MEANDERED MICRO-STRIP PATCH ANTENNA FOR UWB APPLICATIONS

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ABSTRACT

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The project encompasses, design of rectangular micro-strip patch antenna for UWB frequency range. The designed antenna covers entire UWB specified by FCC i.e. 3.1-10.6 GHz. The antenna has been optimized for minimum possible dimensions i.e. a rectangular patch of 16 mm x 21 mm and ground plane of 35 mm x 30 mm fed with a micro-strip line of 13 mm x 3 mm covering the desired band. The chosen center frequency for design is 5.78 GHz basing on the geometric mean of FCC specified UWB. The concepts of bandwidth enhancement are reflected through physical application of some of the bandwidth enhancement techniques i.e. Meandering, Edge Truncation, and Ground Plane reduction. The parameters for which the design has been analyzed and optimized are Return loss, VSWR, Gain, Radiation pattern and Surface Current Density as per the international standards. Primarily Ansoft HFSS has been used as the designing tool for the antenna designing process. The optimized final design has been fabricated and tested at SMRIMMS. Results obtained thus conform to the simulated data thereby meeting international standards of an operating antenna device.

CERTIFICATE

It is certified that the work contained in this thesis entitled **“Meandered Micro-Strip Patch Antenna for UWB Applications”** carried out by Capt Ehsan ul Haq, Capt Gulfam Hussain and Capt Muhammad Usama under the supervision of Assoc Prof. Dr. Farooq Ahmad Bhatti for the partial fulfillment of degree of Bachelors of Telecom (Electrical) Engineering is correct and approved.

Assoc Prof. Dr. Farooq Ahmad Bhatti

Project Supervisor

Dated:

DECLARATION

No portion of work presented in this dissertation has been submitted in support of another award or qualification either at this institution or elsewhere.

Dedicated to

Almighty Allah for His blessings,

Teachers and friends for their help

and Our Parents for their support and prayers

ACKNOWLEDGEMENT

We would like to express our gratitude towards our advisors Assoc Professor Dr. Farooq Ahmad Bhatti and Assistant Professor Zeeshan Zahid for all the help, invaluable guidance, critics and generous support throughout our final year project.

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We would also like to thank all our friends and all those, whoever has helped us either directly or indirectly, in the completion of our final year project and thesis.

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KEY TO SYMBOLS

UWB	Ultra Wide Band
FCC	Federal Communication Commission
VSWR	Voltage Standing Wave Ratio
IEEE	Institute of Electrical and Electronics Engineers
HFSS	High Frequency Structure Simulator
AUT	Antenna under test
HPBW	Half Power Bean Width
FNBW	First Null Beam Width
LPD	Low Probability of Detection
PR	Pseudorandom
GPS	Global Positioning Satellite
UMTS	Universal Mobile Telecommunication System
WLAN	Wireless Local Area Network
PIFA	Planar Inverted F- Antenna
RMSA	Rectangular Microstrip Antenna
VNA	Vector Network Analyzer
CPW	Co Planar Waveguide

CHAPTER 1

INTRODUCTION

1.1. OVERVIEW

This chapter gives the basic information about the project. The chapter covers the project background, objectives, scope and the thesis outline. The problem statement of the project will also be carried out in this chapter.

1.2. PROJECT BACKGROUND

According to IEEE, “antenna is a device for radiating and receiving electromagnetic waves”. Nowadays wireless communication has significant importance and antenna is one of the most important and best means of wireless communication. Small size and compact antenna with high gain and accuracy is the present day demand. There are many types of antenna, but micro strip patch antennas are most popular and common among all types because they are small in size, have low profile and, top of all, easy to fabricate [1]. Along with the advantages there are some disadvantages of micro strip patch antennas like they have narrow bandwidth but at the present time several techniques and methods have been introduced to enhance bandwidth.

Ultra Wideband antennas have many applications. Some of them include satellite communication, radar imaging. Ultra wide band antennas have broad spectrum and are for unlicensed applications [1].

1.3. PROJECT OBJECTIVE

In this project, an Ultra Wideband antenna using meandered path micro-strip patch is proposed.

The project includes the design of the antenna with their simulated and fabricated results.

- To propose and design antennae for ultra wide band applications.
- Antennae should cover UWB range from 3.1 to 10.6 GHz.
- Enhance Bandwidth using bandwidth enhancement techniques.
- Study return loss, radiation pattern, gain and surface current density of design
- Verify the results on HFSS simulator.
- Design a simple, light weight UWB antenna.

1.4. Antenna Fundamentals

In this chapter, basic fundamentals of antenna are discussed. Radiation pattern of antenna is explained in detail with its major components. Also the concept of near-field and far-field is explained. Characteristics of antenna are studied and their use in particular fields depends upon antenna fundamentals and for this; antenna directivity, gain, its beam width and beam efficiency is thoroughly studied. Moreover bandwidth, polarizations and its different types are also explained in detail.

1.5. Radiation Pattern

Radiation pattern is a mathematical function or graphical representation of the radiation properties of an antenna as a function of space coordinates. In most of the cases, radiation pattern is measured in far field. Radiation pattern is represented in 3-D but for the sake of simplicity it can also be represented in 2-D [1].

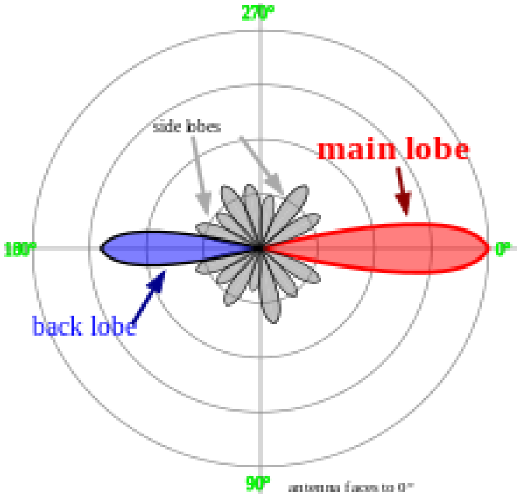


Figure-1.1: Radiation Pattern

Radiation properties of an antenna depend on Power flux density, Radiation intensity, Field strength, Directivity, Phase or polarization, Different parts of radiation pattern are called its lobes and they are classified as Main or Major Lobe, Minor Lobe, Side Lobe, Back Lobe.

1.5.1 Major Lobe

No antenna is able to radiate energy in only one particular direction. Some energy is certainly radiated in other directions as well. The lobe which contains maximum concentration of radiations is called major lobe of the radiation pattern. Major lobe is along the forward axis and gives the effect of a beam [1].

1.5.2 Minor Lobe

Any other lobe in the far field of antenna radiation pattern, except the major lobe is minor lobe. Minor lobe has far less concentration of radiations. They represent the radiations in unwanted directions normally. Like major lobe, minor lobe is also measured in decibel units and occurs for both transmit and receive conditions of the antenna. Minor lobe is also called the secondary lobe.

1.5.3 Side Lobe

A side lobe is adjacent to the main lobe and contains less power as compared to the main lobe.

1.5.4 Back Lobe

The lobe making a 180° angle with the beam of the antenna is known as back lobe. Or we can say that it is a three-dimensional portion of the radiation pattern that is directed away from the intended direction.

1.5.5 Surrounding Fields

Surrounding space around an antenna is termed as field and is classified into near field and far field [2].

1.5.6 Near Field

The region just close to the antenna is near field of the antenna. The portion of the near field which immediately surrounds the antenna is called reactive near field while the portion of the near field between the far field and the reactive near field is called radiative near field or Fresnel region.

