CPW fed Ultra Wide Band antenna design techniques for wireless applications

DISSERTATION-II REPORT

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by

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CERTIFICATE

This is to certify that Jaspreet Kaur bearing Registration no.11205788 has completed objective formulation of thesis titled, **“**CPW fed ultra-wideband antenna design techniques for different applications**”** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of degree of Masters of Technology in Electronic and Communication Engineering.

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DECLARATION

I, Jaspreet Kaur, student of Btech-Mtech(Dual degree)-ECE under Department of Electronics and Communication Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

The main of this thesis is to design an Ultra-wideband antenna which operates in the range of 3.1-10.6 GHz according to the specifications of Federal Communication Commission. So this report presents all the basics and fundamentals of antenna to study the effect of the various parameters on the design of the antenna. The simulation of the antenna was carried out using the CST microwave studio which is available for commercial use.

The antenna presented is UWB which can be used in various UWB systems and wireless applications. First the U-shaped stub with rectangular slot was inserted on the patch. Later on slots were embedded on the stub to enhance bandwidth of the antenna and get better return loss. The feeding technique used is Co-planar Waveguide which provided ease of fabrication as only one side of substrate need to be fabricated. Two resonating frequencies is provided by the proposed antenna with operating range of 3.6-11.5 GHz and peak gain of 6.64 dBi. The complete analysis of the results is carried out by varying the geometrical dimensions of the antenna and studying the change caused by the variations.

Further the fabrication of the antenna is done by photoengraving and etching. Then the antenna is tested using Network analyzer. The results are then compared with the simulated results for verification of the antenna bandwidth and there was good agreement between the simulated and measured results.

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CHAPTER 1

INTRODUCTION

1.1 ANTENNA BASICS

21st century is the era of science where there are numerous advancements in science and technology. Communication between different people all around the world only possible due to the recent innovations in technology. The world is completely covered with electronic gadgets which are produced at a faster rate for communication to take place. Antenna is therefore become an important part of day to day life of an individual as it is the most important component for communication to take place which is found in every device which surrounds man from a simple mobile phone to the GPS satellites for tracking location. The very basic example of an antenna is in the Television where a good performance antenna can improve the broadcast reception. Antenna is a metallic device which acts as a transitional structure to radiate or receive radio frequency waves. Antenna can be categorized into two types:

Transmitting Antenna: It is present at the front end of the communication system to radiate the electromagnetic waves through the transmission line.

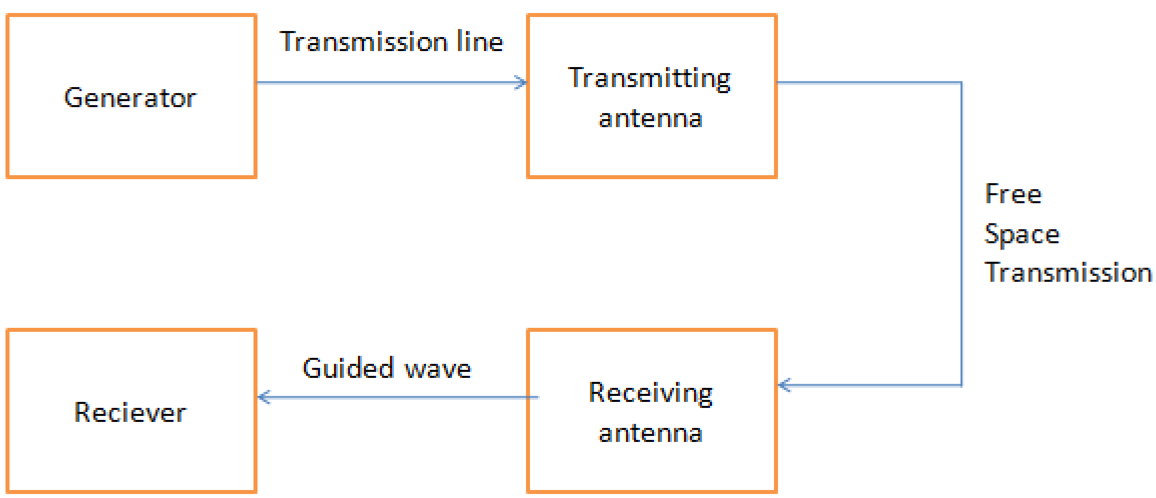


Fig. 1.1 Antenna as a transition device

Receiving Antenna: It is the latter part of the communication system which is fed by alternating current which in turn produces RF waves.

Other important part of antenna system is transmission line which serves as guiding medium for transfer of electromagnetic waves from transmitter to receiver. Theoretically a loss less transmission line is considered for the complete delivery of power from transmitter to receiver but practically this is not possible.

1.2 TYPES OF ANTENNA

Antenna is categorized into different types depending on their characteristics and their usage. The following are the various types of antenna:

1.2.1 Wire Antenna

This is the most common type of antenna found almost everywhere in our day to day life ranging from the most common devices like mobile phones, automobiles to sophisticated devices like aircraft, spacecraft etc. Wire antenna's can vary in shape. These can be helical, circular, rectangular, straight wire or loop shaped. Most of the times circular shape of antenna is preferred due to its easy construction.

1.2.2 Aperture Antenna

Since with the advancements of technology there is demand for more sophisticated antenna's with high frequency utilization, aperture antenna's have gained a high importance. These antennas are widely used in applications related to aircraft and spacecraft due to their ability to be easily flush mounted onto the surfaces of aircraft or spacecraft. These can easily be protected from undesirable environmental conditions by coating them with dielectric material.

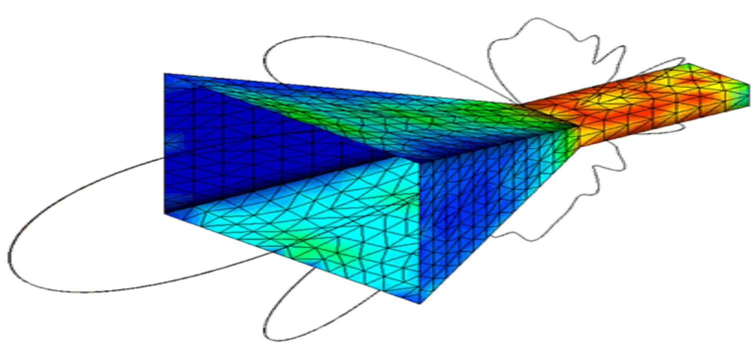


Fig. 1.2 Aperture antenna [8]

1.2.3 Microstrip Antenna

Microstrip antenna consist a patch of metal on a grounded substrate. The metallic patch of circular and rectangular configuration is most common. These antenna provide certain characteristics like low profile, inexpensive fabrication, robustness and exhibit versatility in terms of polarization, impedance and resonant frequency. These antennas's find great importance in aircraft, spacecraft for providing high performance.

1.2.4 Array Antenna

Since single element in antenna is unable to achieve the desired radiation characteristics, so n number of elements are arranged electrically or geometrically to attain the required radiation characteristics. This is known as array antenna. Elements in an array are arranged in such a manner that each elements radiation either combine to give maximum radiation in particular direction or oppose each other to suppress the radiation in particular direction.

1.2.5 Reflector Antenna

As there were advances made in the technology and communication devices were driving importance, sophisticated antennas were required for long distance communication in order to communicate over longer distances in miles. These are referred to as parabolic reflector antenna. Since large distance needs to be covered so there is need of large diameter of about 305m. This leads to increase in dimensions of the antenna which are in turn needed for high gain for longer distance communication.

1.2.6 Lens Antenna

Basic purpose of a lens is to prevent the incident energy from spreading into undesired directions and focusing it into a narrow beam. This concept is used in Lens Antenna, where by adjusting the geometry and choosing a proper material of lens, incident energy can be converted into plane waves. These antenna's are used mainly for high frequencies as at low frequencies they acquire large dimensions and weight.

1.3 CHARACTERISTICS OF ANTENNA

It is necessary to know certain characteristics of antenna to determine the performance of antenna in order to be used for any specific application. These characteristics can either be related to each other or independent.

1.3.1 Radiation pattern

Directivity, power flux density, polarization are some of the radiation properties of antenna. The graphical or mathematical representation as a function of space coordinates of the radiation properties of antenna is referred to as Radiation pattern. This can be represented in 2-D or 3-D. Radiation can either be amplitude field pattern which plots the electric field at constant radius or it can be amplitude power pattern where power density's variation with respect to radius is spatially represented.

1.3.1a Radiation Pattern Lobes

A radiation lobe is defined as a part of radiation pattern of antenna which is bounded by regions of relatively weak radiation intensity. These are classified into four parts:

Major lobe: It is the lobe which specifies the direction where radiation is maximum.

Minor lobe: The lobe is considered to be minor if it occupies any part except for the major lobe. These produces radiation in directions where radiation is not desired.

Side lobe: It is a lobe which radiates in any direction except the main lobe.

Back lobe: This is lobe which makes 180 degree angle with the main beam of antenna. It is kind of minor lobe which is opposite to the major lobe.

Side lobe level is defined as the ratio of power density in minor lobe to that of major lobe. It must be low for some applications like radar to avoid false indications of target by minimizing side lobe level. Less side lobe level results in radiation to be maximum at major lobe thereby increasing the directivity of antenna.

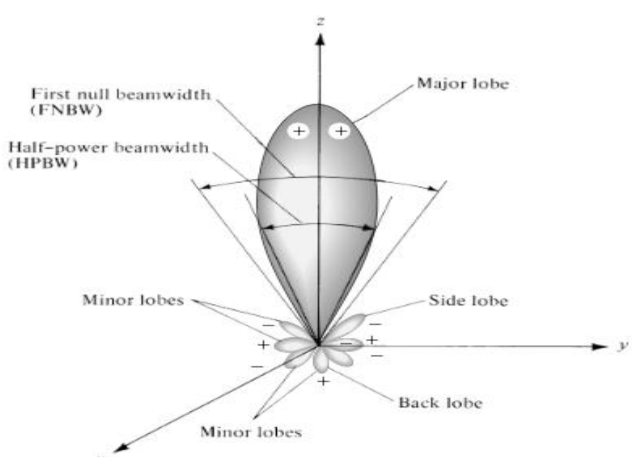


Fig. 1.3 Radiation lobes [8]

1.3.1b Field Regions

EM waves exhibit different characteristics when generated by an antenna depending on the distance from antenna. So the area around the antenna is divided into different zones in order to differentiate the properties exhibited by EM waves in different regions.

Reactive near field: In this region, electric and magnetic field are out of phase. This region is nearest to antenna and surrounds it and is reactive in nature. Electromagnetic energy is completely stored here.

$$R_1 = 0.62\left(\frac{D^3}{\lambda}\right)^{\frac{1}{2}}$$

Radiating near field (Fresnel): This region lies between the reactive near field and far field. With the increase in distance from antenna, electromagnetic field becomes less reactive, that is, some part of EM energy gets converted into radiation. The shape of radiation may vary with distance from antenna.

$$R_2 = \frac{2D^2}{\lambda}$$

Far field (Fraunhofer) region: With further increase in distance from antenna EM field becomes completely radiative and there is negligible reactive field. Unlike Fresnel field, shape of radiation does not vary with distance. In this case electric and magnet field are in phase as well as orthogonal to each other.

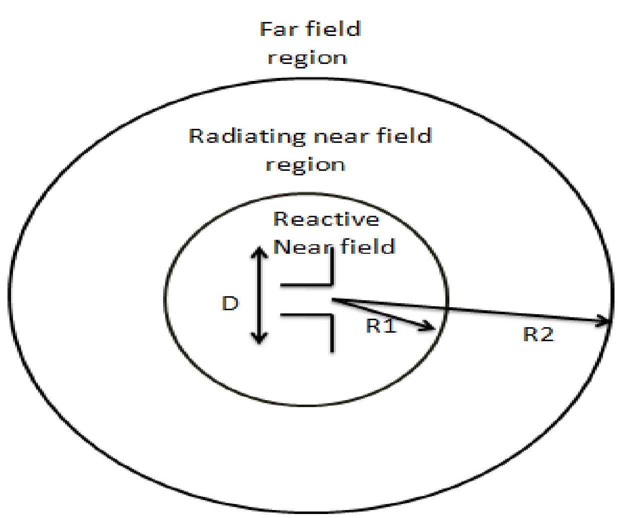


Fig. 1.4 Field regions

1.3.1c Radiation intensity

Electromagnetic power is generated by EM waves. This radiated power has variable magnitude which depends upon the distance from antenna and observation's direction. Therefore a normalized power density is required which is independent of distance from antenna in far field. This is referred to as radiation intensity.

$$U = r^2 W_{rad}$$

It can also be defined as power radiated by an antenna per unit solid angle. It denotes a far field parameter. It is given by the equation:

$$P_{rad} = \iint_0^{\pi} U \sin\theta \, d\theta d\varphi = \iint Uo\, d\omega$$

$$= Uo \iint d\omega = 4\pi Uo$$

1.4 BEAMWIDTH

The beamwidth of a radiation pattern is defined as angular separation between the same points on opposite side of pattern maximum. It is an important parameter which follows inverse relation with the side lobe, that is, with increase in beamwidth, side lobes decreases. The important beamwidths are:

Half power beamwidth(HPBW): It is defined as the angular separation between two opposite points in the direction of maximum beam where radiation intensity is one half the value of the beam.

First Null Beamwidth(FNBW): It is defined as the angle between the first nulls of radiation pattern. The relation between the two beamwidths can given by the equation:

$$HPBW = \frac{FNBW}{2}$$

1.5 DIRECTIVITY

Directivity of antenna is defined as the ratio of radiation intensity in given direction to averaging of radiation intensity over all the directions. Its mathematical expression can be given as:

$$D = \frac{U}{Uo} = \frac{4\pi U}{\text{Prad}}$$

$$\text{Dmax} = \frac{\text{Umax}}{Uo} = \frac{4\pi \text{Umax}}{\text{Prad}}$$

The antenna which radiates in all directions have zero directionality and it's directivity is one or 0 dB. The more is the directivity of antenna, more it is focused or directional. However low directivity is desired in case of mobile phones as they have to pick the signal coming from any direction. But directivity must be high in case of satellite dish antenna as they have to receive signal only from a fixed direction. Different antenna's have different directivities [18] which is summarized in table 1.1.

TABLE 1.1 DIRECTIVITIES OF DIFFERENT ANTENNAS [18]

Type of antenna	**Typical directivity**	**Typical directivity (dB)**
Short wave dipole antenna	1.5	1.76
Half wave dipole antenna	1.64	2.15
Microstrip patch antenna	3.2-6.3	5 to 8
Horn antenna	10 to 100	10 to 20
Dish antenna	100 -10,000	20-40

So antenna must be chosen with a specific directivity depending on the application for which it is used. Antenna's which need to radiate or receive in specific direction must have high directivity whereas antenna which needs to radiate or receive from all directions should have low directivity. It must be noted that since isotropic source radiates power equally in all directions, therefore its directivity is one.

1.6 GAIN

Gain of antenna is defined as ratio of intensity in a given direction to radiation intensity that is attained when power accepted by antenna were radiated isotropically. Gain is expressed as:

$$gain = \frac{4\pi U(\theta,\varphi)}{Pinc}$$

Gain is more efficient in determining the performance of antenna. Unlike directivity, gain not only determines the directional capabilities but also tells about the efficiency of antenna. When directionality of antenna is not known, gain is considered to be in direction where there is maximum radiation. Gain does not take into account loses due to polarization mismatch and impedance mismatch.

1.7 ANTENNA EFFICIENCY

Efficiency is defined as ratio of power radiated to incident power in percentage.

$$e = \frac{Prad}{Pinc}$$

Since the entire power incident to antenna is not delivered to the receiver due to certain loses occurring in the transmission line. Efficiency can also be obtained by multiplication of sub efficiencies which include

Conduction efficiency E_c

Dielectric efficiency E_d

Reflection efficiency E_r

1.8 BANDWIDTH

Bandwidth is an important parameter of antenna which specifies the range of frequencies in which antenna is capable of radiating or receiving energy in efficient manner. It is an important parameter to select an antenna for any specific application [13]. For instance, low bandwidth antennas cannot be used for wideband operations. It is given by equation:

$$\text{Bandwidth} = f_h - f_l$$

Where, f_h =Highest frequency component

f_l= lowest frequency component

Bandwidth can be characterized by VSWR or polarization. For instance, an antenna may be operating at 125-400 MHz having VSWR<1.5. This means that reflection coefficient is 0.2 for the specified range, that is, out of the total power delivered to antenna, only 4% is reflected back. But this not means that 96% is delivered to antenna, there are some loses which need to be taken into account. Bandwidth of different antenna types [8] can be shown using Table 1.2

TABLE 1.2 BANDWIDTH OF DIFFERENT ANTENNAS [8]

Antenna	Center frequency	Frequency range	% bandwidth
Patch	1000 MHz	985-1015 MHz	3.00%
Dipole	1000 MHz	960-1040 MHz	8.00%
Horn	1000 MHz	154-1848 MHz	169.40%
Spiral	1000 MHz	95-1900 MHz	180.50%

1.9 VSWR

VSWR stands for Voltage Standing Wave Ratio which is the measure of total power reflected. VSWR should be as low as possible which means that almost all the incident power is delivered to antenna and there is no reflections or standing waves created. VSWR for ultra-wideband antenna is shown in figure below.

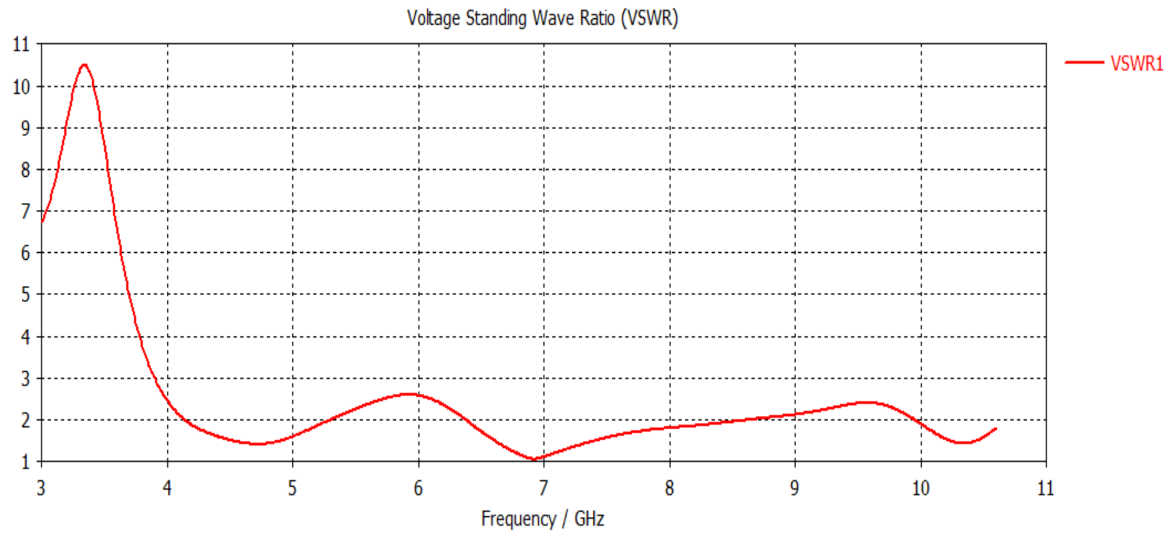


Fig. 1.5 VSWR plot

CHAPTER 2

TERMINOLOGY

- **Bandwidth(BW):** It is defined as the frequency range within which the antenna is capable of transmitting the information in the form of waves. In case of UWB antenna, the bandwidth ranges from 3.1-10.6 GHz.
- **Co-planar waveguide (CPW):** It is form of a transmission line which acts as a conductor and lies above the dielectric material, between the ground plane. The patch, ground plane and feed line lie in the same plane thereby producing compactness and it is relatively easy to fabricate.
- **Federal communication commission (FCC):** It is a regulatory body in order to regulate communication related to satellite, wire, television, radio and cable in the interstate over all in the 50 states. It has its headquarters in Washington, USA.
- **CST microwave studio:** It is a tool which is used for 3-D simulation of various components like antennas, filters, couplers etc. It provides various modules like current distribution, far field pattern, Gain, directivity etc.
- **Vector Network Analyzer(VNA):** It is tool which is used for testing Radio frequency and microwave frequency devices performance in terms of scattering parameters. This device is available in antenna labs and is used for viewing the performance of antenna.
- **Gain(G):** This antenna parameter depicts how effectively the input power into antenna is headed in a particular direction. It is expressed in dBi.
- **Band Notching:** It is a method where a specific range of frequencies is “notched” or “removed” from the overall operating band. In antenna design, this can be attained by use of filters, additional circuits or introduction of slots.
- **Slot:** A long or short cut that is embedded in to the antenna in order to attain band notching or to enhance the antenna parameters.
- **Stub:** It is a form of transmission line which is attached on the one side and the other side is not connected to any thing.
- **Impedance bandwidth:** This is defined as the range of frequencies over which there is good impedance matching and the VSWR is less than 2 such that the input power is completely transferred with minimum loses.

