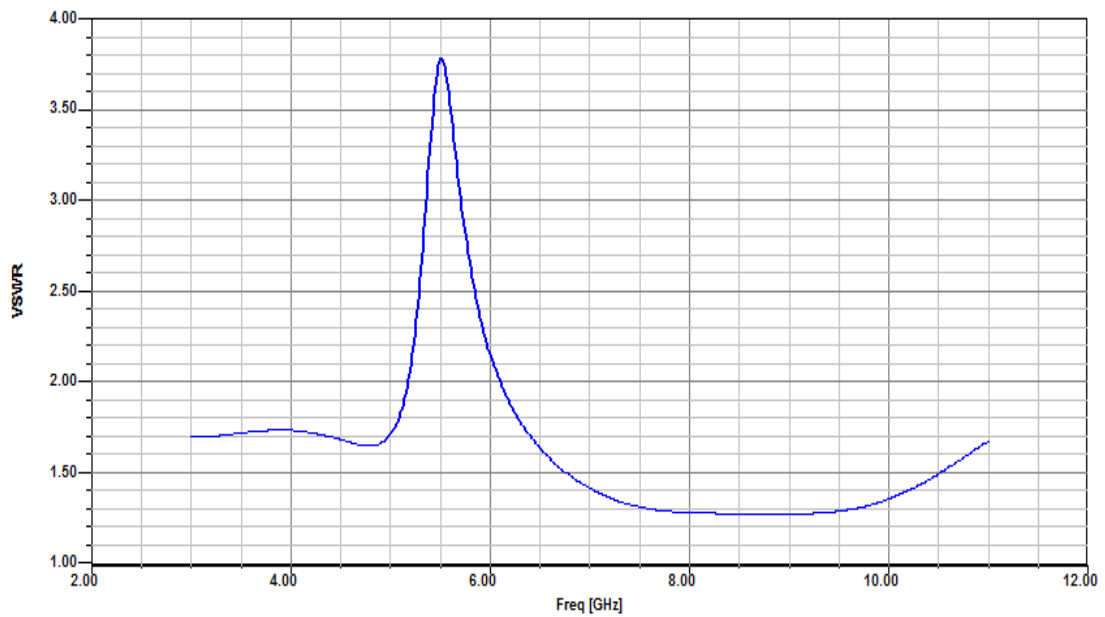


Fig. 5.4: Simulated VSWR of antenna A2 with optimal dimensions.

In this case by using equation 2.2 and 5.1 the signal loss is 35% at 5.5 GHz, the antenna is not working or in other words we can say the linear phase response between input and output is not constant.

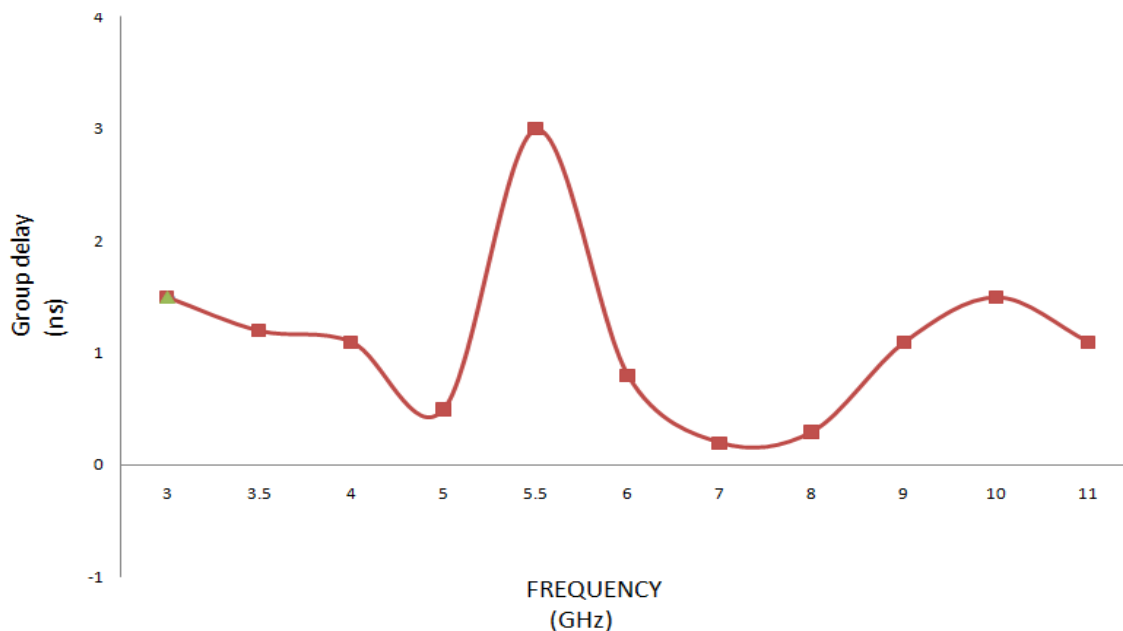


Fig. 5.5: Simulated group delay of antenna A2 with optimal dimensions.

Fig. 5.5 shows the group delay graph which shows that at 5.5 GHz, input and output are not in phase.

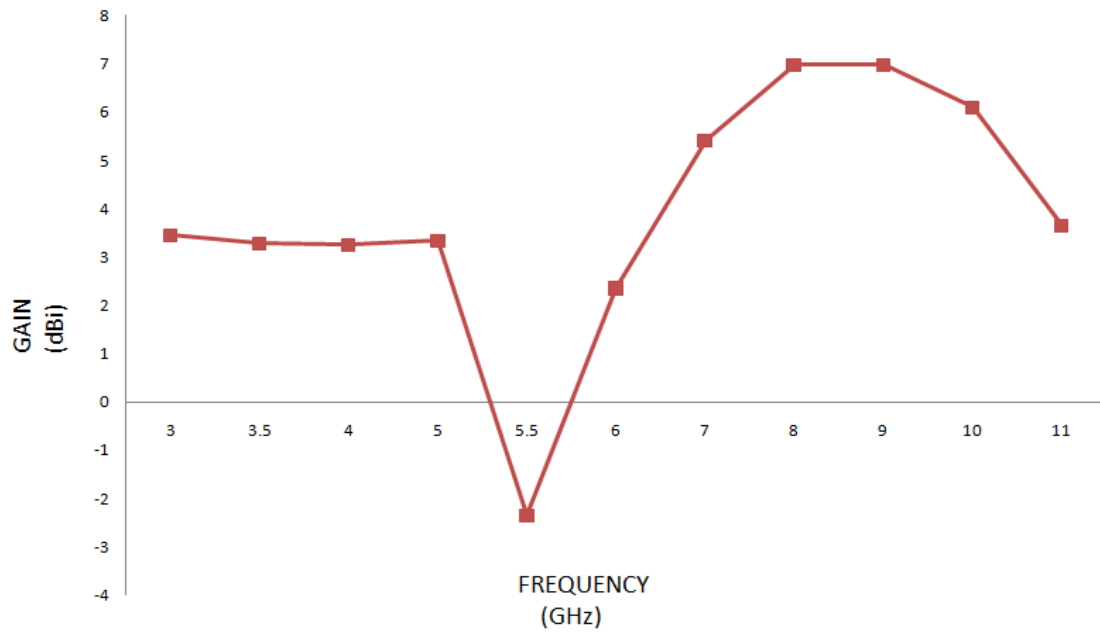


Fig. 5.6: Simulated gain of antenna A2.

Fig. 5.6 presents the simulated gain for antenna A2. The antenna gain in the UWB band is about 3.5–6 dBi. The variation in gain in over all bandwidth is 2.5 dBi but at 5.5 GHz the gain is -3 dBi so at this frequency the loss will be occur.

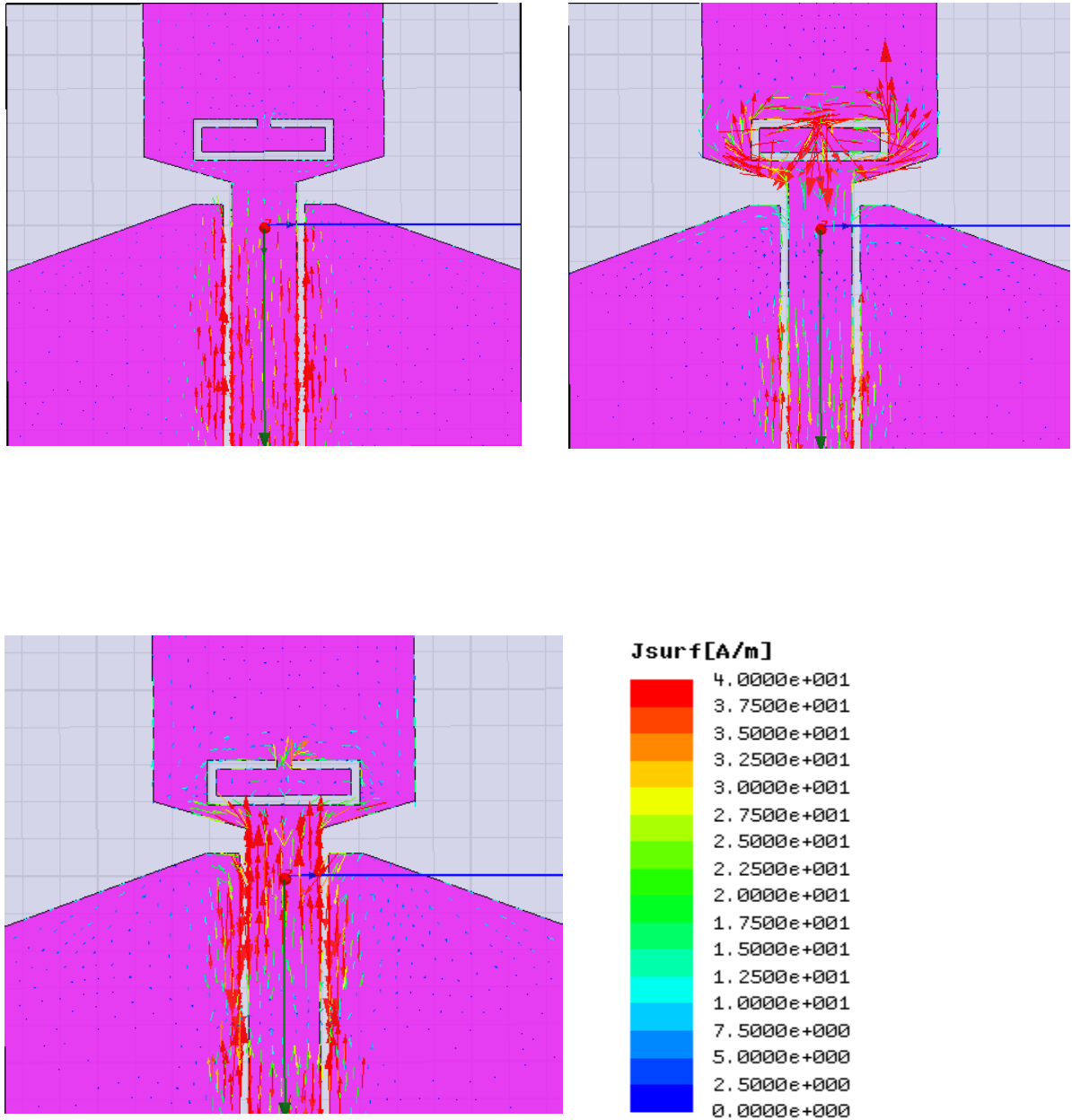


Fig. 5.7: Current distribution at (a) 3 GHz (b) 5.5 GHz (c) 8 GHz

Fig. 5.7 shows the simulated current distributions at different frequencies. At 3 GHz and 8 GHz, the current mainly flow along the feed line, while around the C-shaped slot the current is small. At 5.5 GHz the current mainly flows around the C-shaped slot. In this case, destructive interference (indicated by the oppositely phased vectors around the slot) for the excited surface currents in the antenna occurs, which causes the antenna to be nonresponsive at that frequency. The impedance near the feed-point changes acutely making large reflection at the desired notched frequency.