1.5.7 Far Field

The distance that is larger as compared to the size of the antenna and larger than the wavelength is known as far-field region. It is the region where the angular field is independent of the distance from the antenna.

1.5.8 Directivity and Gain

Directivity of an antenna is the ratio of maximum radiation intensity to average intensity value of the radiations.

Gain is related to the radiation intensity in a particular direction and intensity of radiations by an isotropic antenna.

An antenna can have maximum gain equal to 1. Gain can be calculated by comparing the maximum power density of antenna under test (AUT) with a reference antenna of known gain.

1.5.9 Beam width

Beam width is the angle between the direction in which there is maximum intensity of beams and the direction containing half of the maximum intensity of beams. It is also described as angle between two points on the radiation pattern. As the beam width decreases, the side lobes increase.

Beam width can be categorized as

- Half power beam width (HPBW)
- First null beam width (FNBW)

HPBW is the angular beam width at a level when power is half or when E-field level is -3 dB. And the beam width between first nulls is known as FNBW.

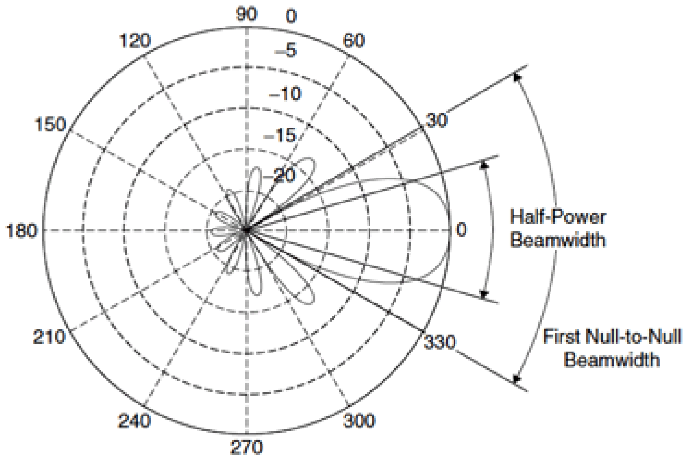


Figure-1.2: Half Power & First Null Beam Width

1.5.10 Bandwidth

Bandwidth is the range of frequencies over which an antenna works efficiently. For some classes of antenna, bandwidth is taken as ratio of upper to lower frequencies of acceptable operation [1].

1.5.11 Polarization

It is orientation of oscillations of electromagnetic waves in space. Polarization is the property of electromagnetic waves which describes the time varying direction and magnitude of the electric field vector.

Polarization phenomenon is categorized into

- Linear polarization.
- Circular polarization.
- Elliptical polarization.
- Linear polarization is further classified into
    - Horizontal polarization
    - Vertical polarization.

1.5.12 Beam Efficiency

Beam efficiency of minor lobe is the ratio of the beam area of the minor lobe to the beam area of the antenna. It is also known as stray factor.

1.5.13 Voltage Standing Wave Ratio (VSWR)

Voltage standing wave ratio is the measure of how well the impedance of the antenna is matched with the transmission line to which it is connected or it shows how well the load impedance is connected to the source impedance if the VSWR is smaller than maximum power is transmitted to the antenna.

1.5.14 Return Loss

These are merely the reflections in signal power caused by the insertion of a device in transmission line. It is the magnitude of reflection coefficient given in dB.

CHAPTER TWO

LITERATURE SURVEY

2.1 Ultra Wide Band

Taking into account the term "Ultra Wide Band" (UWB) as a comparatively new term to illustrate an innovative technology, this was brought into consideration in the early 1960’s [3]. It was referred to as an "impulse", “carrier-free”, or "base-band" technology in the orthodox description. Like a short pulse, the main idea is to generate, transmit and receive a very brief duration impulse of radio frequency (RF) energy. The pulse generally lasts a few tens of picoseconds to some nanoseconds. These pulses depict one to only a few cycles of an RF carrier wave; therefore, as for resultant waveforms, highly broadband signals can be obtained. Generally, it is challenging to figure out the real RF center frequency for a very short pulse; therefore, the phrase "carrier-free" arrives. A few mill watts is the total of the power delivered, which usually generates very low spectral power densities when coupled with the spectral spread. The Federal Communication Commission (FCC) bounds that the emission limits should not be greater than -41.3 dBm/MHz or 75 nW/MHz between 3.1GHz and 10.6 GHz [3]. The total power in this range is only 0.5 mW. These spectral power densities settle well underneath a receiver noise level. Standard UWB signals are presented in Figure-2.1 which includes major frequency spectra.

2.2 Introduction to Ultra Wideband Antennae

An antenna is a device that can also be deemed as an impedance transformer in between an input impedance and free space. A conventional radio broadcast antenna for amplitude modulation (AM) can be viewed as an

UWB antenna. The fractional bandwidth of an AM broadcast antenna is about 100 percent as it handles a frequency range of 535 kHz to 1705 kHz. On the contrary, the AM receivers are built and tuned in such a way that they receive distinctive narrowband channels of 10 kHz bandwidth. This is because of the modulation scheme. Consequently, the fractional bandwidth is only 0.6 to 1.9 percent. It is this fractional bandwidth over which the antenna has to operate in amplitude coherence. Conventionally, UWB antennae operate, generally, in a multi-narrowband scheme. Nevertheless, the modern UWB antennae must be capable enough to transmit and receive a single coherent signal that handles the whole operating bandwidth. Furthermore, a UWB antenna is expected to receive or transmit all desired frequencies in the same time. As a result, across the operating bandwidth, the radiation patterns and impedance matching should be unvaried.

Ideally, an UWB antenna has zero dispersion and a fixed phase center. In actual UWB antennae, finite dispersion can be compensated only if the waveform is foreseeable. Log periodic antenna can be counted among the examples of a dispersive antenna [3]. The log-periodic antenna employs its small-scale parts to radiate the high frequency range whilst its large-scale parts are dedicated to radiate low frequencies. This antenna produces a dispersive signal. In addition, numerous waveforms will be produced beside different azimuth angles.

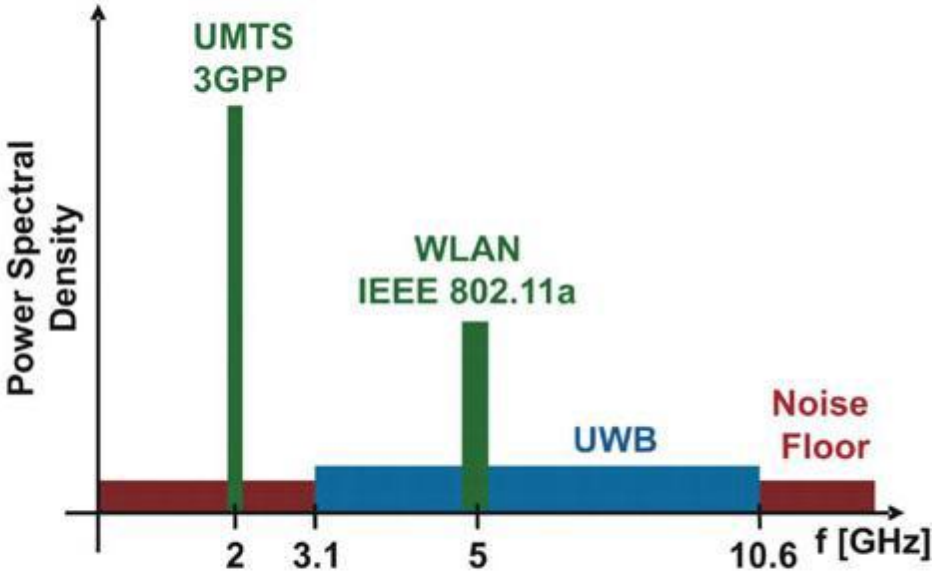


Figure-2.1 UWB Spectrums

Ultra wideband antennae can be brought into use for indoor environment applications having short-range communications for high data rates or outdoor environment applications which have long-range communications but for very low data rates [3-4].