- **Return loss or S11 parameter:** This parameter defines the power which is reflected back. For instance, if S11=0 dB, the power is completely reflected back.
- **Photoengraving:** This is a process which uses some sort of photoresist which is sensitive to light and acts as a mask to protect certain areas while UV-exposure, which etches the un-masked areas. This process is followed while the fabrication is carried out.
- **Patch:** The radiating surface of the microstrip antenna is called a patch. It can be of any shape, most common being circular, square and elliptical.
- **Voltage standing wave ration (VSWR):** It determines the standing waves present while transmission or in other terms it tells the amount of power reflected back. Lower values are preferable. In UWB antennas, VSWR<2 is desirable.

CHAPTER 3

MICROSTRIP ANTENNA

The high performance applications have certain constraint like compact size, low weight, cost, ease of fabrication and installation etc. In order to meet these constraints microstrip antenna are designed. These antennas provide certain features like low profile, simple design, low cost, versatility, ease of fabrication etc. Microstrip antenna can be defined as antenna which has a patch etched on the ground plane with an insulating dielectric substrate [8]. These can acquire any shape like rectangular, circular, elliptical etc. Dielectric substrate is not present in every microstrip antenna. Some antenna can use dielectric spacers above the ground plane which improves the bandwidth. Since these antennas have low profile these can easily be mounted on the surface of aircraft or spacecraft. Rectangular patch microstrip is the most common type of microstrip antenna which is one half wavelength long.

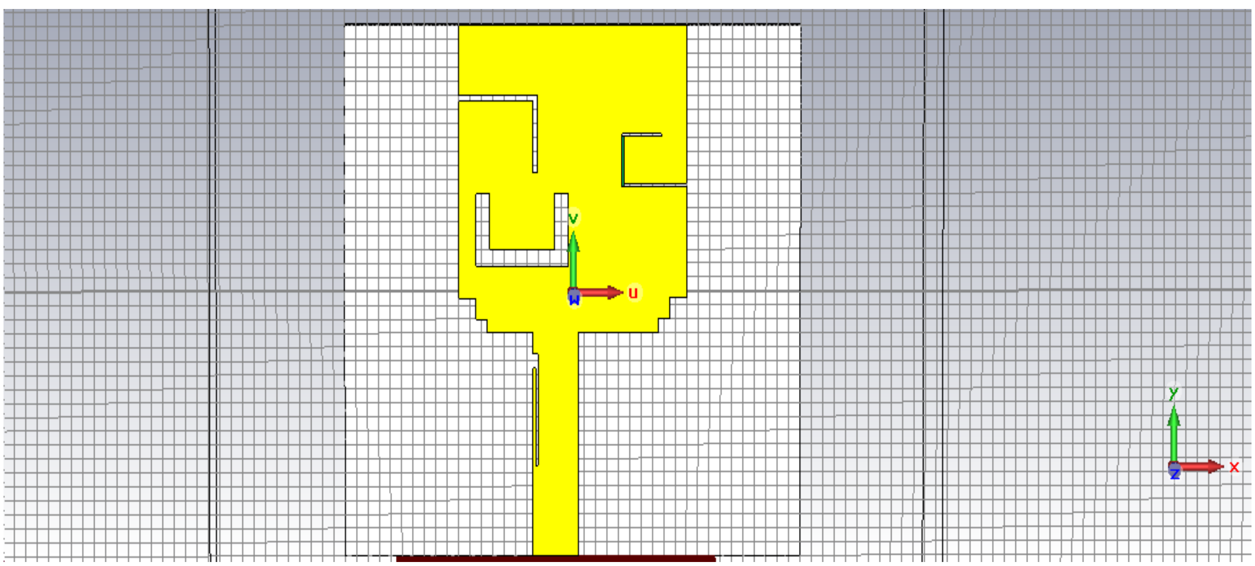


Fig. 3.1 Microstrip Patch antenna

3.1 CHARACTERISTICS OF MICROSTRIP ANTENNA

Microstrip antenna consists of a metallic patch embedded on a ground plane. Designing of microstrip antenna is chosen such as it provides maximum pattern in direction normal to the patch. This can be achieved by choosing a proper method of excitation beneath the patch.

Another important characteristic which must be considered during design of antenna is dielectric constant which is in the range of 2.2 to 12. Thick substrates provide better performance since they provide better efficiency, large bandwidth, radiation into space is loosely bound. But this in turn increases the size of element. So a lower valued substrate is chosen which results in small element size and tightly bounded fields in order to reduce undesired radiation and coupling but have small bandwidth and low efficiency.

Quality factor (Q) of microstrip antenna is very large. Q represents the loses associated with an antenna. With increase in value of Q, efficiency decreases and bandwidth becomes narrow. Q can be decreased by increasing thickness of substrate which leads to increase in size of antenna. Not only this, increase in thickness of substrate leads to delivery of total power from source to surface waves. This results in unwanted power loss as all this power is scattered at bends and leads to degradation of characteristics of antenna. Now to calculate length and width of microstrip patch the following equations are used:

$$W = \frac{c}{2f0\sqrt{\frac{\varepsilon r + 1}{2}}}$$

W=width of patch

$$\in reff = \frac{\in r+1}{2} + \frac{\varepsilon r-1}{2} + \left(1 + 12\frac{h}{w}\right)^{1/2}$$

$\in reff$ =effective dielectric constant

$$Leff = \frac{c}{2f0\sqrt{\in eff}}$$

Leff=length of patch

$$L = Leff - 2\Delta L$$

L=actual length of patch

3.2 ADVANTAGES

Microstrip antenna have a simple 2-dimensional geometry which makes it design relatively easy to manufacture and inexpensive in nature. Wavelength at resonant frequency decides the size of antenna so they work ultra high frequency or higher frequencies. These provide very high directive gain of 6-9dBi. Lithographic techniques help to print patch of arrays. Patch arrays can provide even greater gain than single antenna but more cost is involved in it and it requires a separate matching circuits by printed microstrip feed structures. Due to their ability to provide high gain arrays with low profile, microstrip patch arrays are used in aircraft and spacecraft.

Not only this, microstrip antennas even provide polarization diversity and can provide polarization in vertical, horizontal, RHCP or LHCP with the help of single feed element or multiple feed elements and variation of shape. So these antennas find their use in building various communication links.

Microstrip antenna are used for various embedded devices like hand held devices like mobile phones owing to the low profile property they exhibit. Other advantages of microstrip antenna are:

- Low weight and volume
- Ease of fabrication and implementation
- Mechanically robust when mounted on rigid surfaces
- Provides polarization diversity
- Helps in easy integration with microwave integration circuits

Major advantages like high gain, ease of conformity and low back radiations made microstrip antenna to be widely used in wireless communication as compared to wire antenna.

3.3 DISADVANTAGES

Like the two sides of a coin, despite of providing numerous advantages, there are even some demerits which are produced by microstrip antenna. Following is the list of disadvantages due to design of microstrip antenna:

- Low gain
- Narrow bandwidth
- Presence of conduction and dielectric loses results in relatively low efficiency
- Feeds and junctions provide extra radiations
- Excitation of surface waves
- Low power handling capacity
- Feeding structure in case of arrays results in large ohmic loses
- high cross-polarization radiations

3.4 FEEDING TECHNIQUES

Various feeding techniques are used to feed the antenna elements. It can be broadly categorized into contacting and non-contacting methods. Connecting element such as a microstrip line is used to directly feed the radiating patch with RF power in case of contacting method. In the non-contacting method, process of electromagnetic coupling is used to deliver power to radiating patch of microstrip antenna. The most important feeding techniques are microstrip line, coaxial probe, aperture coupling and proximity coupling.

3.4.1 MICROSTRIP LINE

This is a contacting method to feed antenna element. A narrow strip is directly connected to edge radiating patch of antenna. The width of the conducting strip is small as compared to microstrip patch. This gives the advantage of attaining a planar structure as the strip can be etched on same surface where patch is present. The inset cut is made to match the impedance of feed line to the microstrip patch without the use of any additional matching circuit. So the position of inset cut be adjusted accordingly.

ADVANTAGES

- Planar structure.
- No additional matching circuit required so its designing is simple.
- Ease of fabrication.

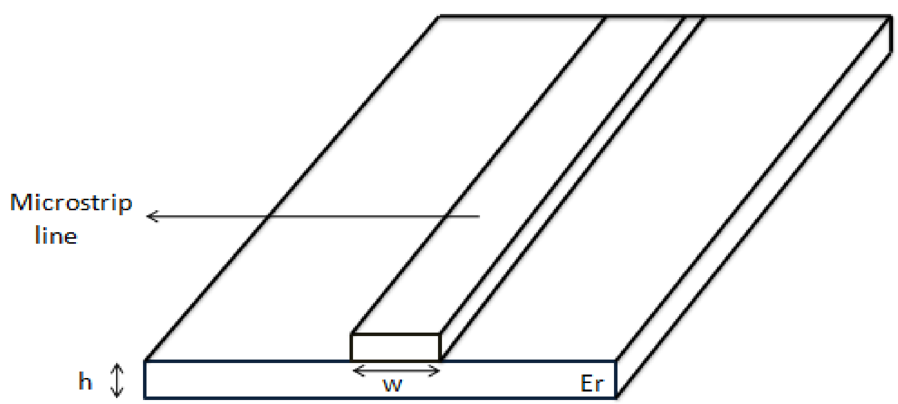


Fig 3.2 Microstrip line

DISADVANTAGES

- Increase in dielectric substrates thickness leads to increase in surface waves and spurious feed radiations.
- Feed radiations leads to increased cross polarization.
- Bandwidth is hampered due to surface waves and feed radiations.

3.4.2 COAXIAL PROBE

It is a form a contacting method as power delivered is via direct connection with microstrip patch. It consists of two conductors, inner and outer conductor. Inner conductor of the coaxial connector extends through the dielectric substrate and gets connected to radiating patch. Outer conductor on the other side connects the ground plane.

ADVANTAGES

- Coaxial conductor can be placed anywhere inside the microstrip patch so as to match the impedance of patch.
- Easy fabrication.
- Low spurious radiations

DISADVANTAGES

- Modeling is difficult as a hole must be drilled inside the substrate and the connector extends from the ground plane, thereby, making the structure non planar for thick substrates an narrow bandwidth.
- In case of thicker substrates, matching problem takes place due to increase in length of probe which makes input impedance more inductive.

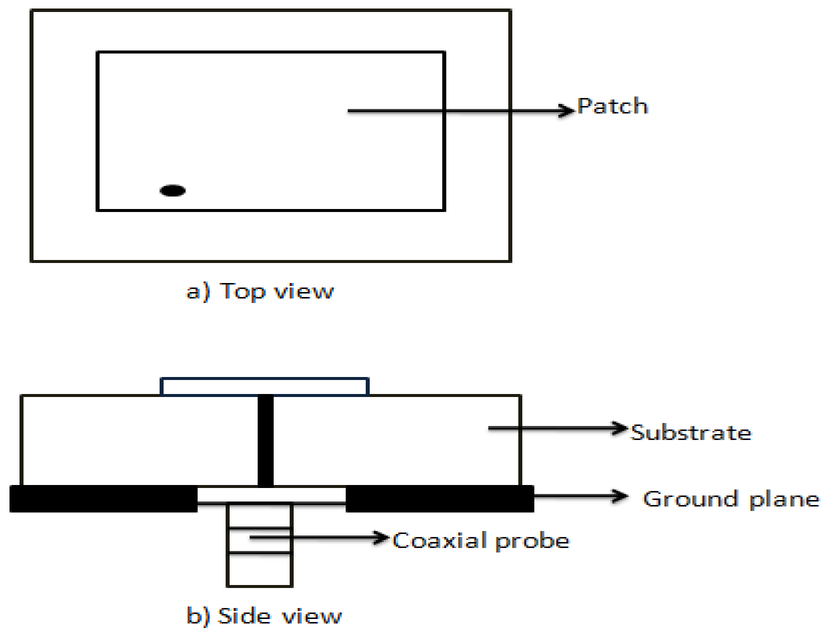


Fig 3.3 Coaxial feed

3.4.3 APERTURE COUPLING

This is a non-contacting method of feeding which involves the usage of two substrates which are separated by ground plane. A slot or aperture is made in the ground plane in order to provide coupling between patch and feed line. Shape, size and location of aperture decide the amount of coupling between patch and the feed line. In order to get optimum radiations, low dielectric material is used for top substrate and high dielectric material is used for the bottom surface.

ADVANTAGES

- Symmetry of configuration is acquired due to presence of coupling slot under the microstrip patch which results in lower cross-polarization.
- Due to the presence of ground plane between the two substrates, spurious radiations are reduced

DISADVANTAGES

- Multiple layers lead to increase in thickness.
- Fabrication is difficult and narrow bandwidth.

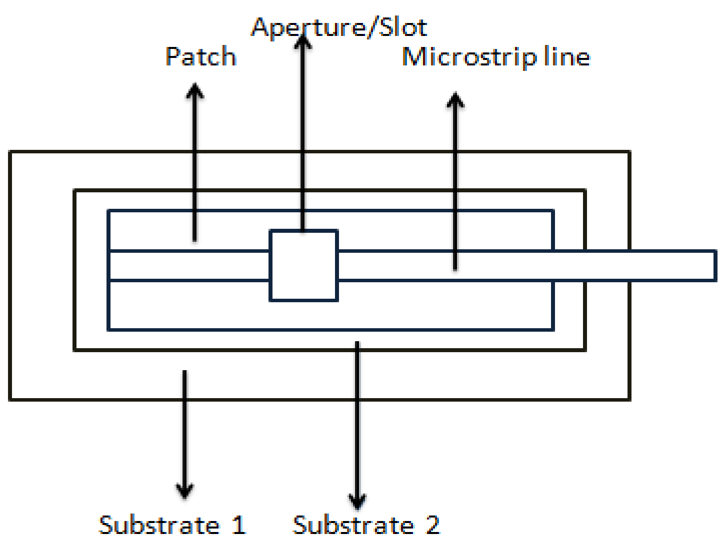


Fig 3.4 Aperture coupling

3.4.4 PROXIMITY COUPLING

This is also known as electromagnetic coupling method and is a non contacting type. In this method, two substrates are placed one above another where feed line is between them and the upper substrates surface contain the radiating patch. Matching is obtained by controlling length of feed line and width-to-line ratio.

ADVANTAGES

- High bandwidth.
- No spurious feed radiation due to increase in thickness of microstrip patch antenna.

DISADVANTAGES

- Increase in thickness of antenna.
- Since two dielectric substrates require proper alignment, fabrication is difficult.

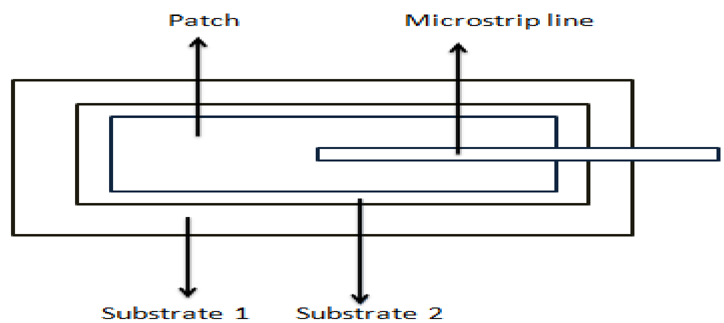


Fig. 3.5 Proximity coupled feed

TABLE 3.1 COMPARISON OF FEEDING TECHNIQUES [8]

Characteristics	**Microstrip feed**	**Coaxial feed**	**Aperture coupled feed**	**Proximity coupled feed**
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

CHAPTER 4
ULTRA-WIDEBAND ANTENNA

4.1 INTRODUCTION

Ultra Wideband technique is of utter importance and gaining prominence in the recent years due to the wide band it offers as well as high data rates for communication over short range. It is a form of microstrip patch antenna except for the wide band it provides. Federal Communication Commission has allotted frequency spectrum ranging from 3.1 GHz to 10.6 GHz as an unlicensed range for use in commercial applications. Primarily it was designed for use in military and RADAR applications. But with increasing demand of higher data rates by the users, ultra wideband had gained great importance in the present era. First ultra wideband antenna was proposed by Oliver Lodge in the year 1898 in the various shapes of dipole like spherical dipoles, rectangular dipoles, bow-tie and biconical dipoles. But after that, there was tremendous increase in design of ultra wideband antennas in the recent years. The major requirement for design of UWB antenna is to have an omnidirectional pattern for the purpose of mobility of user as well as to provide freedom for setting up of transmitter and receiver at any location.

