UWB RF FRONT END SYSTEM

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CERTIFICATE OF CORRECTNESS AND APPROVAL

Certified that work contained in this thesis “UWB RF Front End System”, was carried out by Asghar Mirza, Usman Tariq, Tariq Mahmood and Mudassir Khan under the supervision of Assistant Professor Zeeshan Zahid for partial fulfillment of Degree of Bachelor of Telecommunication Engineering, is correct and approved.

Approved by

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Project Directing Staff (DS)

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DEDICATION

To Almighty Allah, for whose greatness we do not have enough words,

To our parents and friends, whose undaunted support, made a work of this magnitude possible

ACKNOWLEDGEMENTS

Thanks to *Allah Almighty* who helped us, in bringing this project to its successful completion. Along with God Almighty's help there are so many who have contributed to the success of this journey. We would really like to thank Mr. Zeeshan Zahid, our project supervisor, for his utmost efforts and expert advice during the understanding and development of this project.

ABSTRACT

UWB RF FRONT END SYSTEM

This is the project report on the Final Year Project titled "UWB RF Front End System". Micro strip patch antennas are gaining popularity day by day because they are very compact in size having low weight and easy for integrating with devices. Micro strip patch antennas can be designed in different shapes and configurations for different characteristics of band such as dual-band, multi-band, wide- band and ultra wide band for GSM, WLAN, WI-Max and other wireless technologies. Ultra wide band antennas actually enable low power consumption, high data transmission rates in wireless communication application. In this project a simple UWB micro strip-fed antenna, Wilkinson power divider, and Microwave filters are proposed. The antenna is composed of circular patch converted into key like shape with help of slits and slots in order to improve results, and a partial ground plane having slit. Using one antenna for each individual band is costly and space taking, instead we are designing a front-end system for multiple bands where these bands are separated by using microwave filters. We are combining different specifications in one system. The main emphasis was to design an antenna which covers the bandwidth of ultra wide band applications such as WI-Max, WLAN, and Satellite C Band etc. This patch antenna is designed and simulated in Ansoft HFSS 11 (High Frequency Structure Simulator).In many devices there are two or three different antennas are used for different applications, hence they are space taking and expensive .This design will combine different specifications in one system such as by using one system we will able to get Bluetooth, WIMAX, WLAN and satellite C band signals. The simulated and measured results show that system is working properly.

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Chapter 1

Project Overview

1.1 Overview:

Wireless communication technology is progressing rapidly day by day. Cords are been replaced by wireless because wireless can provide mobile access to the users, which is a current issue [5]. Without suffering from managing yards of expensive cables, wireless local area access can provide services to the users. Ultra wide band is one of the technologies of wireless communications. Ultra wide band antennas actually enable low power transmission levels, high data transmission rates and in wireless communication applications. In this project a simple micro strip-fed antenna is designed with ultra wide band characteristics. Nowadays, compact micro strip patch antennas are current topic for researchers. Micro strip patch antennas are very popular now-a-days because they are very small in size having low weight and easy for integrating with devices [1].

1.2 Objective and Scope

Many antennas are designed and tested by different designers for different applications. The main theme of designing is ultra wide band characteristics and small size. Compactness and ultra wideband characteristics are main considerations of design and our design covers these aspects.

The scope of this project is to design simulate and fabricate ultra wideband micro strip patch antenna for wireless applications and then design a UWB Wilkinson power divider which will divide the power of UWB antenna equally in two or more parts and fed power to microwave filters. The main consideration in this project is that the antenna is small in size and covers the desired bandwidth and instead of using different antennas for different applications this design contains a front end system which is for multi standard purposes. The performance of the proposed antenna, power divider and microwave filters are investigated in terms of bandwidth and radiation pattern.

1.3 Methods Used:

To achieve the objective mentioned above, firstly a comprehensive literature review on ultra wideband antennas is required and was done in order to get full knowledge of developments on ultra wideband micro strip antennas.

For the process of designing and simulation, software HFSS v11.0 and ADS is used.

1.3 Report Outline:

This report consists of six chapters. Each chapter consists of different issues related to this project. The outline of the each chapter is discussed in following paragraphs.

Chapter one covered the introduction and overview of the project background, problem statement, objectives, scope of work and methodology to carry out this project.

Chapter two shows historical overview and fundamentals of antenna, theory of antenna.

Chapter three explains the ultra wide band its applications and uses.

Chapter four describes Micro strip patch antenna in detail. All its parameters along with feeding mechanism, substrate material advantages and limitations of micro strip antenna along with their solutions are explained.

Next, the *chapter five* explain on the design procedures and antennas design. The proposed antennas design, geometry structures and specifications are being presented. Simulated results are provided with 2d and 3d plot also rectangular plot of S_{11} parameters.

Chapter six includes the design of Wilkinson power divider and microwave filters of desired specification.

Chapter eight presents the conclusion and future works in order to enhance the performance of this antenna.

Chapter 2

Historical Overview and Fundamentals of Antenna

2.1 Introduction

Antenna is one of the most important components of communication. It is the main building block behind wireless communication system. The IEEE defines an antenna as “the part of a transmitting or receiving system that is designed to radiate or receive device electromagnetic waves”. Antenna can be defined as a structural design which acts as a transition between guided waves and free-space waves. Waves are guided towards the direction in which we want to transmit them and then they move into free-space. Devices which are used to guide these waves are coaxial cables, waveguides, couplers etc.

There are different types of antennas, such as helical antenna, array antenna, reflector antennas, lens antennas, micro strip patch antennas etc [2]. One of the most common of these days is patch antenna, which is useful in various applications too. Antennas have certain parameters, by using those parameters in good combination, we can get good results.

2.2 History

Different kind of natural antennas are all around us like insect’s antennas of senses, and natural antennas of dolphins to communicate within the huge seas but the antennas which human race developed for their communication have been created in the late 18^{th} century. Heinrich Rudolf Hertz in 1886 developed “Hertz antenna receiver” and transmitting type of “dipole antenna” to transmit and receive VHF or UHF radio waves. He was the German physicist and professor at the Technical Institute in Karlsruhe, Germany. He assembled that apparatus which we now call as a complete radio system operating at meter wavelength with an end-loaded dipole as the transmitting antenna and a resonant square- loop antenna as receiver and further he also experimented with a parabolic reflector antenna [2].

Hertz work remained to the laboratory, and then Guleilo Marconi add tuning circuits and ground systems for larger wavelengths and was able to transmit signal over large distances.

At the beginning of World War II, centimeter wavelengths started to become popular. Now, hundreds of communication satellites started revolving around the earth and now antennas are the essential link for aircrafts and ships.

And now the antennas are the important component of every kind of wireless and landline land communications and the need of an antenna will grow to an unprecedented degree. The field of antenna is very vast and dynamic and over last fifty years antenna technology has been very important partner of the communications revolution.

2.3 Fundamentals

2.3.1 Frequency:

Frequency is one of the most important parameter of antenna. Frequency is basically the no of waves passing through a point in one second. Frequency is the most important concept in the universe. All the antennas that are designed, operates at some particular frequency [8].

2.3.2 Bandwidth:

There are different interpretations by different people on bandwidth; Balanis defined bandwidth in his book as “Bandwidth is the range of frequencies on either side of the centre frequency where the antenna characteristics are within a suitable value of those at the centre frequency” [2]. It can be said that bandwidth of an antenna is the range of frequencies on which the antenna is effectively operational. For the antenna to be efficient it should have higher bandwidth and it can be possible to increase the bandwidth of an antenna by applying different broad-banding techniques such as partial ground technique. Description of bandwidth is shown in figure -2.1.

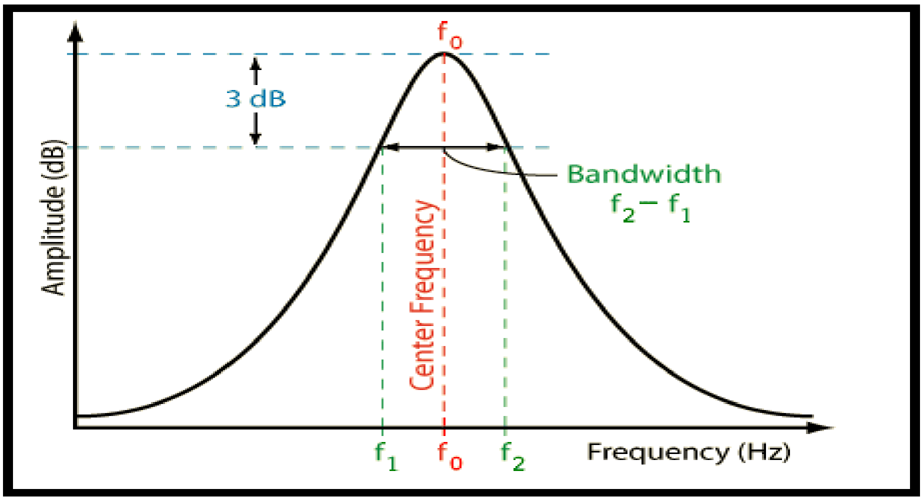


Figure-2.1: Description of the Bandwidth

2.3.3 Radiation Pattern:

Radiation pattern can be defined as the variation of power radiated by an antenna as a function of space coordinates away from the antenna. It can be farther explained as the graphical representation of radiated power density in far field region [6]. Radiation pattern can be made both in 2-D and 3-D. In 2-D plot it can be represented by two angles, Elevation angle and azimuth angle. Elevation pattern represents the side view radiation pattern of an antenna while azimuth is the top view.3-D plot of radiation pattern can realize as a donut shaped. In x-y plane the radiation is maximum. These plots can help in understand the directions in which antenna radiates power as shown in figure 2.2 [3].

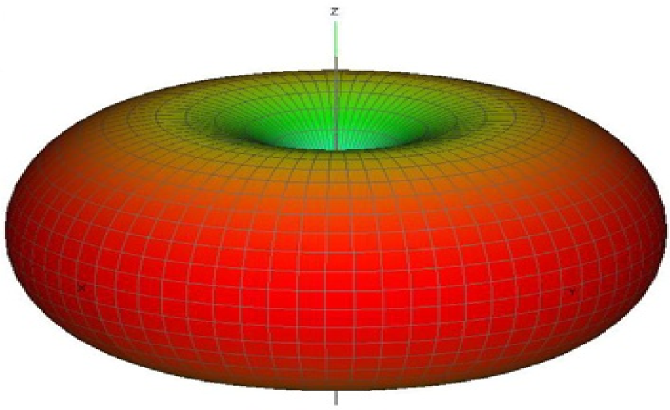


Figure 2.2: 3-D Radiation Pattern

Radiation pattern consist of many lobes. The major lobes of radiation pattern are described below.

2.3.3.1 Main Lobe:

Main lobe contains the maximum energy transmitted by the antenna. The width of the main lobe is defined as the angle between two points at which the power is 3dB or half of the maximum power. The radiation pattern of most antennas shows a pattern of lobes at various angles, directions where the radiated signal strength reaches the maximum, separated by nulls.

2.3.3.2 Minor Lobes:

The lobes other than the major or main lobe are called minor lobes. They can also be called as secondary lobes. These lobes contain less energy. This is the lobe other than main lobe .Minor lobe contains less energy as compared to main lobe. Minor lobes represent unwanted in undesired directions. The side lobe in opposite direction from main lobe is called back lobe.

2.3.3.3 Side Lobes:

The far field lobes are considered as side lobes. Minor lobes can be considered as side lobes but side lobes cannot be minor lobes. Side lobes represent unwanted radiation in unwanted direction. The side lobe in opposite direction from main lobe and is called back lobe. The power density in side lobes is much less as compared to main lobe or main beam. The peak of side lobes is lower as compared to main lobe.

2.3.3.4 Back Lobes:

Back lobe is the lobe making an angle of 180° from major lobe. If the radiation pattern is viewed in 3D then back lobe is it’s that 3D part that is opposite from the desired direction. The power density of side lobe is much less as compared to main lobe .The points at which the energy is zero are called nulls and they have no energy. Radiation pattern representing main, side and back lobes is shown in figure 2-3

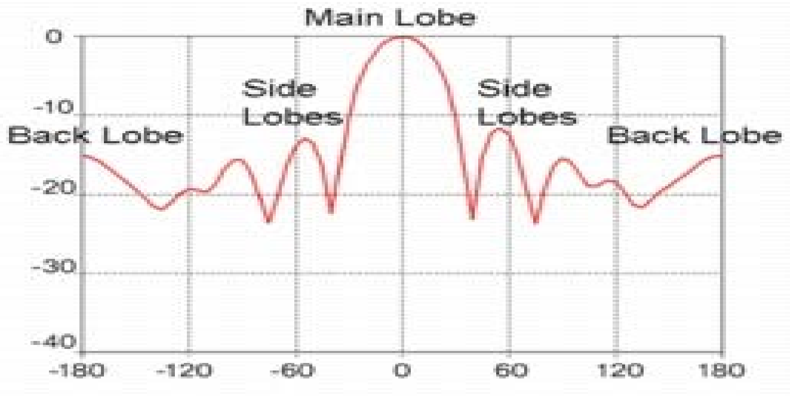


Figure 2.3: Radiation Pattern in Linear Plot

2.3.4 Beam Width:

Beam width is the angular separation between the two points on the radiation pattern. There is another terminology called the Half Power Beam width (HPBW). HPBW is defined as the angular separation between the half powers or 3-dB power points on major lobe of the radiation pattern. HPBW contains the maximum power of the major lobe. Beam width is expressed in degrees. There is another kind of beam width called the First Null Beam width (FNBW). FNBW is defined as the angular separation between the first nulls of the radiation pattern [2]. The beam width of an antenna is shown in figure 2.4

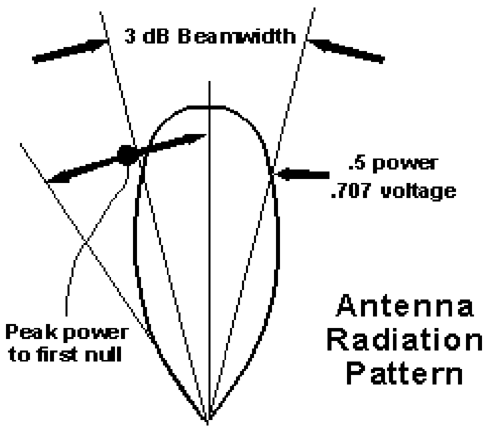


Figure 2.4: 3dB and Null Beam Width.

2.3.5 Directivity:

Directivity is important parameter of an antenna which describes the ability of antenna to radiate in specific direction. Mathematically it can be written as [2].

$$D(\theta,\Phi) = \frac{power\ radiated\ per\ unit\ solid\ angle}{average\ power\ radiated\ per\ unit\ solid\ angle} \tag{2.1}$$

It can also be written as:

$$D(\theta,\Phi) = \frac{P(\theta,\Phi)_{max}}{P(\theta,\Phi)_{av}} \tag{2.2}$$

2.3.6 Gain:

Gain specifies that how much power is transmitted in the direction of peak radiation compared to radiation intensity of an antenna under test (AUT) i.e. an isotropic antenna. [5][6] It's an important fundamental characteristic because it shows how much actual losses are occurred. It is directly related to directivity by an efficiency factor. It can be mathematically stated as:

$$G = k \times D \tag{2.3}$$

Where G is the gain, D is directivity and k is efficiency factor of the antenna.