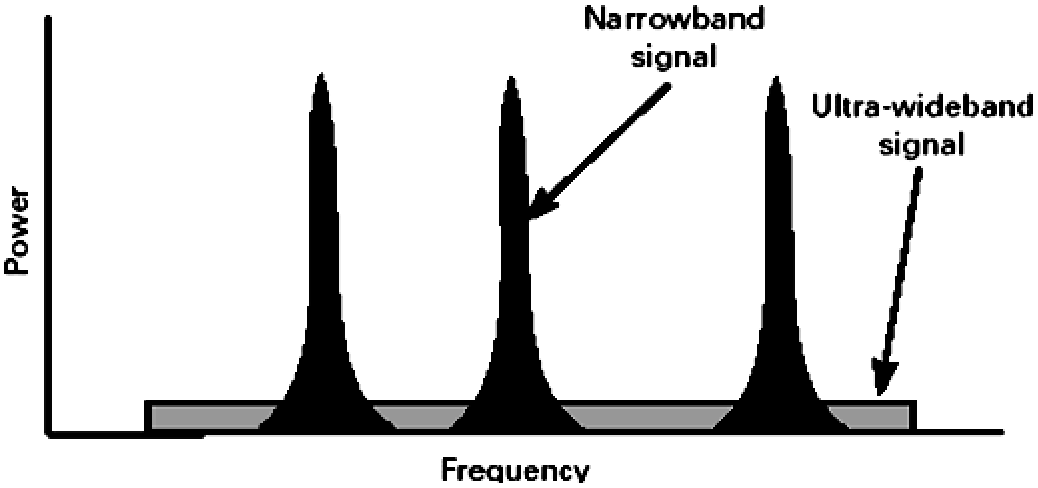


Figure-2.2 Narrow band and wideband signals

2.2.1 Working of UWB Technology

The UWB technology sends small digital pulses which are of very short duration (intervals of 10 Pico-seconds) through a large number of frequency channels simultaneously.

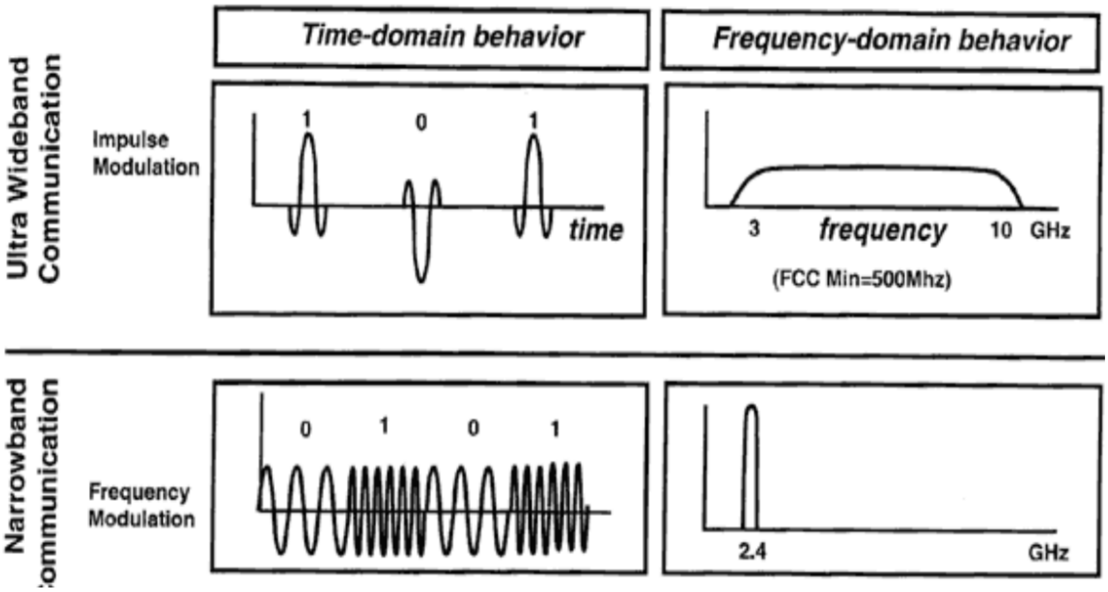
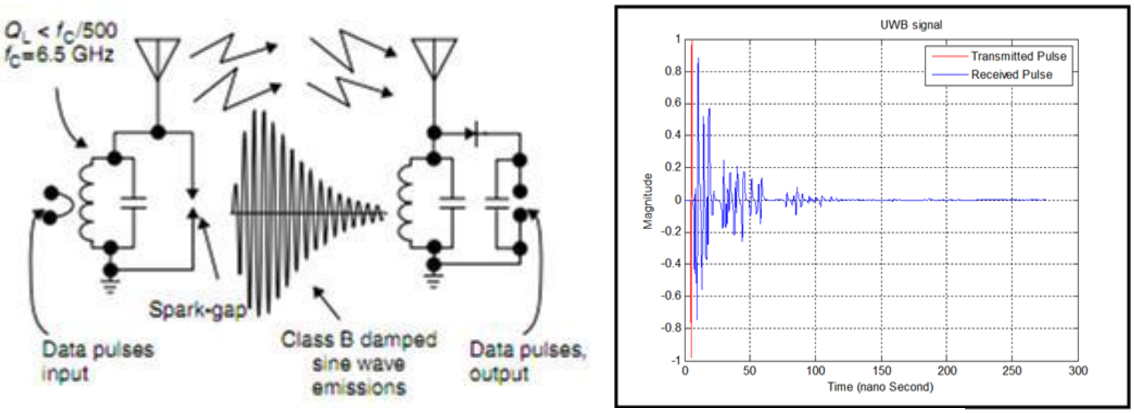


Figure-2.3 Working of UWB

There are numerous ways in which the signal used in UWB can be generated. One of them could be through using the sources of narrowband pulses and letting them through from a band pass filter. This is one of the orthodox methods. Figure- 2.4 (a) shows the relationship between the modern concepts of UWB and the roots of first wireless communications though it does not show the full working of the UWB system.



(a) (b)

Figure-2.4(a) UWB and old wireless technology (b) magnitude vs. time graph

2.2.2 Advantages of Ultra Wide Band Technology

Ultra wideband has emerged as a very promising technology with numerous features. Some of them are listed as follows:

Due to their short time pulse span, UWB waveforms have relatively large bandwidths. For instance, fairly high data rate performance can be offered by UWB pulses in communications in multi-user network applications. Even for applications related to radars, very good range resolution and accurate distance and placement measurement abilities can be attained by the same pulses [5].

Short span waveforms have comparatively fine immunity to multi-path cancellation effects as noticed in handheld cell phones and indoor environments. Multi-path cancellation effect happens when a high power reflected wave eliminates the direct path signal. Usually the reflected wave turns up out of phase when compared with the direct path signal. As a result, the receiver receives a reduced amplitude response. In the UWB signal, no cancellation occurs due to its very short pulse feature. This is because the direct path passes before the reflected signal turns up. For that reason the handheld wireless devices are, specifically, best suited for UWB technology to put into action [5].