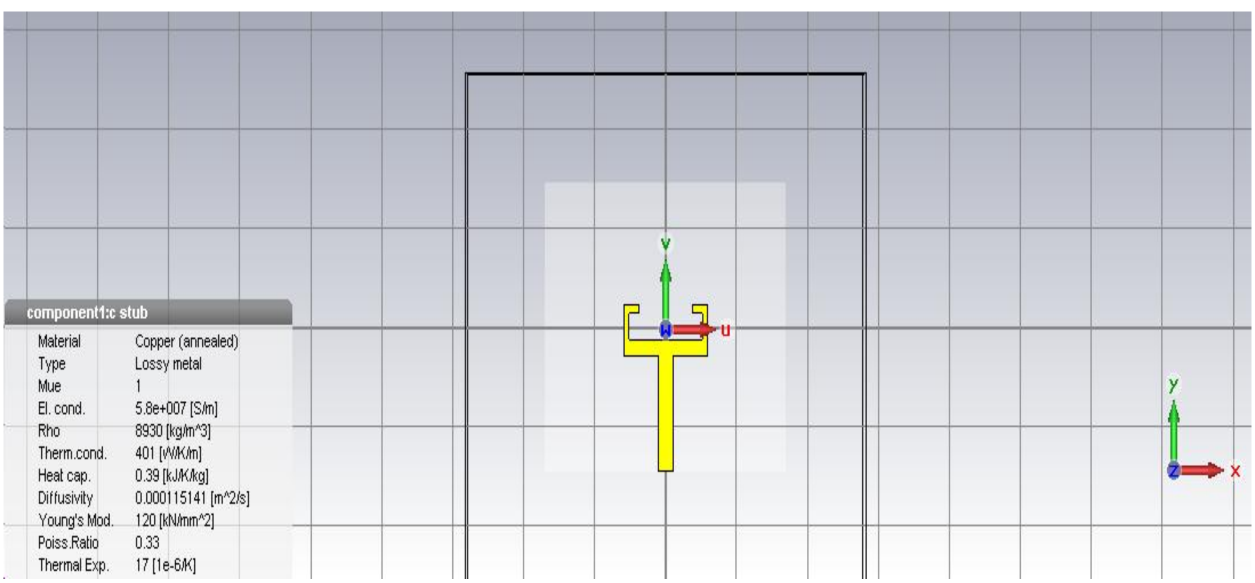


Fig 4.1 C-stub ultra-wideband antenna

4.2 CHARACTERISTICS OF UWB SYSTEMS

The two major reasons for the use of ultra wideband reasons is the people's increasing demand for higher data rates in the recent years as well as low power transmission required for ultra wideband [11]. For these systems UWB antennas are required. The following are the major characteristics of ultra wideband antenna:

- **Large bandwidth**: Since Federal Communication Commission has provided frequency spectrum ranging from 3.1 to 10.6 GHz, so a wider bandwidth is available for use. It exceeds 500 MHz or has minimum 20% of the central frequency.
- **High data rates**: Ultra wideband technology results in higher data rates for short range communication which is 150 Mbps for 30 feet (10 m). This property can be explained via the Shannon capacity theorem which is given as:

$$C = B\ log2(1 + SNR)$$

Here C=capacity

B=Bandwidth

SNR= Signal to Noise ratio

Now in the above equation capacity is in direct relationship with bandwidth. So with increase in bandwidth, capacity increases which results in an increase in data rate. Since ultra wideband provides wider bandwidth, thereby it provides high capacity in accordance with above equation.

- **Short pulse transmission**: In comparison with the conventional narrowband systems like 802.11a, Bluetooth where information was transmitted in the form of sinusoidal waves, here in case of ultra wideband technology, information is transmitted over channel in the form of pulses of very short duration. This makes them suitable for providing very fine time resolution.
- **Low power transmission**: Power is a major constraint while design of any system for wireless application. But ultra wideband requires power for transmission of data less than 1mW. This causes the battery life to last longer. As a result of this, UWB technology can be used for wireless applications where replacement of battery is not possible and this technology can operate for longer duration due to low power consumption.
- **Immunity for multipath effects**: Ultra wideband involves the transmission of pulses which are of very short duration. So this reduces the probability of overlapping of the

original or incident signal with the reflected signal. So effect of multiple signal superpositions at the receiver end is minimized.

- **Voltage Standing Wave Ratio:** Standing waves are produced as a resultant of incident wave with the reflected wave. These reflected waves are generated due to the losses present in the transmission line or the improper termination of the line. These standing waves accounts for the inefficiency in antenna. UWB provides VSWR<2.

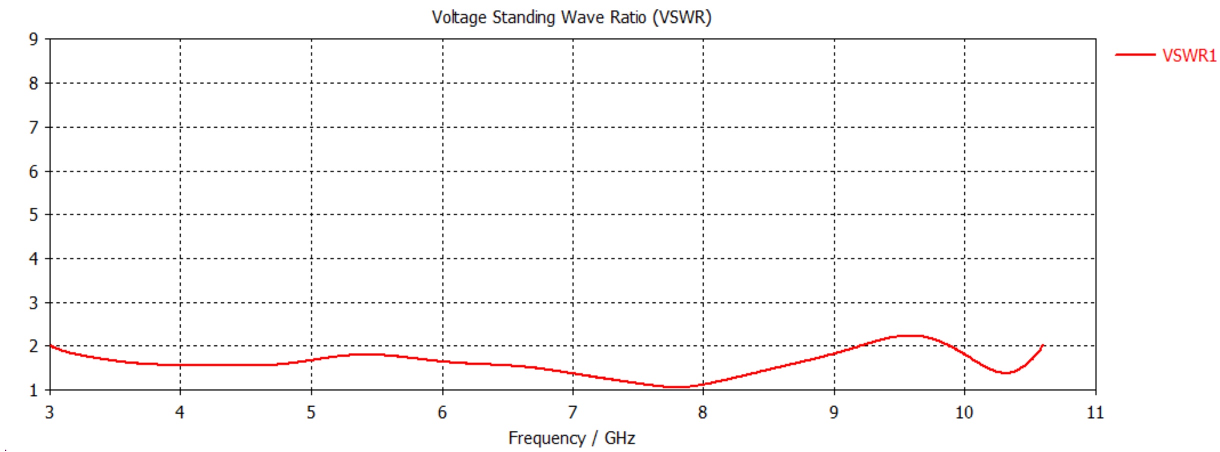


Fig 4.2 VSWR<2 in Ultra-wideband antenna

4.3 BAND NOTCHING IN UWB ANTENNA

Federal Communication Commission has allocated diversified range for UWB applications. So there exist certain bands like WLAN, WiMAX, C and X band which have the operating frequency which lie in the same band of UWB antenna, thereby resulting in overlap of these frequencies. Some of the frequency bands overlapping with ultra wideband are listed in the table 4.1.

TABLE 4.1 COMPARISON OF DIFFERENT BANDS

Bands for unlicensed use	Operating frequency (GHz)
Ultra wideband	3.1-10.6
WiMAX	3.43-3.7
WLAN	5.15-5.825

Due to the overlapping of these bands, there exits interference which disrupts the normal working of these specified bands. So it is necessary to avoid these interferences which is known as band notching as shown in figure 4.3 by insertion of slots. In the olden days, the very first method to avoid this interference is to utilize filters to prevent overlapping. But the use of the filters in the design leads to increase in the complexity of the design and thereby increasing the cost. The length of slot [2] is given as

$$L = \frac{c}{2fb\sqrt{\varepsilon e}}$$

Next step to avoid the interference was the embedding of slots either in the radiating patch or the ground plane. This serves the purpose of two things. Firstly, it leads to avoidance of interference of band within same frequency spectrum as that of Ultra wideband. Secondly, insertion of slots leads to improvement in the antenna characteristics like Bandwidth, gain, return loss, VSWR etc.

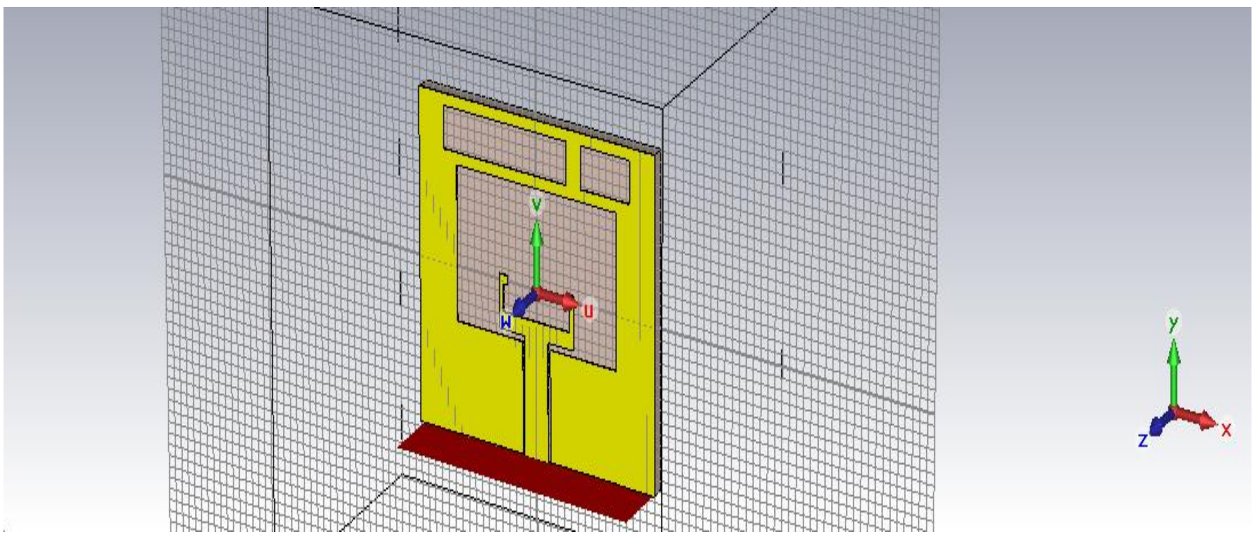


Fig 4.3 Band Notching obtained by inserting slots

Slot can be of any shape like U-shaped slot, L-shaped, pie shaped, E shaped etc. But there is one major disadvantage in the use of slots. These slots tend to leakage of electromagnetic wave, thereby producing an interference with the devices connected adjacent to the antenna or other electronic components present in the equipment. Apart from this, the leakage due to introduction of slots affects the radiation pattern of ultra wideband antenna.

Various shapes of stubs were incubated in the design pattern of ultra wideband antenna. These act as resonant filters. But it is not an easy job to insert a stub of any particular shape like C in the patch of antenna. Apart from these methodologies, parasitic elements can be used.

4.4 USE OF UWB ANTENNA IN UWB SYSTEMS

Ultra-wideband antenna, also known as ultra-band antenna, operates on a wide bandwidth ranging from 3.1 to 10.6 GHz. The major use of Ultra-wideband system is in wireless communication as it provides non line of sight communication, i.e., it can penetrate through doors and walls. It is a major advantage for its use as wireless communication systems are preferred if they provide same range in room of its location as well as the next room instead of a system which requires installation of transmitter in each room.

Another reason for use of UWB systems is its short range communication as it is capable of transmitting large amount of information across wider range of frequency. Moreover, power in the order of -41.3 dBm/MHz is required as signal is sent in the form of short pulses thereby reducing the effects of interference [1]. In other words, the amount of energy required for transmission is less for providing internet access, video telephony and digital voice services.

TABLE 4.2 MERITS AND BENEFITS OF UWB SYSTEMS

S.No	Merits	Benefits
1	Reduced multipath issues	High performance capability in adverse conditions
2	Less power requirement	Highly secure with very less probability of detection
3	Works with even low signal to noise ratio	Makes it useful for noisy environment
4	Capacity of channel is high	Provision of high data rates by UWB makes it useful in wireless personal area networks
5	Resistance to jamming	Highly reliable
6	Simple design	Facilitates low power
7	Coexistence with current narrow and wide band systems	No requirement of license

Rather than this, there is very less probability of eavesdropping and jamming of signal. This is due to two reasons. The first reason being the short range of about 30 feet is provided by UWB.

This makes it difficult to jam the signal as the jammer needs to be in very close vicinity of the antenna. Secondly, short pulses are transmitted and data rate is very high which makes it difficult to be accessed by a hacker. The benefits of UWB antenna is specified in table 3.2.

4.5 APPLICATIONS OF UWB ANTENNAS

Due to changing environment of wireless communication, UWB antenna has been considered as the most promising technology with wide range of applications which include:

- Radar Imaging: UWB is used in radar imaging due to various reasons. First of all, it transmits very short pulses which help in providing a very fine time resolution. This can help in detection of any location precisely. Moreover, the probability of intercept signals is very less and there is detectible material penetration which makes it useful for ground penetrating radar and wall radar.
- Impulse based Technology: These antennas can be used in locating systems and positioning applications like precision altimetry. These can be used in Radio Frequency Identification (RFID) for tracking and identifying the tags attached to the objects. This can be used for personnel localization. Higher security is provided by this as acceptation of login credentials takes place when badge of person is next to the computer.
- Military use: The transmission of narrow pulses are modulated in time and encoded using certain algorithms making them reluctant to security attacks. These picoseconds pulses are transmitted at very less power thereby snoopers need to be in close vicinity of antenna. Due to these reasons, it is used for tactical handheld and Low Probability of Interception and Detection (LPID) radios which are desirable for governmental and military use.

CHAPTER 5

REVIEW OF LITERATURE

This chapter provides the overview regarding the “ultra-wide band” antenna. Out of the papers read by me, some of them are represented below. All the papers presented below are from various journals and conferences both national as well as international.

Kisk et al. (2004) [3] proposed a paper with rectangular slot which provides UWB antenna. This antenna structure composes of a rectangular slot etched on the copper plane and a U-shaped stub of copper which together leads to wide bandwidth. The antenna operates in the range of 2.79-9.48 GHz. The size of the slot and stub helps in enhancement of bandwidth and can lead to change in resonant frequency. The radiation provided by antenna is bi-directional and radiates in same in both the directions.

Chang et al. (2005) [4] proposed an antenna which consists of a U-shaped structure with CPW fed and the ground plane has cuts at its edges. The overall size of antenna is 22×29.5 mm^2.The acquired frequency range of antenna is 3.8 to 18.6 GHz with maximum gain of 2.9 dBi and the radiation pattern attained is Omni-directional in nature.

Ruan et al. (2006) [5] presented an antenna for enhanced bandwidth for comparing the microstrip and the CPW feed lines. In this paper, there is comparison of the two feed line i.e. microstrip and CPW. The design consists of a slot of arc shape and patch with square having round corners. The bandwidth provided by CPW feed is 1.90-18 GHz which is more than that with microstrip line which is 1.91-16.25 GHz.

Shih-Hsun Hsu et al. (2006) [6] proposed an antenna which have a simple structure with a fork shaped patch and the ground plane is simple rectangle. The antenna is etched on Rogers 3850 with thickness of 0.0507 mm. Due to smaller thickness of the substrate; it is used for etching on clothes or vehicles. The bandwidth of the antenna is 3-11 GHz and maximum gain is 5.5 dBi.

Ma et al. (2006) [7] provided with an antenna which is etched on roger's substrate with the tapered ring slots etched on the patch which is fed by Co-planar waveguide feed. The bandwidth attained by this antenna is 3.1-12 GHz with the voltage standing wave ratio < 2.

Abbosh et al. (2008) [9] presented a paper where the study related to different shapes of monopole antennas were carried out. This paper makes comparison of the monopole antenna with shape of circle and ellipse. In terms of return loss, elliptical shape provides better return loss than circular but the gain provided by circular patch is more than elliptical antenna.

Mehdipour et al. (2008) [10] proposed an antenna which acted as UWB antenna and also rejected the frequency band of WLAN operation by insertion of slot. In this design, a bell shaped radiating patch is formed where the ellipses in the shape leads to smooth surfaces which leads to greater flexibility while optimization of antenna. Further U-shaped slot is cut which provides notching for WLAN. The antenna operates at frequency range of 3.1-10.6 GHz and attains a maximum gain of 5.34dBi. It also provides notching property at WLAN's frequency operation with help of U-slot in the bell-shaped patch.

Ranjan et al. (2010) [12] proposed a band notched antenna. In the proposed antenna, ground plane is elliptical in shape and the radiating patch is made up of hexagonal shape with a U-shaped cut to achieve band notch characteristics. At the notch frequency, current flows through the U-shaped slot, destructive interference takes place so no radiations of antenna takes place.

Mahmood et al. (2012) [14] reported an antenna which consists of a very complex shape of the patch with hexagonal slots etched and it is etched on Rogers R04003 substrate. The three hexagonal slots provide band notching by avoiding interference from WLAN bands. The fractal slots of the antenna eliminate the 5-5.7 GHz band and operate in range of 3.1-10.6 GHz.

Thiripurasundari et al. (2013) [15] designed a reconfigurable antenna without the use of an actual switch and there was no requirement of extra circuit and no filters were used. This antenna consists of a rectangular slot with U-shaped stub. Further a slot is inserted to attain band notching at WLAN and WiMAX band and making it reconfigurable by inserting a slot of ideal switch size. The slot and stub combination provided UWB antenna and the gain of antenna designed is 4.9 dBi.

Nornikamn et al. (2013) [17] proposed an antenna with rectangular shaped patch whose width was calculated by the given formula. Further enhancement of bandwidth was obtained by inserting four L-shaped slots in the rectangular patch. CPW feed was used and simulation was done using CST microwave studio. These slots lead to notching at WiMAX band. Bandwidth can be increased by stacking a rectangular patch over the patch with the help of microstrip line and separation of 10 mm.

Denisov et al. (2014) [19] presented a structure of antenna for UWB applications. In this antenna structure, the radiating patch is of semi-circle and the ground plane is made of certain deformations with curves on both the sides. The antenna has a very small size of 25mm×25mm×1.5mm and is etched on FR4 substrate. Miniaturization is attained and the operating range of antenna is 3-16.6 GHz and VSWR<2 in the entire range.

Roshna et al. (2014) [20] composed a compact antenna with Co-planar Waveguide feed on both the sides of the ground plane. The antenna is etched on FR4 substrate with the patch constituting of staircase structure and in the ground plane, there is symmetrical slot at the bottom. The gain attained by the antenna is 3 dBi with bandwidth of 8.3 GHz.

Gunavathi et al. (2014) [21] presented an antenna in this paper which have a very simple structure of the polygon shaped stub and rest of the area is covered with ground plane which is etched on FR4 which is inexpensive substrate. The antenna attained the bandwidth ranging from 3.1-10.6 GHz and the peak gain obtained is 4dBi.The antenna dimensions are comparatively low.

Pratama et al. (2015) [22] designed an antenna with small dimensions. This antenna is designed for microwave imaging and the structure constitutes of dipole like structure with CPW feed with size of 30× 25 mm2 etched on FR4 substrate. The antenna operates in the UWB range with the gain of 0.73 dBi.

Another compact antenna was proposed by **Shen et al. (2015) [23]**. The shape of the antenna is complex such that there are mixed slots. The patch consists of two semicircle and one rectangular slots and the ground plane consists of quarter circles and rectangular slots. The size of antenna is reduced and the wide bandwidth is obtained by slots in radiating patch (3.1-11.1 GHz) and the ground plane slots tend to improve the impedance match.

Ding et al. (2015) [24] added another antenna to the list of miniaturized antennas with UWB applicability. The design is optimized by providing CPW feed to half elliptical antenna on FR4 substrate with major current distribution in the feed line and at periphery of ellipse. This geometry results in smaller size with frequency range of 3.1-10.5 GHz.

Seera Dileep Raju et al. (2015) [25] gave the comparison of four antenna designs with different configuration of swastika slot antenna. Antenna with pair of inverted L-shaped slots in ground plane provided maximum bandwidth (3.9-10.8 GHz) and smallest return loss (-50.57 dB). The important factor in this design is the distance between two slots which must minimize coupling between each other by being as far as possible from each other. Concentric rings are etched on the radiating patch around the swastika slot.

Sanjiv Tomar et al. (2015) [26] reported an antenna with triple band notch characteristics. First band notch is obtained by inverted U shaped slot, second by C-shaped slot and third band notch is acquired by etching another U-shaped slot on the microstrip feed. The length of the slot is taken to be one half of the guided wavelength of the centre frequency of the respective notched bands. The three notched frequencies are 3.5, 5.5 and 7.8 GHz. Radiation pattern in H-plane is Omni-directional and in the E-plane, it is bidirectional.