5.3 ANTENNA A3

Two C- shaped slots were incorporated to achieve dual band notched characteristics. The interior notch length of 18mm at 3.4GHz and exterior notch of 26.5mm were cut to exhibit band notch design.

5.3.1 Effect of geometrical parameters on antenna performance.

Every geometrical parameter has different effects on the performance of the antenna. Four parts of CPW fed antenna is discussed.

5.3.1.1 Effect of trapezium length W_2

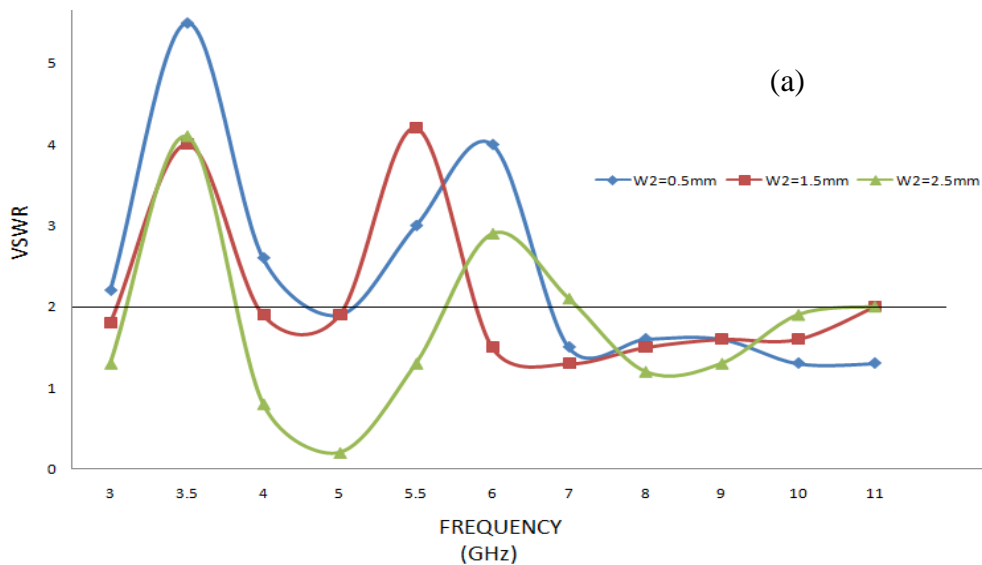
Fig 5.8a shows the simulated VSWR of the antenna as a function of frequency for 3 different values of W_2 . Increasing W_2 from 0.5mm to 2.5 mm increases the center frequency of notched band from 5.5 GHz to 6 GHz. It can be seen that the VSWR of center notch frequency varies from 5.2 to 4 for the lower band and 4.2 to 3 in the upper band. From this result, one can conclude that the VSWR of the center frequency of the notch and filtering frequency is controllable by changing the width W_2 .

5.3.1.2 Effect of bent patch angle Θ

The effect of bent angle on the antenna performance is studied by varying Θ as in Fig5.8b. As Θ is increased from 14.5° to 18.5° VSWR varies from 4 to 3.2 in the lower band and from 4 to 3.5 in the upper band, where as center frequency of the notch band remains almost fixed and VSWR bandwidth increased from 8 GHz to 10.6 GHz due to the electromagnetic coupling between the patch and the ground plane.

5.3.1.3 Effect of Ground plane length W_3

Fig 5.8c indicates the simulated VSWR results of the antenna in terms of W_3 . For $W_3= 9.2, 14.7$ and 17mm with other dimensions fixed, the VSWR varies from 5.1 to 3.2 in the lower notch band and 6 to 4 in the upper notch band , with fixed center notch frequency.



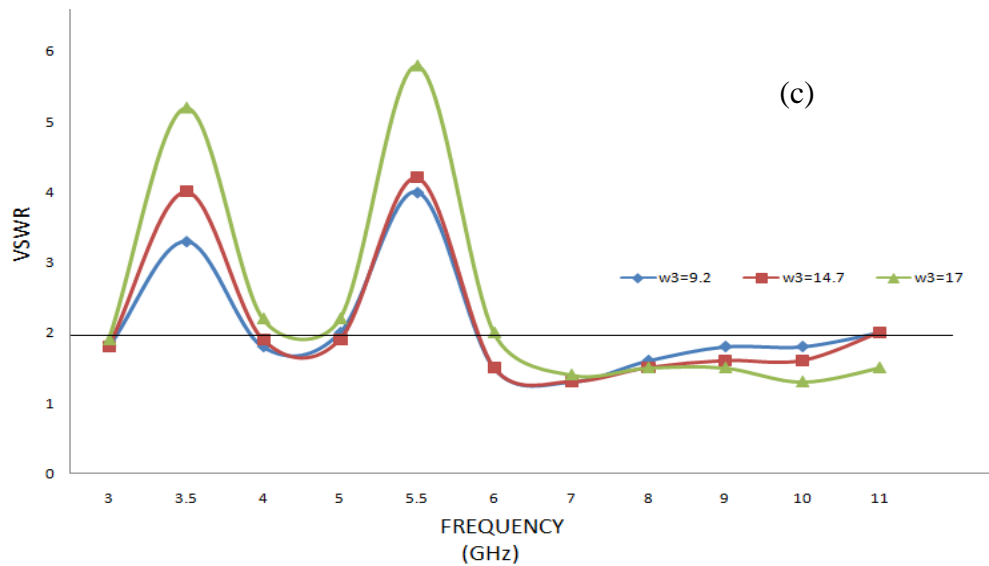
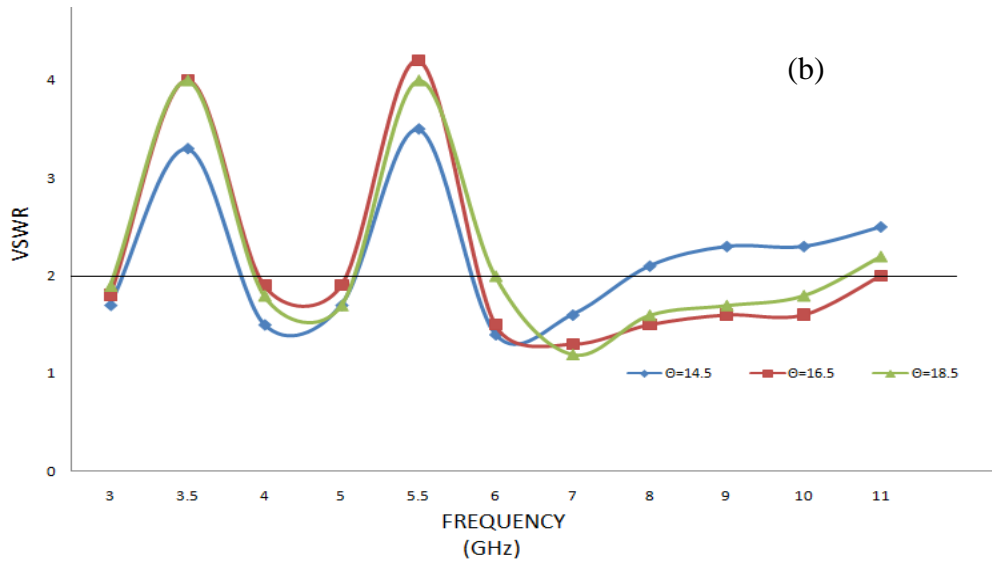


Fig. 5.8: Simulated VSWR of antenna A3 (a) variation of θ (b) variation of w_3 (c) variation of w_2 .

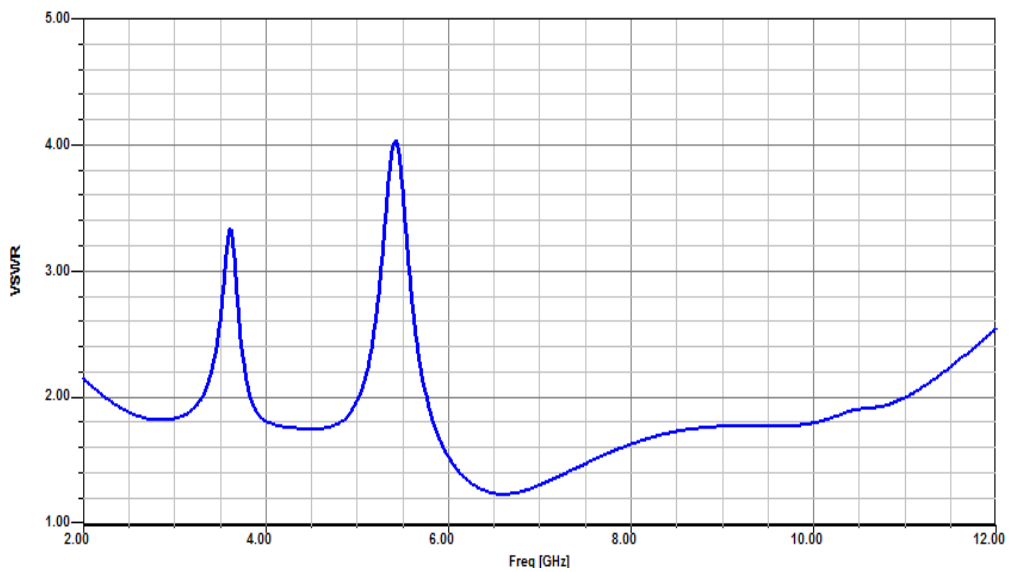


Fig. 5.9: Simulated VSWR of antenna A3 with optimal dimensions

Fig. 5.9, 5.10 and 5.11 shows VSWR, group delay and gain respectively of antenna A3 for optimal dimension. The group delay is almost constant throughout band width except 3.27-3.82GHz and 5-5.82GHz notch frequency band and the variation in gain is 3 dBi only.

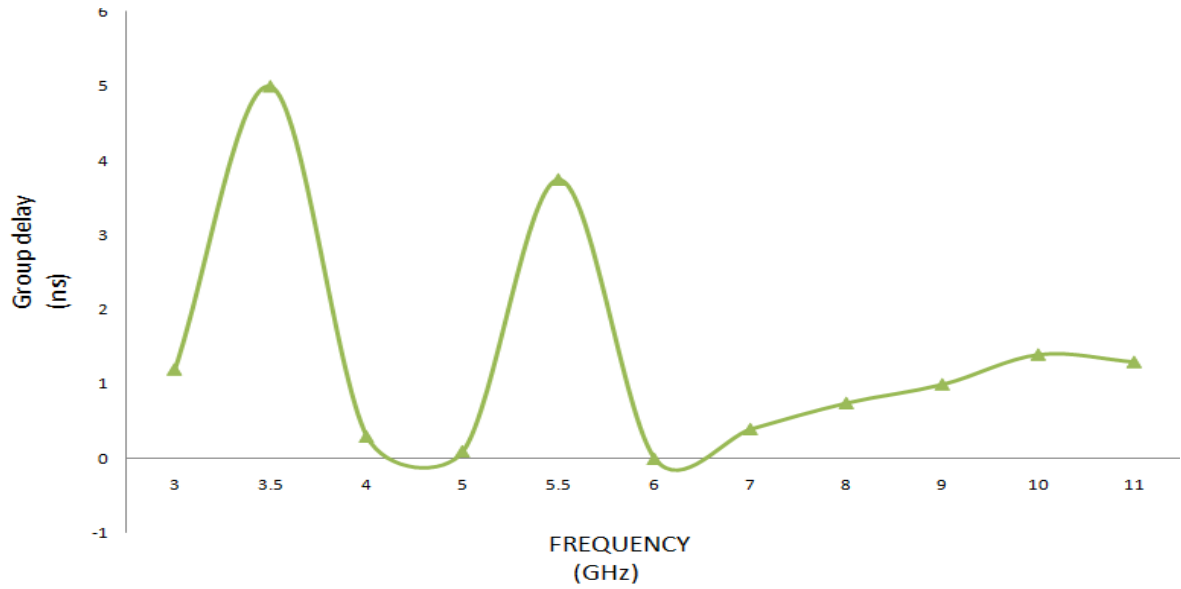


Fig. 5.10: Simulated group delay (ns) of antenna A3 with optimal dimensions.