Very short pulse duration, in the time domain, is equivalent to very large bandwidth in the frequency. Energy density, due to the large bandwidth, can be quite low. This low energy density can be converted into even low probability of detection (LPD) RF signature. This LPD signature is of use in several military applications like covert communication and radars etc. Furthermore, minimal interference to proximity systems as well as minimal RF health hazards is produced by LPD signature. Due to its low energy density and pseudo-random (PR) characteristics of transmitted signal, UWB signal is noise-like. Consequently, this feature enables the UWB system to refrain from interference to existing radio systems. As said earlier, these characteristics are of high importance to, both, military as well as commercial applications [5].

Low design complexity and low cost are the best features of the UWB systems. These advantages come up from the baseband nature of the signal transmission. Short time domain pulses are capable of propagating even without needing an extra RF mixing process when compared with traditional radio systems. This leads to the less complex nature of the design structure. Additionally, UWB systems can be made very close to “all-digital” with minimal RF or microwave electronics leading to minimum cost of the system [5].

2.2.3 Disadvantages of Ultra Wide Band Technology

Engineering is all about tradeoffs. No single technology exists in this universe which, alone, is good for everything. Likewise, UWB has numerous advantages but still it is, unfortunately, among those technologies which have certain disadvantages too. The disadvantages are listed as under:

Interference with GPS (Global Positioning satellite) is one the disadvantages observed with the UWB technology. GPS, at the moment, have more than 10 million users and its basic applications are used for public safety such as aircraft flight and approach guidance etc. UWB brings up a problem to GPS since their frequencies overlap and GPS signal is highly sensitive to interference.

The output power of the UWB systems is limited due to its overlapping frequency bandwidth with other radio systems. Usually the power cannot be transmitted for above one kilometer range with high gain antenna and for the regular antenna, the limit decreases to ten to twenty meters.

As UWB is relatively a new technology, therefore, setting up the UWB systems worldwide would disturb the economic balances of the regions. Moreover, the existing cable setups will be counted among obsolete equipment and the investors will have to invest a relatively huge sum to deploy the new technology.

2.3 Previous Work on UWB

There are numerous and well-known methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of various impedance matching and feeding techniques, the use of multiple resonators, and the use of slot antenna geometry. A novel meandered patch antenna with achievable impedance bandwidth of greater than 39% has been demonstrated. A novel meandered H-shape patch is investigated for multiband application. Many techniques have been reported to reduce the size of micro strip antennas at a fixed operating frequency. In general, micro strip antennas are half wavelength structures and are operated at the fundamental resonant mode TM_{01} or TM_{10}, with a resonant frequency given by (valid for a rectangular micro-strip antenna with a thin microwave substrate)

$$f \cong \frac{c}{2L\sqrt{\varepsilon_r}}$$

Where c is the speed of light

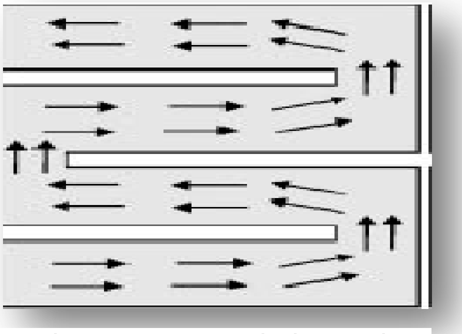


Figure-2.5 Meandering path

L is the patch length of the rectangular micro strip antenna, and

ε_r is the relative permittivity of the grounded microwave substrate.

Meandering the excited patch surface current paths in the antenna's radiating patch is an effective method for achieving a lowered fundamental resonant frequency for the micro strip antenna. For the case of a rectangular radiating patch, the meandering can be achieved by inserting several narrow slits at the patch’s non radiating edges. It can be seen in Figure-2.5 that the excited patch’s surface currents are effectively meandered, leading to a greatly lengthened current path for a fixed patch linear dimension. This behavior results in a greatly lowered antenna fundamental resonant frequency, and thus a large antenna size reduction at a fixed operating frequency can be obtained [6].

The rapid development of electronics and wireless communications led to great demand for wireless devices that can operate at different standards such as the universal mobile telecommunications system UMTS, Bluetooth, wireless local-area network (WLAN) and also satellite communications. However, frequency steering capability shows that it is difficult to keep the frequency fixed without any changes. In addition, compact small size is a demand factor for several applications as mobile devices. These two requirements have triggered research on the of compact and single or multiband antennas operation. Micro strip patch antennas are widely used because of their many merits, such as the low profile, light weight and conformity. However, patch antennas have a main disadvantage i.e. narrow bandwidth. Researchers have made many efforts to overcome this problem and many configurations have been presented to extend the bandwidth. Small-size multi-band micro strip antennas have attracted much attention due to the dramatic growth in wireless communications. Several design approaches based on different structures have been proposed for single-feed dual-frequency operation. Capacitive loading of micro strip patch antennas has been proposed for dual-band operation, where the chip capacitor is used to reduce the antenna size. Compact dual band planar inverted-F antennas (PIFA) have been reported in and are achieved with etched slots in the radiating element [6].

CHAPTER THREE

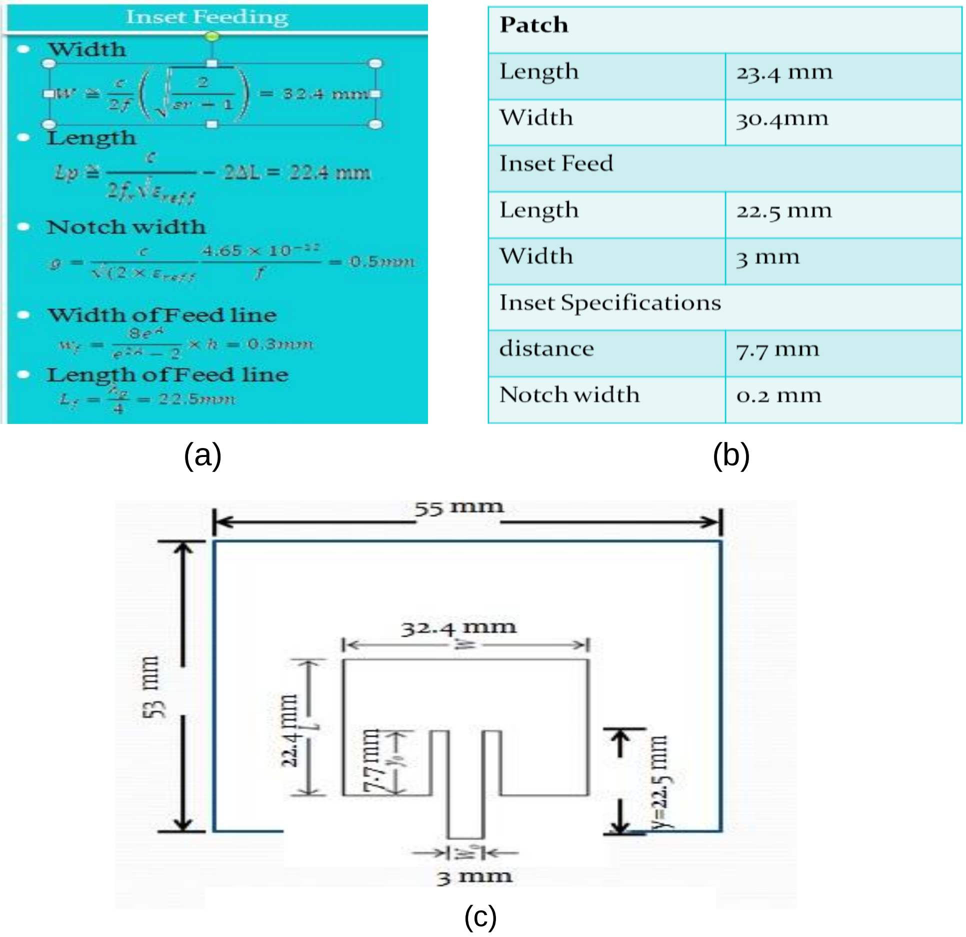
Design Process

3.1 Design and development

3.1.1 Step 1- Designing at center frequency 3 GHz

In the first step antenna was designed at center frequency of 3 GHz using inset feeding technique. The design process involved calculation of antenna dimensions [8].