Geethananda et al. (2015) [27] proposed an antenna with multiple concentric rings separable by 1.3 mm of width which helped to attain wide bandwidth ranging from 2.6-13.5 with reduced size. The reason behind the enhanced bandwidth was the multi-resonance effect that is obtained by multiple rings. The area of the antenna is reduced in comparison to previously introduced ring- like antennas. To improve the return loss of the specified antenna, a slot with the shape of rectangle was introduced.

Omar et al. (2016) [28] presented a spiral antenna with complex shape and reduced dimensions. The design consists of CPW fed antenna with spiral radiating patch whose ground plane is tapered and 75 ohm load is used to terminate the spiral. This design leads to reduction in size of the spiral antenna in comparison with the previous papers and operates at 4-10 GHz.

Safia et al. (2016) [29] proposed an antenna with circular patch which is embedded with multiple small circular slots. The reported antenna consists of large circle for operation at higher frequency of UWB i.e. 10 GHz. This large circle is filled with multiple small circles for operation at lower frequency i.e. 3.1 GHz. The antenna produces higher order harmonics in comparison to simple circular patch antenna.

Aissaoui et al. (2016) [30] presented an antenna that comprises of hexagonal patch on the CPW feed and fractal slot. The slot elements are present opposite to each side of the hexagon. With the help of fractal slot antenna becomes UWB. The operating range of antenna is 2.27-12.46 GHz which s due to the fractal slot in the design with peak gain of 7.3 dBi.

Surjati et al. (2016) [31] came forward with design of an antenna with stacked structure where one layer is stacked on the other layer of substrate. The realization of this antenna is done on two layers substrate where on the top there is rectangular patch with slits in it and at bottom a slit is present a center of the rectangular element which is fed by CPW feed. This provides a UWB antenna for various applications like WiFi, LTE etc.

Deshmukh et al. (2016) [32] proposed a bow tie antenna which was applicable in the ground penetrating radar. In this structure, the conventional bow-tie antenna structure is changed by tapering the sides of the triangles on either side and inserting two more triangles of smaller dimensions within the existing antenna. This lead to increment in bandwidth and s-parameter of the antenna. Gain of 5.36 dBi is obtained.

Syed at al. (2016) [33] designed an antenna with a different shape of a Cup and studied the characteristics provided by it. This design consists of CPW ground plane on either side of the feed with the radiating patch in the shape of a cupcake. First a semicircle is etched on the substrate followed by capping it with an ellipse. The dual band was obtained by a semicircle whereas after forming cup-shape, UWB antenna was formed with bandwidth of 9.7 GHz and Omni-directional pattern is obtained by the antenna.

Yuan et al. (2017) [34] reported an antenna which combines the affects of multi-mode resonance and the surface Plasmon wave. The patch constitutes of meshed structure which acts as a multi-mode resonator and the ground acts as surface Plasmon wave generator by having a patterned plane. Microstrip feed is provided to antenna and it is etched on FR4 substrate. The antenna acts as a UWB antenna with return loss less than -10 dB and maximum gain obtained by the antenna is 5.8 dBi. The radiation pattern obtained at low frequencies is similar to a monopole antenna but at high frequencies, side lobes are produced.

CHAPTER 6

RATIONALE AND SCOPE OF STUDY

There has been tremendous increase in the utilization of Ultra-Wideband systems recently due to the increased transmission and reception of information with very little consumption of power. Apart from the less power used, UWB systems offer certain other advantages in terms of higher data rates, increased bandwidth to support wide range of applications [16]. Some of these include medical imaging systems, indoor positioning, mobile systems, vehicular radar systems etc. In order to design these systems, UWB antennas plays a major role. UWB systems engage in transmission of short pulses which can be optimally provided by enhanced efficiency and low pulse distortion, which are provided by the compact size and low profile features of UWB. Frequency band ranging from 3.1GHz to 10.6 GHz is allocated for the commercial use by the Federal Communication Commission (FCC) [1]. With proper utilization of this large frequency range for transfer of information, high data rates are attained in wireless communication.

Patch antennas are generally employed in telecommunication due to less weight and volume and their structure is modified with respect to the application for which these are designed. The main element considered while the design of patch antenna is the thickness of the substrate. The thick substrate provides better performance but at the cost of the size whereas the thin substrates offer low element size [8]. These antennas can be fed using different techniques like microstrip line, coaxial probe, CPW (Coplanar Waveguide) etc.

In order to cover the required range, many antennas were designed with various shapes [4]-[6], [9],[10],[14],[23],[27],[28]. But they are of large size whereas some of the applications require small size antennas which can be easily inserted in the systems like in the case of microwave imaging system. So CPW antennas were designed. But some of them still offer large size [3],[7], [31]. On the other hand some of the CPW fed antennas are of relatively smaller physical size but they tend to be complex and thereby causes difficulty while fabrication [18],[22],[29]-[30]. With the passage of time, more CPW fed antennas were designed which fulfill both the criteria, i.e. have small size and easy to fabricate, but they had inappropriate low gain and efficiency [19]-[20].

So in this paper, a compact CPW fed Ultra-wideband antenna is proposed. The antenna comprises of U-shaped stub which is embedded with small rectangular slots. This antenna provides a small size, low cost of fabrication along with enhanced bandwidth and gain.

The major scope of study involves the development of an UWB antenna with the bandwidth of 3.1-10.6 GHz for supporting various wireless applications as specified by the FCC. The data collected for the design purpose involved the journals and conference papers which provided assessment in determining the affect of various parameters on the antenna characteristics. In this paper, UWB antenna is designed without any band notching provision so that the entire band covers the UWB range. The CST software is utilized for simulation which is available for commercial use. FR4 material is used for fabrication as it is easily available in the antenna labs and testing was done using Vector Network analyzer using connectors. The comparison was done on the basis of the results obtained after testing antenna and the simulated results.

In order to measure the gain of antenna, anechoic chamber is required. But this is not available in the nearby area of research. So simulated gain is taken into consideration.

CHAPTER 7

OBJECTIVE OF THE STUDY

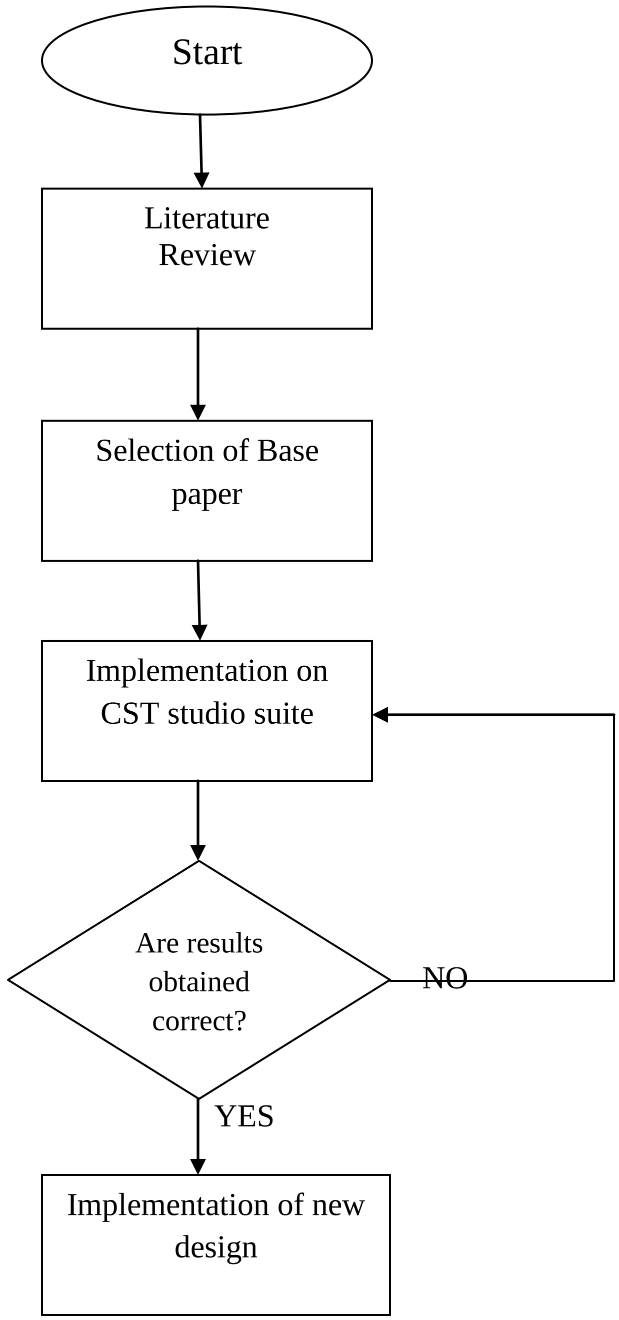
The major purpose of this thesis is to present a UWB antenna with miniaturized size. The following are the objectives of the proposed work:

i. To study the various techniques and parameters which affect the characteristics of Ultra-wide Band antenna.
ii. To implement the Co-planar Waveguide feed technology for design of a compact UWB antenna.
iii. To fabricate and test the designed antenna for real-time applications and in order to compare the measured and simulated results.

CHAPTER 8

RESEARCH METHODOLOGY

In this chapter, there basic flow diagrams showing the procedure of the complete antenna design using CST studio suite. The following procedure was followed for the completion of the antenna design:



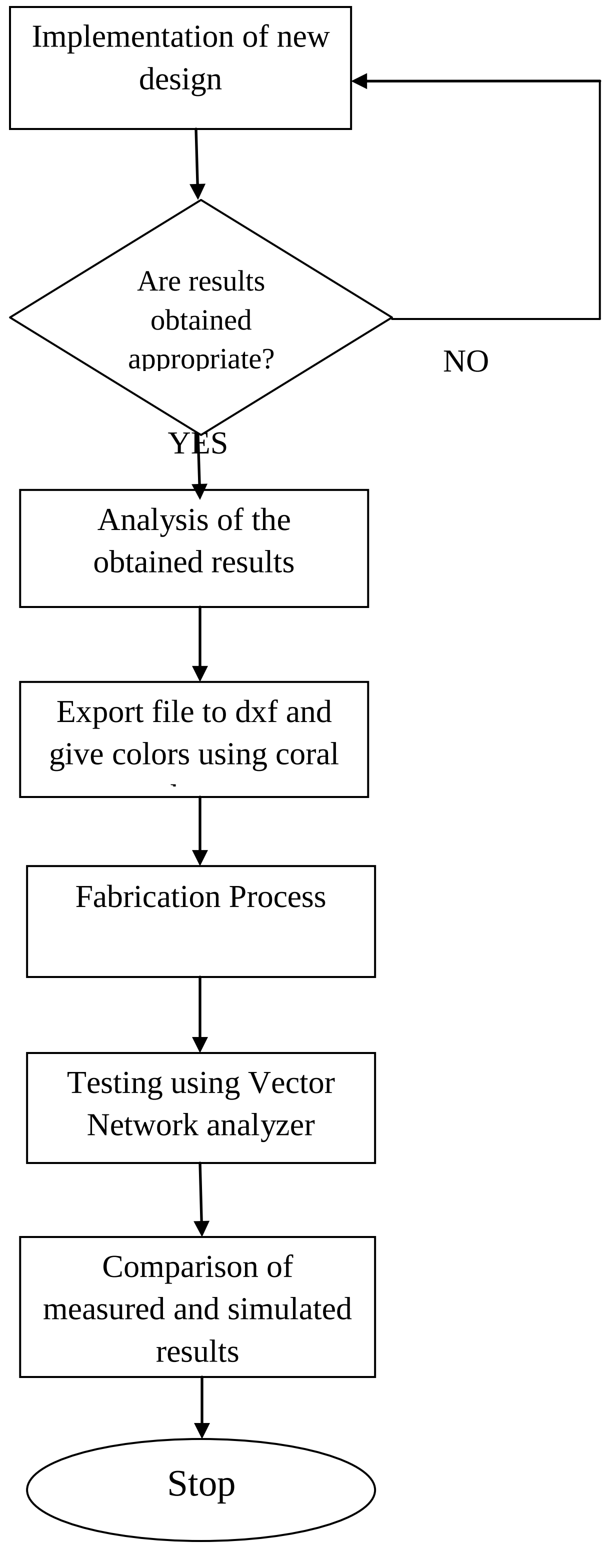
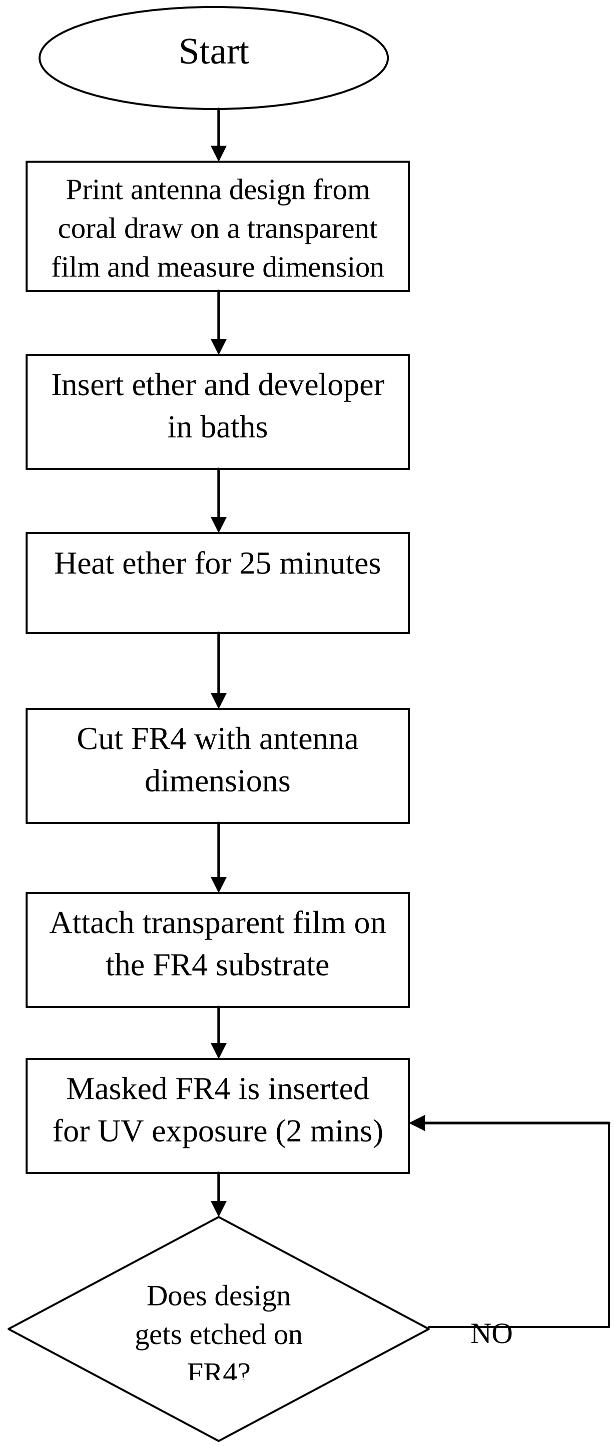


Fig 8.1 Process for antenna design

Fabrication of the antenna was carried out on FR4 substrate as it is cheap and readily available in antenna labs. The complete fabrication process starting from printing onto transparent film to testing using connectors is depicted in figure 8.2 in the following page. Coral draw software was used to properly scale and print the antenna design on the transparent film.



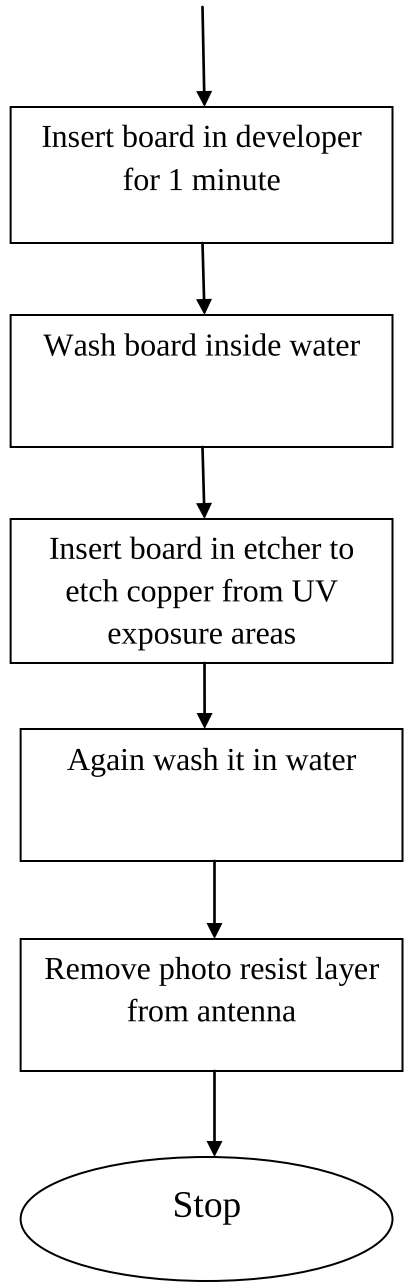


Fig 8.2 Fabrication Process

CHAPTER 9

EXPERIMENTAL WORK

The proposed antenna has the dimensions of 27×21×1.6 mm^3 (L×W×h). The top view of the Ultra-wideband antenna is illustrated in Fig 9.1. The microstrip patch antenna is fed CPW with the characteristic impedance of 50 ohm and the dielectric substrate used is Taconic TLT-6 with dielectric constant of 2.65 and thickness of substrate is 1.6 mm. The proposed antenna comprises of a U-shaped stub with small rectangular slots in it. There is a large rectangular slot of dimension of 12.9×19 mm^2. Another rectangular slot is inserted at the upper part with two another slots of same dimensions as in the U-shaped stub. A gap between the C-stub and CPW ground plane is inserted. The slots inside the U-shaped stub are of dimensions of 4.2×4.99 (L5 × w5 mm^2). The details regarding the optimized antenna dimensions are represented in Table 9.1.

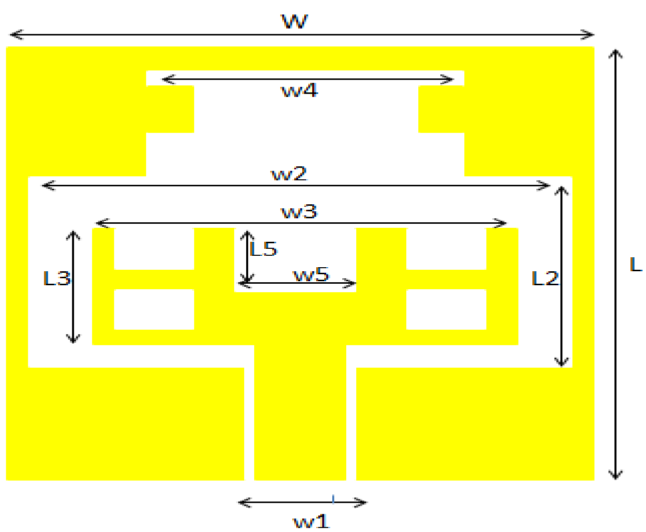


Fig 9.1 Structure of proposed antenna

TABLE 9.1
STRUCTURE DIMENSIONS OF DESIGNED ANTENNA

Parameter	L	W	L1	L2	L3
Value (mm)	27	21	5.3	12.9	8.4
Parameter	L5	W1	W3	W4	W7
Value (mm)	2.1	4	12	8	19

The detailed description of the design process is given in the following steps:

STEP I. Select CST microwave studio → enter the maximum (12 GHz) and minimum frequency (3.1 GHz) → set field monitors → enter finish. The CST window will be activated. Now click on the Local WCS to assign coordinates and double click on brick.