2.3.7 Impedance:

Impedance in terms of antenna can be defined as that it relates the ratio of voltage to current at the input of the antenna. This impedance is consisted of a real and imaginary part. The real part of the impedance shows the part of the power that is radiated away or absorbed by the antenna, while the imaginary part represents the part of power that is stored in near field of antenna.

2.3.8 Polarization:

Polarization is the orientation of E-field radiated by antenna. It represents the time varying direction and relative magnitude of the electric field vectors [2].Polarization has generally three types such as linear, circular and elliptical etc as shown in figure 2.5.

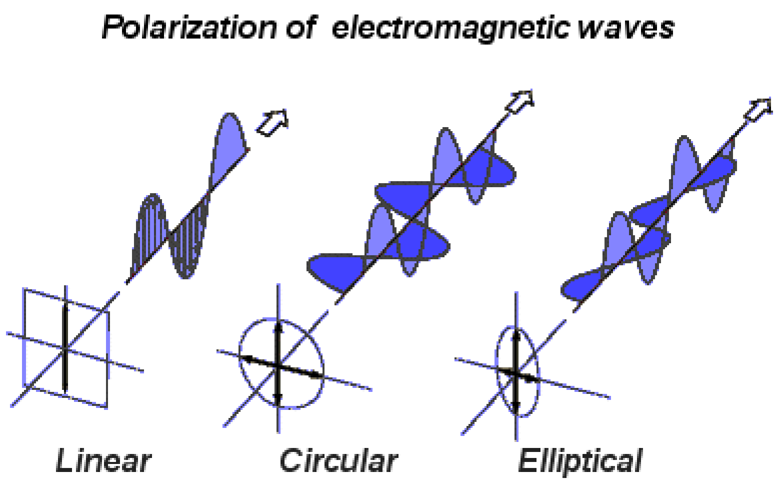


Figure 2.5: Types of Polarization

2.3.8.1 Linear Polarization:

Polarization is linear when the orientation of the E-filed is in one direction as shown in figure 2.6.

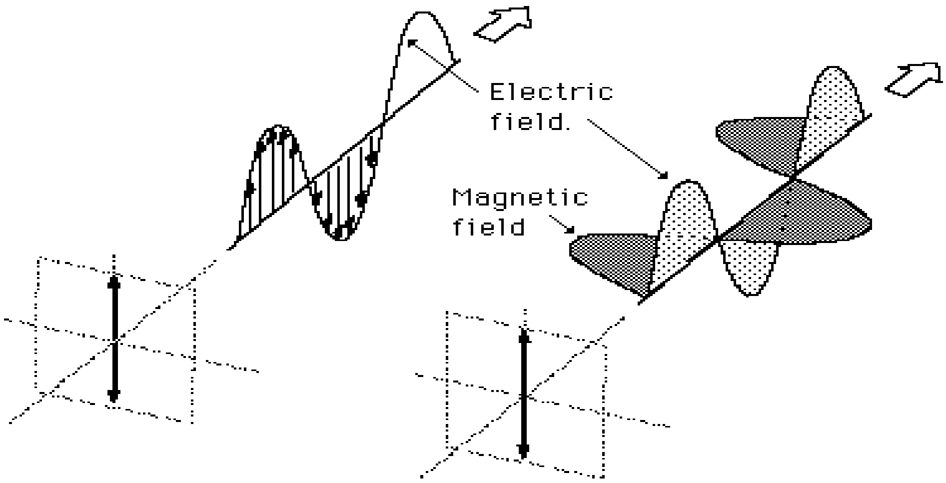
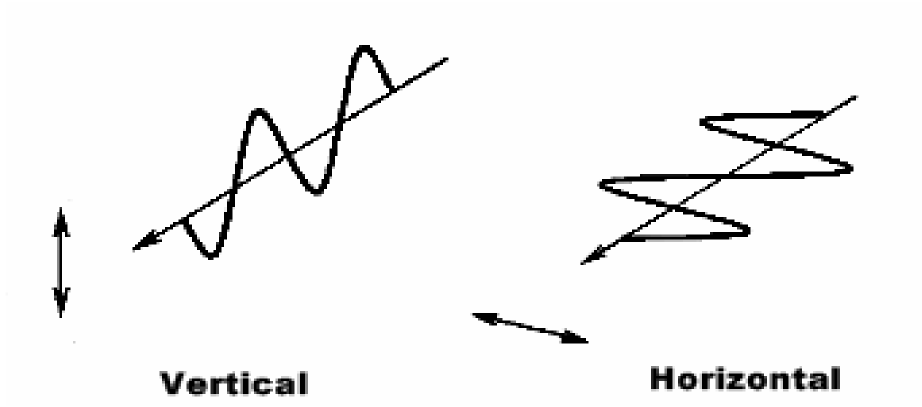


Figure 2.6: Figure illustrating Linear Polarization

Linear polarization could be vertical or horizontal. If the electric field vector is perpendicular to the surface then the polarization is said to be vertical polarization. If the field vector is directed horizontal to the surface then the polarization is horizontal. The figure 2.7 shows the vertical and horizontal polarization:



(a) (b)

Figure 2.7: a) Vertical Linear Polarization. b) Horizontal Linear Polarization.

The Linearly polarized wave of an antenna at certain angle is shown in figure 2.8.

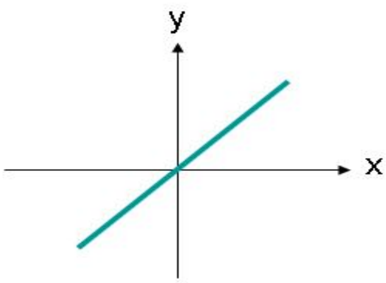


Figure 2.8: Linearly Polarized Wave at a certain Angle

2.3.8.2 Circular Polarization:

A wave propagating along two of its components in horizontal as well as vertical direction keeping in view that both have same magnitude is called a circularly polarized wave. Both the components are in a phase difference of odd multiple of 90 as shown in figure 2.9.

The three conditions for circular polarizations are,

The E-field must have two orthogonal components.

The E-field components must have equal magnitude.

The perpendicular components must be 90 deg out of phase.

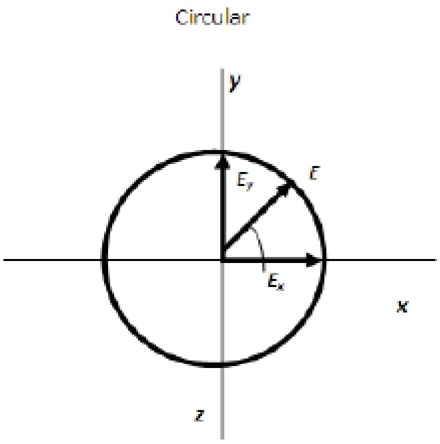


Figure 2.9 Circular Polarization

The expressions representing it mathematically,

$$E_y = E_1 sin(\omega t - \beta z) \qquad (2.4)$$

$$E_x = E_2 sin(\omega t - \beta z + \delta) \qquad (2.5)$$

It can be classified as,

Left hand circularly polarized (LHCP)

Right hand circularly polarized (RHCP)

2.3.8.2.1 Left hand circularly polarized (LHCP):

If the wave is propagating in a clockwise direction, then it is said to be left hand circularly polarized wave. The Left Hand Circularly Polarized wave is shown in the figure 2.10.

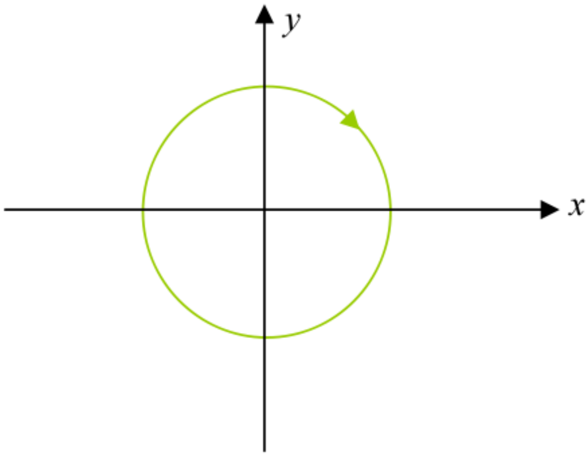


Figure 2.10: Left hand Circularly Polarized Wave

2.3.8.2.2 Right hand circularly polarized (RHCP):

If the wave is propagating in anti-clockwise direction, then it is said to be right hand circularly polarized wave. The Right Hand Circularly Polarized Wave is shown in the figure 2.11.

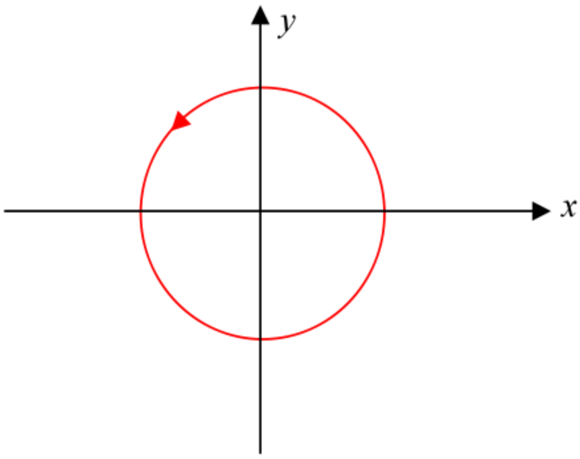


Figure 2.11: Right Hand Circularly Polarized Wave

2.3.8.3 Elliptical Polarization:

In elliptical polarization there are both the components of the electric field i.e. the horizontal and vertical component. In both components there is some phase difference. In electromagnetic radiation the slope of electric field vector makes the shape of the ellipse on any stable plane, normal to the direction of propagation as shown in figure 2.12.

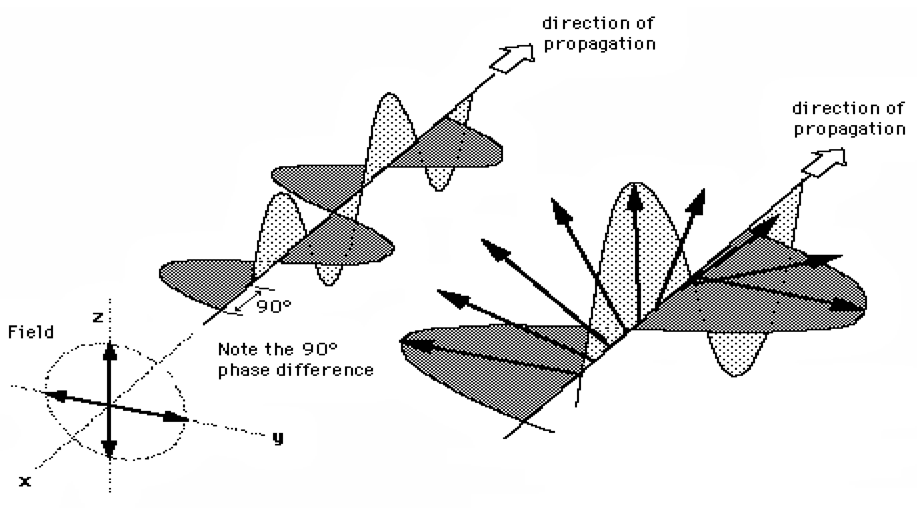
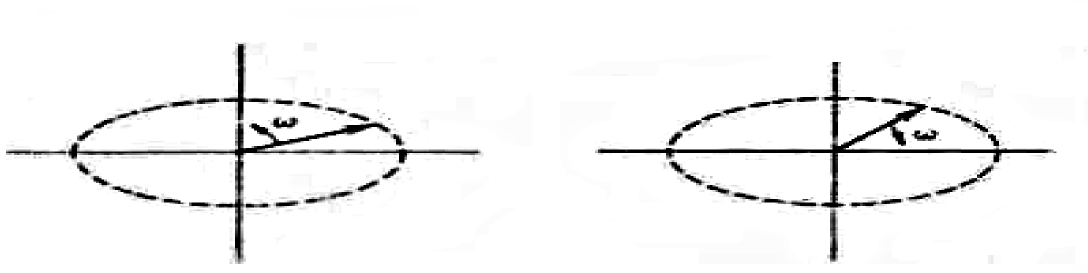


Figure 2.12: Elliptical Polarization of the Wave.

Elliptical polarization is either LHEP or RHEP. In left handed elliptical polarization the vector of the E-Field rotates counter or anti-clockwise and goes into the paper where as in right handed elliptical polarization the vector of the E-Field moves clockwise and comes out of the paper. Elliptical polarization of an antenna is shown in figure 2.13.



(a) (b)

Figure 2.13: a) Left Handed Polarization. b) Right Handed Elliptical Polarization.

2.3.9 Voltage Standing Wave Ratio:

Voltage standing wave ratio is measure of how well an antenna is matched to transmission line. If there is mismatched impedance between antenna and transmission line then reflection occurs and there will be losses. This reflection can be constructive and destructive interference to the input wave. The main concern is mismatching of input and load impedance [1].

It is defined as a ratio of maximum voltage to minimum voltage.

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \tag{2.6}$$

Where Γ is reflection coefficient, it is given by the formula,

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o} \tag{2.7}$$

Where Z_L is Load impedance and Z_O is characteristic impedance. The smaller the value of VSWR, the better the antenna is matched.

2.3.10 Return Loss:

It is the efficiency of the power delivered to the load from the transmission line. It can also be said that it is the power reflected back into the transmission line due to some losses [8]. Mismatching also results in increasing return loss. Return Loss of an antenna is shown in figure 2.14.

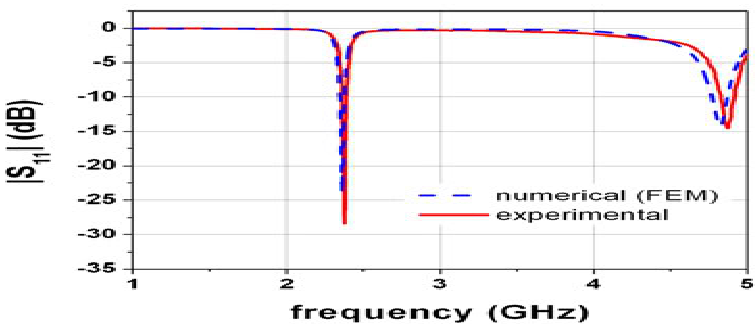


Figure 2.14: Return Loss Characteristic

Chapter 3

Ultra Wideband Overview

3.1 History and Overview

Ultra Wide Band Communications started receiving interest rehabilitated 1970 years. At this time, the "bond of communication" was called in around 1973, that short pulses, the signal across a wide range by the interferences not substantially interfere with them and not accepted. However the issue of multiple access interference of non-users remains a big problem. So in 1970 and 1980 UWB communication was mainly used in military, where the power spectrum of secondary importance was studied. Multiple access interference problems introduced in early 1990, where the pioneer work of Win and Scholtz showed that radio could be a big blow not keep the users assigned to solve the weather was like grains of different users.