The designed antenna showed promising results for return loss, VSWR and gain complying with the international standards. This design when applied with band width enhancement techniques to achieve the desired band the results were not very satisfactory. Figure-3.1 shows the dimensions;



Inset Feeding

- Width
  $W \cong \frac{c}{2f}\left(\sqrt{\frac{2}{\varepsilon r + 1}}\right) = 32.4\ \text{mm}$
- Length
  $Lp \cong \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L = 22.4\ \text{mm}$
- Notch width
  $g = \frac{c}{\sqrt{(2 \times \varepsilon_{reff}}} \frac{4.65 \times 10^{-12}}{f} = 0.5mm$
- Width of Feed line
  $w_f = \frac{8e^A}{e^{2A} - 2} \times h = 0.3mm$
- Length of Feed line
  $L_f = \frac{\lambda_g}{4} = 22.5mm$

Patch	
Length	23.4 mm
Width	30.4mm
Inset Feed	
Length	22.5 mm
Width	3 mm
Inset Specifications	
distance	7.7 mm
Notch width	0.2 mm

(a) (b)

(c)

Figure-3.1(a) Inset Feeding parameters (b) Patch parameters
(c) Design centered at 3 GHz

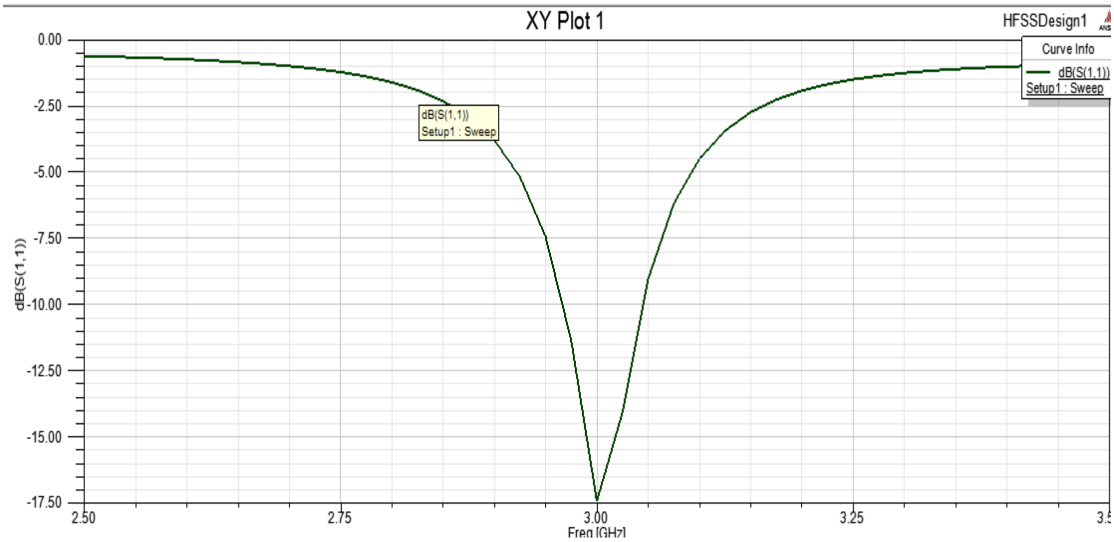


Figure-3.2: Simulated Return Loss For 3 GHz

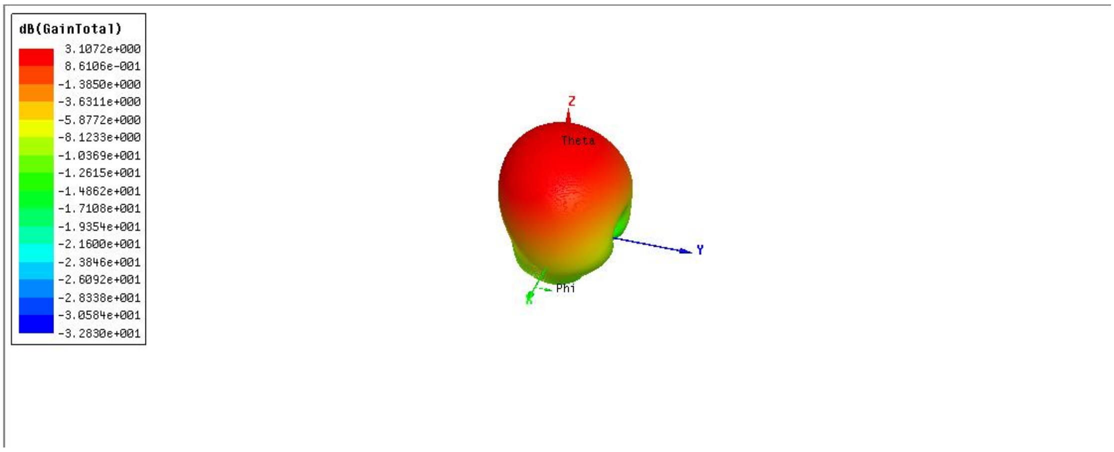


Figure- 3.3: Simulated 3D Gain at 3 GHz

Hence it was necessary to debug the design and look for the error in design.

3.1.2 Step 2-Design at center frequency 5.78 GHz

The next step was to debug the design so the literature was reviewed on said problem which lead to solution that center frequency for UWB antennas better be selected by taking the geometric mean of the desired band [9]. The modified design consists of rectangular patch antenna centered at 5.78 GHz. The calculations of center frequency design are done using the following;

1) Selection of substrate depending upon center frequency using formula as:

$$h \geq 0.06 \frac{\lambda_{air}}{\sqrt{\epsilon_r}}$$

We will use FR4 for our project, now for center frequency solving above equation we got:

1.6 mm≥1.36 (choice of substrate validated for 5.78GHz to be central freq)

2) Calculation of patch width using formula as under

$$W \cong \frac{c}{2f}\left(\sqrt{\frac{2}{\epsilon_r + 1}}\right) = 21.4 \text{ mm}$$

3) For width of patch calculated above the ε_{reff} is calculated using formula as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W_p}\right]^{-1/2} \quad \text{for } W_p / h > 1$$

=4.348

4) ΔL, the normalized extension of length is calculated as:

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W_p}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W_p}{h} + 0.8\right)}$$

=0.747mm

5) Calculate Patch Length Using Formula as:

$$L_p = \frac{v_o}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L$$

= 16 mm

6) The impedance matching is done with micro-strip line feed of 13x3 mm at 50 Ohms.