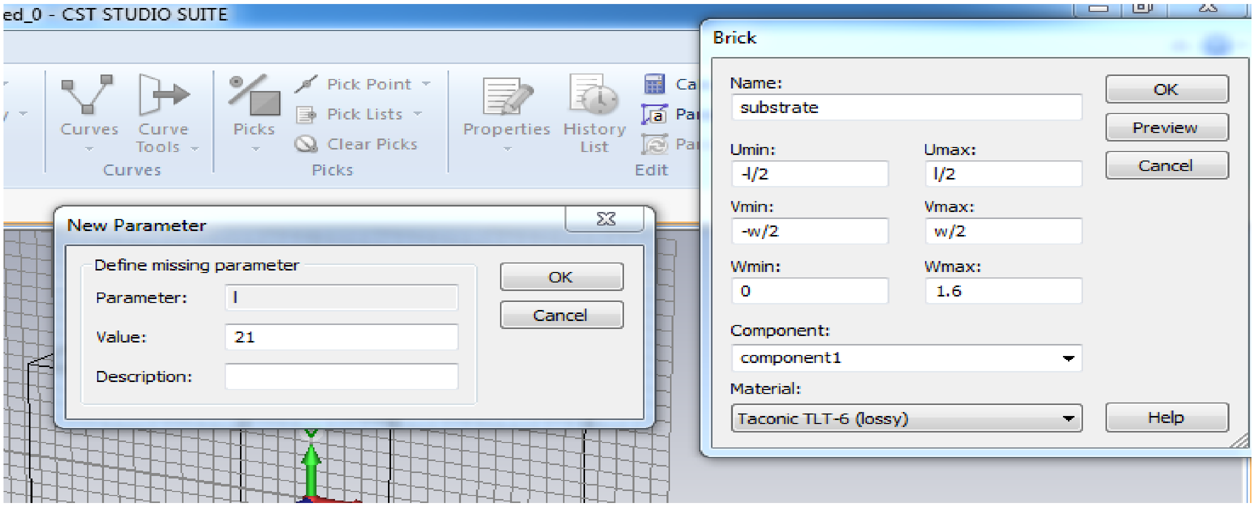


Fig 9.2 Defining variables in the brick

The antenna is fabricated on Taconic TLT-6 substrate 27×21 mm^2 (L×W) which has a thickness of 1.6 mm and dielectric constant of 2.65. Figure 9.2 and 9.3 shows the parameter list and the substrate respectively.

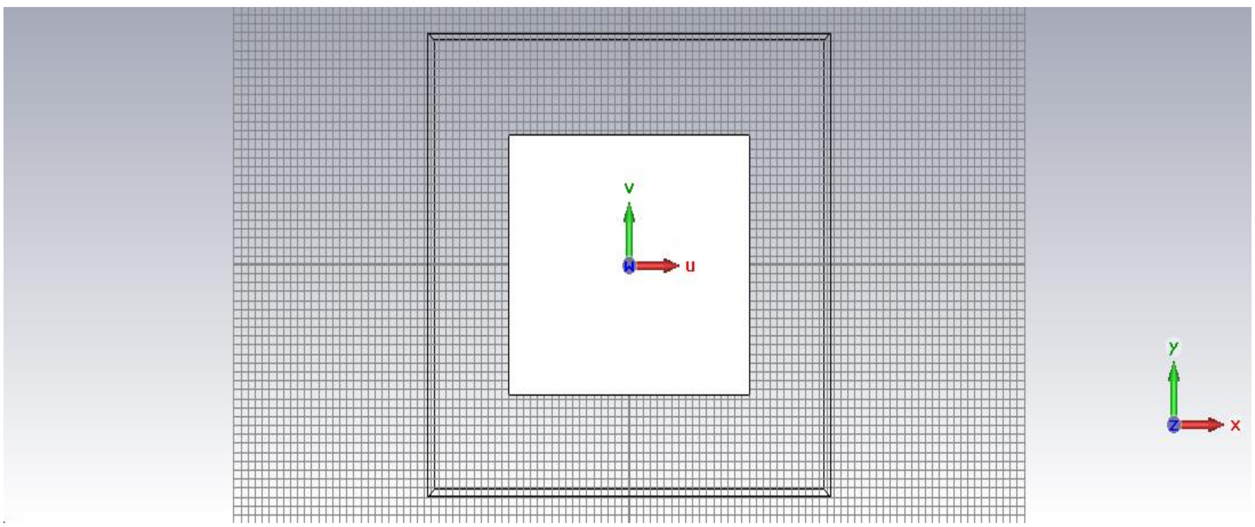


Fig 9.3 Taconic TLT-6 substrate etched on x-y plane

STEP II. A copper plane is etched onto the substrate of same dimensions as that of the substrate. A rectangular slot is then inserted with dimensions of 12.9×19 mm^2 which is shown in the figure 9.4.

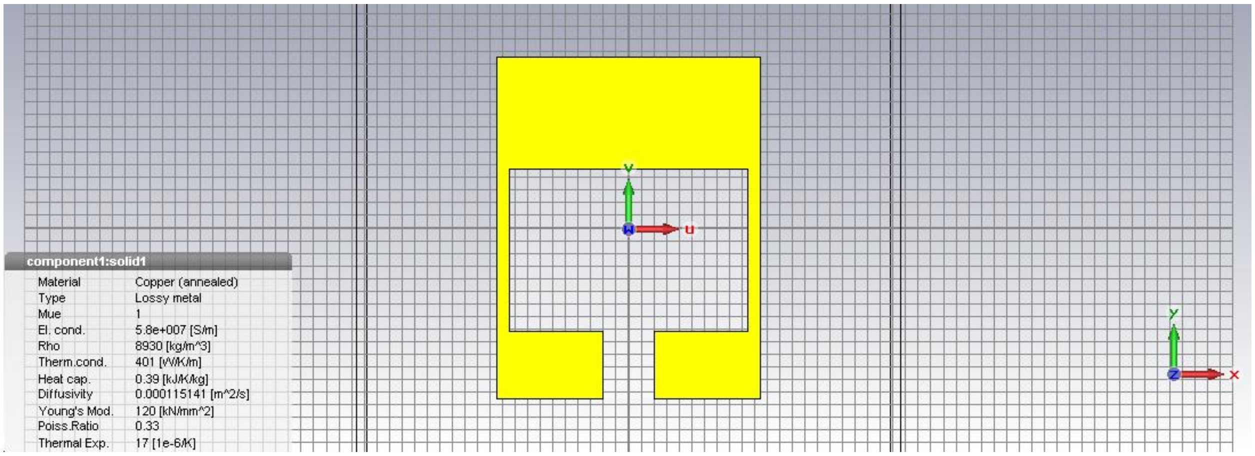


Fig 9.4 Rectangular slot etched on x-y plane

STEP III. Now after the insertion of slot, a U-shaped stub is added on the patch with feed line length 7.3 mm. U-shaped stub is made in following steps:

a. First feed line is constructed as shown in figure 9.4a with dimensions of 7.3×3.2 mm^2.
b. Then a rectangle is added to the feed line as shown in figure 9.4b with dimensions of L3×W3 mm^2.

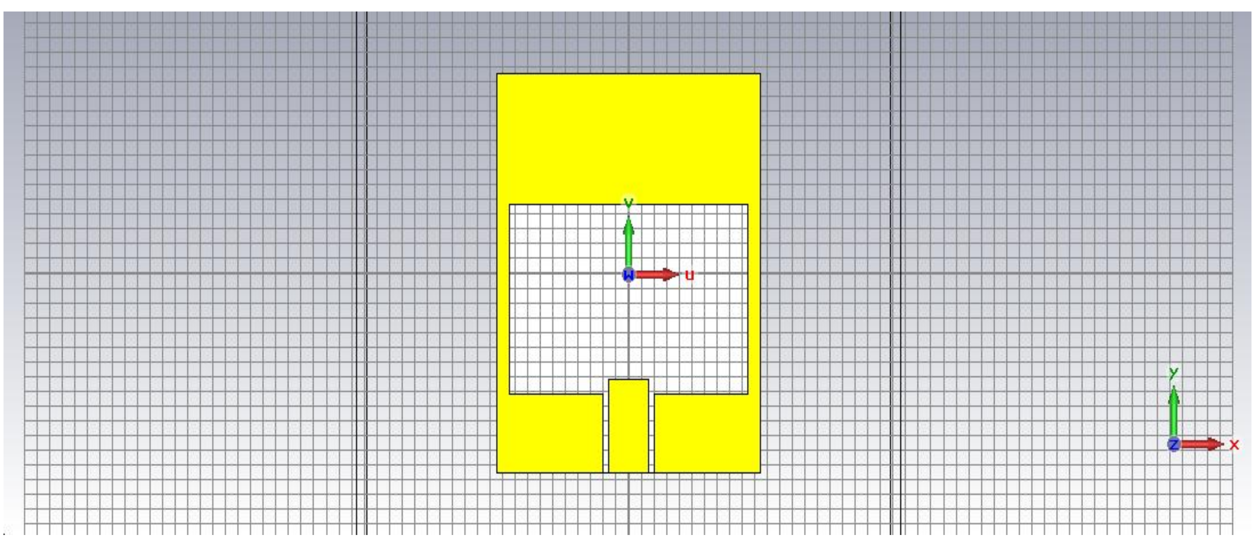


Fig 9.4a Insertion of feed line

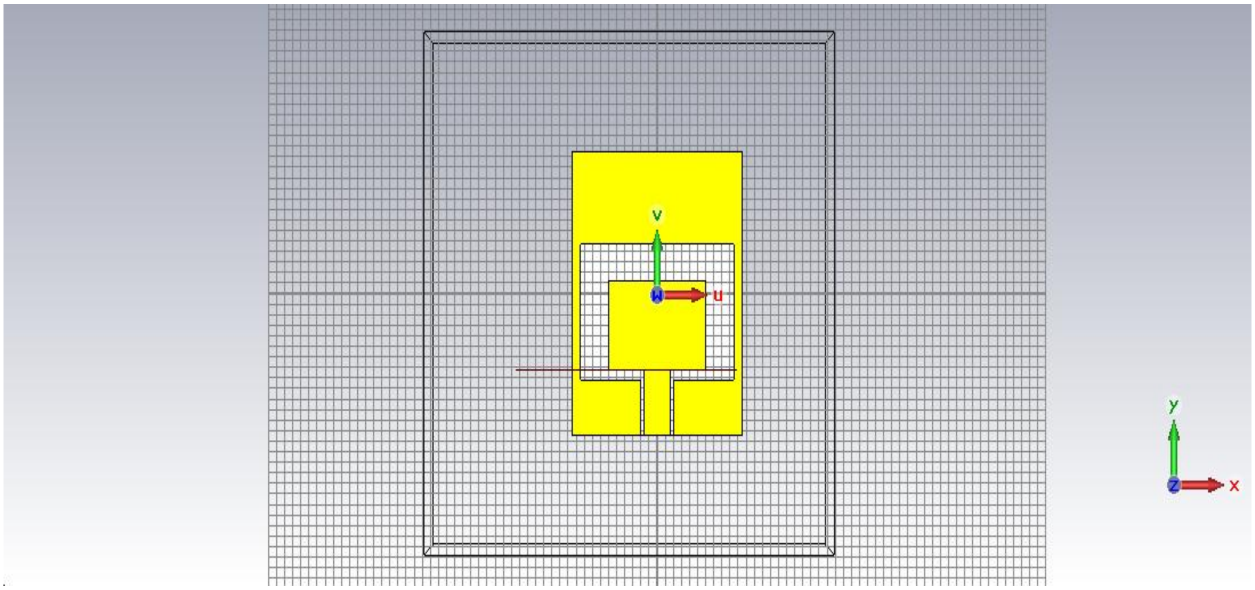


Fig 9.4b Addition of Rectangle on feed line

c. Then a slot is inserted to give final shape of U-stub.

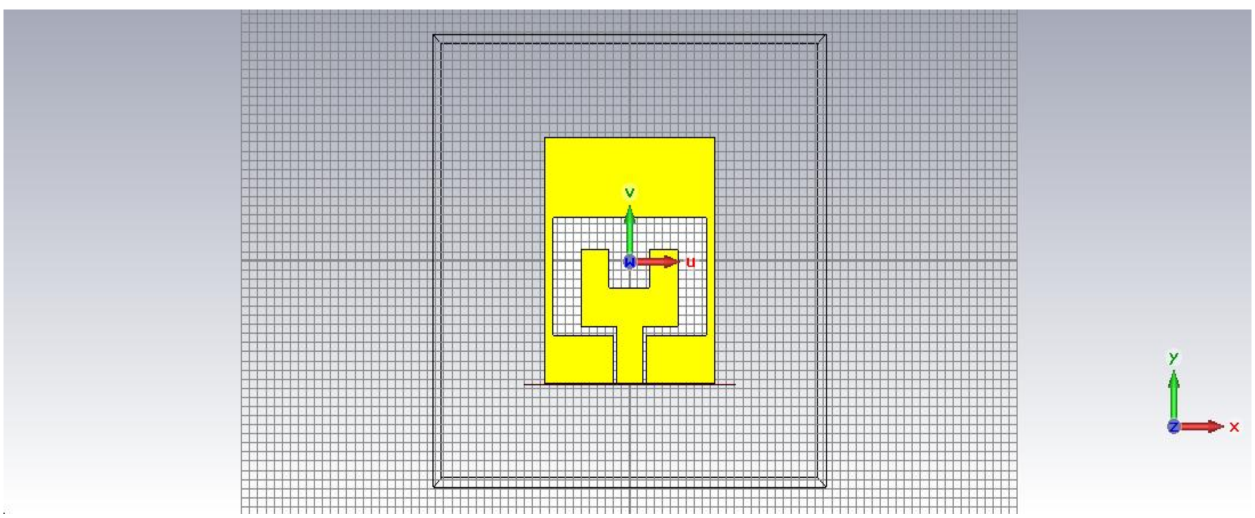


Fig 9.4c U-shaped stub

STEP IV. The next step is to insert slots in the U-shaped stub as shown in figure 9.5. Total of four slots are embedded in the stub where current distribution takes place.

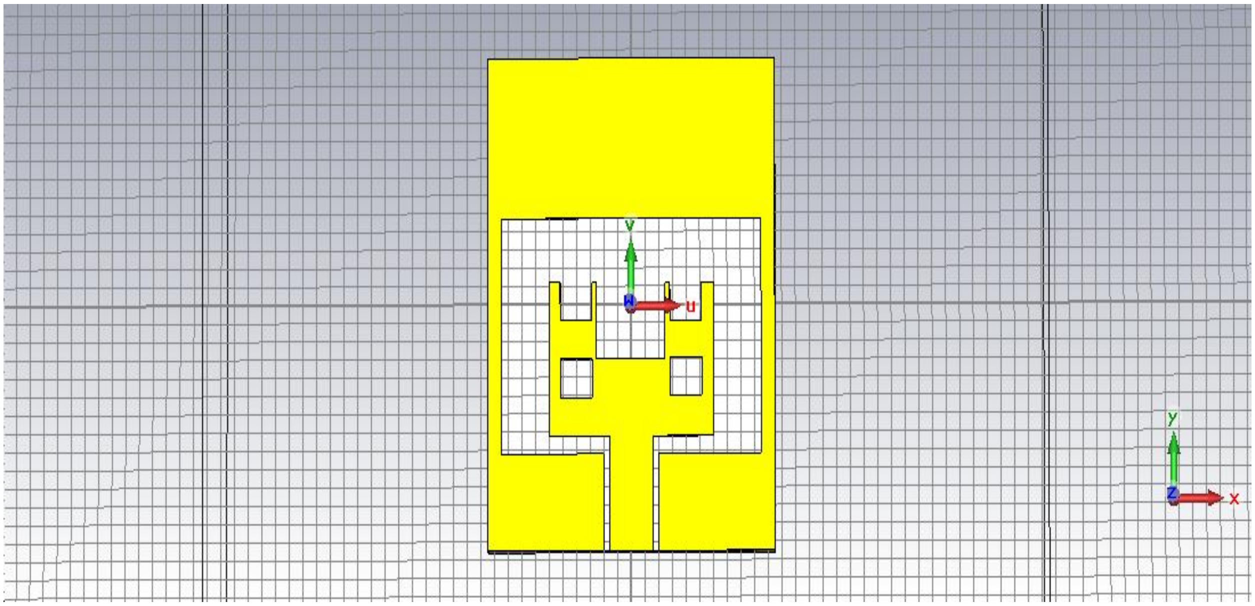


Fig 9.5 Insertion of slots in stub

STEP V. Then an upper slot of rectangle is cut in the ground plane which leads to improved return loss of the proposed antenna which is depicted in figure 9.6

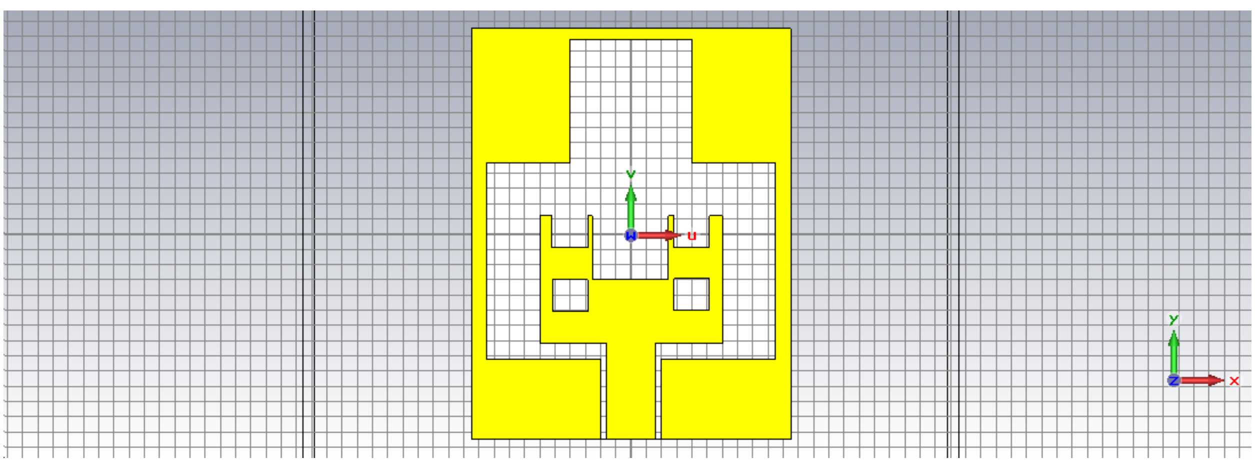


Fig 9.6 Inserting a rectangular slot at upper part

STEP VI. The final step in the antenna design is to add two copper slots in the upper part of antenna as given in figure 9.7.