In 2002 FCC allocated a bandwidth of 7.5GHz from 3.1 GHz and 10.6 GHz to UWB applications. BW allowed, subject to certain limitations in the power spectrum release [10].

Ultra wideband communication usually uses very narrow pulses of the duration of a nanosecond or sub-nanosecond range for the data transmission. This allows high data transfer rates exceeding 100Mb / s .UWB systems will coexist with other traditional communication systems, the same frequency group by using lower power levels. Federal Communications Commission to designate the United States at 3.1 to 10.6 GHz with a group of effective isotropic radiated power of below -40 dBm / kHz for UWB communications.[11] The use of UWB systems need to provide effective antennas for acceptable bandwidth requirements, and radiation pattern characteristics of the entire designated UWB spectrum. It is generally accepted that the antennas should be classified as ultra - wideband, will satisfy the requirement of the minimum fractional bandwidths of at least 20% or 500 MHz or more and nearly omni directional radiation pattern.

Ultra wideband (also known as UWB or as digital pulse wireless) is a wireless technology for transmitting huge amounts of digital data over a wide spectrum of frequency bands at very low power levels for a short distance. Ultra wideband radio not only can carry a huge amount of data over a distance up to 230 feet at very low power (less than 0.5 mill watts), but it has the ability to carry signals through doors and other hurdles that tend to reflect signals at more limited bandwidths and a higher power. Ultra wideband can be compared with another short-distance wireless technology, Bluetooth, which is a standard for connecting wireless devices with other similar devices and with desktop computers [10].

Ultra wideband broadcasts digital pulses that have very precise time on a carrier signal across a very wide spectrum (number of frequency channels) at the same time. Transmitter and receiver must be synchronizing to send and receive pulses with an accuracy of trillionths of a second. On any given frequency band that may already be in use, the ultra wideband signal has low power than the normal and anticipated background noise so theoretically no interference is possible. Time Domain, a company applying to use the technology, uses a microchip manufactured by IBM to transmit 1.25 million bits per second, but says there is the potential for a data rate in the billions of bits per second.

Ultra wideband has two main types of application:

Applications including radar, in which the signal penetrates nearby surfaces but reflects surfaces that are farthest away, allowing objects to be detected behind walls or other coverings and around corners.

Voice and data transmission using digital pulses, allowing a very low powered and relatively low cost signal to carry information at very high rates within a small range.

3.2 Advantages of UWB:

It offers very reliable power solutions.

It has very high capacity as high as hundreds of Mbps or even Gbps.

UWB systems based on impulse radio low cost complexity arising from the fundamental nature of the transmission base band signal. UWB does not modify the carrier waveform so it does not require components such as mixers, amplifiers filters, amplifiers or resistive circuits.

UWB system needs low levels of power transmission through the signal power over a huge frequency spectrum. The effect of any frequency is below the acceptable noise floor.

UWB systems don’t make significant interference on other wireless systems.

3.3 Fractional Bandwidth:

Fractional bandwidth of an antenna is used to measure the band characteristics of an antenna. If the center frequency covered by the antenna is $f_{c,}$ lower frequency is f_l and higher frequency is f_h then fractional bandwidth can be shown by the formula.

$$FBW = \frac{fh - fl}{fc} \qquad (3.1)$$

Table 3.1 Fractional Bandwidth

Narrowband	$Bf < 20\%$
Wideband	$20\% < Bf < 50\%$
Ultra-wideband	$Bf > 50\%$

Chapter 4

Micro Strip Patch Antennas

4.1 Introduction to Micro strip Antenna

The development in the field of micro strip patch antenna began at the end of 1970’s. In the beginning of 1980’s the developments in micro strip patch antennas elements and arrays became more significant in terms of design and modeling [5]. In last few years a lot of work is done on micro strip patch antennas because of their many advantages on other types of antennas and radiating systems. At present most of the mobile, radio and wireless communication systems make use of these micro strip patch antennas because of their better efficiency, light weight, small size, low cost and possibility of integration with active devices and microwave circuitry.

A micro strip antenna consists of a radiating patch which is made of a grounded substrate**.** The radiating patch is a very thin metallic strip that is place on a grounded substrate. These antennas can be of different shapes and sizes. The size of a micro strip antenna mainly depends upon the length (L) and width (W) if the antenna is rectangular shapes and radius (a) if the antenna is circular patch micro strip antenna. The size also depends upon the thickness of the substrate (h) that is used to fabricate the antenna as shown in figure- 4.1.

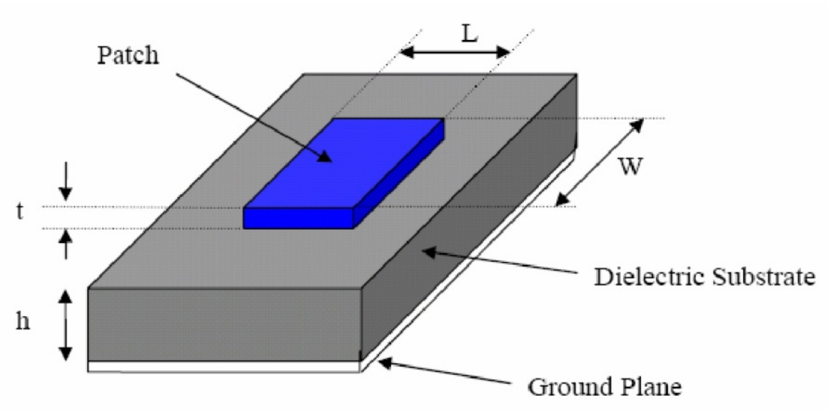


Figure-4.1: A Rectangular Patch Micro strip Antenna

The substrate has a very important role in the performance of the antenna. To achieve better performance of a micro strip patch antenna the substrate should have low dielectric constant and its thickness should be high. A large number of substrates can be used for the designing of micro strip patch antennas. The dielectric constant of the substrate is normally in the range of $2.2 \leq \varepsilon_r \leq 12$. Substrates with lower dielectric constants are more suitable for performance of the micro strip patch antennas that is because they provide better affiance and higher bandwidth. But there is a drawback of low ε_r and more height that is the size of the antenna increases and it becomes too bulky**.**

The radiating patch of micro strip antennas can be of various shapes. The patch can be square, rectangular, hexagonal, circular, thin strip, circular, elliptical, triangular, or any other geometrical shape. The most common shapes used are square, rectangular and circular because these are easily analyzed and fabricated; moreover they have good radiation characteristics. [2] Different patch shapes are illustrated in Figure-4.2.

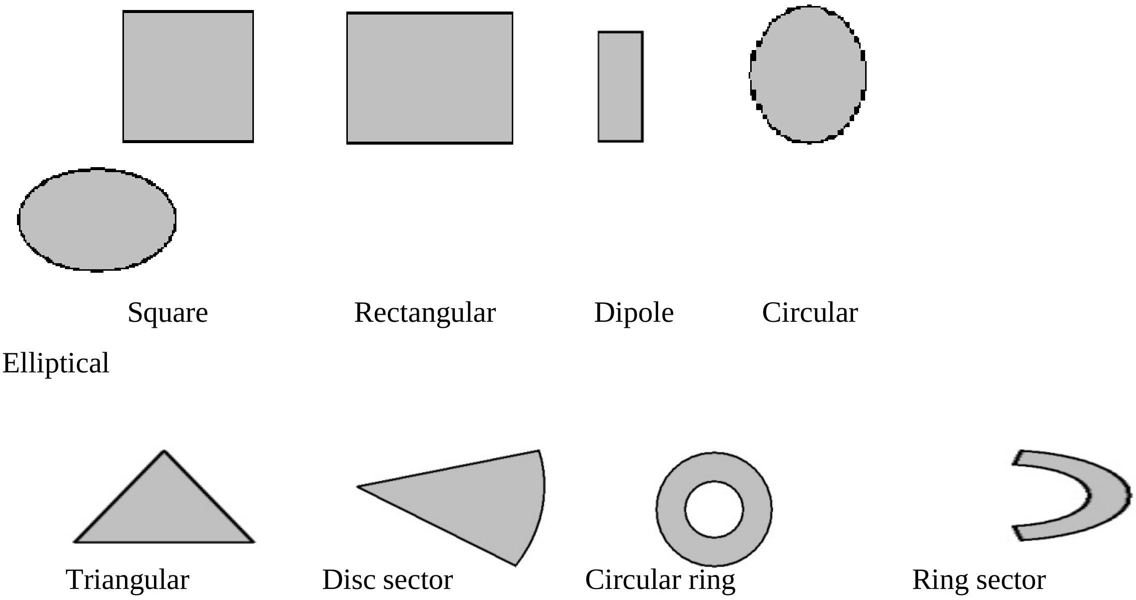


Figure-4.2: Common shapes of micro strip patch elements

4.2 Advantages and Disadvantages

The major advantages of the micro strip patch antennas are

- Light weight, small size and ease of fabrication.
- Support both linear and circular polarization
- It can operate at multiple frequencies
- Low fabrication cost
- No cavity backing is required
- Can be integrated active devices and microwave integrated circuit
- Various feeding techniques are possible.
- Operating frequencies are 100 MHz to 100 GHz

The disadvantages of a micro strip patch antenna are

- Low efficiency
- Low gain (-6 dB) and narrow bandwidth
- Lower power handling capacity

Surface wave excitation results in losses

Large ohmic losses

Excitation of surface wave results in discontinuities.

High performance arrays require complex feed structures

Polarization purity is difficult to achieve

Because of these advantages of micro strip antennas they are very much suitable for the use in mobile and wireless communications. Although micro strip antennas have several disadvantages but these antennas can be altered so that they can be used in different wireless communication applications dealing with different types of polarizations. [8]

4.3 Feeding methods

There are varieties of feeding techniques to feed Micro strip antennas. The most popular ones include coaxial probe feed, Micro strip transmission line feed, aperture coupled feed, and proximity coupled feed.

4.3.1 Transmission Line Feeding

This method of feeding is the simplest method. The radiating patch is fed using a strip made of a conducting material attached directly to the edge of the patch. The width of this strip is smaller as compared to the width of the patch. If this feed is not of proper length and width than it can induce losses. These losses can limit the bandwidth of the design. To reduce these losses the strip should have a substrate with high dielectric constant and low height. In this way fields are limited within the line which is shown in figure- 4.3.

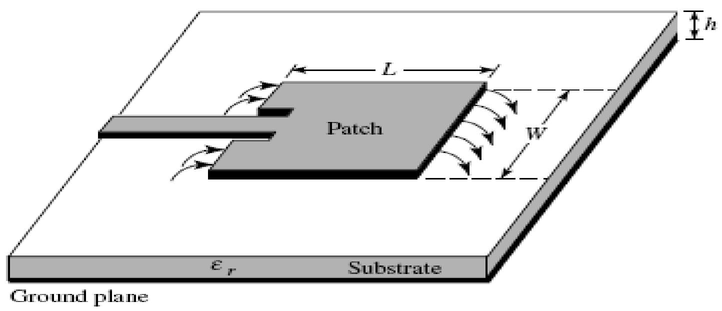


Figure-4.3: Transmission Line Feeding

4.3.2 Coaxial Probe Feed

In this method of feeding two conductors are used, inner conductor and the outer conductor. The inner conductor is attached to the radiating patch and the outer conductor is connected to the ground plane as shown. The advantage that we get from this type of feeding is that we can place feed at any required point in the patch in order to match the input impedance. The coaxial feed is easy to fabricate. However it is difficult to model and it provides narrow bandwidth similar to micro strip feed line. Coaxial Probe Feeding technique is shown in figure-4.4.

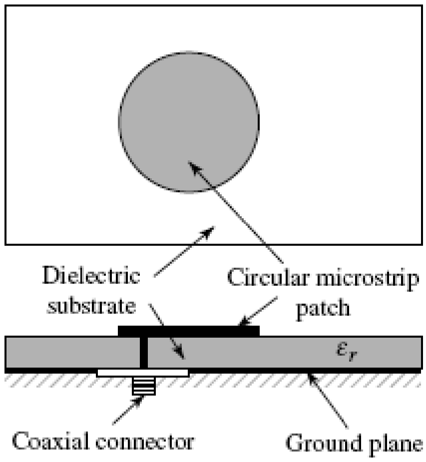


Figure-4.4: Coaxial Probe Feeding

4.3.3 Aperture Coupled Feed:

In this type of feeding method there are two substrates which are separated by a ground plane. A micro strip feed line is present in the lower substrate that is used to couple the energy to the radiating patch. The energy is coupled from the strip to the patch using a slot that is present in the ground plane which separates the two substrates. or optimization electrical parameters of substrate, slot size, width of feed line and position of slot can be used as shown in figure 4.5.

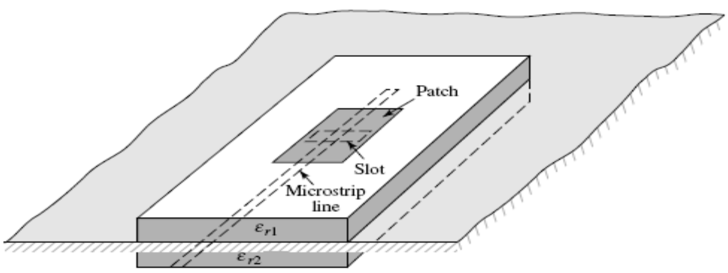


Figure 4.5 Aperture Coupled Feed

4.3.4 Proximity coupled feed

The proximity coupling gives us the highest bandwidth up to 13% of among all of the four techniques discussed here. Micro strip line feed is placed between the two substrates and the patch is placed on the upper substrate, but the fabrication of such type of method is difficult. In order to match the impedance one has to play with the width-to-line ratio of the patch. The proximity coupling technique is shown in figure-4.6[5].

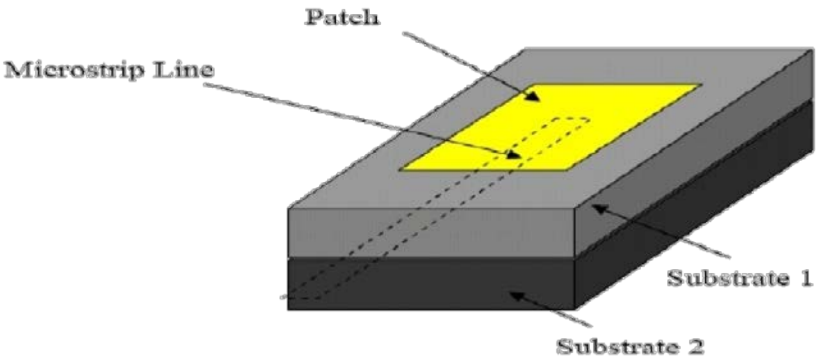


Figure 4.6 Proximity Coupled Feed

Calculating the Size of the Patch:

The size of patch rather radius in this case is calculated by using following formulae.