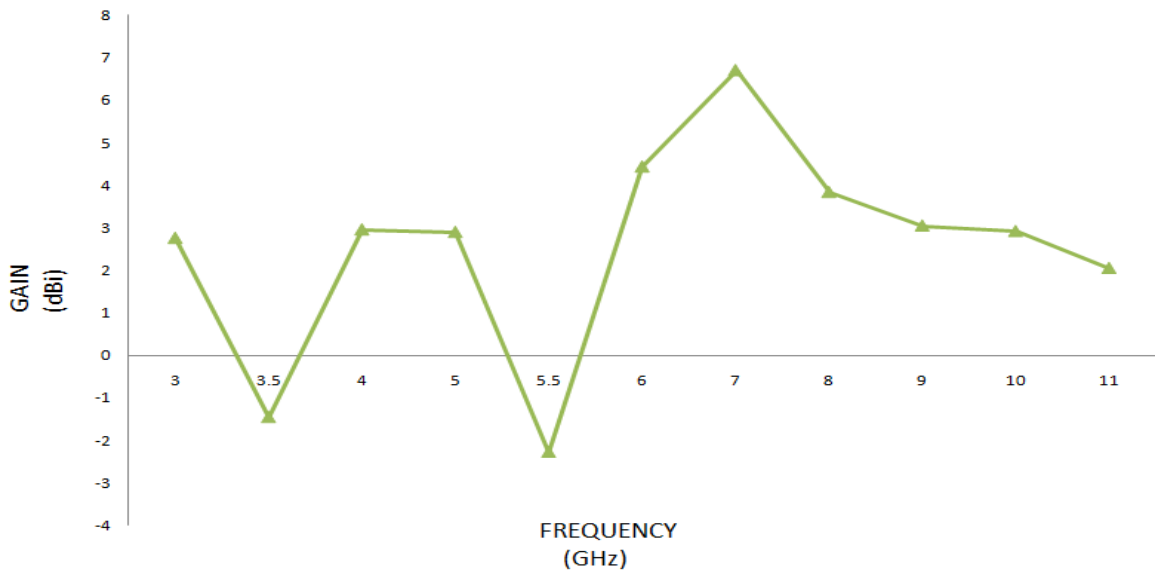


Fig. 5.11: Simulated gain of antenna A3.

Since UWB system uses pulse transmission, an important issue is pulse distortion by the antenna. Ideally, a linear phase response (constant group delay) is desirable. Fig. 5.12 and Fig. 5.13 show the simulated group delay and simulated gain of antenna A1, antenna A2 and antenna A3 respectively. The variation of the group delay of antenna A1 over the UWB band is less than 1 ns. The group delay variations of antenna A2 and antenna A3 highly exceed 4 ns in the vicinity of notch bands. However, in the un-notched frequency part, the group delay variations are small showing good characteristics. These group delay characteristics demonstrate that the proposed antennas exhibit phase linearity at desired UWB frequencies.

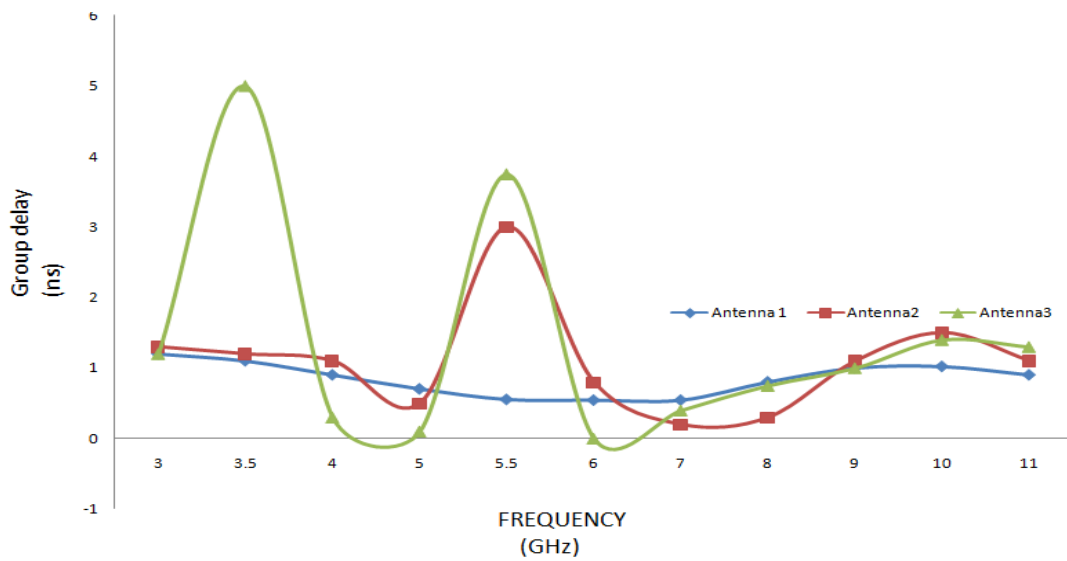


Fig. 5.12: Simulated group delay (ns) of antenna A1, A2, A3 with optimal dimensions.

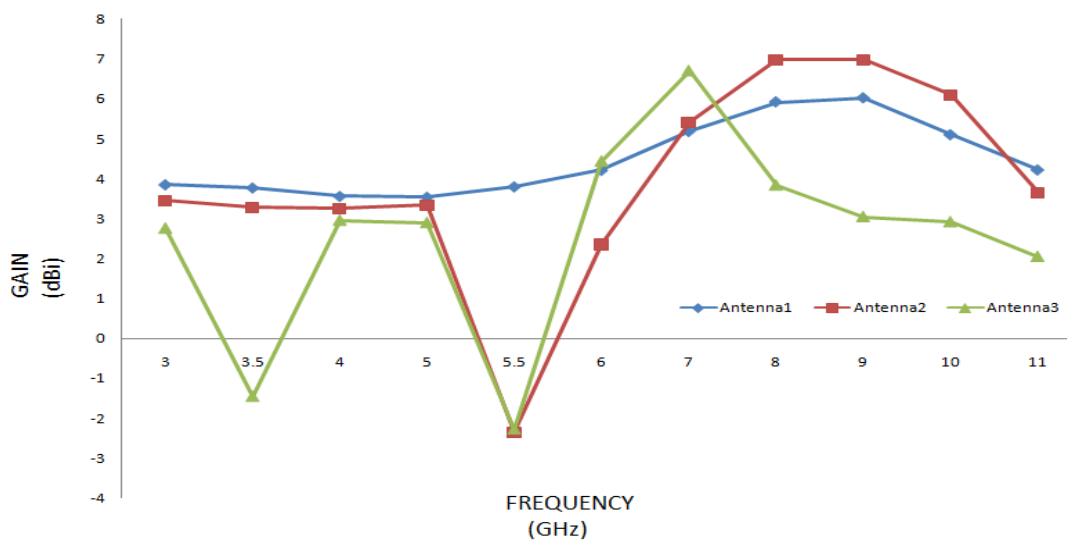


Fig. 5.13: Simulated gain (dBi) of antenna A1, A2, A3 with optimal dimensions.

Radiation pattern

The simulated radiation patterns of antenna 3 in the E-plane (xz-plane) and H-plane (yz-plane) for three different frequencies 3, 8 and 10 GHz are shown in Fig. 5.14. The patterns in the H-plane are quite omni directional as expected. In the E-plane, the radiation patterns remain roughly a dumbbell shape like a small dipole leading to bidirectional patterns.

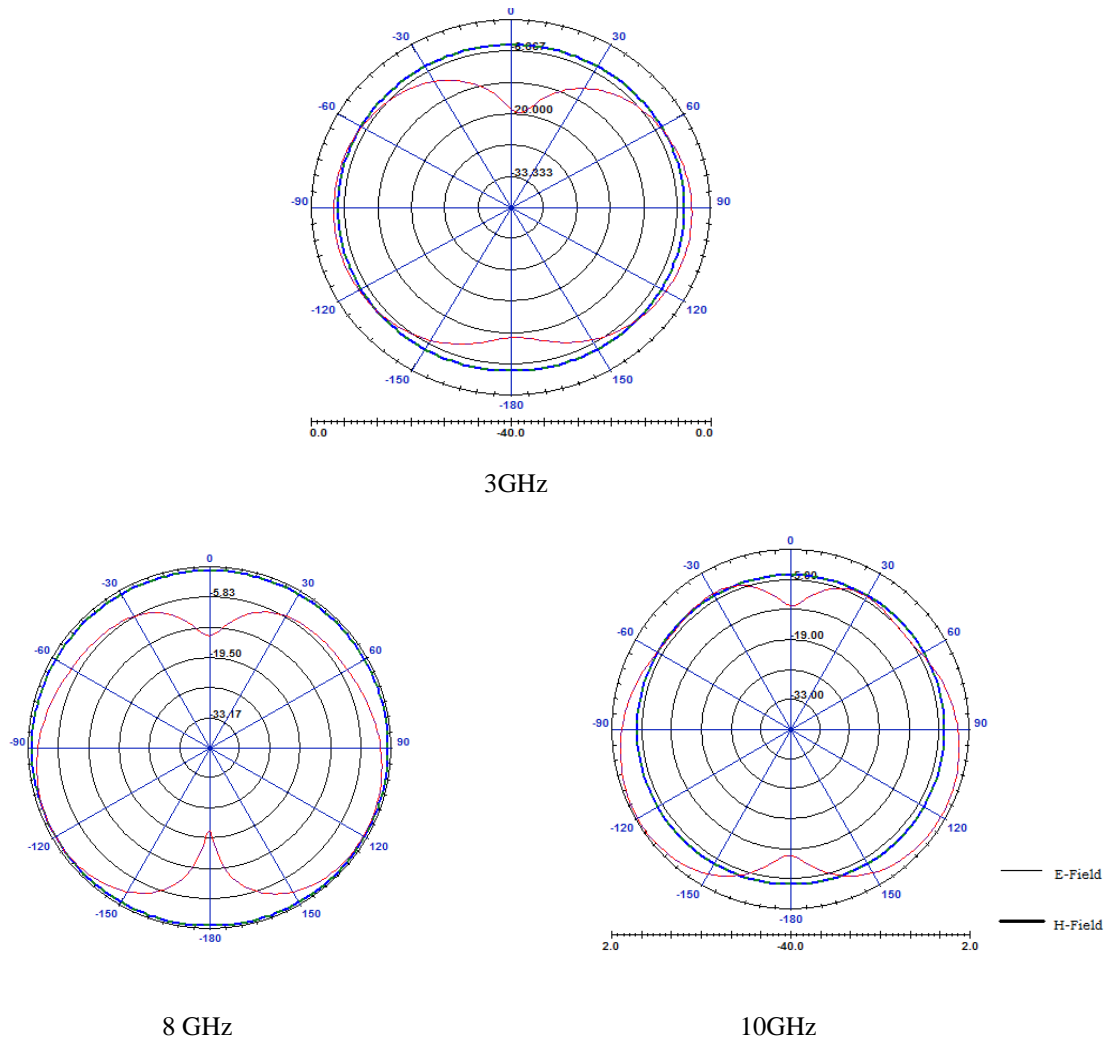
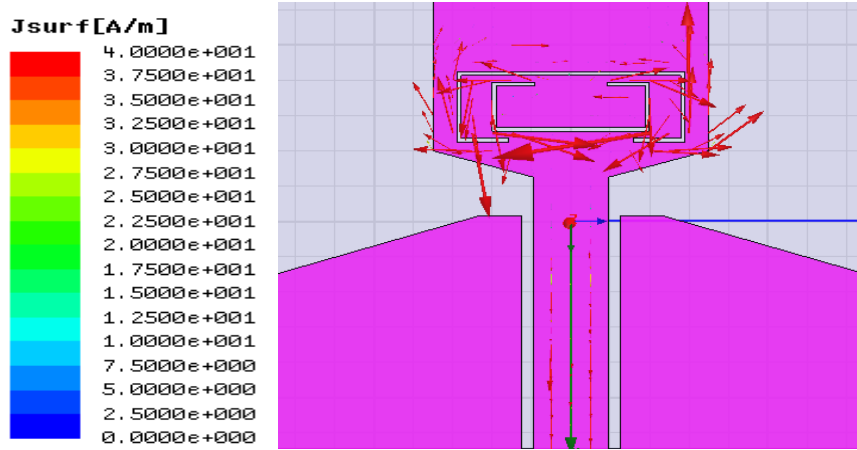
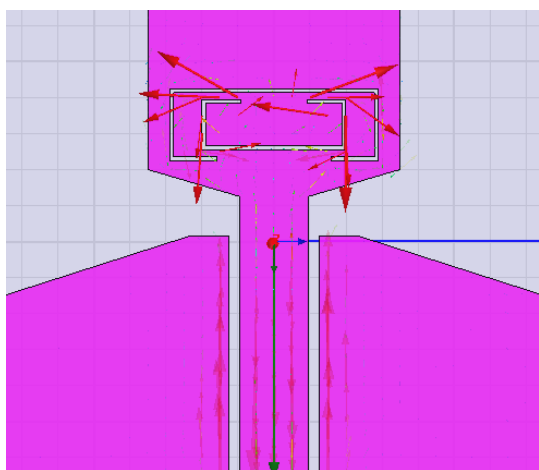