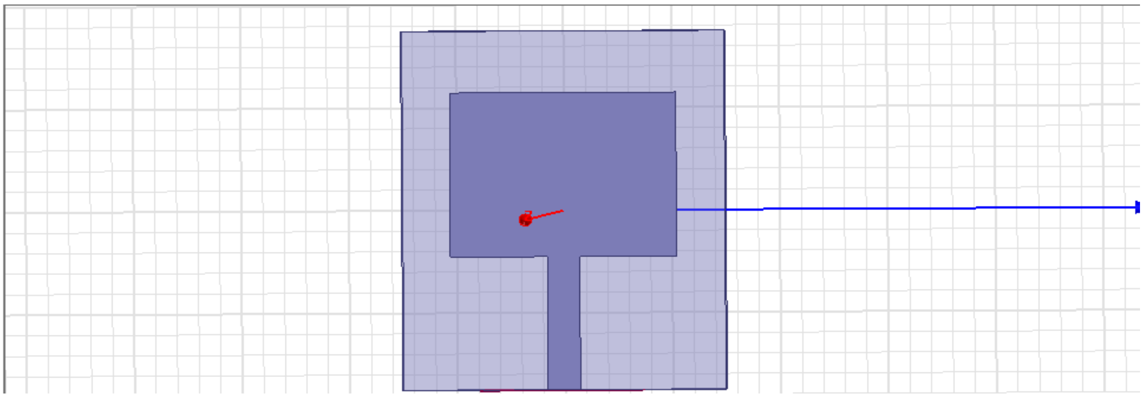


Figure-3.4: Modified Design Centered at 5.78 GHz

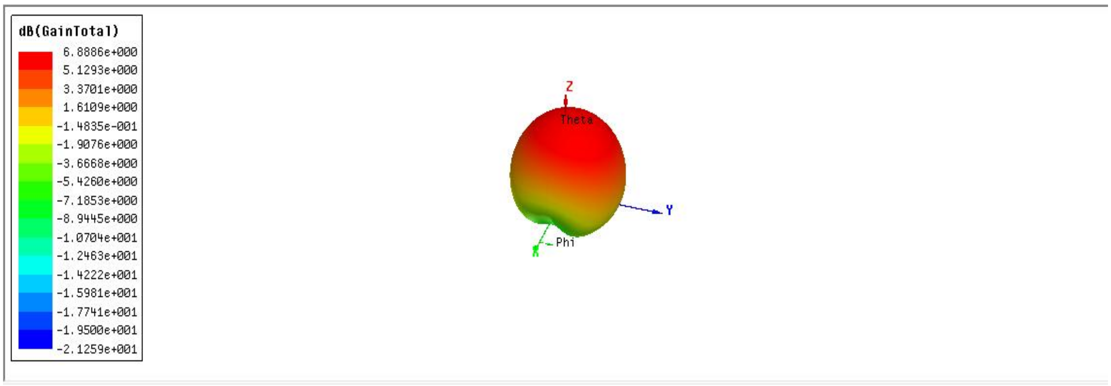


Figure-3.5: Simulated 3D Gain For centre Frequency design

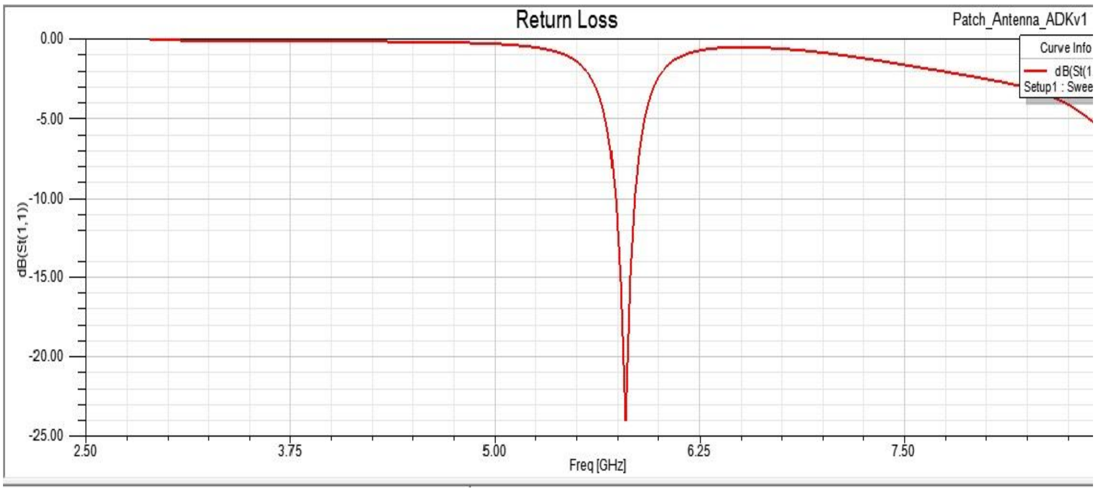


Figure-3.6: Simulated Return Loss for 5.78 GHz design

3.2 Step 3-Bandwidth enhancement

3.2.1 Introduction of meandering slots to patch

The Bandwidth of an antenna can be significantly enhanced by placing slot inside the patch or the top layer [10]. This technique can be efficiently used while carefully chosen slot geometry. In our design we have chosen meandered shape slot placement for its obvious advantage of increasing the current path and thereby aiding to overall increase in electrical size of the antenna. The increase in current stay duration inside antenna lowers the resonance frequency resulting in bandwidth increase as a whole. The greater the length of the slot more enhancement of bandwidth can be achieved. But gain puts limitation to slot length on the patch. As for slot placement, part of the patch has to be taken out of its geometry which negatively affects the gain of antenna. After placing number of slots at various locations on the patch the selection of meandered slot geometry was done and only one slot was optimized of best possible bandwidth achievement while maintaining a gain that adhered to the gain bandwidth criteria of international standards. The Optimization of no of slits in the design is shown in Figure- 3.7;

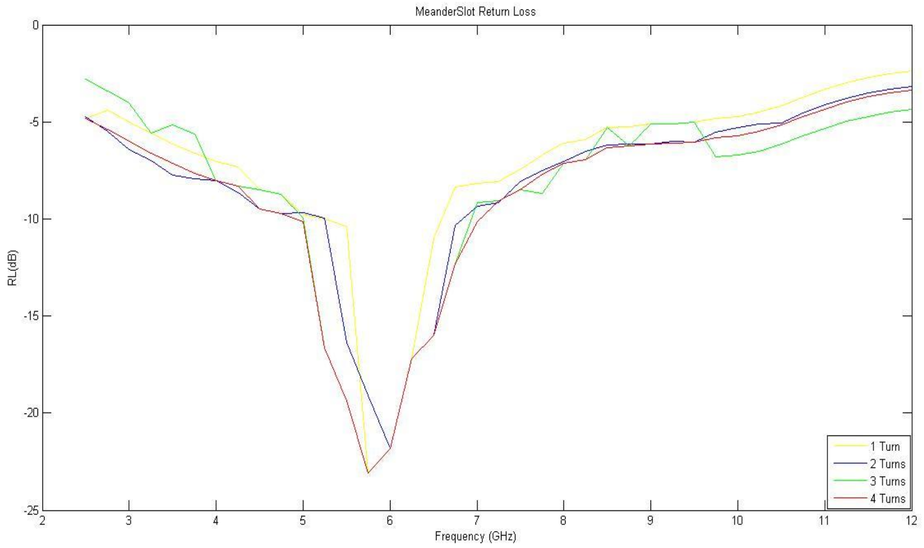


Figure-3.7: Parametric Analysis with different no of Turns

The final optimized design for this step and results of slot placement are shown in Figure-3.8;