To find the radius a of the patch, we have [1]

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h} + 1.776\right)\right]\right\}^{\frac{1}{2}}} \quad (4.1)$$

Where,

a= radius of the patch,

h=height of the patch,

F is given by formula [1] [9].

$$F = \frac{8.791X10^9}{f_r\sqrt{\varepsilon_r}} \quad (4.2)$$

Where,

f_r= resonant frequency

ε =permittivity of the substrate,

Geometry of circular patch antenna is shown in figure 4.7.

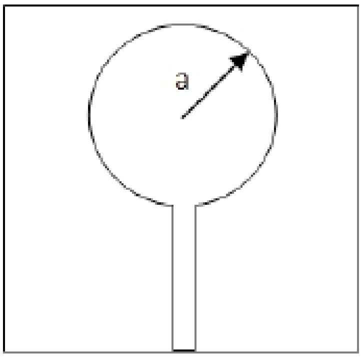


Figure 4.7: Radius of Patch

Chapter 5

Proposed Design and Simulated Results

5.1 Proposed Antenna design:

This micro-strip patch antenna is designed for Ultra Wide Band. The Ultra Wide Band antennas usually have a bandwidth of 8 GHz. Our main focus is to cover the bandwidth of 8 GHz.

The radiating patch is printed on a FR-4 substrate of size 30×30 mm^2 with thickness of 1.6mm and partial ground plane of size 30×11 mm^2 is used. The value of dielectric constant and tangent loss (tanδ) are 4.4 and 0.02 respectively. The antenna is fed by using a micro-strip line feeding technique, whose width is 3 mm and length is 12 mm, which provides 50Ω input impedance. We require a 50 Ω resistance in order to have good impedance matching with the load which is same as radiating patch. The antenna as a whole acts as a two wire system, in which the ground plane acts as negative, while the radiating patch acts as positive. As a two wire system, the antenna can support TEM mode of transmission. Antenna acts as a two wire system which is a two port device. The proposed design of UWB antenna is shown in figure 5.1.

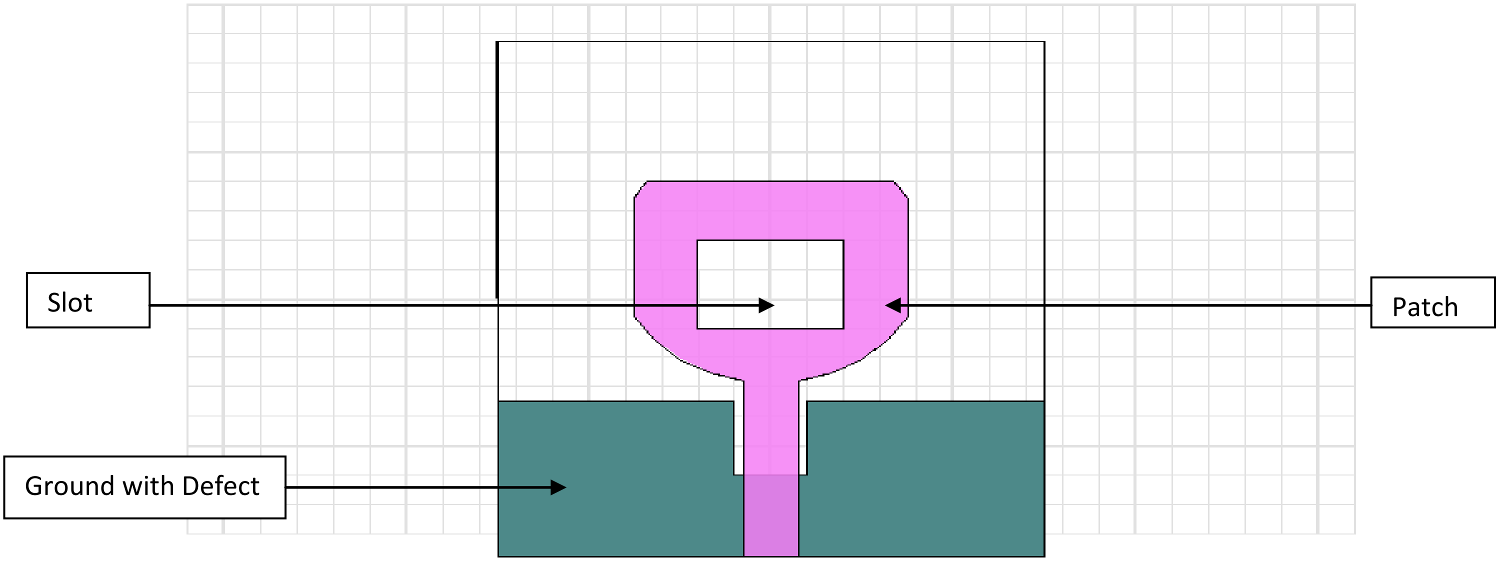


Figure 5.1 Proposed Design

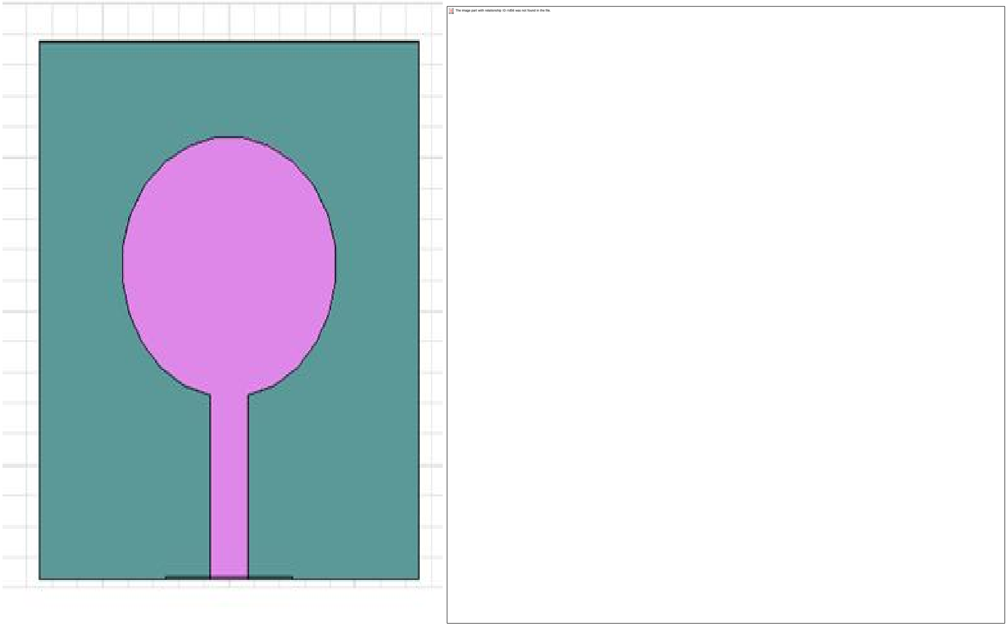
5.2 Results and Discussion:

The basic aim of this project is to design a micro strip patch antenna for Ultra wide band applications. Due to the demand of compact portable, small and light weight communication devices is increasing rapidly, a compact wideband antenna is design and ultra wideband characteristics are achieved.

The performance of the antenna is measured experimentally by iterative simulations. The results used for analysis are return loss, VSWR, bandwidth comparison and radiation pattern.

5.2.1 Initial Design and Iterations:

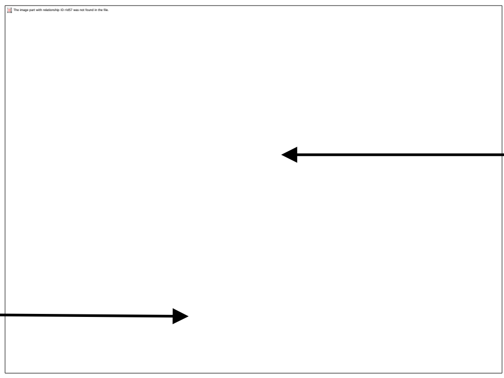
In Initial Design circular patch was made of radius 8.5 mm without any slit and slot, with full ground plane. To achieve the desired bandwidth, different bandwidth enhancement techniques like partial ground plane, addition of slits and slots in patch and truncation of geometry. Simple patch antenna and its return loss are shown in figure 5.2.



(a) (b)

Figure 5.2 (a) Initial Design (b) Result

Different band width enhancing techniques are applied on the patch antenna. As in case of patch antenna bandwidth is narrow. These techniques increase the bandwidth of antenna. Iterations in the patch antenna are shown in figure 5.1.

Ground height (mm)	**Design iteration**
30	

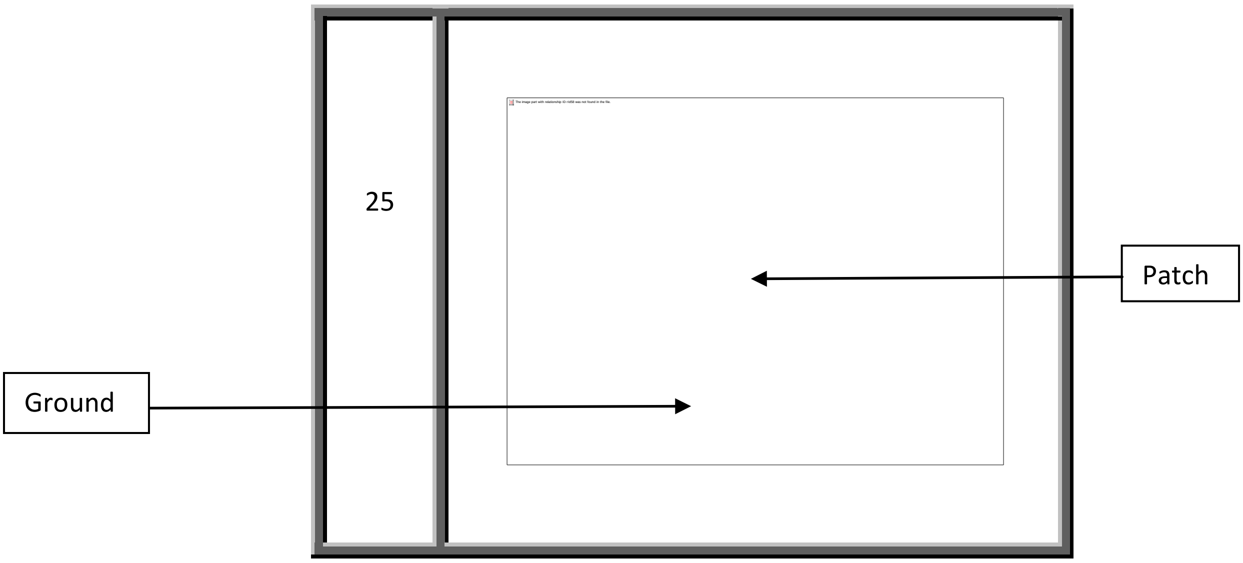


Table 5.1 Iterations in Ground Plane

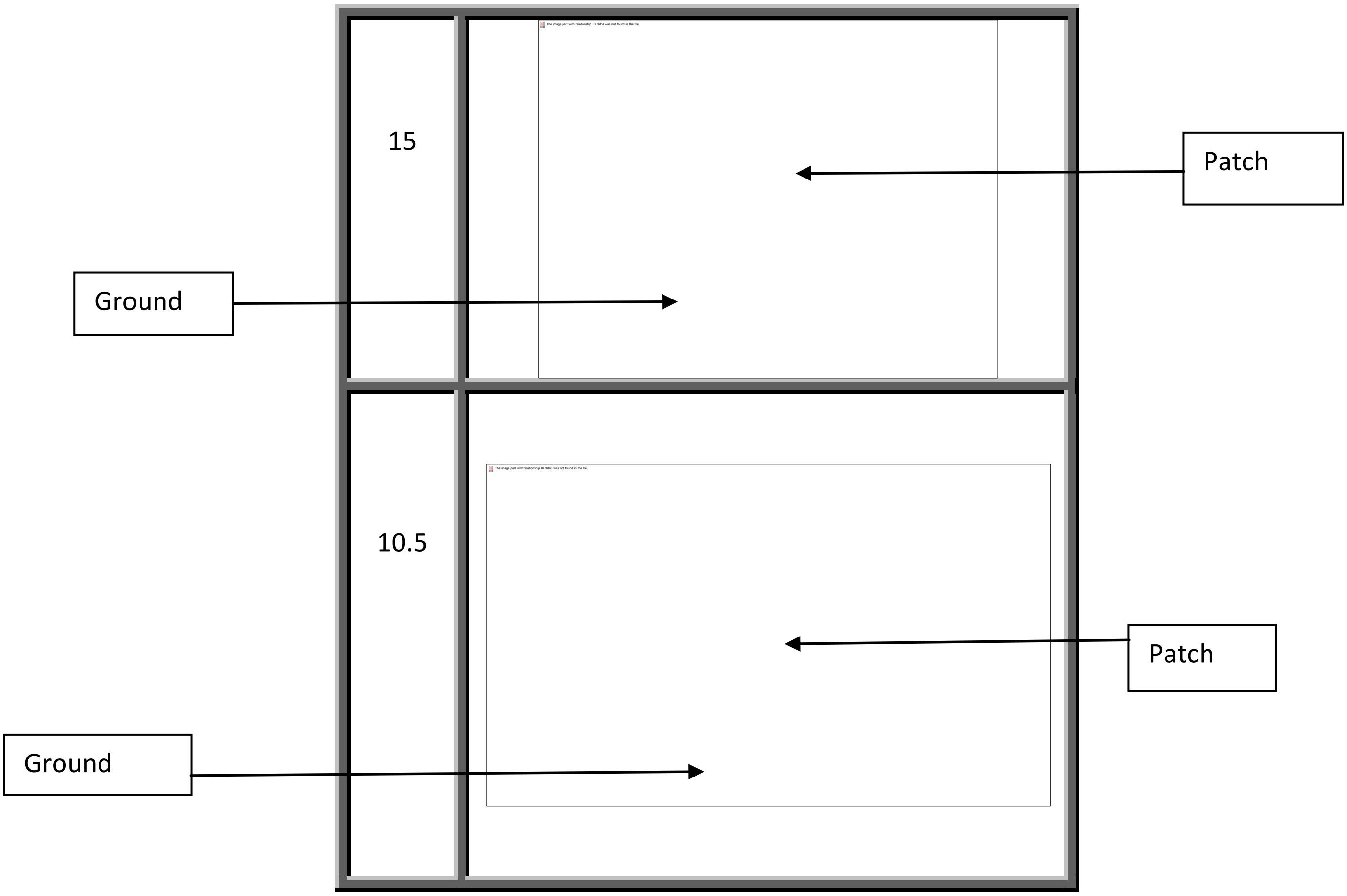


Table 5.2 Iterations in Ground Plane

The results of different iterations in ground plane are shown in figure 5.3.