Fig. 5.14: Simulated radiation patterns of antenna A3 at 3, 8 & 10 GHz E-Field and H-Field

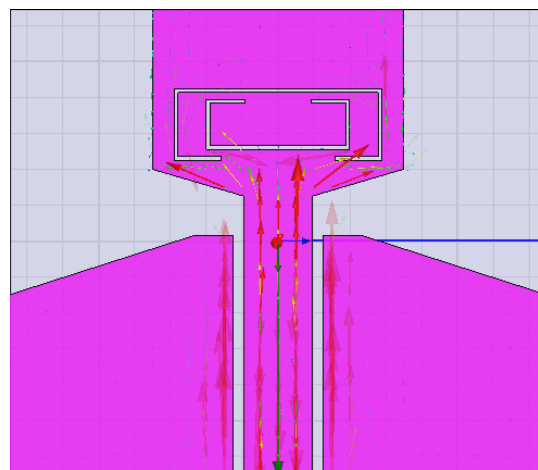
It has been seen that this antenna A3 has nearly Omni-directional radiation pattern like normal monopole antennas. However, the Omni-directional radiation properties have a little deterioration as frequency increases. Over the entire bandwidth, it's similar to a conventional wideband monopole antenna.



(a)



(b)

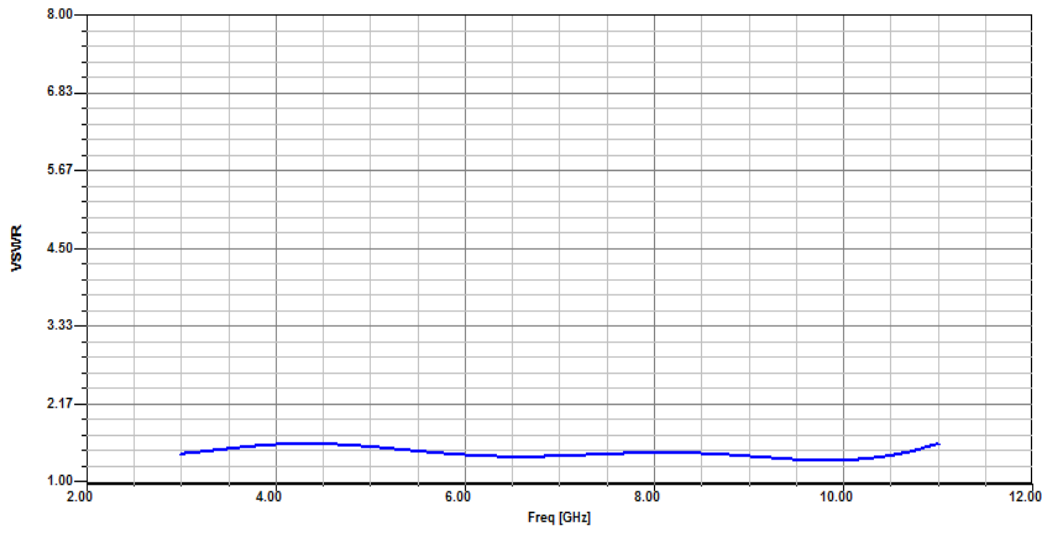


(c)

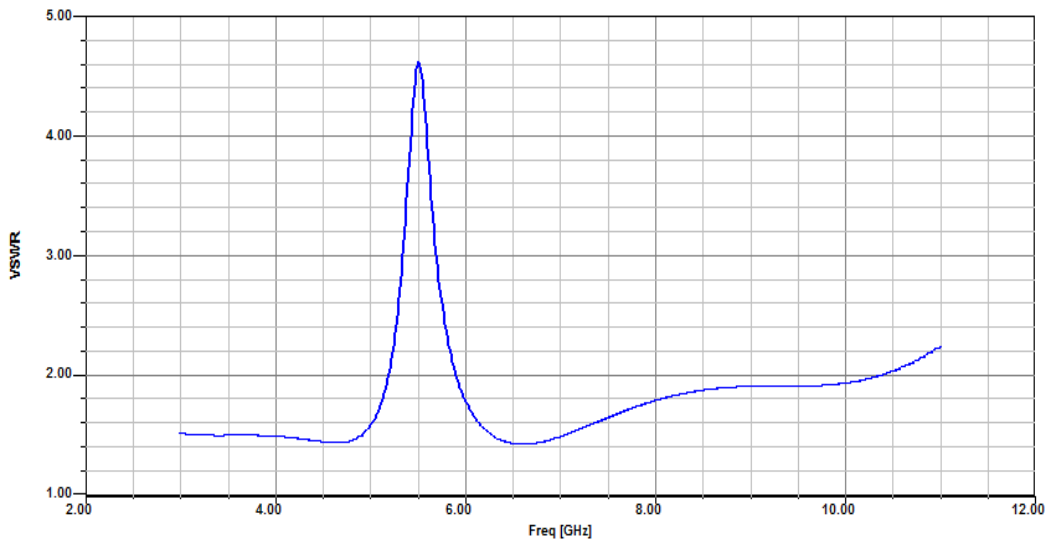
Fig. 5.15: Shows the current distribution of antenna A3 at (a) at 3.5 GHz, (b) at 5.5 GHz, (c) 8 GHz

5.4 Design 2 using rectangular ground plane

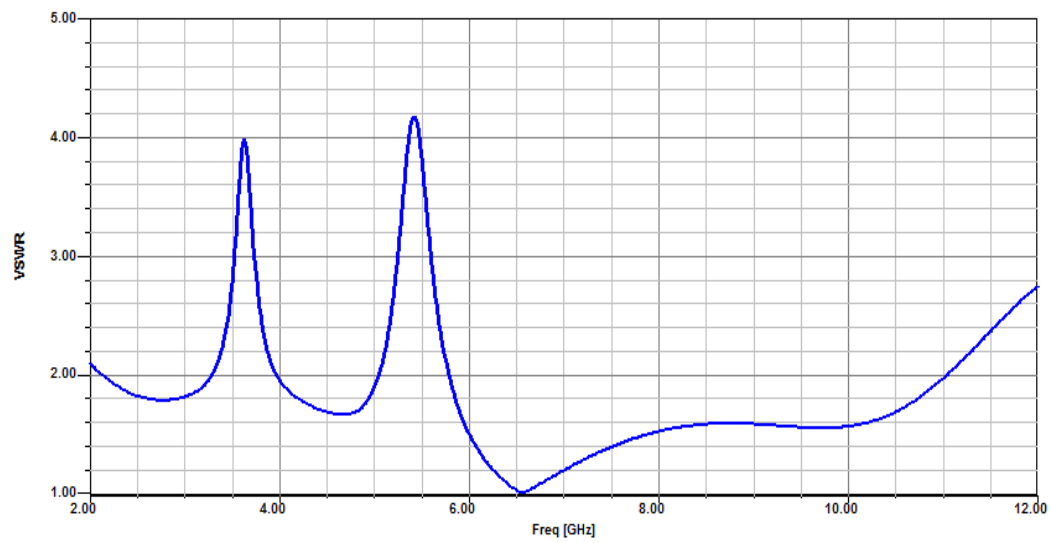
It is noted that, as the ground plane size is small, a few leakage currents may distribute along the external conductor of the SMA connector and may affect the radiation patterns. To tackle this problem, an optimized ground plane dimension is needed. Fig. 5.16 a, b, c shows the VSWR of antenna B1, B2 and B3.



(a)



(b)



(c)

Fig. 5.16: Simulated VSWR of antenna B1 (a), B2 (b), B3(c) with optimal dimensions

Fig. 5.17 shows the compression between simulated and measured result of antenna B3. In entire BW of UWB the impedance is perfectly matched except notch band (3.3-3.8 and 5-6GHz) but in measured case the notch band is slightly shifted to 0.3 GHz towards right due to the soldering problem.

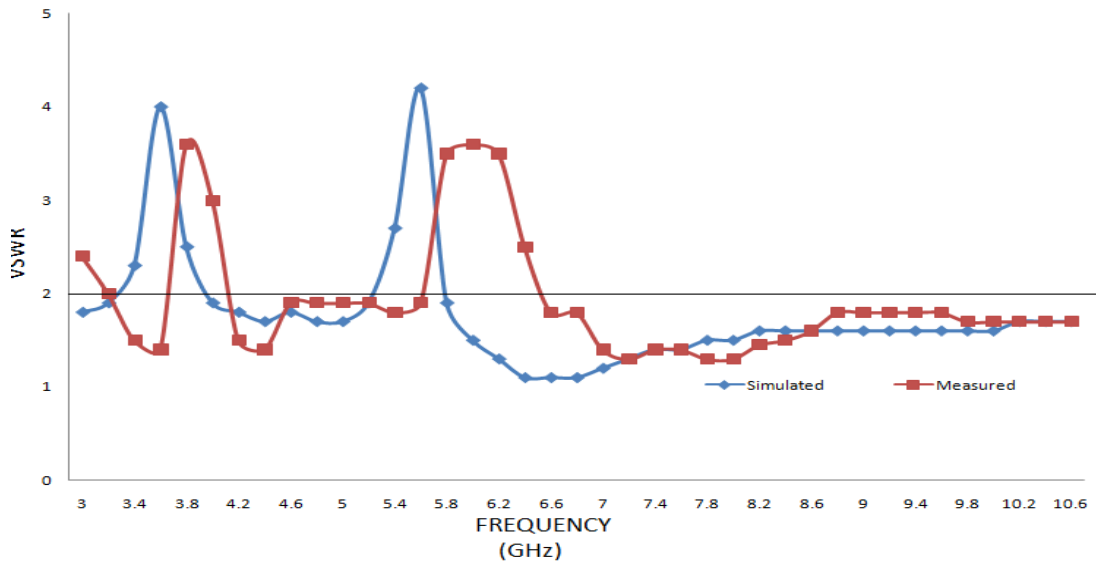


Fig. 5.17: Simulated and measured VSWR of antenna B3 with optimal dimensions

Fig. 5.18 and 5.19 shows the group delay and gain of antenna B1, B2, B3.