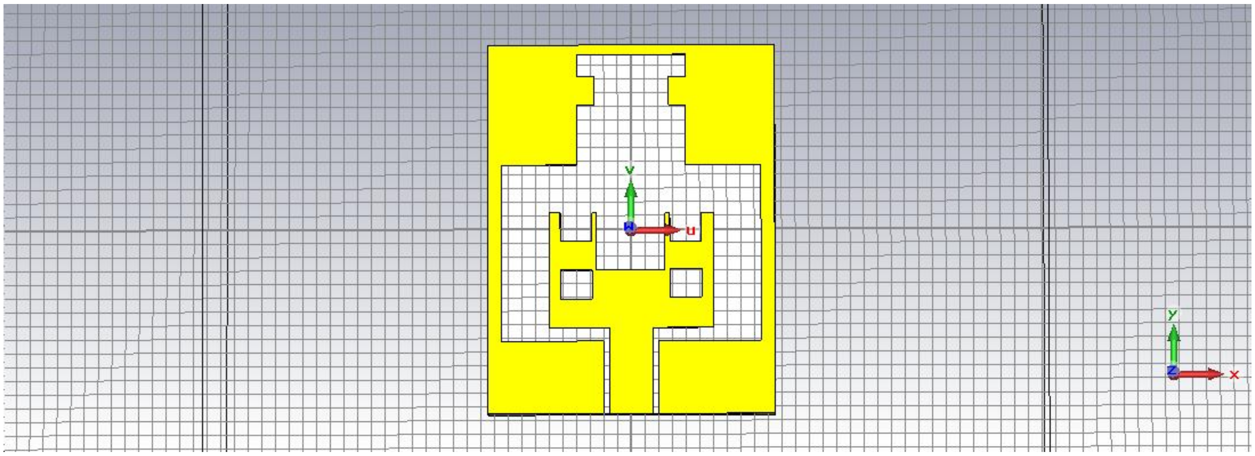


Fig 9.7 Proposed antenna design

STEP VII. Now since the design is complete, ports need to be defined for simulation purpose. After the completion of design, the port is assigned to the feed line via the waveguide port where width of 5×Wf is considered as shown in figure 9.8. First go to Pick→Pick face→simulation→waveguide port.

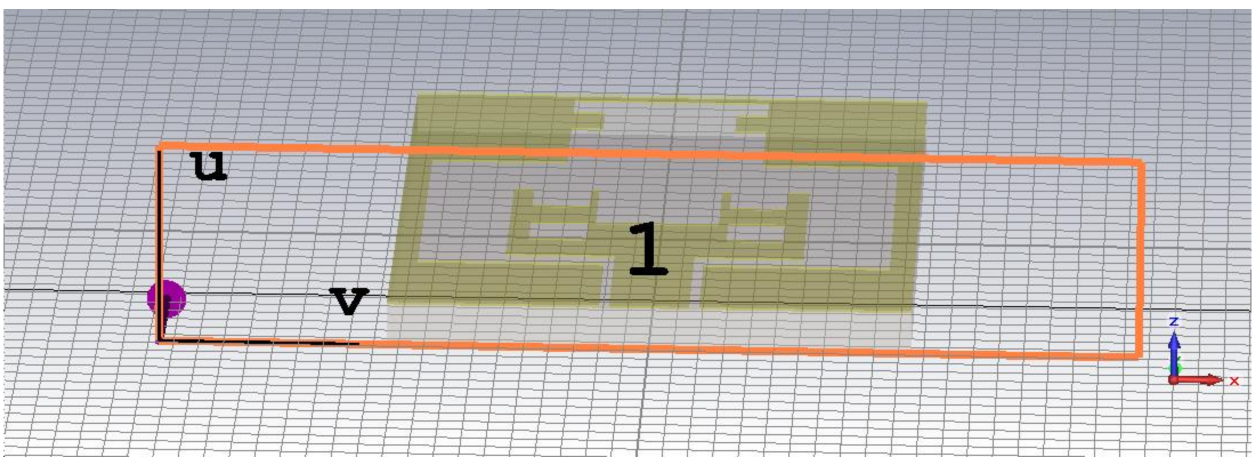


Fig 9.8 Assigning ports

Base paper design: In the base paper implementation, band notched antenna was designed for the removal of interference of WLAN and WiMAX band. It included C-stub with rectangular slots for notching the frequencies. The implemented design is shown in figure 9.9. The antenna is fabricated on FR4 substrate 34×29 mm^2 (Lg×Wg) which has a thickness of 1.6 mm and dielectric constant of 4.4. This antenna is a reconfigurable UWB antenna where a copper patch of dimensions of ideal switch is used to provide band notch. In the ON state, band notching to WLAN is provided but when the switch is OFF WiMax band is covered.

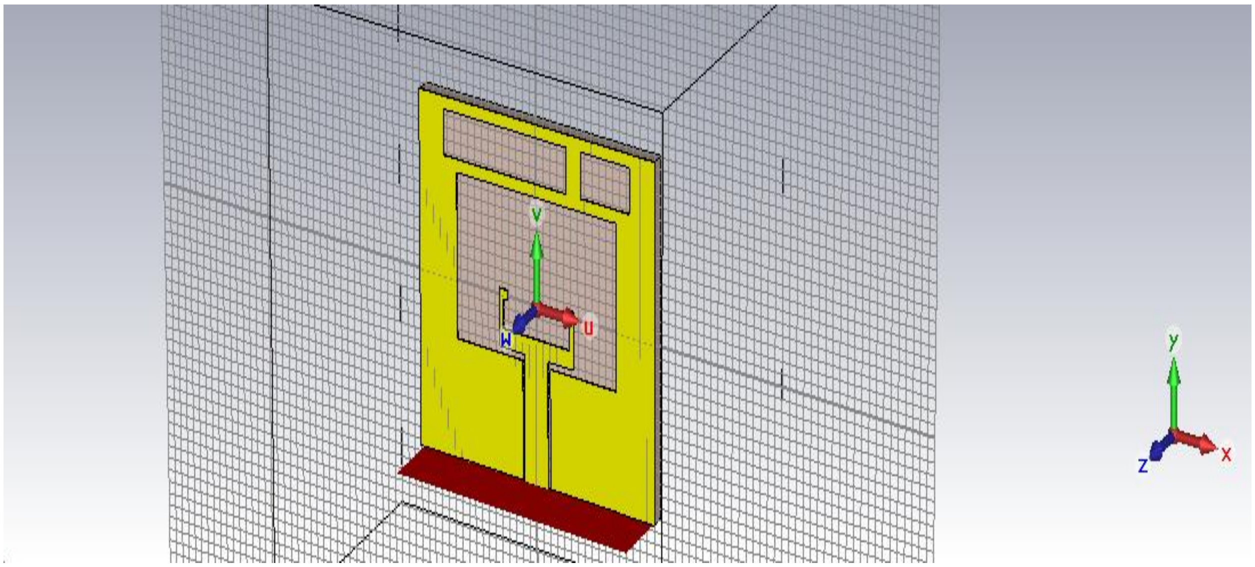


Fig 9.9 Implementation of base paper design

CHAPTER 10

RESULTS AND DISCUSSION

The simulation of the proposed antenna was carried out using CST microwave studio with the units being set to GHz for frequency and mm for length. First only rectangular slot is simulated and then U-shaped slot is inserted which offers wide bandwidth ranging from 2.8-11.6 GHz but the resonance provided by antenna was not optimum. So further slots were embedded into the u-shaped stub to improve the return loss characteristics. The proposed antenna has two resonant frequencies at 7.33 and 9.05 GHz, which forms the wide bandwidth as shown in figure 10.1. It shows the variation of the reflection coefficient in dB with the change in frequency in GHz. The observation is made that wide bandwidth operating from 3.6 GHz to 11.5 GHz. In order to analyze the design, study of various parameters and the substrate material is conducted in terms of S-parameters and VSWR.

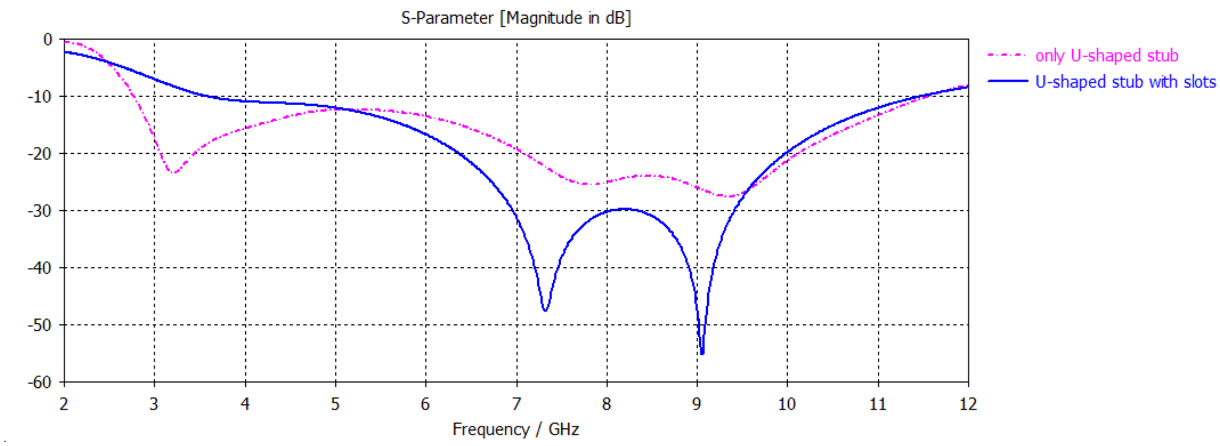


Fig 10.1 S-parameters of the proposed antenna with and without slots

a. Analysis by varying the feed line

Figure 10.2 gives the variations in the s-parameters with the change in the width of the parameter. When the feed line length is decreased, the bandwidth of the antenna gets reduced. When the feed width is taken to be 3.2 mm i.e., it is reduced by 0.4m from the original feed width, then the operating frequency of the antenna is from 5 GHz to 10.8 GHz. Similarly with 0.2 mm decrease in the feed width, the operating frequency gets reduced to 4.8 GHz to 11 GHz.

On the other hand, with increase in the feed line width, the antenna has very poor resonating frequencies.

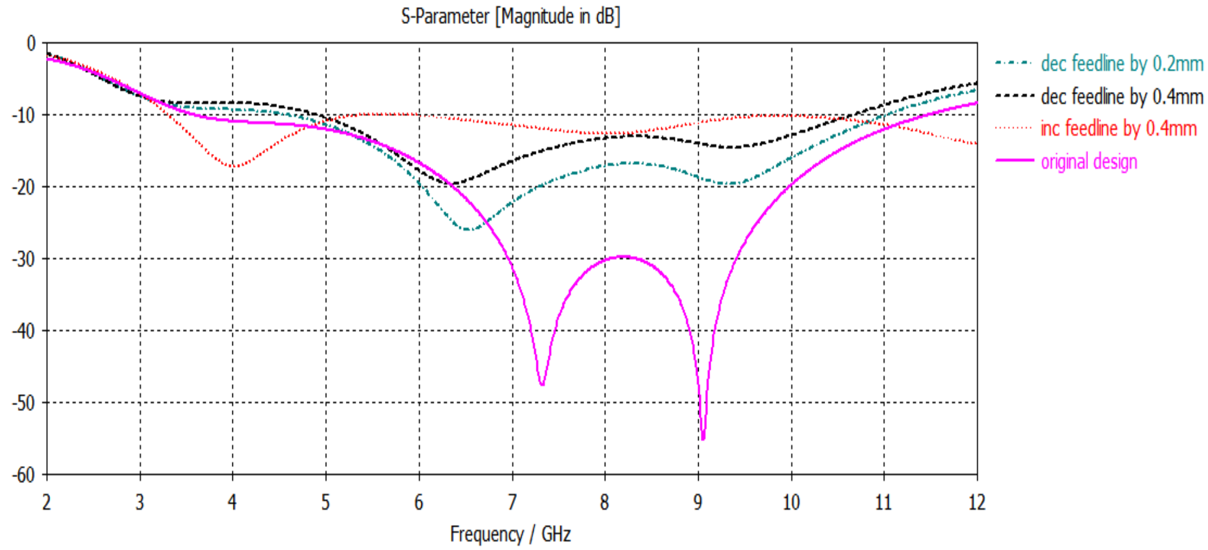


Fig 10.2 Simulated return loss due to variations in the feed width of the antenna

The VSWR of the antenna using different feed width is depicted in figure 10.3. The original design has the optimum VSWR whereas with increase or decrease of the feed width, VSWR>2 for some frequencies.

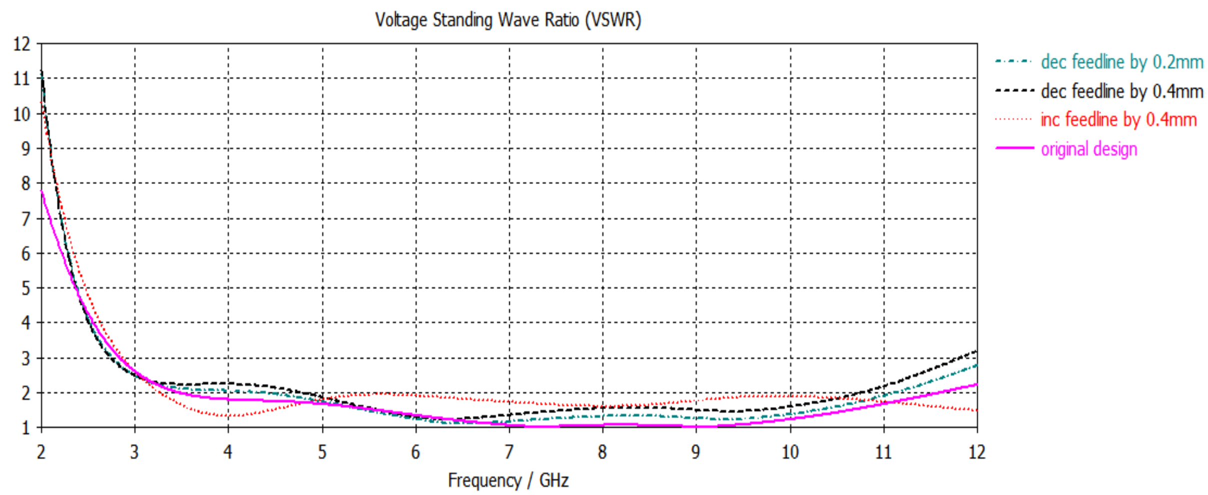


Fig 10.3 Simulated VSWR plot by varying the feed width of the antenna

b. Analysis by varying the rectangular slots of U-shaped stub

In order to get optimized size of the slots embedded in the U-shaped stub, return loss for different values were observed. This is shown in figure 10.4. With the decrease in the values of the L5 and L6, different return loss was attained. In nutshell, with the decrease in the length of the slots, the values of the return loss in dB gets increased from -54 dB in the original design to -35 dB when the slot length is reduced by 1mm. But there is very little effect on the bandwidth of the antenna with these variations.

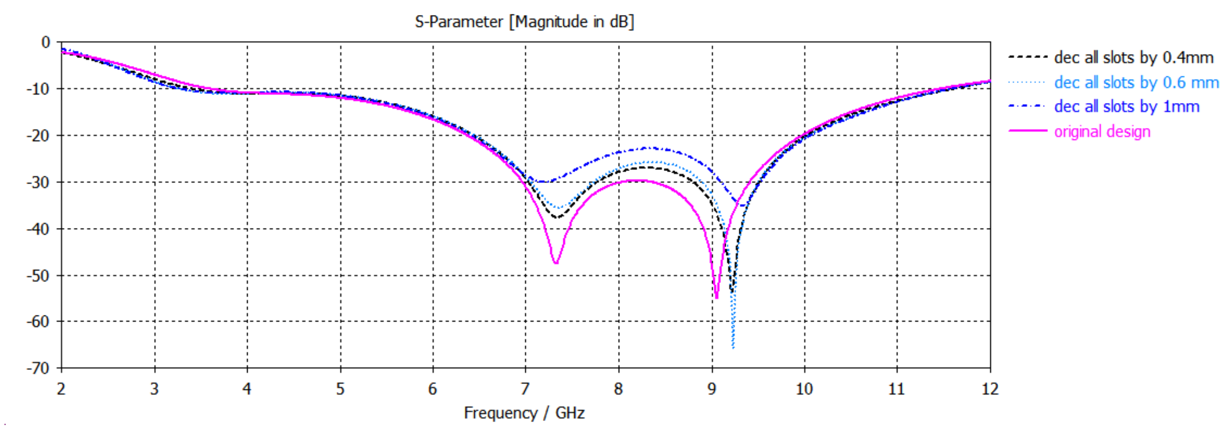


Fig 10.4 Simulated return loss for different lengths of the slots in U-shaped stub

The major requirement of design of any antenna is that the VSWR should be as low as possible so that there is no power which is lost during transmission. Figure 10.5 shows the VSWR for different lengths of the slots.

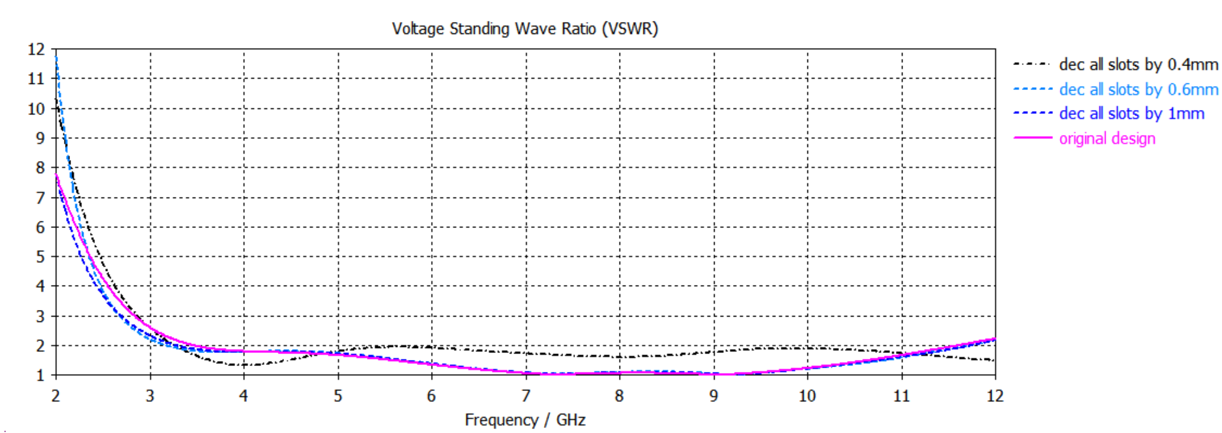


Fig 10.5 Simulated VSWR for different lengths of the slots in U-shaped stub

c. Analysis by varying the large rectangular slot (L2×w7 mm^2)

During the design of the proposed UWB antenna, a rectangular slot of dimensions L2×w7 mm^2 is used. The changes in the length of the slot provide resonance at different frequencies which is shown in figure 10.6. As the slot length is decreased, the resonant frequency changes and the value of return loss get reduced. The optimum value is provided by the original length of 12.9 mm. Similarly VSWR plot is obtained as shown in figure 10.7.