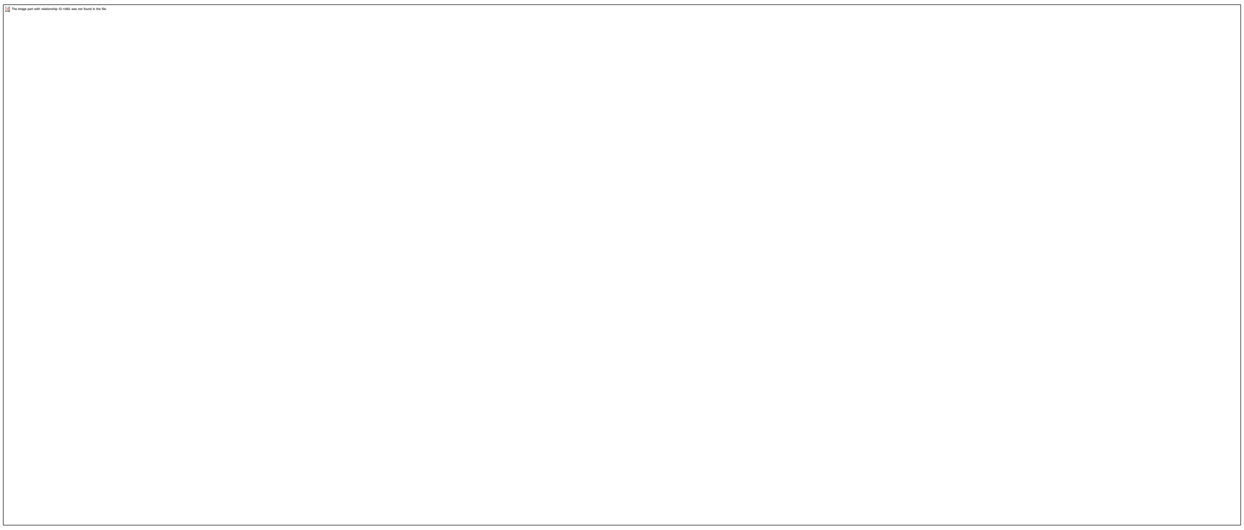
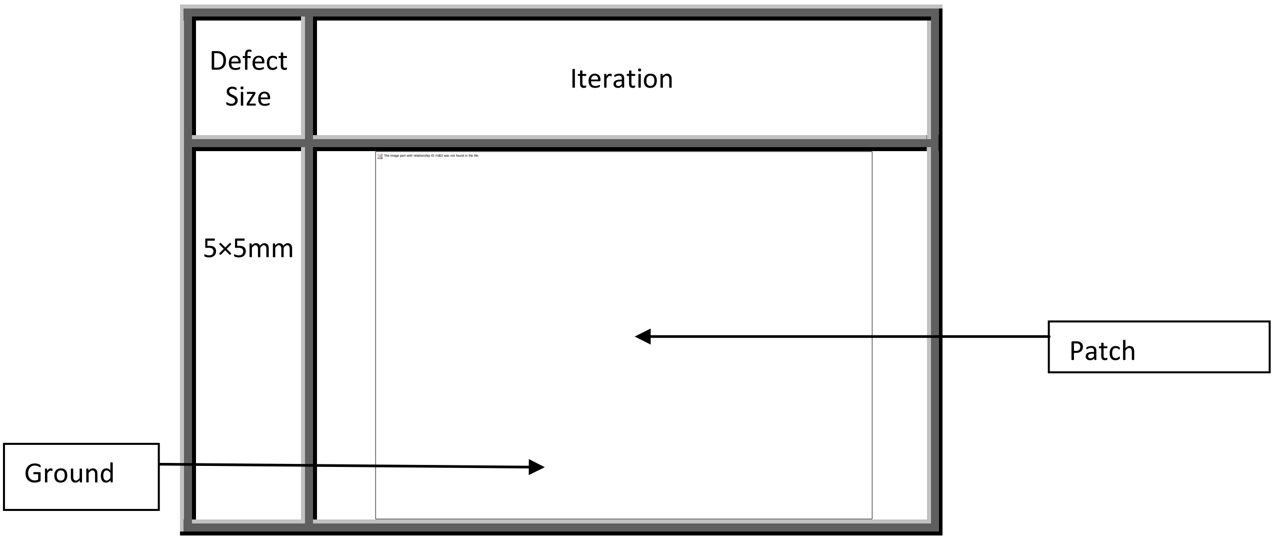


Figure 5.3 Results of Ground Plane Iterations

As from the above figure it is clear that partial technique helped a lot in improvement of bandwidth we get the most better result at ground height of 10.5mm. Partial ground technique helps in matching of impedance as the impedance match losses will be less and maximum power can be transferred.

5.2.2 Defect in Ground Plane

At ground height of 10mm we get a bandwidth of 5.5 GHz from 2.4 GHz – 7.9 GHz. By using technique of adding slit in ground at height of 10.5 mm in order to achieve more bandwidth. Defect in ground also enhance in bandwidth by proper spreading of current vectors otherwise current vectors nullify vectors which is wastage. Iterations in the ground plane are shown in figure 5.3.



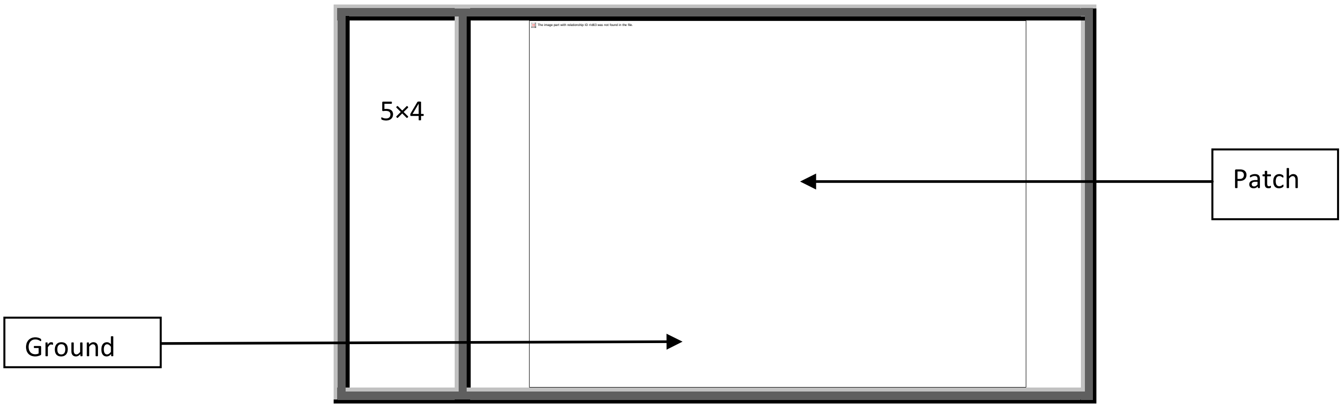


Table 5.3 Iterations for Adding Slit in Ground Plane

As in above iterations desired bandwidth covering the band from 2.2 GHz to 11.5 GHz is achieved. In these iterations we added a slit in ground where ground is at height of 10.5mm.The results of iterations for adding slit is shown in figure 5.4.

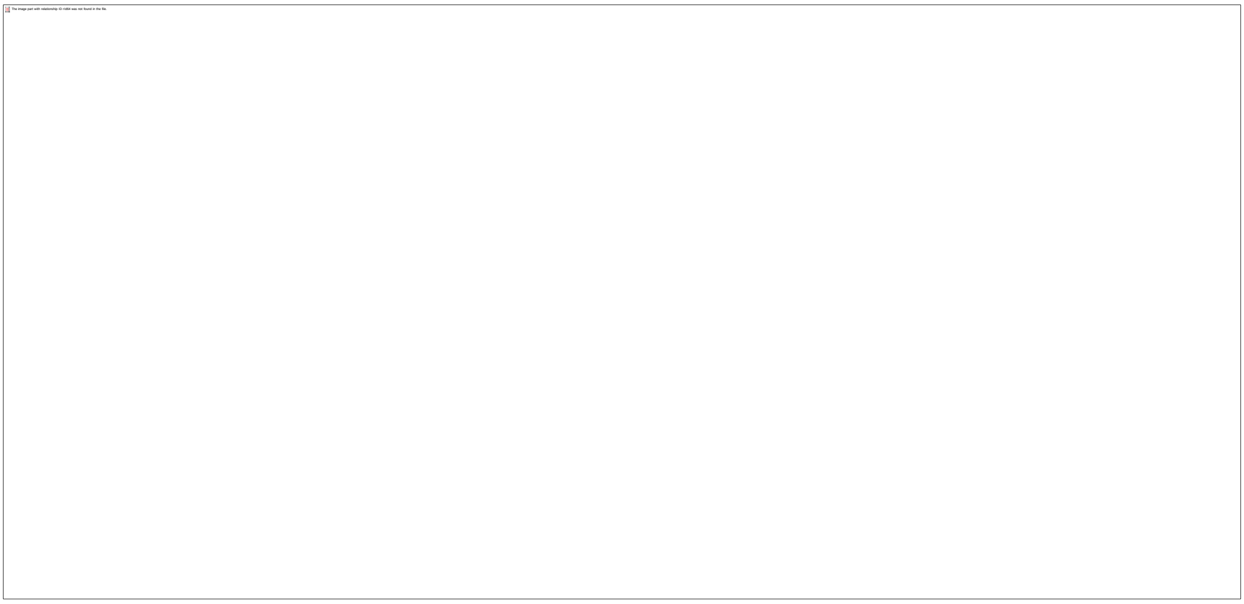


Figure 5.4 Results of Defects in Ground

5.2.3 Truncation and Adding Slot

For further improvement we truncated the patch from sides using box 2 and box 3 and top using box 1 with this truncation corners of the patch remain in circular shape

which helps the current to flow smoothly around the whole patch and helps in

improving bandwidth. .

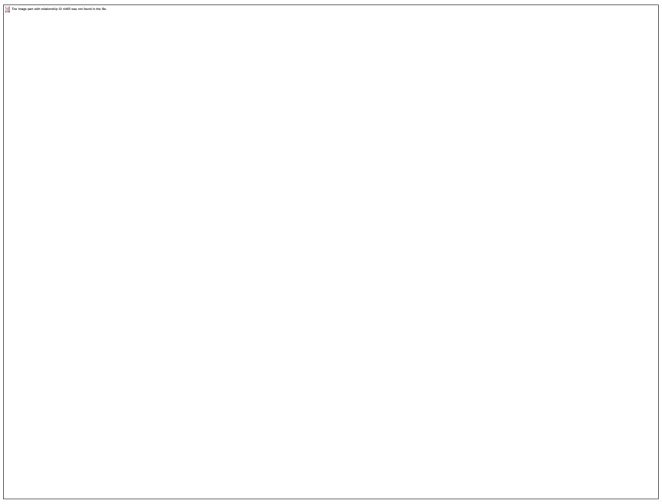


Figure 5.5 Adding Slits and Slots

After step of subtracting slots there is a final design which is shown in figure 5.6.

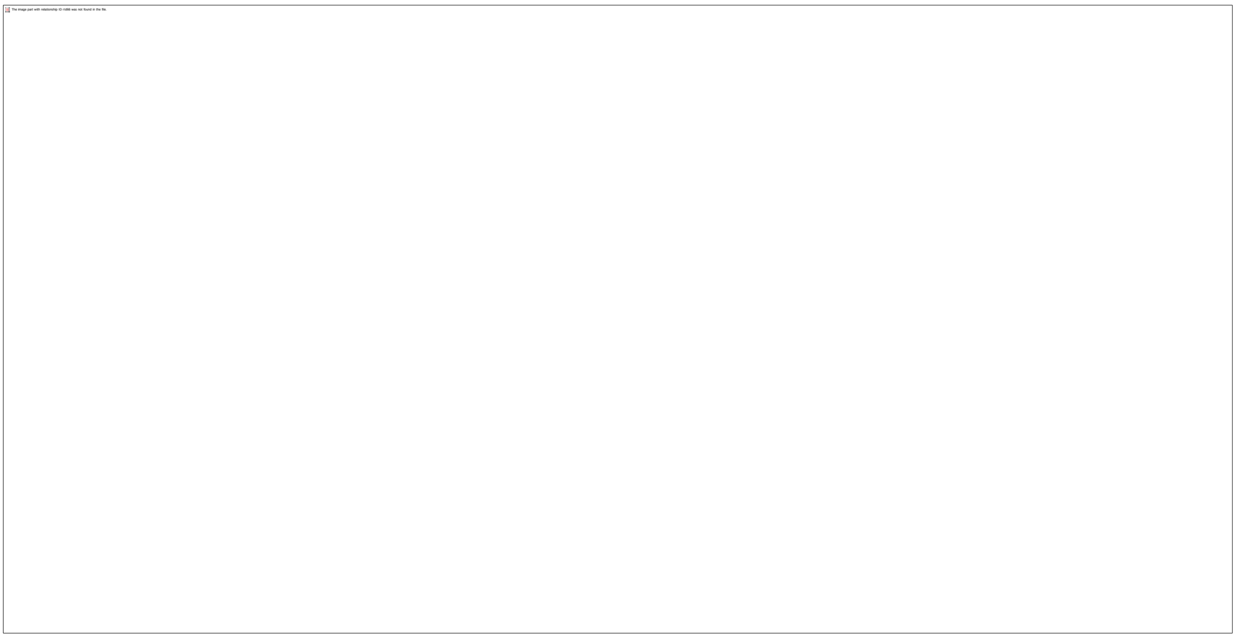


Figure 5.6 Final Design

This design covers the bandwidth of around 12 GHz from 2.4 GHz to 14.5 GHz having resonant frequencies at 3.53 GHz, 6.17 GHz, 8.94 GHz, and 11.52 GHz which is shown in figure 5.7.

5.2.4 Results of Final Design

Figure 5.7 Result of Final Design

5.2.5 Radiation Patterns

Radiation pattern is the graphic representation of the strength and direction of radiated power. Radiation pattern at 3.5 GHz, 5.5 GHz, 7 GHz are shown below in figure 5.8.

5.2.3.1 2-D Plots of Radiation Pattern

Radiation pattern of UWB antenna at frequency 3.5 GHz is shown in figure 5.8.

Figure 5.8 Radiation Pattern at of UWB Antenna for E_{Θ} Rotation at Frequency 3.5 GHz

It shows the radiation plot in xz plane when phi =0 and theta=-180 to 180

It shows the radiation plot in yz plane when phi is 90 and theta=-180 to 180

Radiation pattern of UWB antenna at frequency 5.5 GHz is shown in figure 5.9.