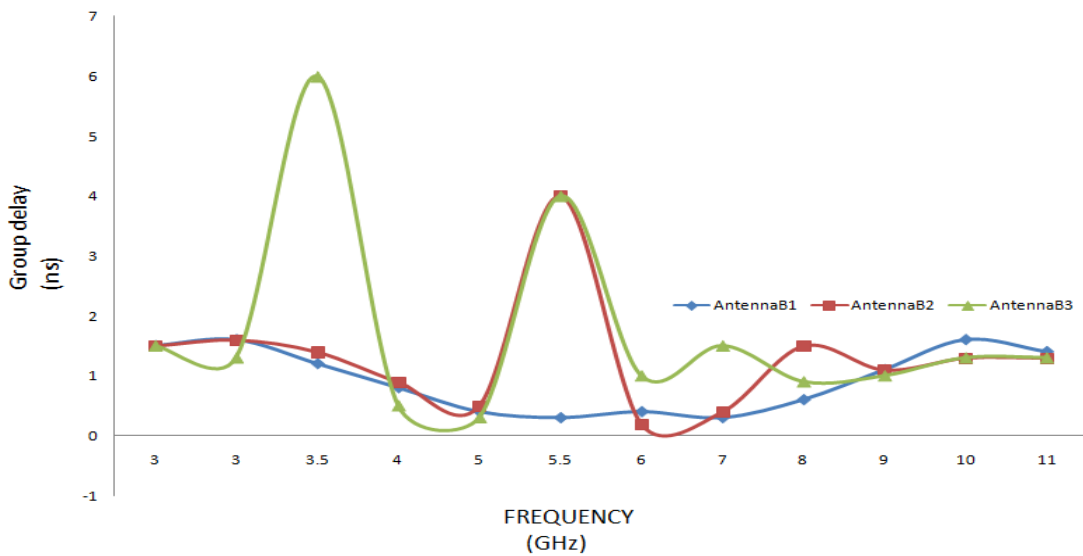


Fig. 5.18: Simulated group delay (ns) of antenna B3, B2, B3 with optimal dimensions.

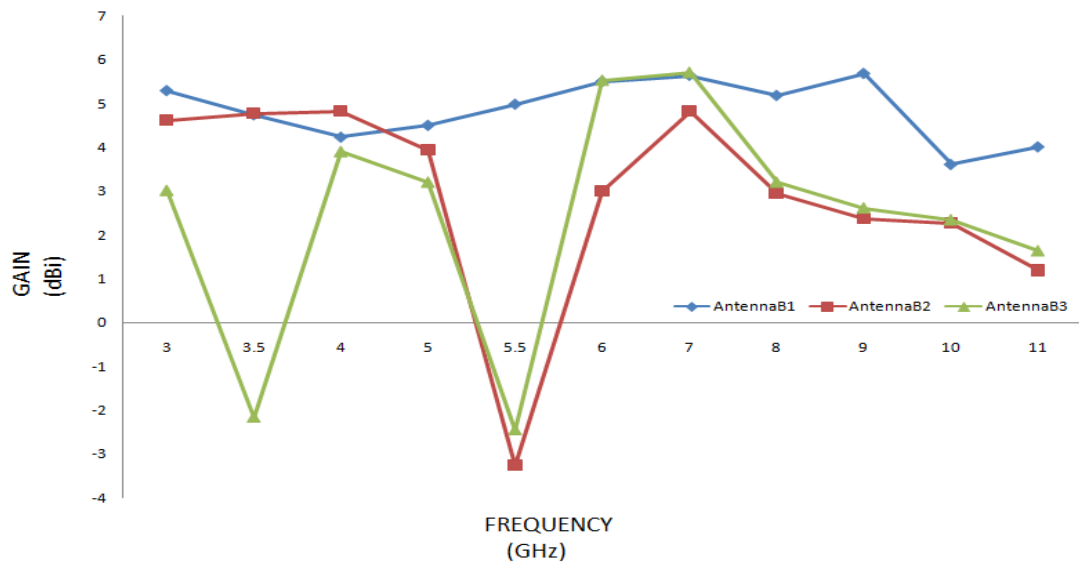


Fig. 5.19: Simulated gain of antenna B1, B2, B3 with optimal dimensions.

CHAPTER SIX

CONCLUSION AND FUTURE PROSPECTIVE

CONCLUSION

In wireless communications, ultra wideband has many advantages. This thesis introduces the design of UWB antenna to minimize the potential interferences between the UWB system and the narrowband systems, a compact CPW-fed planar UWB antenna with dual rejection bands at WiMAX /WLAN frequencies has been designed and discussed. The relationship between the total length of the C-shaped slot and the band-rejected operation has been given. Stable radiation patterns and constant gain in the UWB band are obtained.

With regard to power consumptions, UWB wireless communication systems can provide better battery life for devices with less harm to the human body. This thesis has developed a method for improving the performance of transmitting antenna without potential interferences with the narrowband systems. By using this method, users can have better signal performance by better placing of the transmitting antenna. Users can easily design their devices for implantation, reducing cost and development time.

The simulation results of the proposed antenna shows a good agreement in term of the VSWR, antenna gain and radiation patterns. Accordingly, this antenna is expected to be a good candidate in various UWB systems.

FUTURE PROSPECTIVE

Based on the conclusions drawn and the limitations of the work presented, future work can be carried out in the following areas:

Firstly, it has been shown that UWB antennas operate in a hybrid mode of standing and travelling waves. A more detailed understanding of the travelling wave mechanism and the impedance variations could lead to improved design of UWB antennas.

Secondly, in the future UWB systems, antenna might be embedded inside a laptop or other devices. Thus, the devices effects on the antenna performances to be investigated. When the antenna is built on a portable device, the impact from human body should also be considered.

Thirdly, UWB antenna with small size is always desirable for the WPAN applications, especially for mobile and portable devices. Future research may focus on finding out new methods to further reducing the sizes of UWB antennas.

Fourthly, UWB systems operate at extremely low power level which limits its transmission range. In order to enhance the quality of the communication link and improve channel capacity and range, directional systems with high gain are required for some applications. Therefore, research on UWB directional antenna and antenna array could be carried out.

Lastly, good time domain performance is a primary required for UWB antennas. Studies can be carried out to investigate the antenna effect on the transmitted signal and improve the time domain behaviours by optimizing the antenna configuration.

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APPENDIX

1 SIMULATION PROCESSES

1.1 What is HFSS?

HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modelling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S Parameters, Resonant Frequency, and Fields.

1.2 The HFSS Interface

The main HFSS interface is shown in Figure 1, they are summarized as follows:

1-3D Modeller Window - This is the area where you create the model geometry. This Window consists of the model view area (or grid) and the history tree as shown in Figure 1. The history tree documents the actions that have been taken in the model view area, and provides an alternative way to select objects in the model view area.

2-Project Manager with Project Tree - The project manager window displays details about all open HFSS projects. Each project ultimately includes a geometric model, its boundary conditions and material assignments, and field solution and post processing information. An expanded view of the project manager is shown in Figure 1.

3-Properties Window - The properties window consists of two tabs. The command tab displays information about an action selected in the history tree that was performed to either create an object or modify an object. The attribute tab displays information about the material and display properties of a selected object.

4-Progress Window - This window is used when a simulation is running to monitor the solution's progress.

5- Message Manager - This window displays messages associated with a project's development (such as error messages about the design's setup).

1.3 Setting of HFSS

Before you can use HFSS for the first time, there are a couple of items that need to be configured for efficient and accurate operation.

1. On the Tools menu, select Options => General Options ..., click the Default Units tab and ensure that Length is set to mm. Click OK.
2. On the Tools menu, select Options => HFSS Options..., ensure the Include ferrite materials check box is checked. Click the Solver tab, set the number of Processors to 4. Desired RAM Limit (MB) to 6000 and the Maximum RAM Limit (MB) to 8000. Click OK.

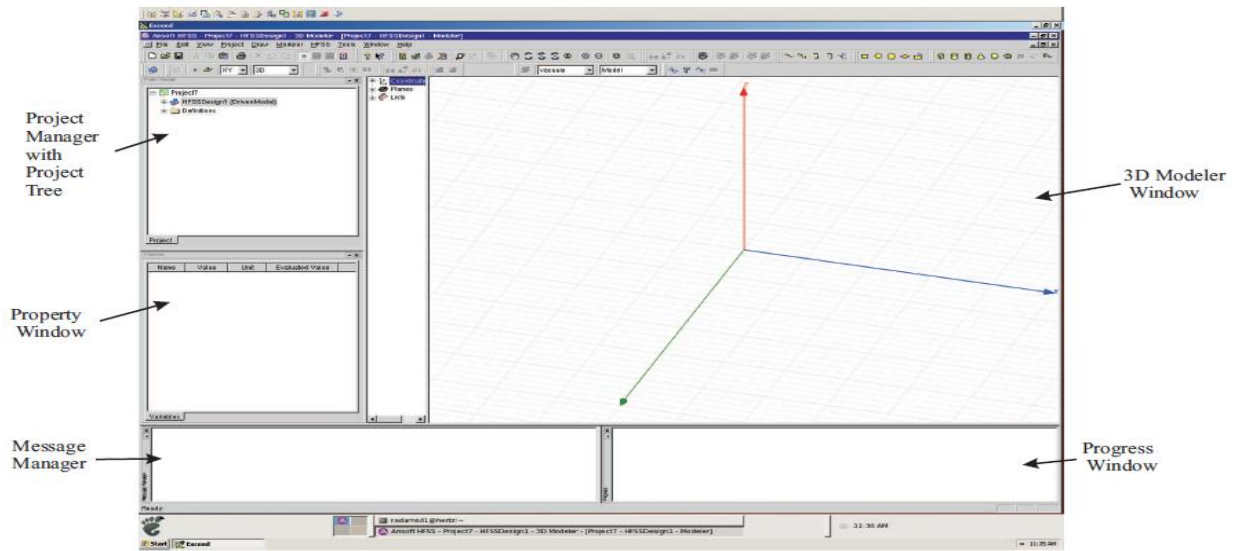


Fig.1 Main screen of HFSS

1.4 Ansoft HFSS flow-chart

The Ansoft HFSS provides an intuitive, easy-to-use interface for developing passive RF device models. Creating designs, involves the following:

1. Parametric Model Generation – creating the geometry, boundaries and excitations
2. Analysis Setup – defining solution setup and frequency sweeps
3. Results – creating 2D reports and field plots
4. Solve Loop - the solution process is fully automated

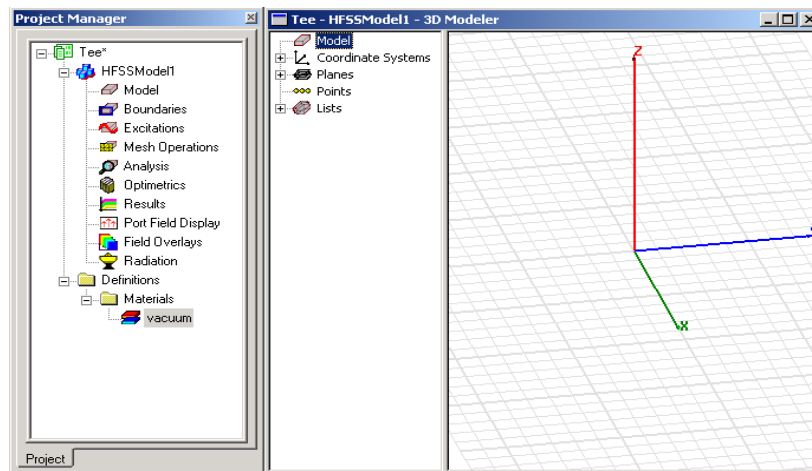
1.5 DESIGN PROCESSES

Open HFSS and Save a New Project

A project is a collection of one or more designs that is saved in a single *.hfss file. A new project is automatically created when HFSS is launched. Open HFSS and save the default project by a new name.