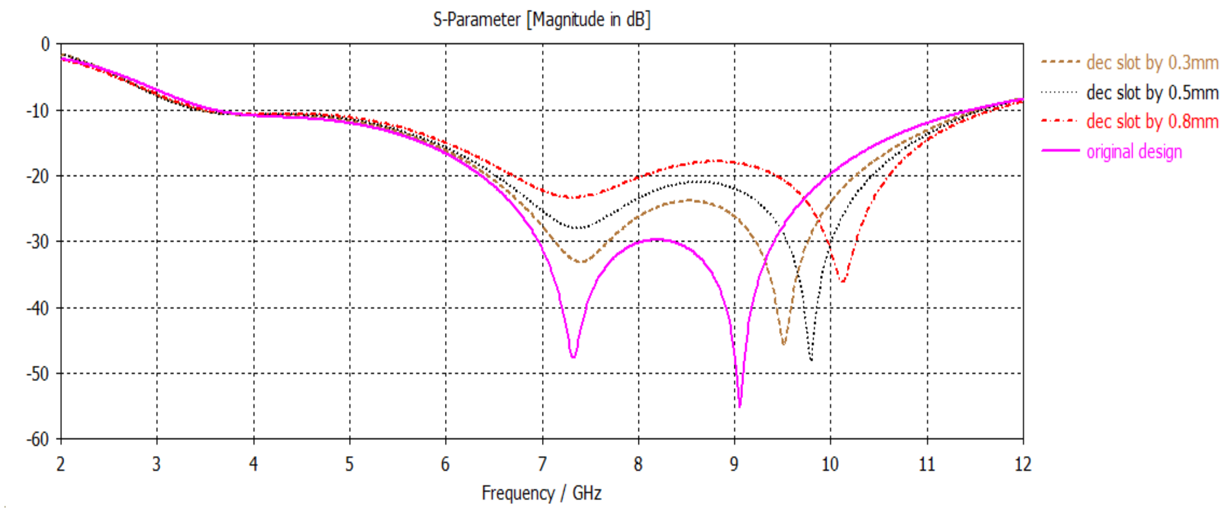


Fig 10.6 Simulated return loss for different lengths of large rectangular slot

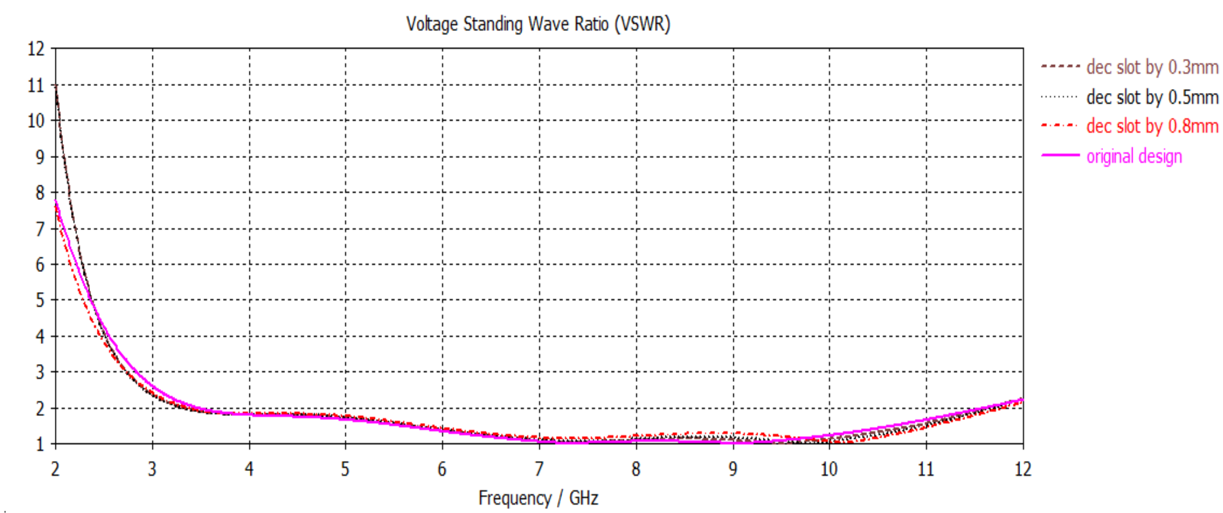


Fig 10.7 Simulated VSWR for different lengths of large rectangular slot

d. Analysis by varying the substrate material

Various substrates were utilized to see the effect that they have on the antenna. The return loss and VSWR of the different substrates is shown in figure 10.8 and 10.9 respectively. The substrates used were FR4, polyimide, Rogers RT5880 and Taconic TLT-6 with the dielectric constants of 4.3, 3.5, 2.2 and 2.65.

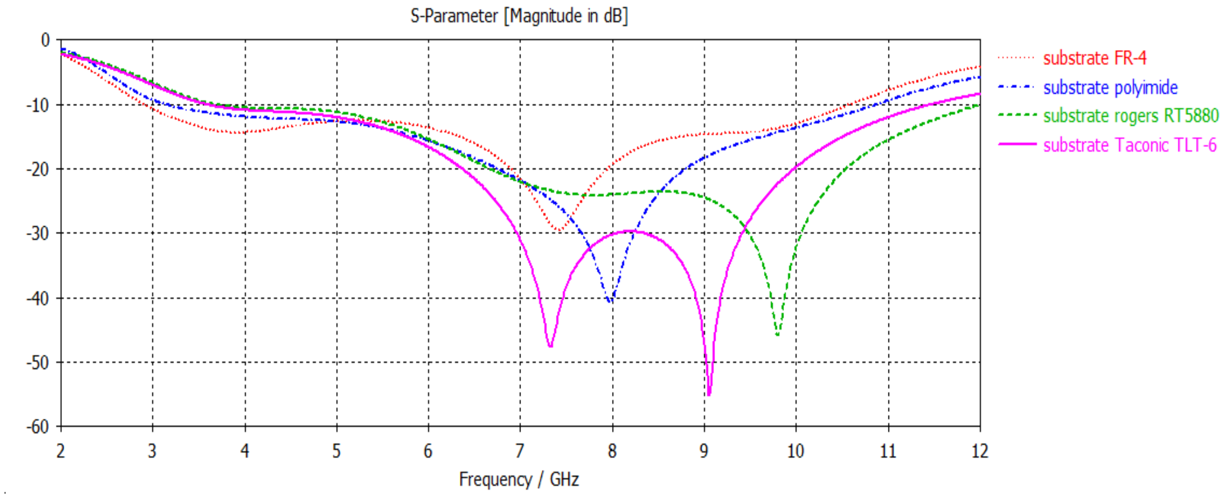


Fig 10.8 Simulated return loss for different substrates used in UWB antenna design

It is observed from the return loss graph that all the substrates provide only one resonant frequency whereas Taconic TLT-6 gives two resonant frequencies. Apart from this, better return loss is provided the substrate Taconic TLT-6 so it is used in this proposed antenna design.

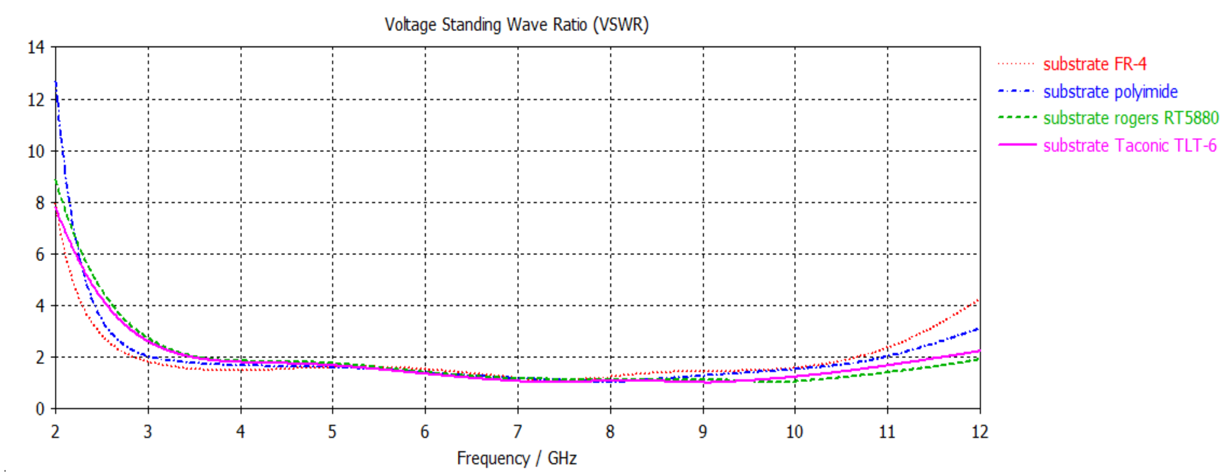


Fig 10.9 Simulated VSWR for different substrates used in UWB antenna design

e. Analysis by varying the space between the patch and primary slot (g)

The resonance provided by varied space (g) is different. With decrease in the value of g from 1mm to 0.8 mm results in reduced antenna bandwidth. On the other hand, with increase in the value of g, the return loss gets reduced with every increase in the value. The return loss and VSWR is presented in figure 10.10 and 10.11 respectively.

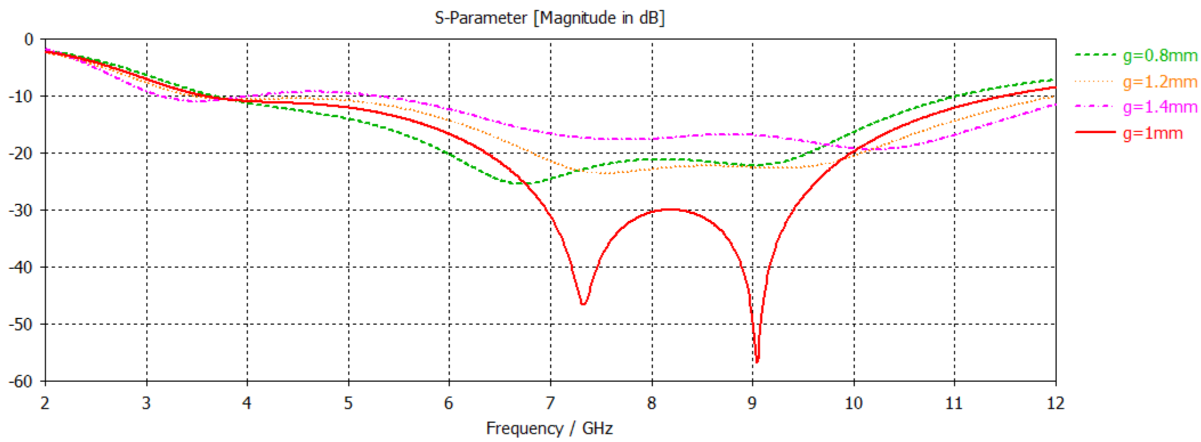


Fig 10.10 Simulated return loss for different space between patch and primary slot (g)

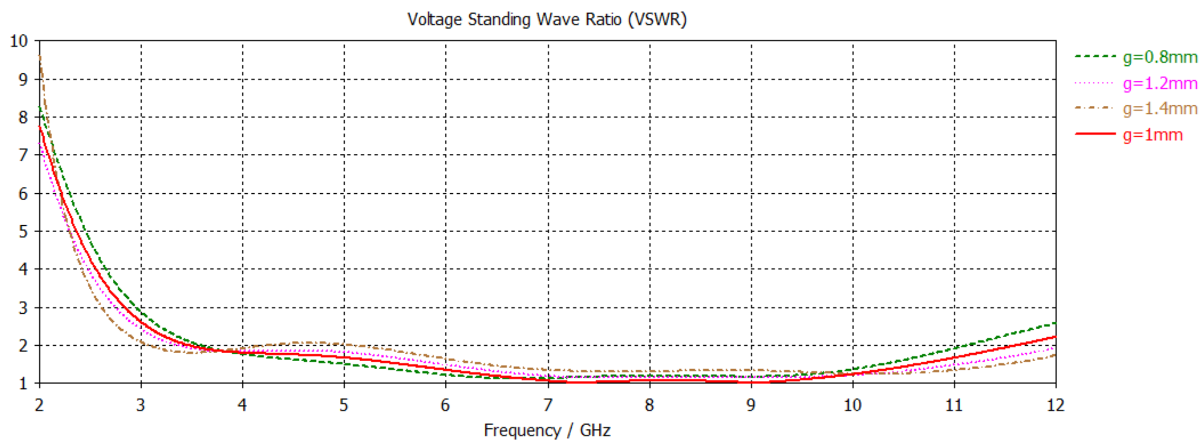


Fig 10.11 Simulated VSWR for different space between patch and primary slot (g)

In addition to the analysis carried out by variations of dimensions, radiation pattern of the proposed antenna is presented in figure 10.12 at the four different frequencies of 4, 6, 8and 10

GHz. Omni-directional pattern is obtained in the H-plane and in E-plane bidirectional pattern is obtained which is required for the UWB antenna.

Apart from this, comparison was carried out of the papers which were proposed in previous years with the antenna proposed in this paper. It has attained high gain of 6.64dB with smaller dimensions which can be utilized for compact wireless applications. This is shown in table 10.1.

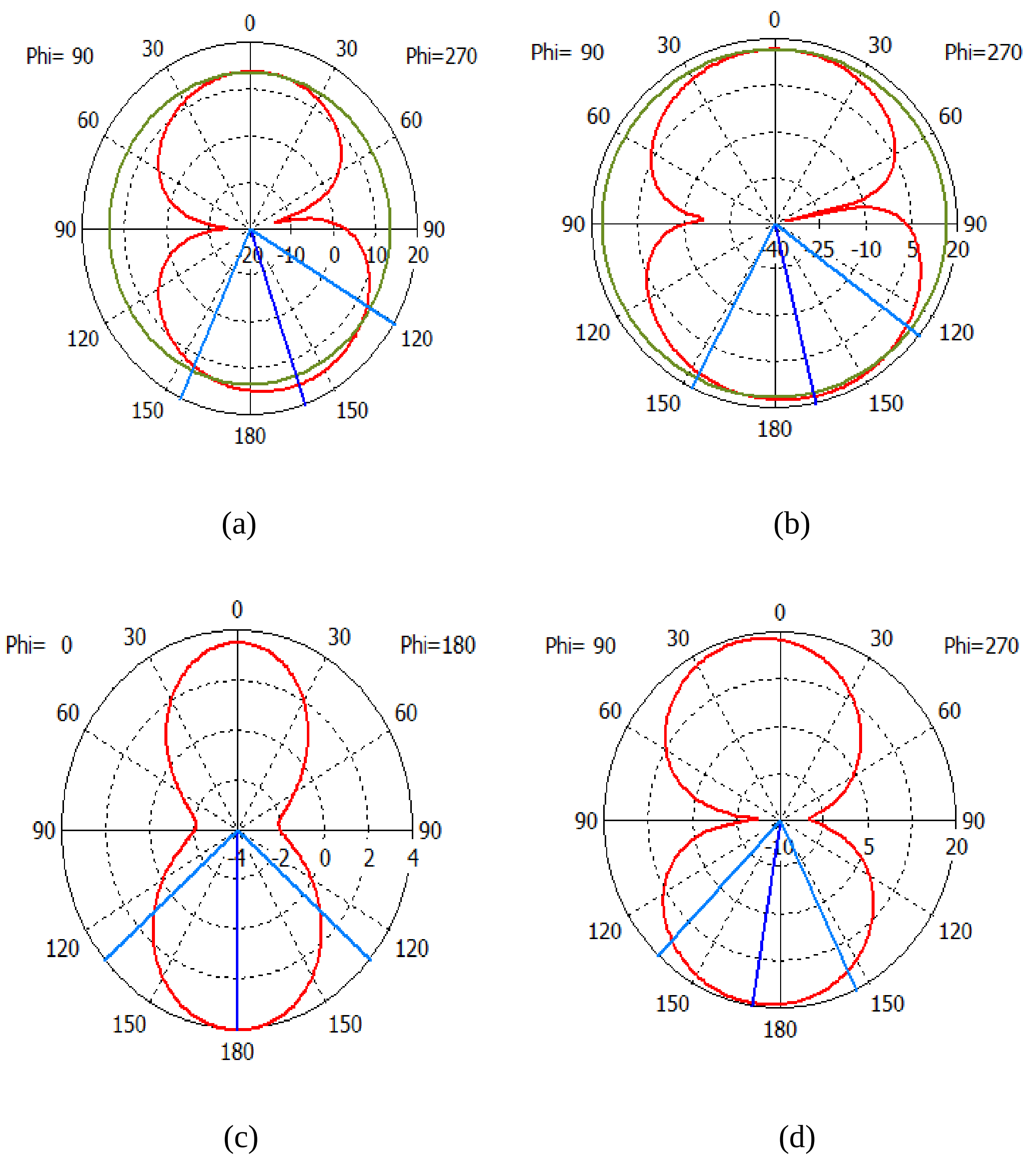


Fig 10.12. Simulated radiation pattern (a) 4 GHz in E-plane; (b) 6 GHz in E-plane; (c) 7 GHz in E-plane; (d) 8 GHz in E-plane

TABLE 10.1

COMPARISON OF ANTENNA PARAMETERS

Antenna	**Size(mm²)**	**Peak Gain (dBi)**	**Band-width (GHz)**	**Peak Return loss (dB)**	**Substrate**
[4]	22×29.5	2.9	14.4	-48	FR4
[10]	86×77.9	5.34	7.5	-	RT/Duroid 3003
[20]	25×27	3	8.3	-30	FR4
[21]	28×25	4	7.6	-48	FR4
[22]	30×25	0.73	7.5	-50	FR4
[24]	31×28	4.1	7.4	-33	FR4
[28]	51×31.8	5	6 GHz (4-10)	-32	Rogers R04003
[29]	18×18	2.99	7.5	-28	RT/Duroid 6010
[30]	39×40	7.3	5.2	-50	Rogers R03203
[32]	540×220	5.36	1	-38	FR4
[33]	27×28	4.5	9.7	-48	FR4

f. Gain and directivity of the proposed antenna

In the proposed paper analysis of gain and directivity is done at every frequency within the operational Bandwidth of antenna. The average gain is found to be 3.99 dBi with the peak gain of 6.64 dBi and directivity is maximum at 11 GHz with value of 7.18 dBi as shown in figure 10.13 and 10.14.