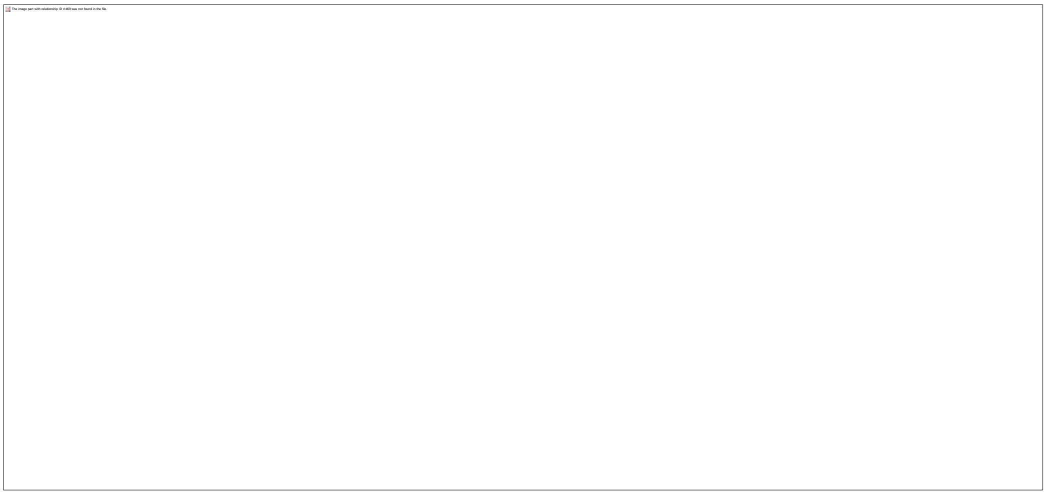


Figure 5.9 Radiation Pattern at of UWB Antenna for E_{Θ} Rotation at Frequency **5.5** GHz

It shows the radiation plot in xz plane when phi =0 and theta=-180 to 180

It shows the radiation plot in yz plane when phi is 90 and theta=-180 to 180

Radiation pattern of UWB antenna at frequency 7 GHz is shown in figure 5.10.

Figure 5.10 Radiation Pattern at of UWB Antenna for E_{Θ} Rotation at Frequency **7** GHz

It shows the radiation plot in xz plane when phi=0 and theta=-180 to 180

It shows the radiation plot in yz plane when phi is 90 and theta=-180 to 180.

Radiation pattern of UWB antenna at frequency 3.5 GHz is shown in figure 5.11.

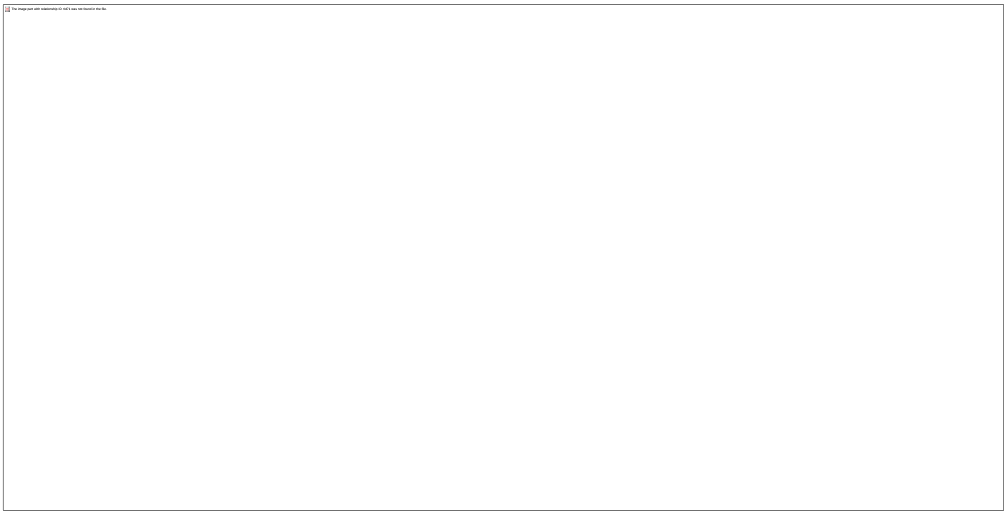


Figure 5.11 Radiation Pattern at of UWB Antenna for E_{Φ} Rotation at Frequency 3.5 GHz

It shows the radiation plot in xz plane when phi=0 to 360 and theta=0

It shows the radiation plot in xy plane when phi =0 to 360 and theta=90

Radiation pattern of UWB antenna at frequency 5.5 GHz is shown in figure 5.12.

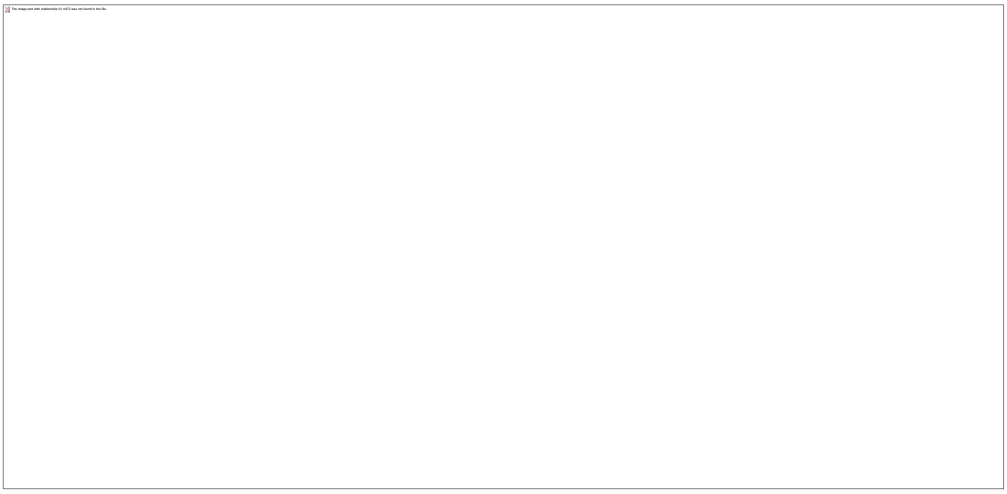


Figure 5.12 Radiation Pattern at of UWB Antenna for $E_{\mathbf{\Phi}}$ Rotation at Frequency 5.5 GHz

It shows the radiation plot in xz plane when phi =0 to 360 and theta=0

It shows the radiation plot in xy plane when phi=0 to 360 and theta=90.

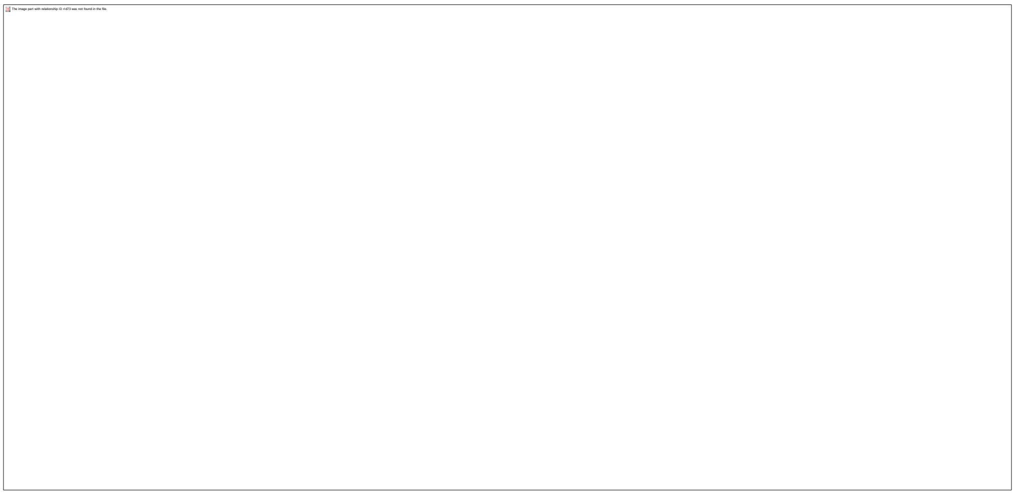


Figure 5.13 Radiation Pattern at of UWB Antenna for E_{Φ} Rotation at Frequency 7 GHz

It shows the radiation plot in xz plane when phi =0 to 360 and theta=0

It shows the radiation plot in xy plane when phi=0 to 360 and theta=90.

3d polar pattern of UWB antenna at frequency 3.5 GHz is shown in figure 5.14.

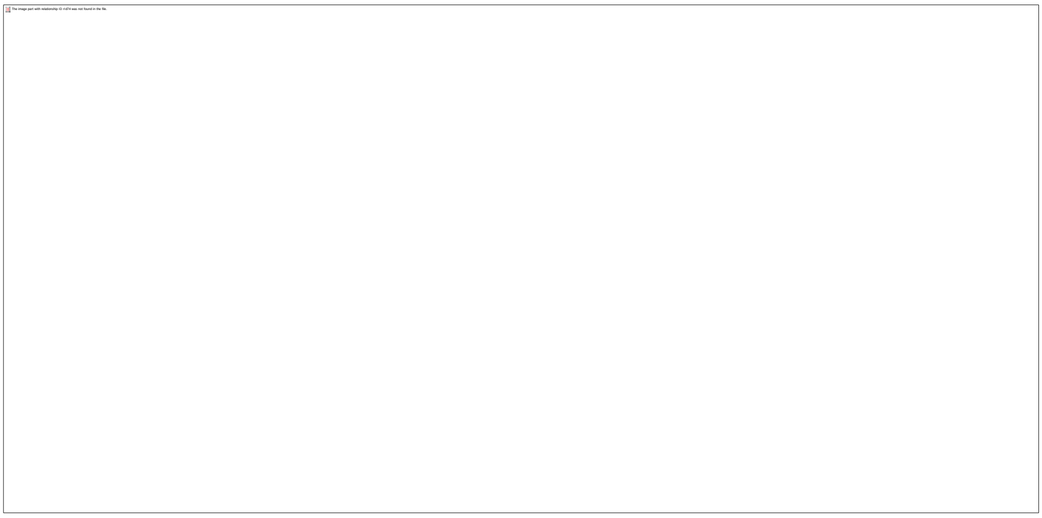


Figure 5.14 3d Plots at 3.5GHz

It shows us three dimensional radiation pattern of an antenna at 3.5 GHz. It looks like an apple which shows the omni directional pattern.

3d polar pattern of UWB antenna at frequency 4.5 GHz is shown in figure 5.15.

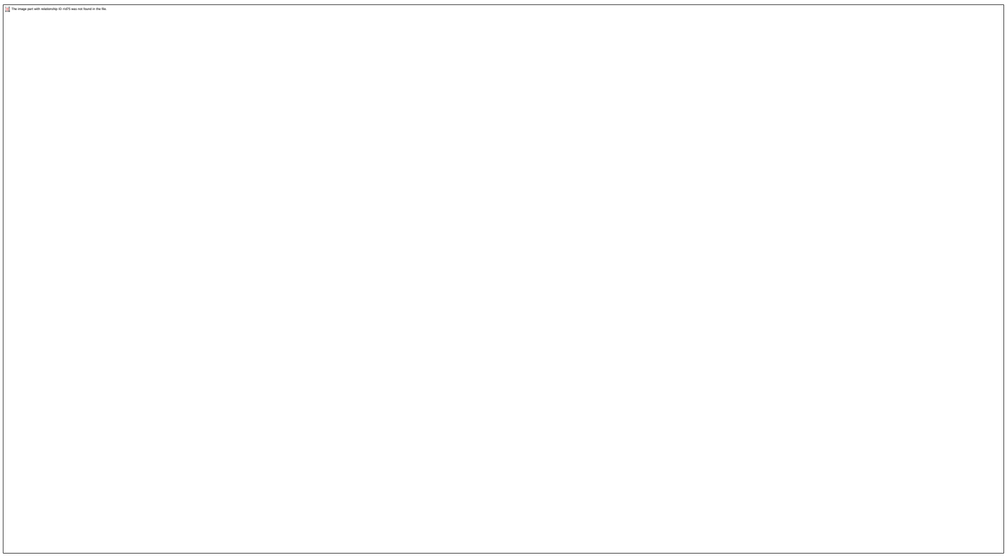


Figure 5.15 3d Plots at 4.5 GHz

It shows us three dimensional radiation pattern of an antenna at 4.5 GHz. It looks like a donut shape which shows the omni directional pattern.

3d polar pattern of UWB antenna at frequency 5.5 GHz is shown in figure 5.16.

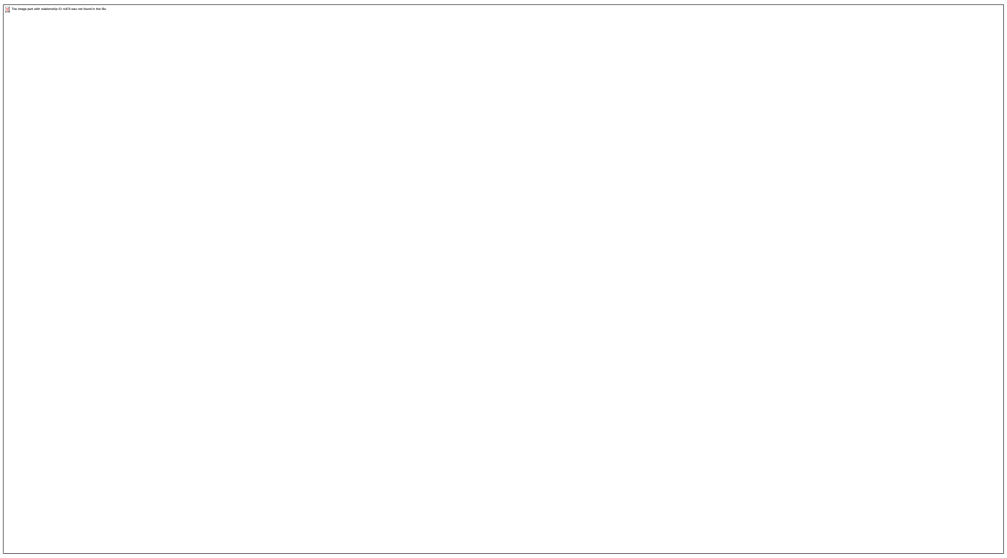


Figure 5.16 3d Plots at 5.5 GHz

It shows us three dimensional radiation pattern of an antenna at 3.5 GHz. It looks like an apple which shows the omni directional pattern.