- 1- Double-click the **HFSS 10** icon on your desktop to launch HFSS.

A new project is listed in the project tree in the **Project Manager** window and is named Project by default. Project definitions, such as material assignments, are stored under the project name.



2- On the File menu click Save As.

3- Use the file browser to locate the folder in which you want to save the project, such as C:\Ansoft\HFSS10\Projects, and then double-click the folder's name.

4- Type CPW feed in the File name text box, and then click Save. The project is saved in the folder you selected by the file name *cpwfeed.hfss*.

Select a Solution Type

Now you will specify the design's solution type. As you set up the design for analysis, available settings will depend upon the solution type. For this design, you will choose Driven Modal as the solution type, which is appropriate when calculating mode-based S-parameters of a passive, high-frequency waveguide that is being "driven" by a source.

1- On the **HFSS** menu, click **Solution Type**.

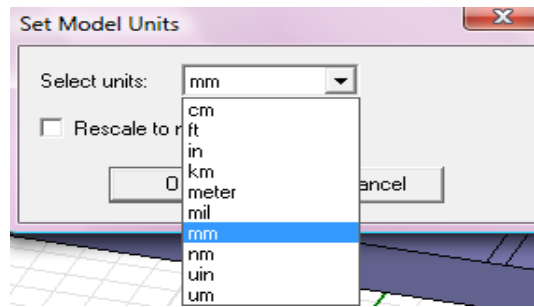
2- In the **Solution Type** dialog box, select **Driven Modal**, and then click **OK**.

Set the Drawing Units

You will now set the units of measurement for drawing the geometric model.

1- On the **3D Modeller** menu, click **Units**.

2- In the **Set Model Units** dialog box, click in the **Select units** pulldown list, and then click **OK**.

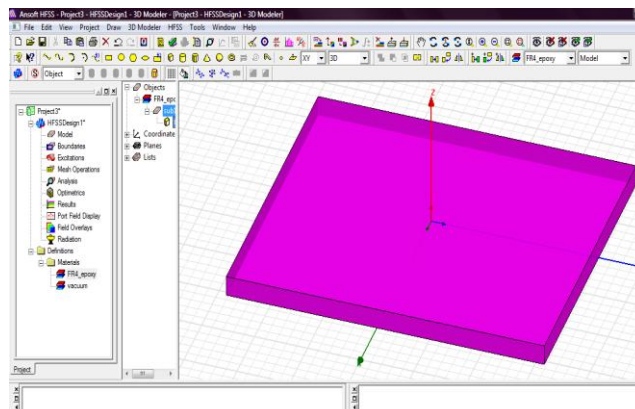
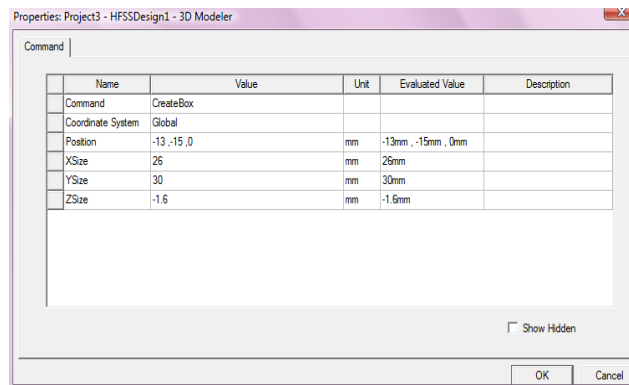


Draw a Box

Draw a 3D box object to represent the first section of the FR4 substrate.

- 1- On the **Draw** menu, click **Box**.
- 2- Specify the base corner of the box as (-13, -15, 0):
 - a. Press **Tab** to move to the **X** text box in the status bar.
 - b. Type **26** in the **dX** box, and then press **Tab** to move to the **Y** box.
 - c. Type **30** in the **dY** box, and then press **Tab**.
 - d. Type **-1.6** in the **dZ** box, and then press **Enter**.

The **Properties** window appears, with the **Command** tab selected, enabling you to modify the dimensions or position of the box.



While the **Properties** window is open, you will use it to assign a name (sub) to the box, confirm its material assignment, and make it more transparent.

Draw the patch

1. Click Draw>Line, or click the Draw line button on the toolbar. The status bar now prompts you to enter the first point of the polyline.
2. Press the Tab key to move to the X box, and then select the first point of the line by entering the following values in the coordinate boxes, pressing Tab to move to the next coordinate text box:
3. Press the Enter key to accept this point. You can delete the last point you entered by right-clicking in the 3D Modeller window and then clicking back up on the shortcut menu.

X coordinate 0

Y coordinate 0

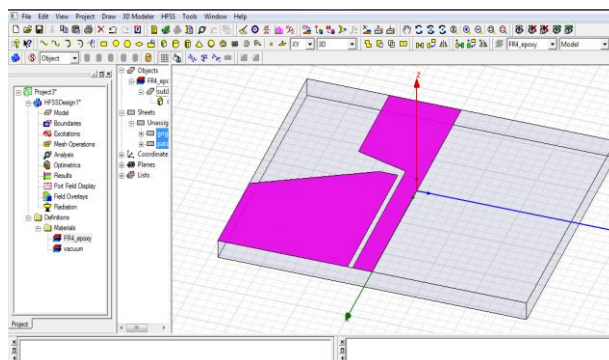
Z coordinate 0

4. Continue with this same method to enter the following 6 points that remain:

Point	X Coordinate	Y Coordinate	Z Coordinate
1	-13	-7	0
2	-4	-7	0
3	-2.5	-1.9	0
4	13	-1.9	0
5	13	0	0
6	-13	0	0

- 5- Right-click in the **3D Modeller** window, and click **Close Polyline** on the shortcut menu. The 2D polyline object appears in the drawing region.

- 6- Assign the name > **patch**.



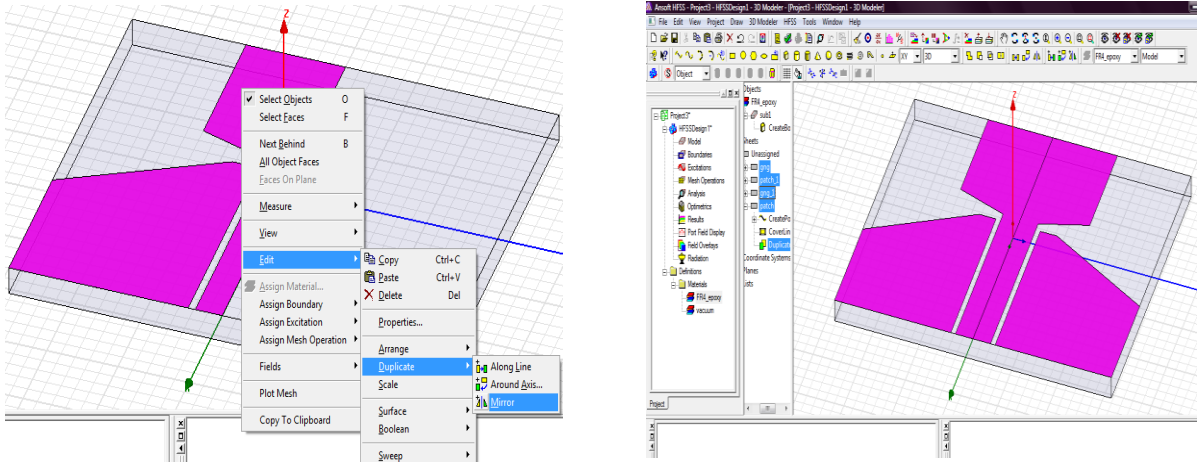
Similarly we should draw ground plane and assign the name >gnd.

Mirror image

1-select the patch and gnd > right click > edit > duplicate > mirror.

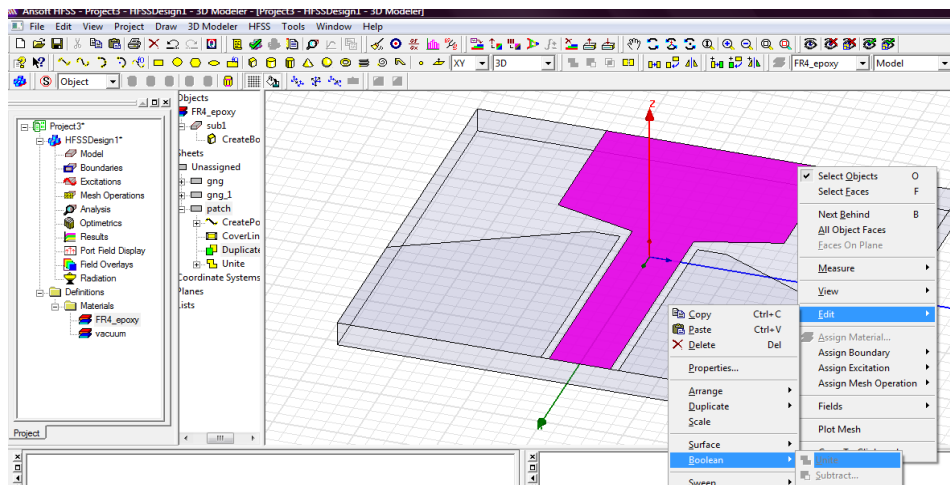
$$x=0 \quad y=0 \quad z=0$$

$$dx=0 \quad dy=1 \quad dz=0$$



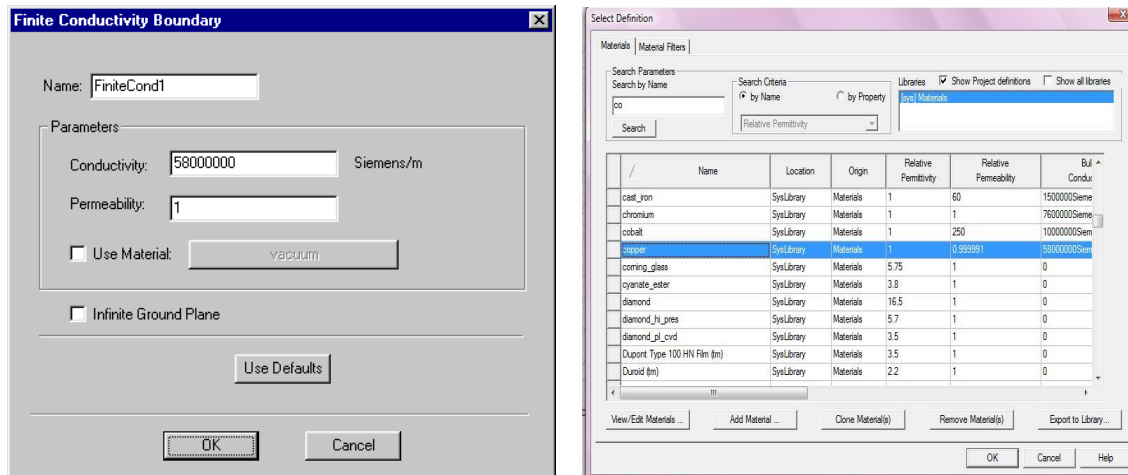
2-Unite- select the patch > right click > edit > boolean > unite.