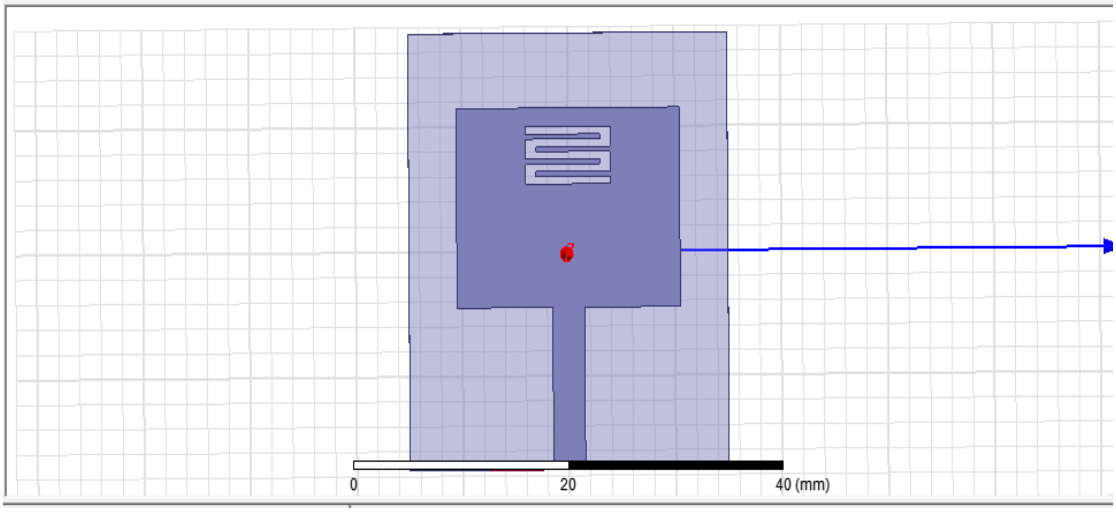


Figure-3.8: Design with Meandered slot of 4 turns

No of Turns in Slot	Lower Freq(F_L) GHz	Higher Freq(F_H) GHz	Bandwidth(F_H-F_L) GHz
1	5.71	5.82	0.11
2	5.49	6.17	0.68
3	5.22	6.43	1.21
4	4.93	7.06	2.76

Table-3.1: Change in Bandwidth with Slot turns

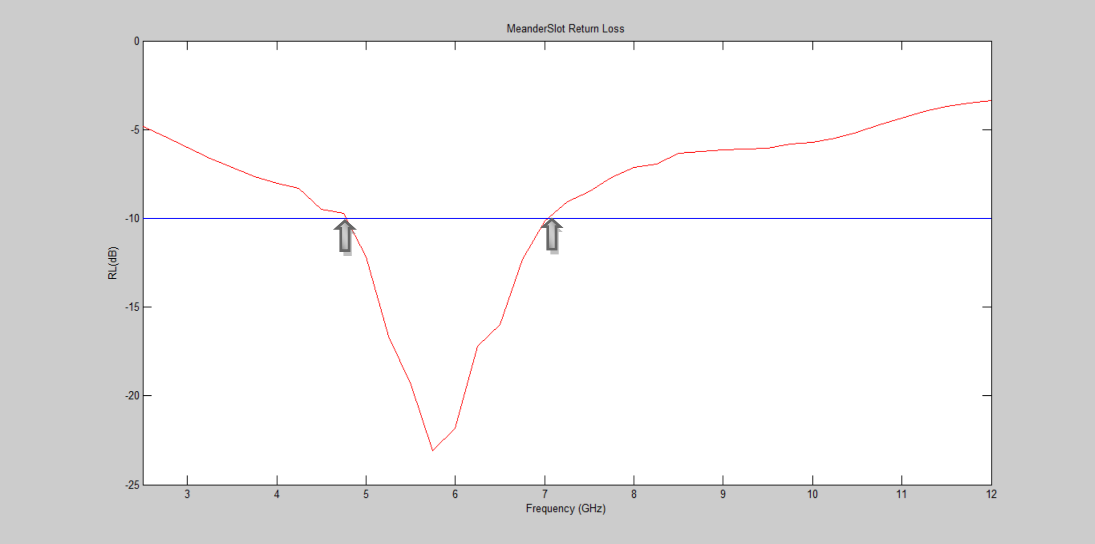


Figure-3.9(a) Simulated Return Loss for Meandered Slot Design

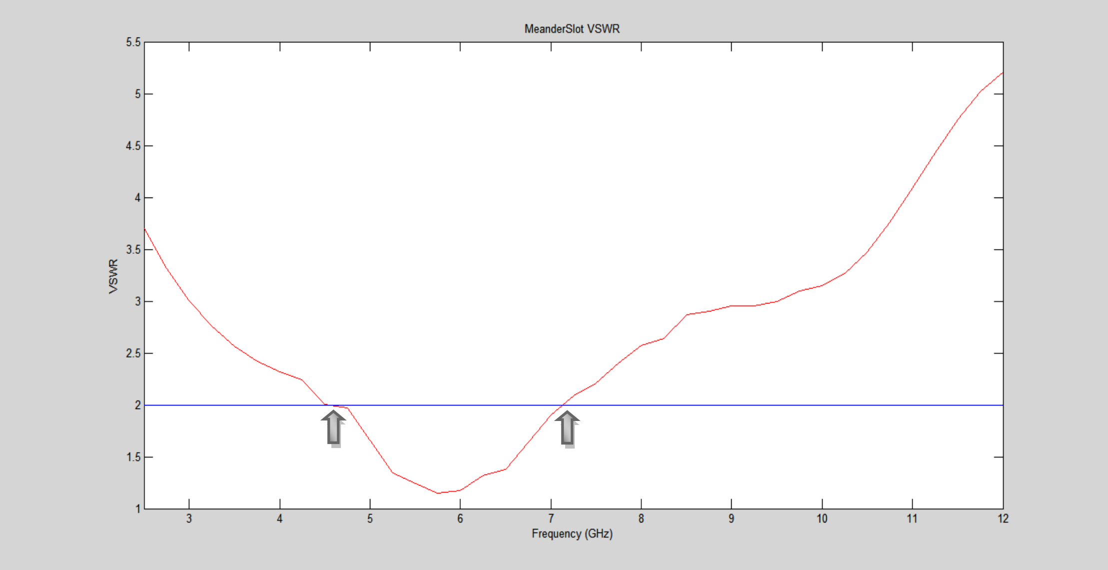


Figure-3.9(b) Simulated VSWR for Meandered Slot Design

3.2.2 Edge Truncation

Bandwidth extension can also be achieved by truncating the patch antenna diagonally at the lower edges. This technique has an effect on the antenna geometry which leads to a discontinuity in the micro-strip line. Cutting corners of RMSA will induce more discontinuity in the flow of wave and increasing reflections will ultimately results in improved bandwidth [13]. To apply this concept the design was tested with different dimensions of truncation at lower corners of the patch and finally optimizing for maximum bandwidth that the technique could provide. The parametric study for different truncated slot dimensions is shown in Figure- 3.10;

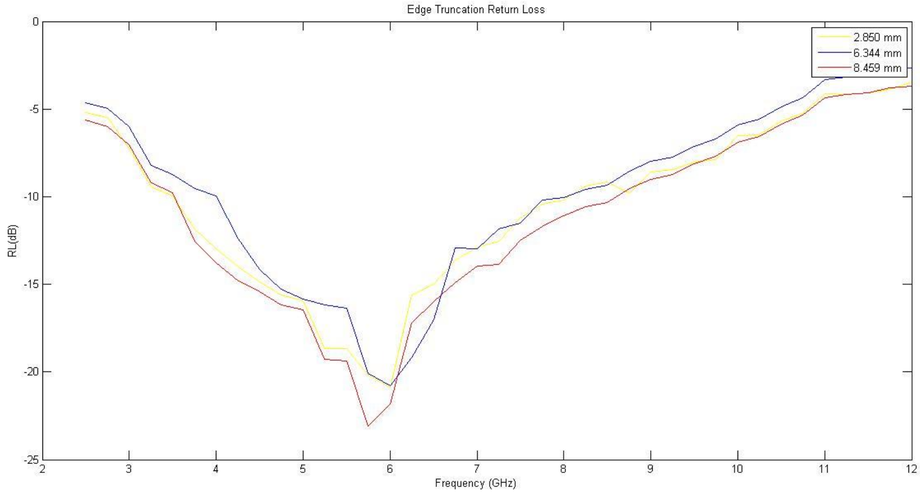


Figure-3.10: Parametric Optimization of Truncated Edges

The design and results thus obtained for the technique are given below;