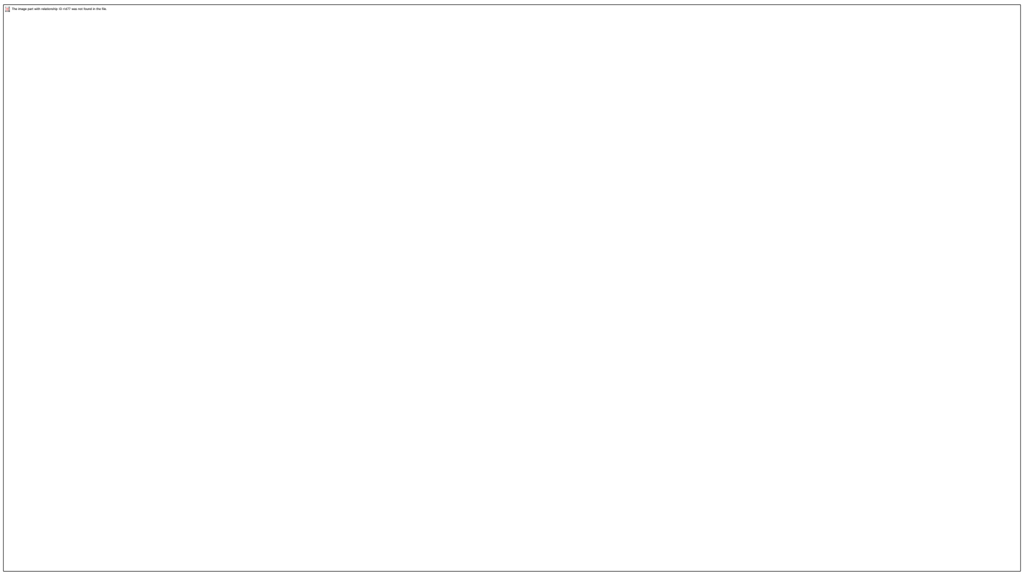


Figure 5.17 3D Plot at 7 GHz

It shows three dimensional radiation pattern of our antenna at 3.5 GHz. It looks like an apple which shows the omni directional pattern. As it can be clearly seen that antenna is omni directional over the entire UWB band.

Chapter 6

Wilkinson Power Divider

6.1 Transmission line circuit

Wilkinson power divider is a three-port network which is lossless when the output ports are well matched; where only reflected power is dissipated through the isolation resistor. There are variety of power dividers such as resistive, T junction and Wilkinson power divider. The only difference between Wilkinson and other power dividers is isolation between output ports. Input power can be dividing into two or more signals which are in phase with the same amplitude. For a two-way Wilkinson divider using impedance transformers having a characteristic impedance of and a lumped isolation resistor of with all three ports matched, high isolation between the output ports is obtained [1]. The design of an equal-split (3 dB) Wilkinson is often made in strip line or micro strip form; all designs considered in this thesis are micro strip. The equivalent transmission line circuit is shown in Figure 6.0.

Figure 6.0 Transmission line circuit model

Table 6.1: Summary of topology advantages and disadvantages

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6.2. Design and Results

Initially the Wilkinson was designed on ADS .The same procedure used in the simulation of the 2:1 dividers was used for the 4:1. The models were made by cascading two stages of 2:1 dividers to form a 4:1 divider. The ADS and HFSS 4:1 Wilkinson divider models and simulation results are shown in Figure 6.1.

Figure 6.1 ADS Wilkinson Design

Size becomes more significant at lower frequencies such as L band and below it. Therefore, a design that reduces the substrate area is important. HFSS model of Wilkinson power divider is shown in figure 6.2.

Figure 6.2 HFSS Wilkinson Design

The transmission line design reduces the size the most but requires close spacing between transmission lines in the quarter lambda section. The close spacing of the lines did not allow them to sufficiently decouple from each other, though the use of coupled lines in the design of Wilkinson power dividers after calculation of even and odd mode impedances has been investigated by. [9] The results of design are shown in figure 6.3.

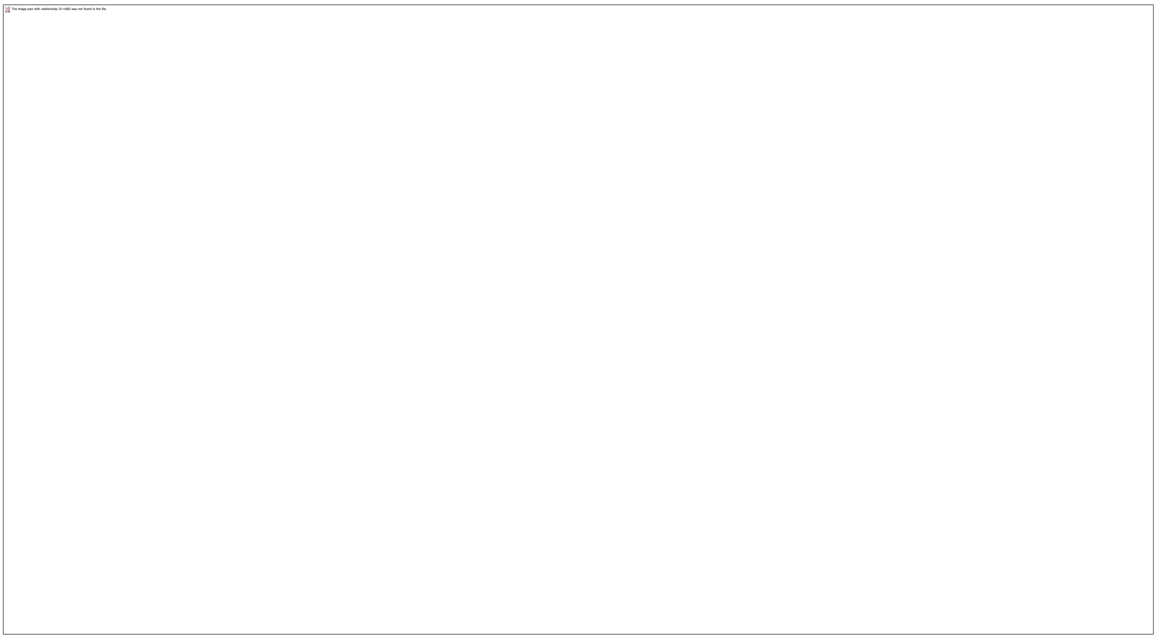

Figure 6.3 HFSS results of Wilkinson Design

Analysis and design of an equal-split Wilkinson power divider were performed with HFSS. In order to achieve wider pass band with return loss at input and output ports less than 10 dB different dimensions of Wilkinson was used and simulated. Important micro strip design considerations were taken when selecting the appropriate substrate. FR-4 substrate has greater losses as compared to other substrates but it is commonly used, readily available, and low cost.

The divider is fabricated on a substrate with dielectric constant of 4.4 and loss tangent of 0.02 and thickness of substrate is 1.6mm.the total size is about 12*50mm.the above results shows that power is equally divide into two output ports .the output ports have insertion loss less than 0.4dB across the entire UWB band. the return loss or s11 parameter at input port is in the range of 15dB across entire operating range of 3.1-10.6GHz and the return loss at output ports is between 10-15dB across entire UWB band. The results show good isolation between output ports.

Chapter 7

Microwave Band pass Filters

A microwave filter is a two port network which is used to control the frequency response at a certain point in microwave system by providing transmission at pass band of the filter and attenuation in the stop band of the filter. Typical frequency responses include low-pass, high-pass, band- pass and band-reject characteristics.

UWB band is 3.1 GHz to 10.6GHz.We have to design filters whose band specification lie within UWB band. We designed a band-pass filter by cascading a low-pass filter and high-pass filter. The two main methods of filter design are image parameter method and insertion loss method. We will use insertion loss method.

7.1 Filter Design Methods

The image parameter method uses two port filter sections which are cascaded to provide the desired cutoff frequencies and attenuation characteristics, but do not allow the specification of a frequency response over the complete operating range. Image parameter method is simple as compared to insertion loss method; the design of filters by the image parameter method often must be iterated several times to achieve the desired specifications.

The method which is used now-a-days to design filters is insertion loss method, uses network synthesis techniques to design filters with a complete specified frequency response. The design is simplified by starting with low-pass filter prototypes that are normalized in terms of frequency and impedance. Prototype design is converted to desired frequency range and impedance level by applying transformation technique. Both the image parameter and insertion loss method of filter design use lumped element circuits such as inductors and capacitors. For microwave applications such designs usually must be converted to use distributed elements consisting of transmission line sections. The Richard's transformations and Kuroda identities are used to convert inductors and capacitors to microwave transmission lines.

The image parameter method of filter design involves the specification of pass band and stop band characteristics for a cascade of two port networks. The method is relatively simple but it has major disadvantage that an arbitrary frequency cannot b incorporated into the design. This is the main difference of image parameter method to insertion loss method. Although, the image parameter method is useful for simple filters and provides a link between infinite periodic structures and practical filter design. Image parameter method has also some applications in solid-state traveling- wave amplifier design [6].

The ideal filter would have zero insertion loss in the pass band, infinite attenuation in the stop band, and a linear phase response in the pass band. As such ideal filters do not exist in practice, so compromise lies in design of filters.

The insertion loss method has great degree of control over the pass band and stop band, amplitude and phase characteristics, with a systematic way to achieve a desired response. The necessary design trade-offs exists to best meet the applications requirements. As if a minimum insertion loss is more important, a binomial response could be used; a Chebyshev response would satisfy a requirement for the sharpest cutoff [6].

7.2 Bluetooth Filter Design and Results

Here is the geometry of Bluetooth band filter .Filter is designed in HFSS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines. The geometry of Bluetooth filter is shown in figure 7.0.

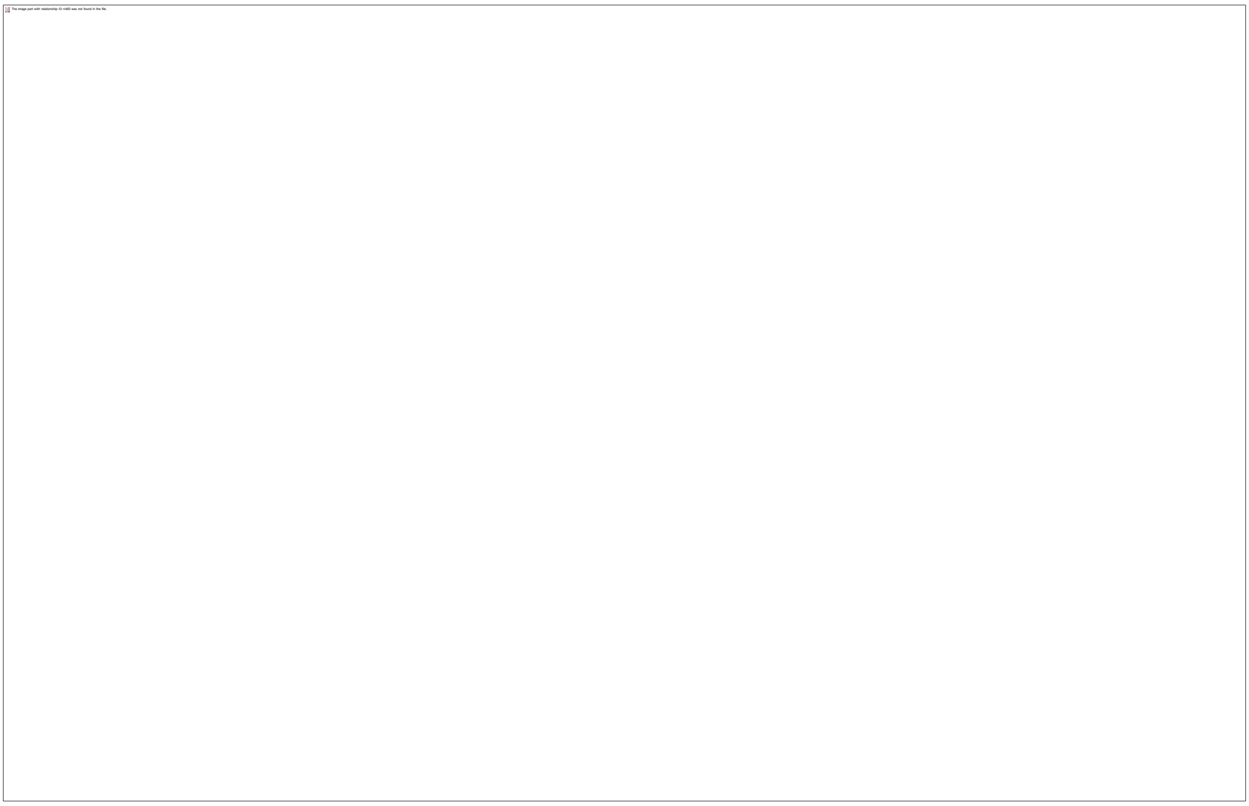

Figure 7.0 Filter for Range 2.4-2.55 GHz

Figure 7.1 shows that filter operates in the range of 2.41 to 2.48 GHz which is the requirement of Bluetooth filter.

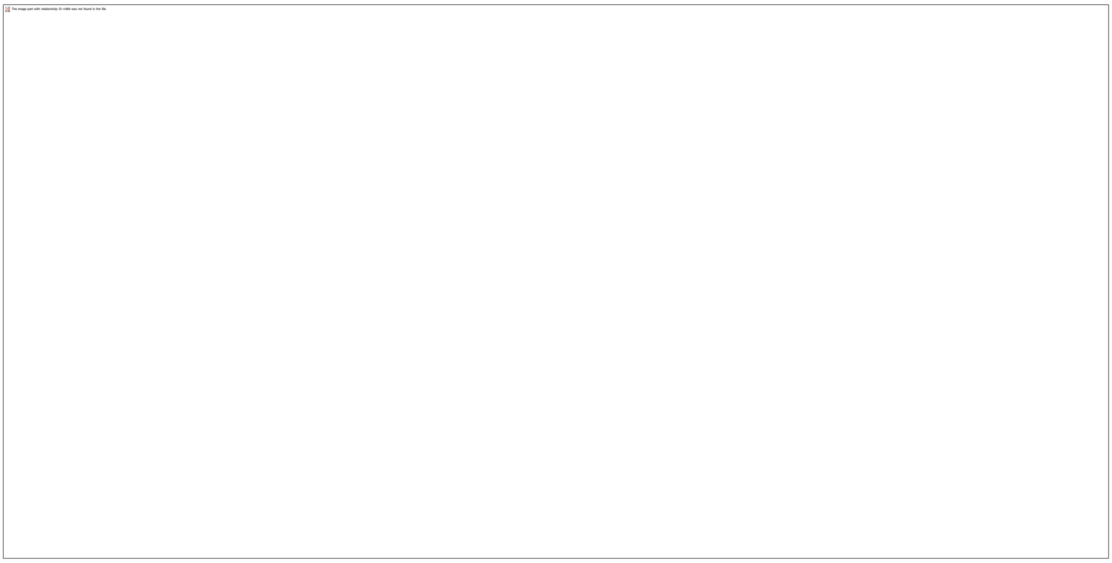

Figure 7.1 Results Filter for Range 2.4-2.55 GHz

7.3. WLAN Filter Design and Results

The geometry of WLAN band pass filter is shown in figure 7.2.