3- Press **Ctrl+D** to fit the object in the drawing region.



Boundary assignment

Select the patch and `gnd` > right click > assign boundary > finite conductivity

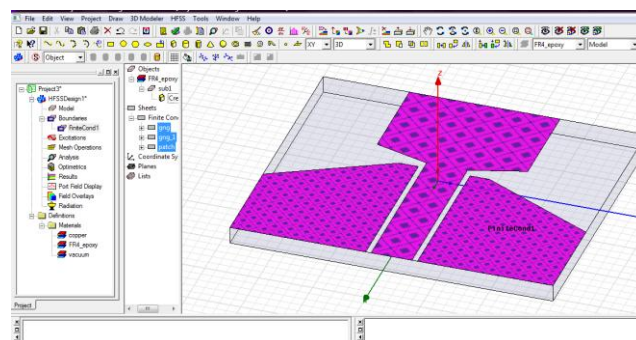


1-Select the **Use Material** check box, and click the material button (where the default vacuum is displayed). The **Select Definition** window appears. By default, this material browser lists all materials in the global material library, as well as the local material library for the current project, which is a subset of the global library.

2- Select **copper** from the list of materials, and then click **OK**. The **Finite Conductivity Boundary** window reappears. The conductivity and permeability values for aluminum are now assigned to the finite conductivity boundary.

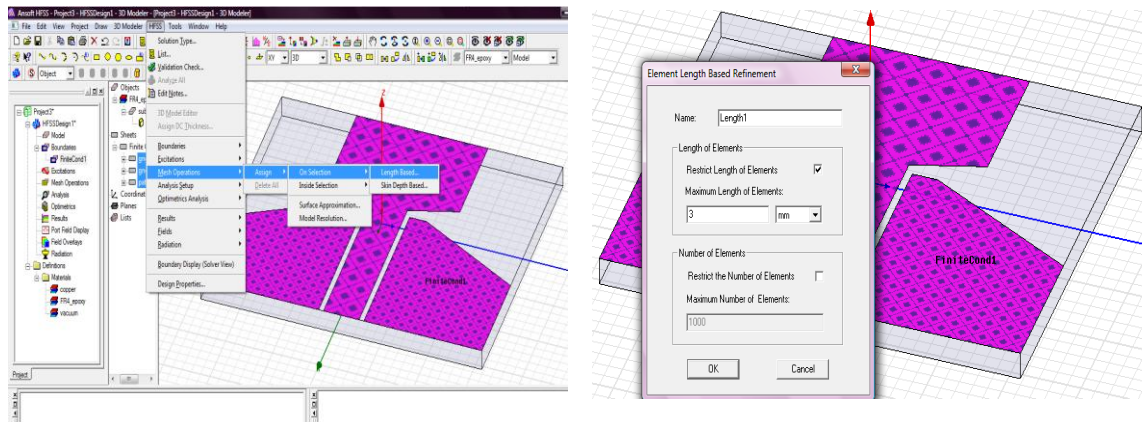
3- Clear **Infinite Ground Plane** if it is selected. If selected, the **Infinite Ground Plane** option simulates the effects of an infinite ground plane. This option only affects the calculation of near- and far-field radiation during post processing. The 3D Post Processor models the boundary as a finite portion of an infinite, perfectly - conducting plane.

4- Click **OK** to accept the default name **FiniteCond1** and apply the boundary



Mesh operation

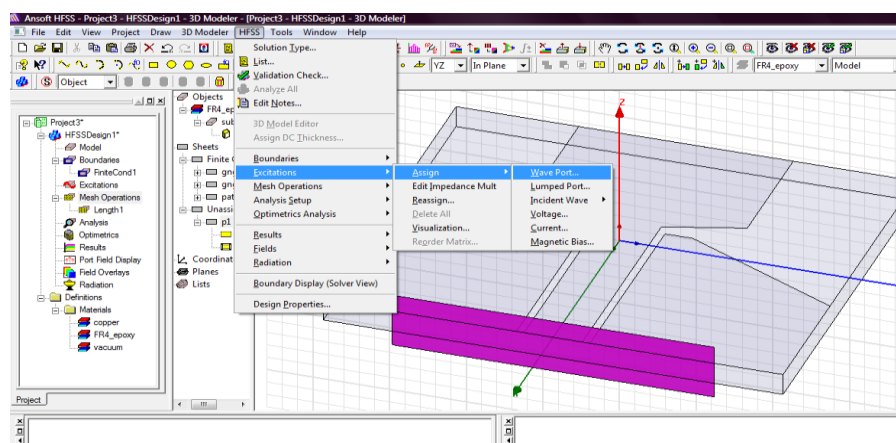
Select the patch and gnd > HFSS > mesh operation > assign > on selection > length based.

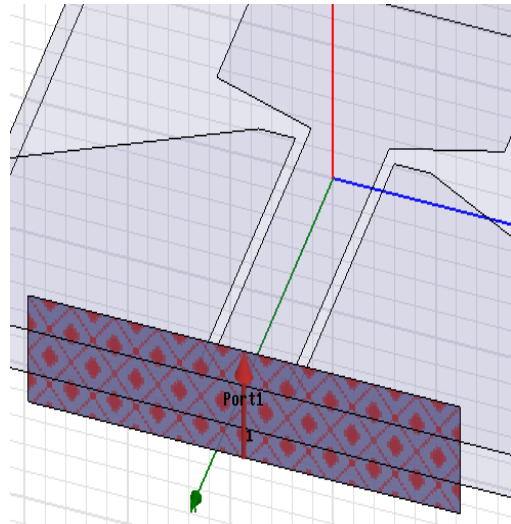
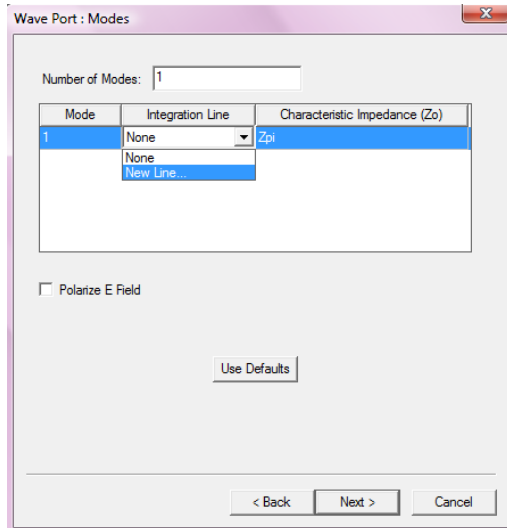


Then click **ok**.

Assign Wave Port 1

- 1- Deselect the perfect E boundary you just assigned, if it is still selected.
- 2- In **Select Faces** mode, select the face of port 1.
- 3- On the **HFSS** menu, click **Excitations>Assign>Wave Port**. The **Wave Port** wizard appears.
- 4- In the **Wave Port: General** step, accept the default name **WavePort1**, and then click **next**.
- 5- In the **Wave Port: Modes** step, accept the default settings, and then click **next**.
- 6- In the **Wave Port: Post Processing** step, accept the default settings, and then click **Finish** to complete the wave port assignment for port 1. **WavePort1** is assigned to the waveguide and now appears as a subentry of **Excitations** in the.

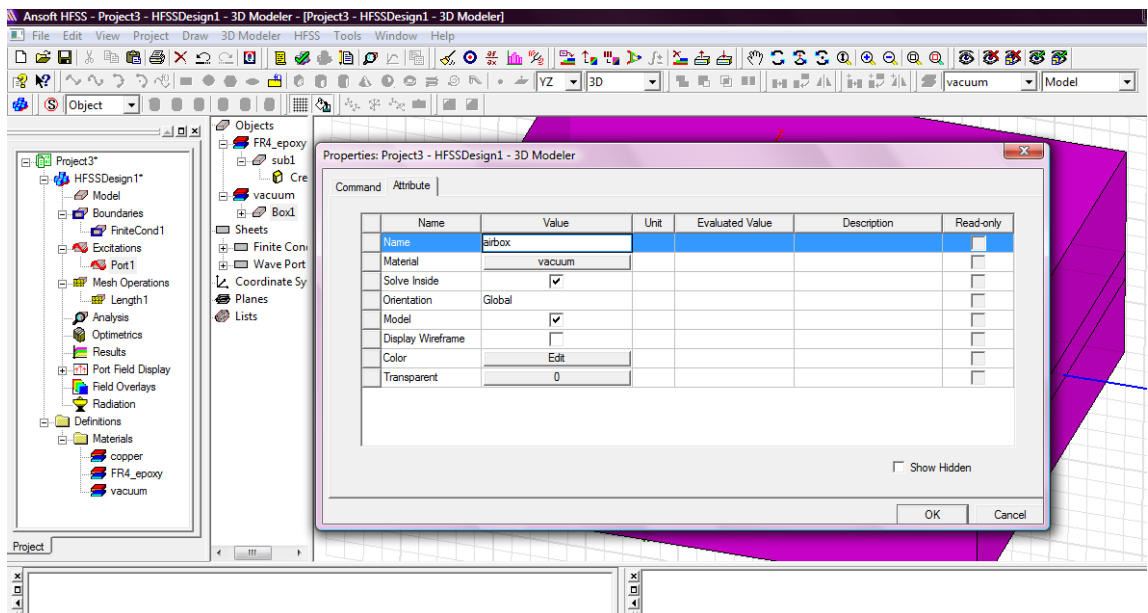




Draw the radiation box

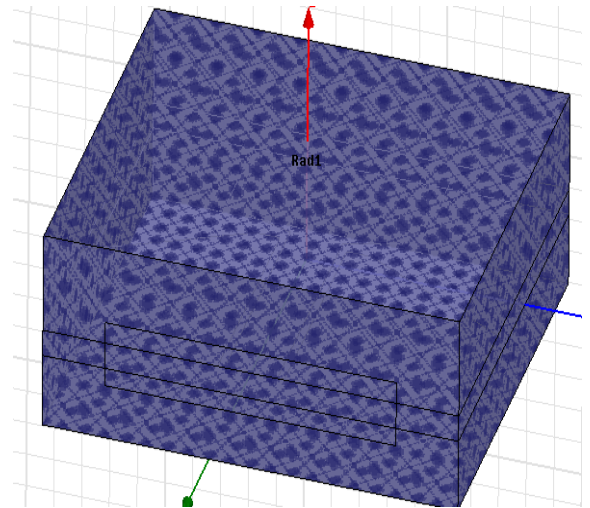
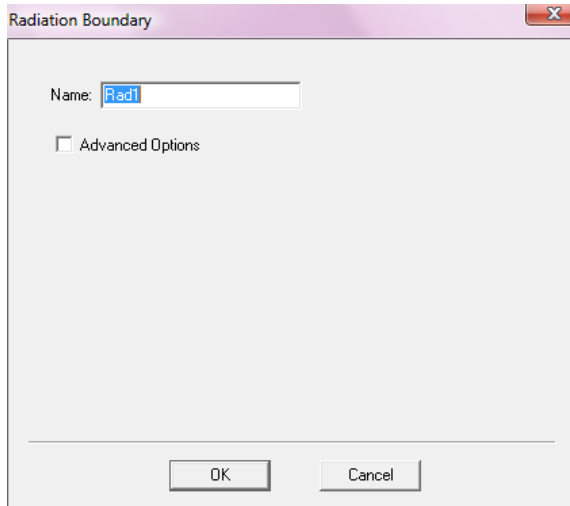
Select vacuum > click box

X=-13, y=-15, z=-6, dx=26, dy=30, dz=-12 > enter.