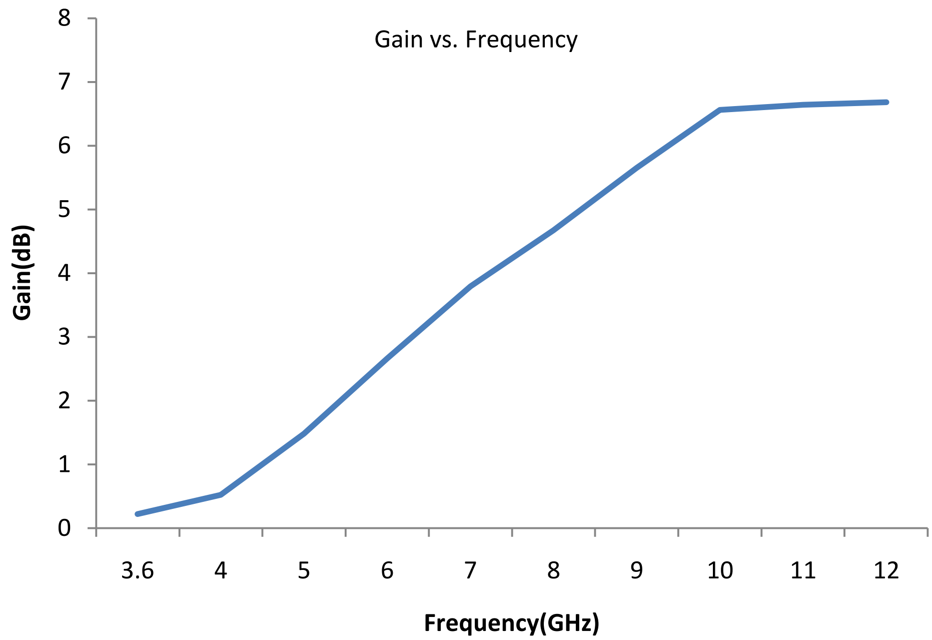


Fig 10.13 Peak gain of the proposed antenna

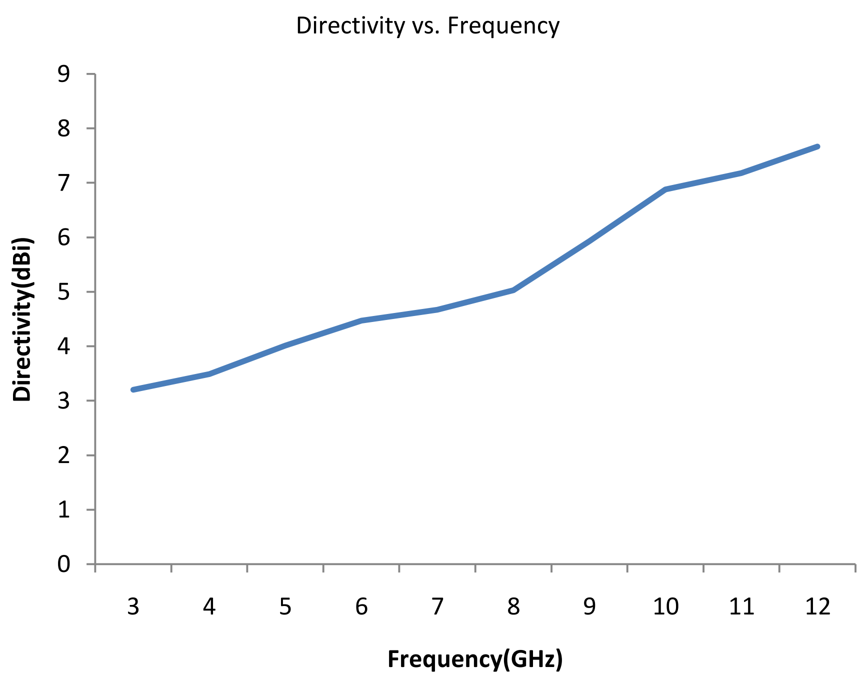
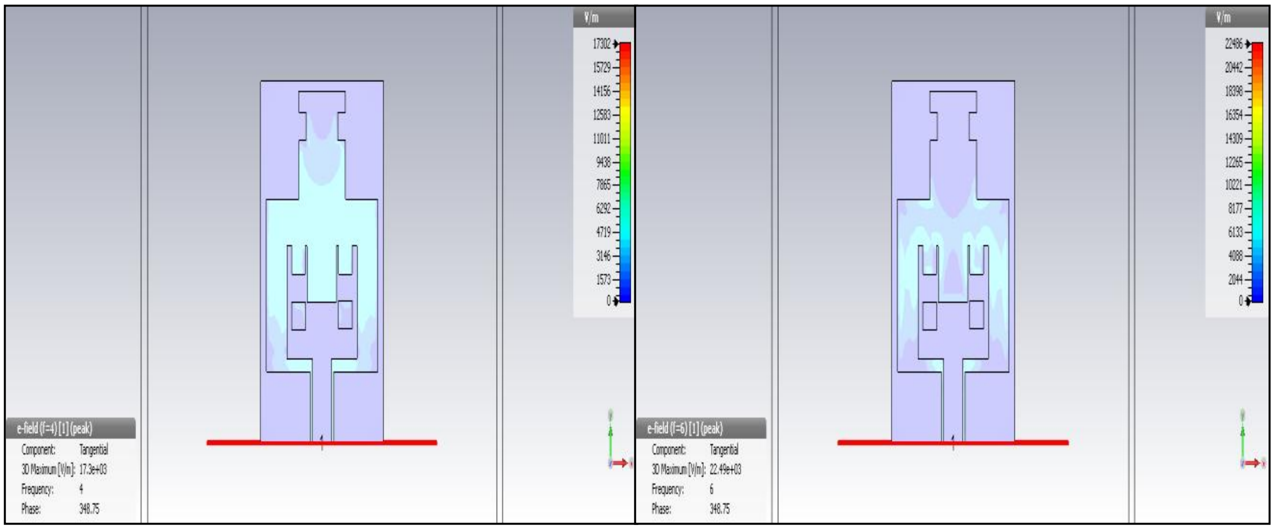


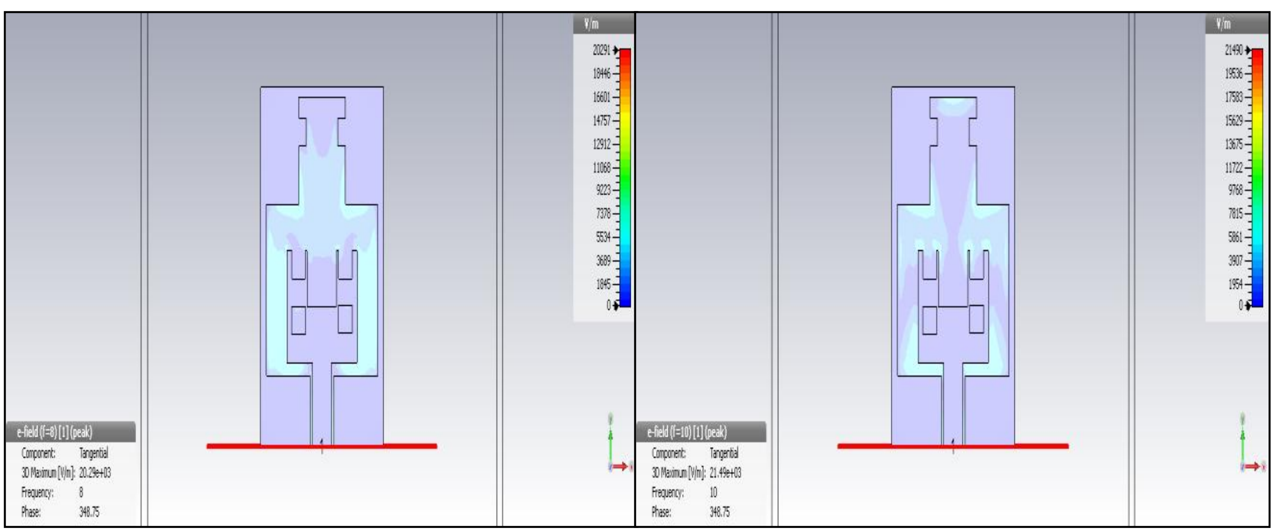
Fig 10.14 Peak directivity of the proposed antenna

g. Current distribution at different frequencies

The current distribution of the proposed antenna at different frequencies is shown in figure 10.15. The current is mainly distributed outside the feed line and then moves upward through the u-stub and is concentrated at the upper slots of the stub and then moves to the upper rectangular slot.



(a) (b)



(c) (d)

Fig 10.15 Current distribution (a) 4 GHz in E-plane; (b) 6 GHz in E-plane; (c) 8 GHz in E-plane; (d) 10 GHz in E-plane

h.) Fabrication results

The antenna is fabricated using the photoengraving and etching process on the FR4 substrate because of easy availability of this substrate in antenna labs. a good agreement is observed between the measured and the simulated results. Network analyser is used to obtan the return loss and bandwidth of the proposed antenna. the fabricated antenna is shown in the figure 10.16 with the size in approximation of the coin. So this antenna can be used in various wireless applications for wireless transmissions which requires small antennas with appreciable bandwidth and return loss.

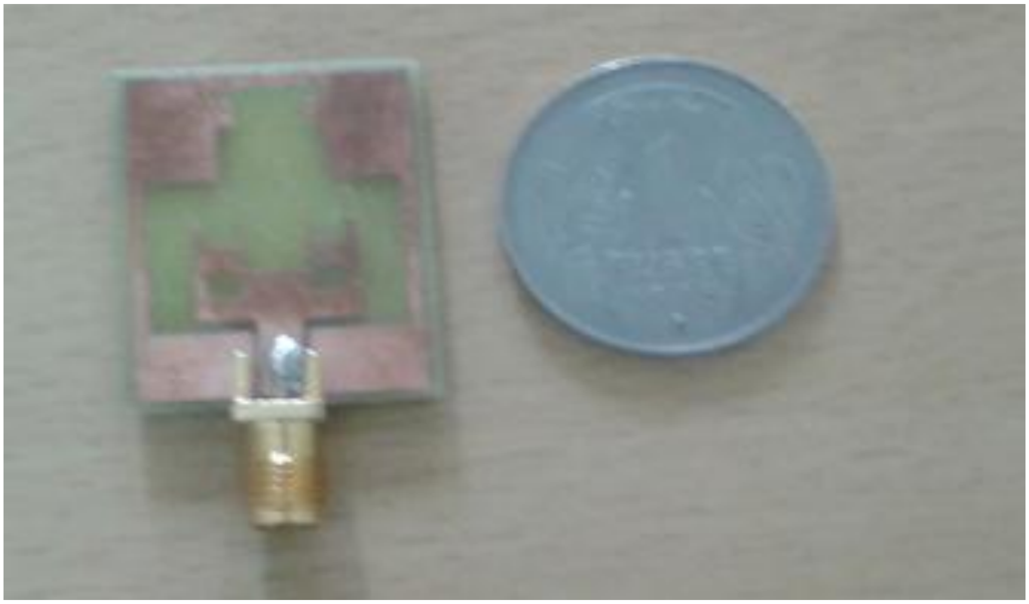


Fig 10.16 Fabricated antenna design

The comparison of the simulated and measured results is shown in figure 10.17. The values are comparable in both the simulated and measured results. The results are measured using Network Analyzer.

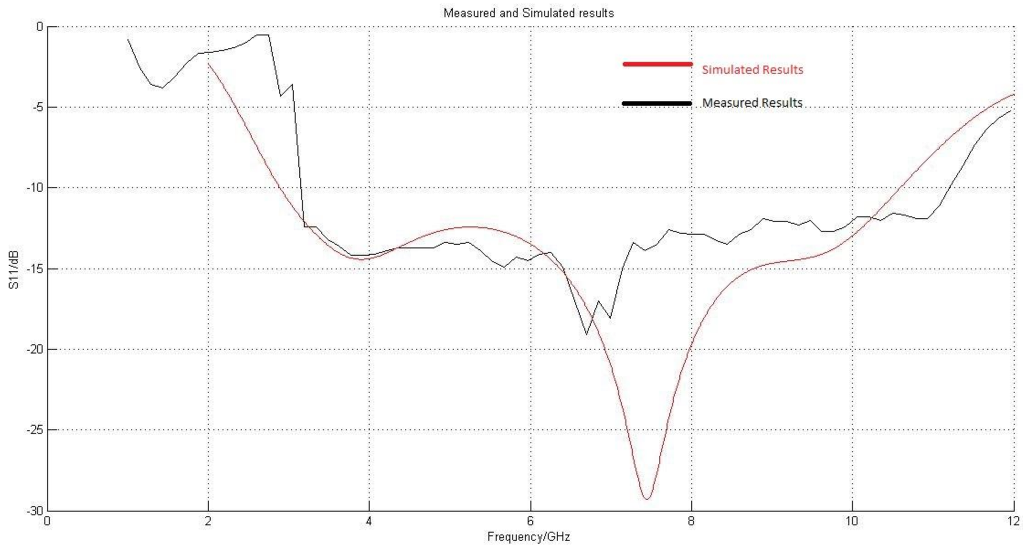


Fig 10.17 Measured and simulated results

Base paper results: First of all the return of the c stub is compared with the return loss of the C stub and the rectangular stub. The bandwidth of the antenna with the insertion of C stub is lower and it is enhanced with the etching of rectangular slot. The comparison is shown in figure 10.18.

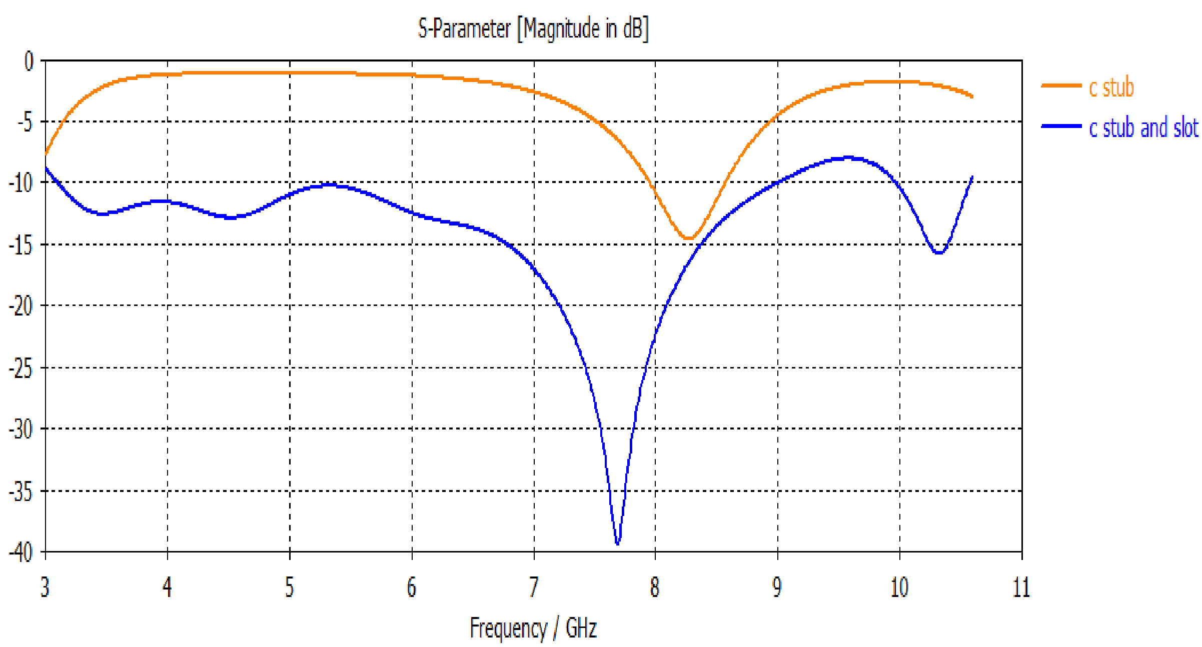


Fig 10.18 S11 parameter of C stub and Rectangular slot

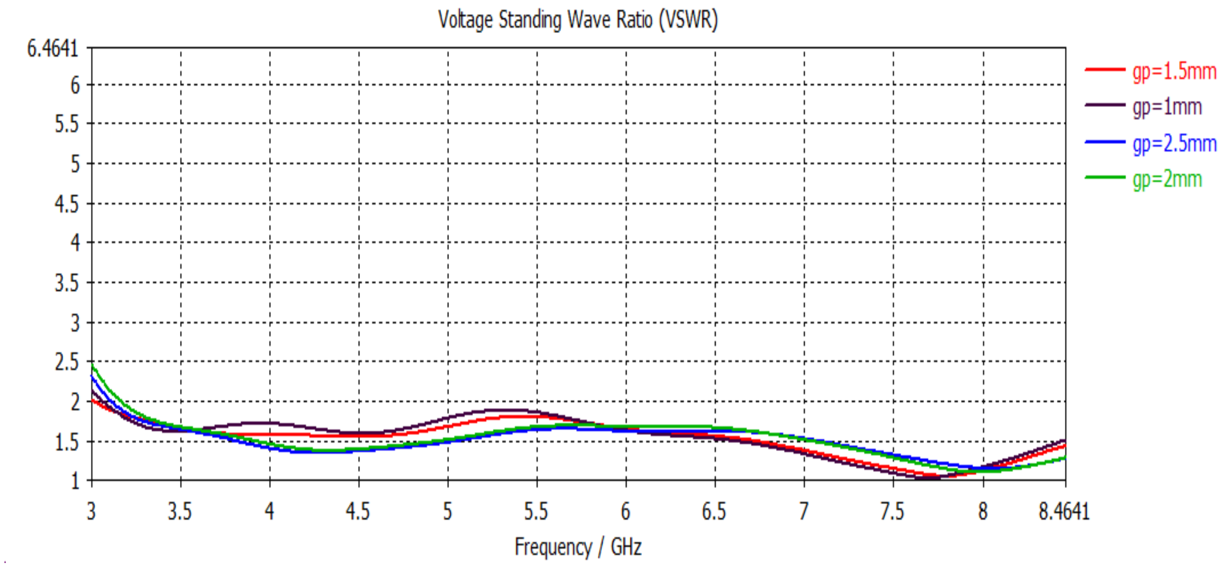


Fig 10.19 VSWR by variation in gap between C-stub and rectangular slot

The comparison of the results of the base paper and the proposed design are presented in the table 10.2.

TABLE 10.2

COMPARISON OF RESULTS OF PROPOSED DESIGN AND BASE PAPER

Parameter	**Base Paper**	**Proposed paper**
Size	34×29 mm^2	27×21 mm^2
Substrate	FR4	Taconic TLT-6
Bandwidth	3.1-9 GHz	3.6-11.5 GHz
Peak gain	3.86 dBi	6.64 dBi
Minimum S11 value	-39 dB	-54 dB

CHAPTER 11

CONCLUSION AND FUTURE WORK

11.1 CONCLUSION

In order to attain the desired research objectives, study of the various antennas with CPW feed has been studied. After the literature review was carried out, a new design is proposed. A new compact ultra-wideband antenna with maximum gain is proposed in the presented research work. The simulation was carried out on the CST microwave studio. The performance of antenna is enhanced in terms of high gain of the antenna. The size of the antenna is reduced to 27×21×1.6 mm^3 which is just the size of a coin and therefore can be used in wireless communication applications without occupying much of the space, which results in compact designing of the devices, and the peak gain of the antenna is 6.64 dB. UWB bandwidth of 3.6-11.5 GHz is attained by utilizing U-shaped stub and embedded slots. The antenna is further improvised by extending the rectangular slot to the top of the antenna. Two resonant frequencies are attained, first at 7.33 dBi and second at 9.05 dBi. The return loss obtained by the antenna is very small which is about -54dB at the second resonant frequency. Omni-directional pattern is achieved by the antenna in H-field and E-field provides bi-directional pattern in the entire working frequency. VSWR attained is less than two for the entire bandwidth of operation which means that there are very less standing waves and the maximum power will be received by the receiver without much loss of power while travelling. The current distribution is mainly found to be concentrated on the upper slots of the U-shaped stub and the feed line. The current travels upward from the feed line to the stub and then terminates at the upper rectangular slot.

11.2 FUTURE WORK

Since there are certain bands like WLAN and WiMAX which creates interference in the operating band of the UWB antenna, so there is a need to eliminate these frequencies from the working frequency of UWB antenna proposed in the paper.

This can be accomplished by adding filters, but this leads to an additional circuitry which makes the system complex. So instead of using filters, slots can be inserted in this antenna which provides mismatching of the frequency within the feed line. So this leads to elimination of the interfering bands and the UWB can operate without disruption.

Another method to do band notching can be addition of extra slot, say rectangular, with the insertion of copper patch of the size of ideal switch. This will act as a switch. When the copper patch is present, then it will be in on state i.e. it will eliminate the interfering band. This will make the antenna reconfigurable.

The proposed antenna design can also be used for sensing in the cognitive radios. In order to sense the white spaces in the spectrum, wideband antenna is required. So this UWB antenna offers wide band and is also of compact size, so it can easily be used in the system. The proposed antenna can also be embedded in the UWB systems for wireless transmission in wireless public area network.

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