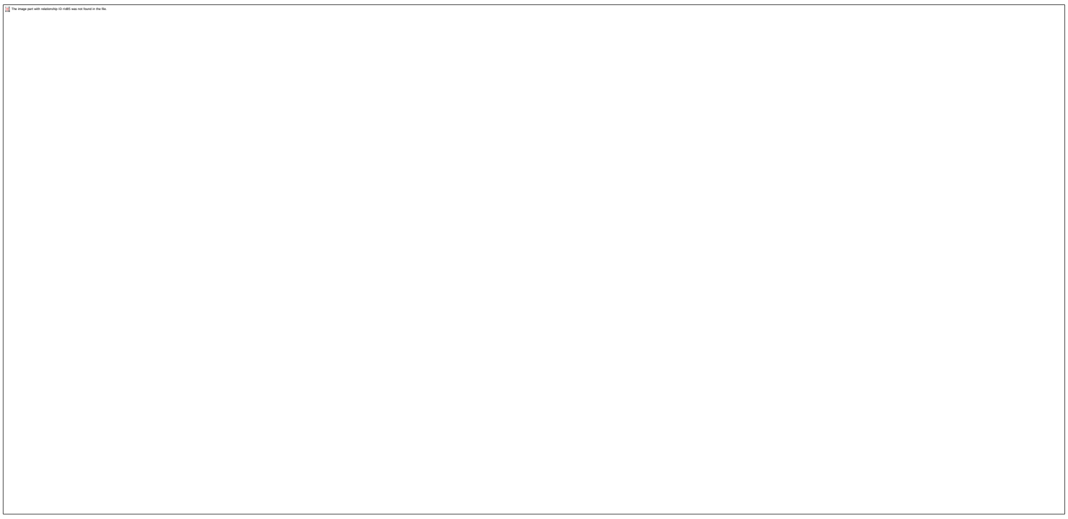

Figure 7.2 Filter for Range 4.8-6.2 GHz

Filter is designed in HFSS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines. The results of WLAN filter are shown in figure 7.3.

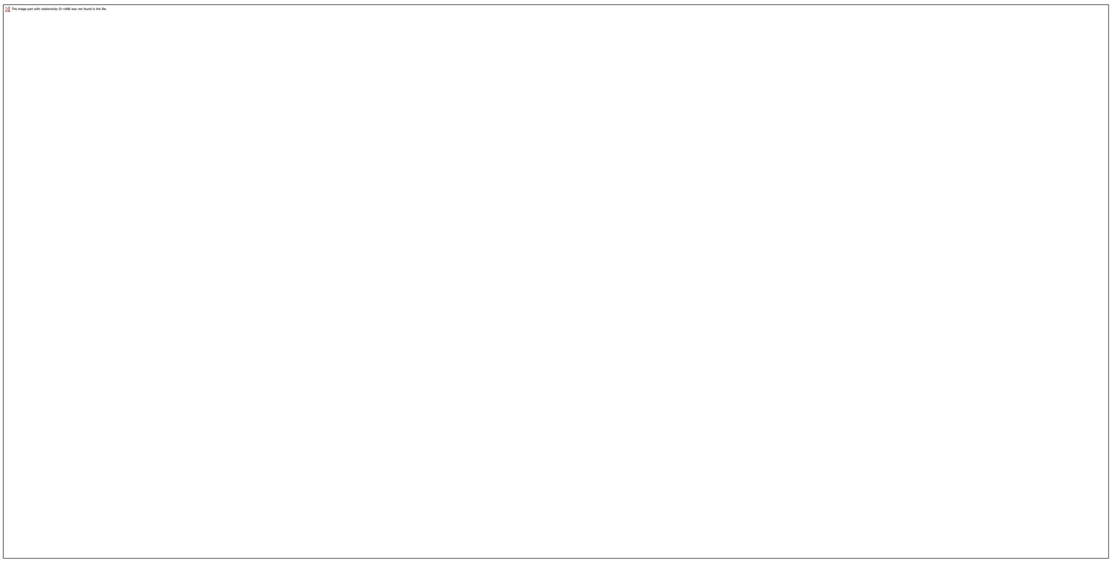

Figure 7.3 Results of Filter for Range 4.8-6.2 GHz

Figure 7.3 shows that filter operates in the range of 5 to 6 GHz which is the requirement of WLAN filter.

7.4. Bluetooth Filter Design and Results

Filter is designed in ADS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines.FR-4 substrate are used for the design of filter. the substrate height is 1.6mm and dielectric constant is 4.4. The geometry of Bluetooth filter is shown in figure 7.4.

Figure 7.4 Schematic Filters for Range 2.4-2.55 GHz

Layout of Bluetooth band pass filter is shown in figure 7.5.

Figure 7.5 Filter for Range 2.4-2.55 GHz

The result of Bluetooth band pass filter is shown in figure 7.6 which shows that filter's operating range is 2.41-2.48 GHz which is the main requirement of Bluetooth band pass filter. The return loss of antenna is less than 10 dB which is from 2.41-2.48 GHz as shown in figure 7.6.

Figure 7.6 Results of Filter for Range 2.4-2.55 GHz

7.5 WIMAX Filter Design and Results

The design of WIMAX band pass filter is shown in figure 7.7.

Figure 7.7 Schematic of Filter for Range 3.5 GHz

Filter is designed in ADS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines.FR-4 substrate are used for the design of filter. The substrate height is 1.6mm and dielectric constant is 4.4. The geometry of WIMAX filter is shown in figure 7.8.

Figure 7.8 Layout of Filter for Range 3.5 GHz

The result of WIMAX band pass filter is shown in figure 7.6 which shows that filter's operating range is 2.41-2.48 GHz which is the main requirement of Bluetooth band pass filter. The S (2, 1) parameter of filter is less than 2 dB from 3.3-3.8 GHz. The return loss S (1, 1) of antenna is less than 10 dB which is from 3.3-3.8 GHz as shown in figure 7.9.

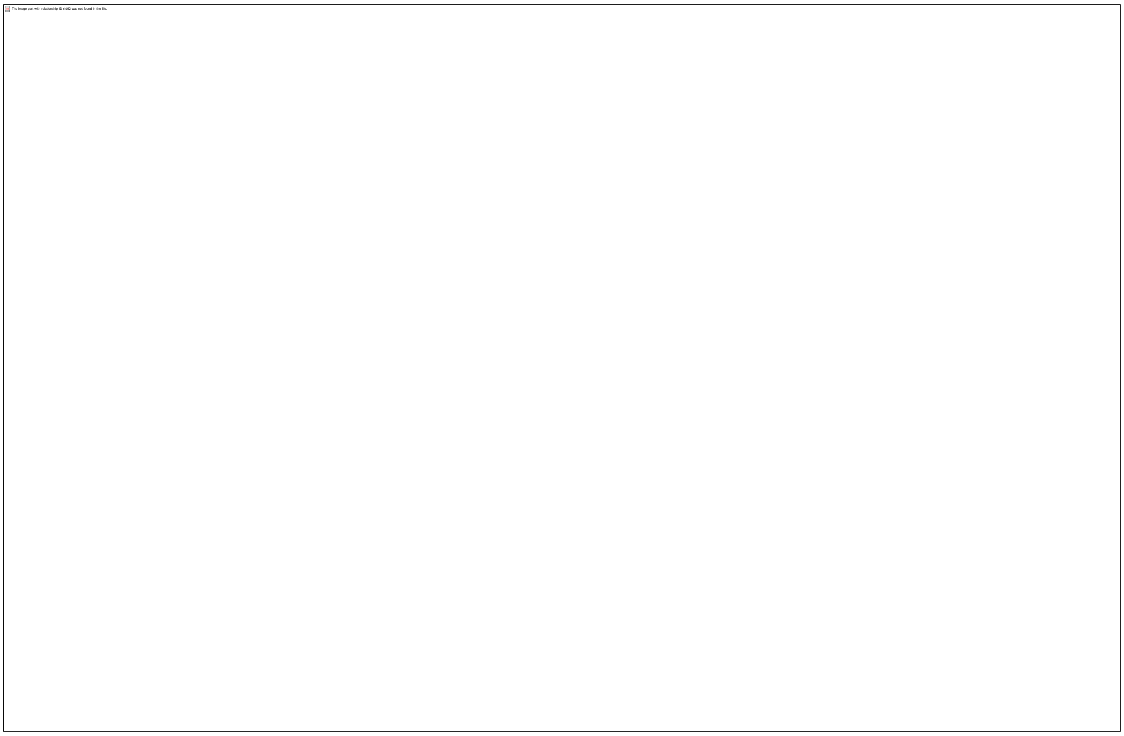

Figure 7.9 Results for Filter for Range 3.5 GHz

7.6 Design 5 (5.2GHz & Results)

Filter design for 5.2 GHz is shown in figure 7.10.

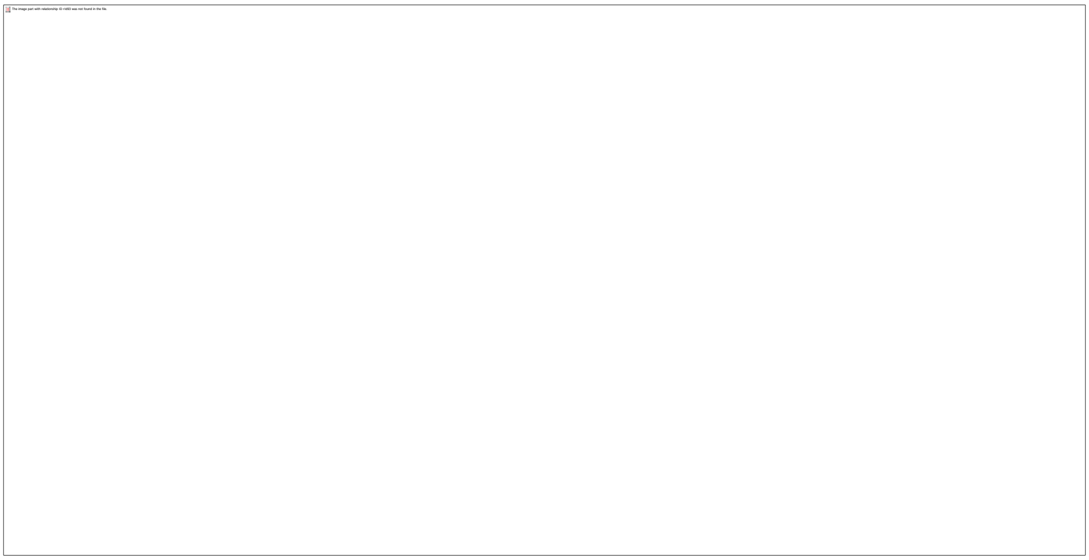

Figure 7.10 Schematic for Filter for Range 5.2 GHz

Filter is designed in ADS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines.FR-4 substrate are used for the design of filter. The substrate height is 1.6mm and dielectric constant is 4.4. The layout of filter is shown in figure 7.11.

Figure 7.11 Layout of Filter for Range 5.2 GHz

The result of band pass filter is shown in figure 7.12 which shows that filter's operating range is 5.15-5.25 GHz which is shown in figure 7.12.

Figure 7.12 Results for Filter for Range 5.2 GHz

7.7 Design 6 (5.8 GHz & Results)

Filter design for 5.8 GHz is shown in figure 7.13.

Figure 7.13 Schematic for Filter for Range 5.8 GHz

Filter is designed in ADS software. Initially active components are used then Richard Transformation is used to convert inductors and capacitors to microwave transmission lines.FR-4 substrate are used for the design of filter. The substrate height is 1.6mm and dielectric constant is 4.4. The layout of filter is shown in figure 7.14.

Figure 7.14 Layout for Filter for Range 5.8 GHz

The result of band pass filter is shown in figure 7.15 which shows that filter's operating range is 5.7-5.8 GHz. The S (2, 1) parameter of filter is less than 2 dB from 3.3-3.8 GHz. S (1, 1) basically the bandwidth of antenna. The return loss S (1, 1) of antenna is less than 10 dB which is from 5.7-5.8 GHz as shown in figure 7.15.

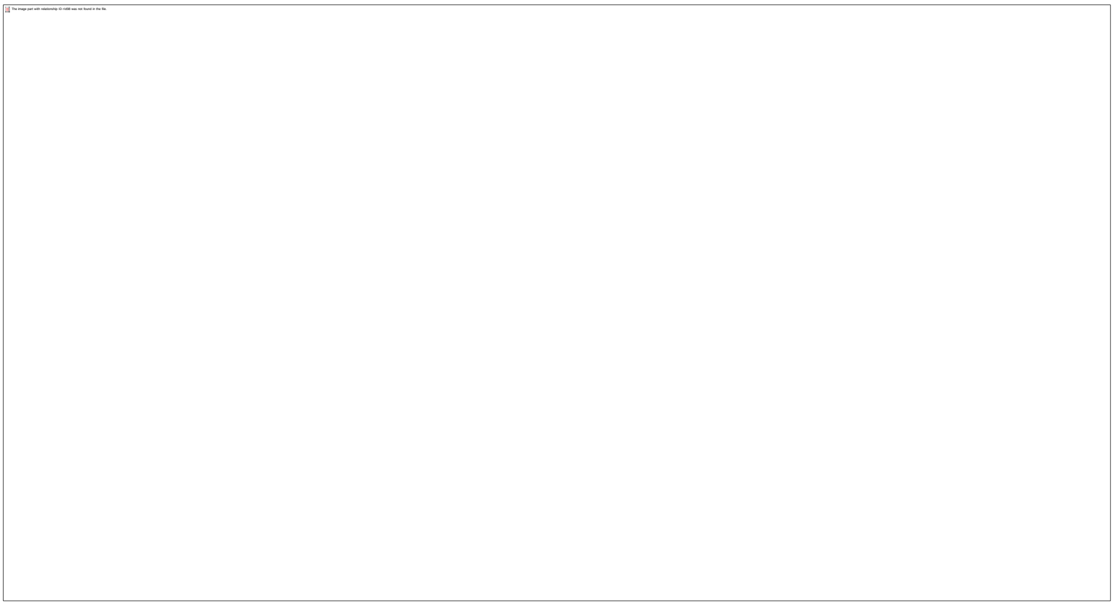

Figure 7.15 Results for Filter for Range 5.8 GHz

Chapter 8

Conclusion and Future Work

8.1 Conclusion

Proposed compact-size and low cost micro strip patch antenna with ultra wide band characteristics, UWB Wilkinson power divider and microwave filters are designed on FR4 substrate and validated through simulation and manually fabricated. The simulation was performed in Ansoft HFSS 11 and ADS software. The design for ultra wide band application has an approximate bandwidth of 7 GHz. All the results achieved are obtained experimentally with iterations.

We conclude that wideband operation can be done by partial ground and adding slits and slots in the patch. The Ultra Wide Band property and small size of key shape micro strip patch antenna allows efficient, broadband and multipurpose device to occupy small space. Design of this patch is new and different. This antenna has fairly Omni directional pattern at most of the frequency. It also provides very good return loss at different resonant frequencies.

8.2 Future Work

Different transmission techniques for feeding to operate antenna at different frequency bands can be used. The different feeding methods can be coaxial probe, coplanar wave guide, aperture couple feeding and proximity coupled feed etc. Percent bandwidth can be increase by using slits and slots techniques. To enhance the gain of the antenna, some new techniques should be applied. Future research may focus on the new method to reducing the size of ultra wideband antennas since the compact antenna is needed to embed inside the portable devices or mobiles and further enhance the bandwidth.

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