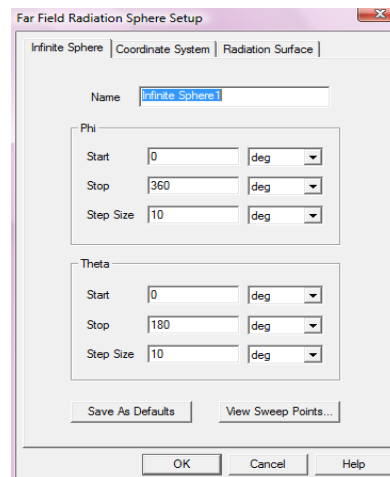


Click ok.

Right click on the box > assign boundary > radiation > ok.



HFSS > radiation > far field setup > infinite sphere.



Click **ok**.

Analysis setup

Perform the following steps to set up the analysis options:

1- Right click on Analysis in the Project Tree, and select >Add Solution Setup"

2- Under the General tab:

- (a) Set the solution frequency to 6.86 GHz
- (b) Set the maximum number of passes to 6
- (c) Set maximum Delta S to 0.02

3- Under the Options tab:

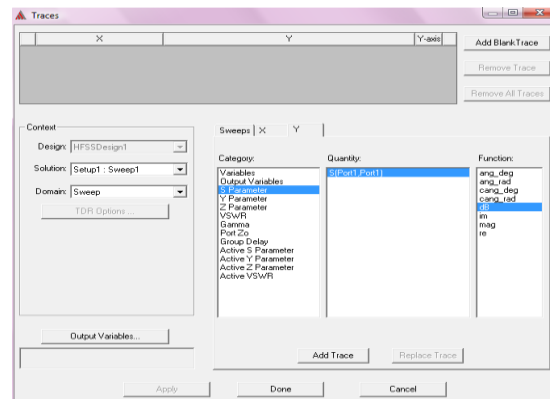
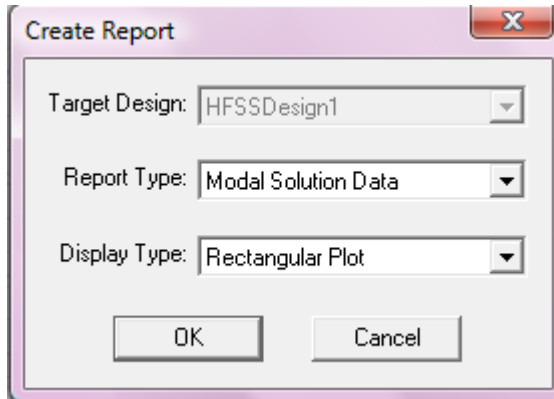
- (a) Set the Maximum Refinement per pass to 20%.
- (b) Set the Order of Basis Functions to Second Order

Perform the following steps to set up the frequency sweep:

- 1- Under the Analysis item in the Project Tree, right-click on Setup1
- 2- Select Add Frequency Sweep...
- 3- Set start frequency to 3 GHz
- 4- Set stop frequency to 11 GHz
- 5- Set step size to 0.02 GHz
- 6- Click OK.

Result

HFSS > result > create report

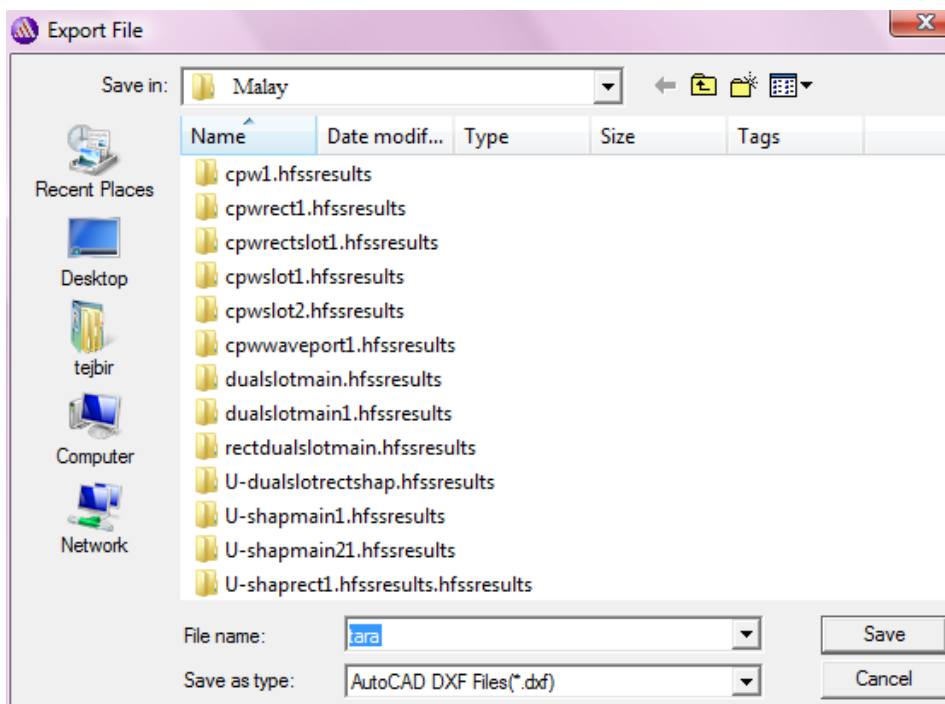


Click ok > vswr > add trace > done.

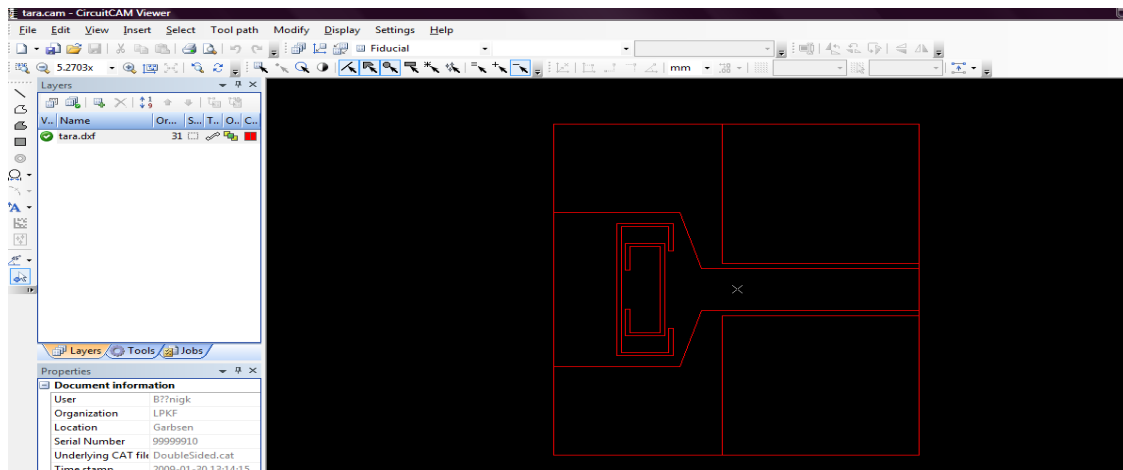
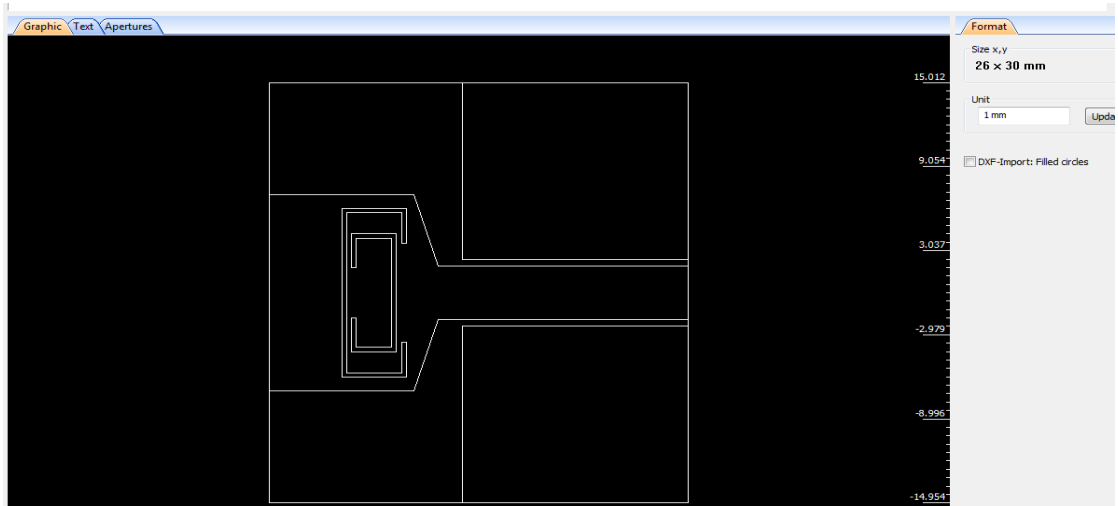
4- FABRICATION PROCESSES

In fabrication processes we have used circuit CAM software.

- 1 – HFSS > 3D modular > export > auto CAD DXF file.

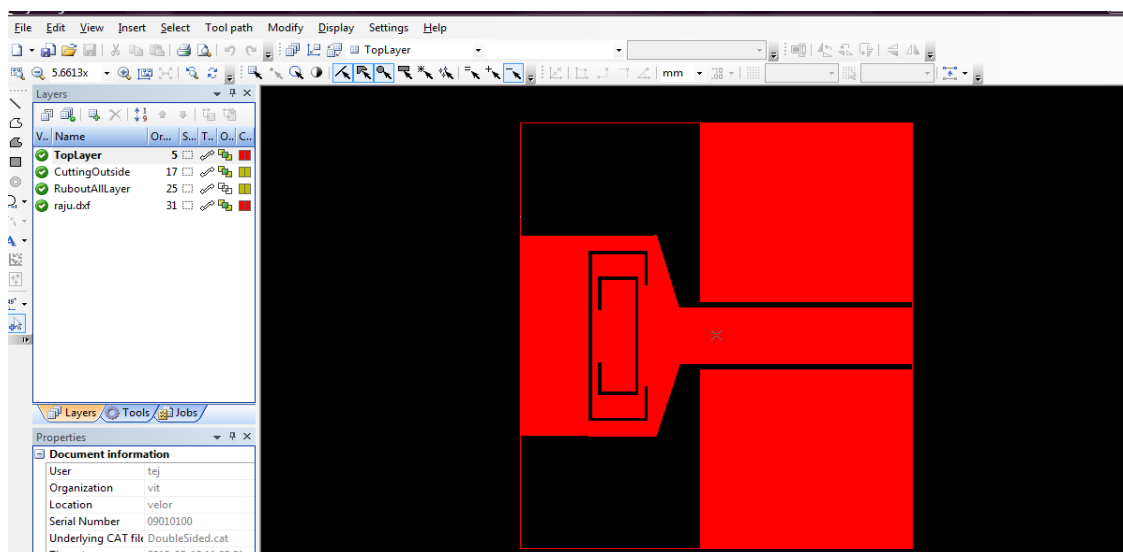


- 2– Open circuit CAM > file > import



Click ok.

The above windows show the layout of the antenna so we should fill the copper where we need. So after filling the copper the file will be as shown below.



With the help of this file the software (circuit CAM) can interface easily with the machine.