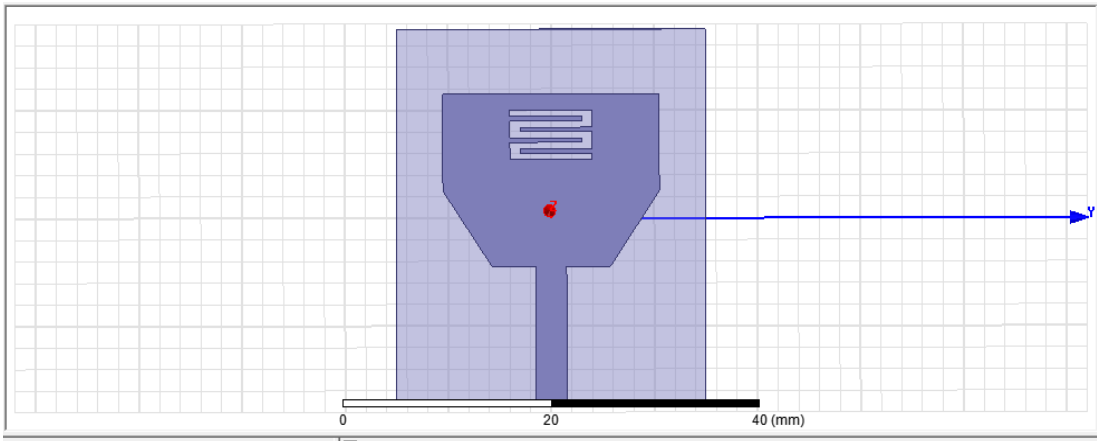


Figure- 3.11: Edge Truncated Design

Length of Cut (mm)	Lower Freq(F_L) GHz	Higher Freq(F_H) GHz	Bandwidth(F_H-F_L) GHz
2.850	4.24	7.59	3.35
6.344	3.87	8.09	4.22
8.459	3.63	8.66	5.03

Table-3.2: Bandwidth Increase with Length of Cut

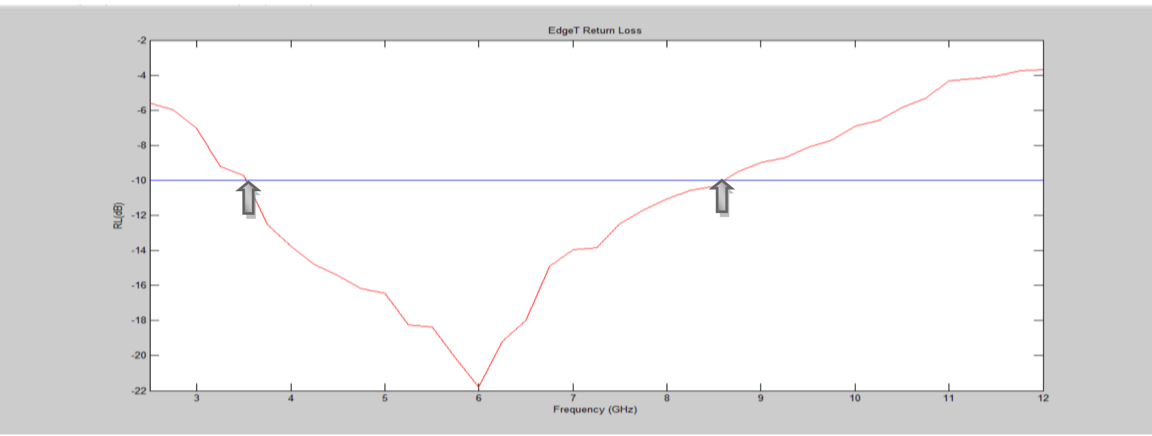


Figure-3.12(a) Return Loss for Truncated Edges

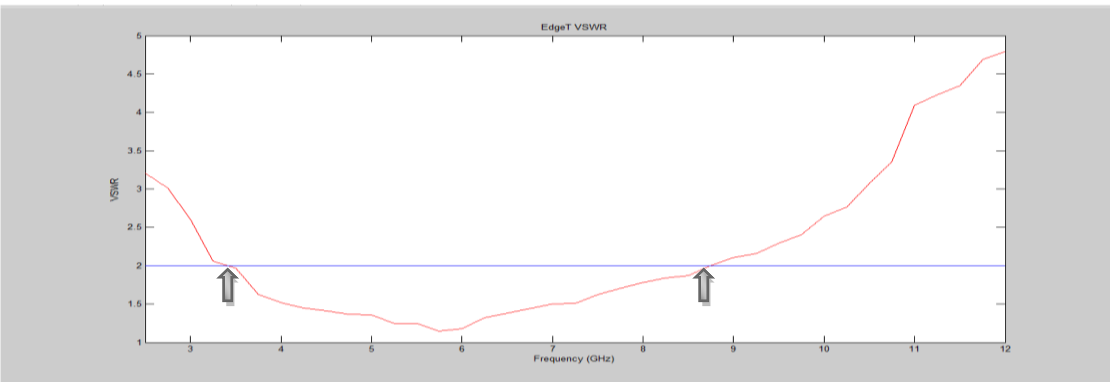


Figure- 3.12(b): VSWR for Truncated Edges

3.2.3 Ground plane reduction

The capacitive coupling between the patch antenna and the ground plane is tuned to achieve a wider impedance bandwidth [14]. The critical factor which effects antenna working parameters is the distance between the top edge of ground plane and the bottom edge of the patch thus the distance has to be optimized for the best possible results. The optimization process results are shown in Figure- 3.13;

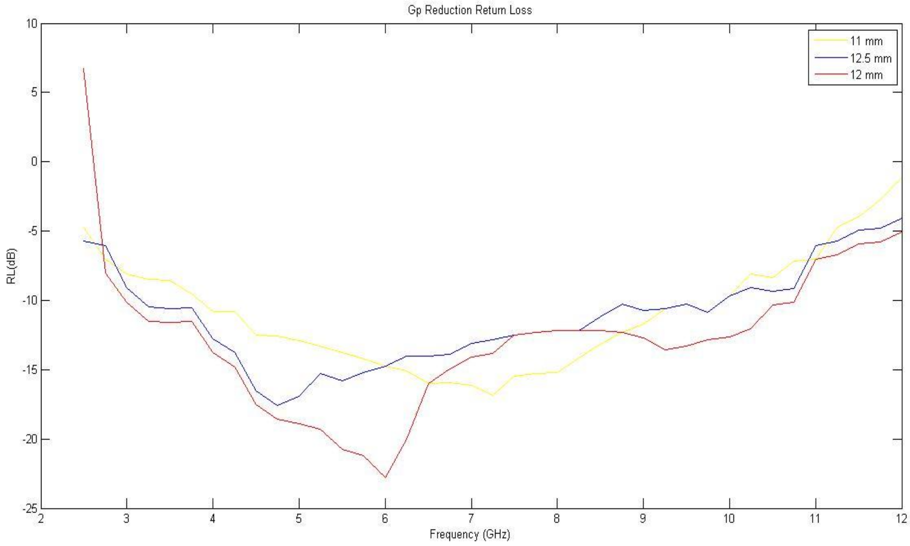


Figure-3.13: Optimization of Ground Plane

The Design shape and results thus obtained after optimization for this technique on our design are given below;

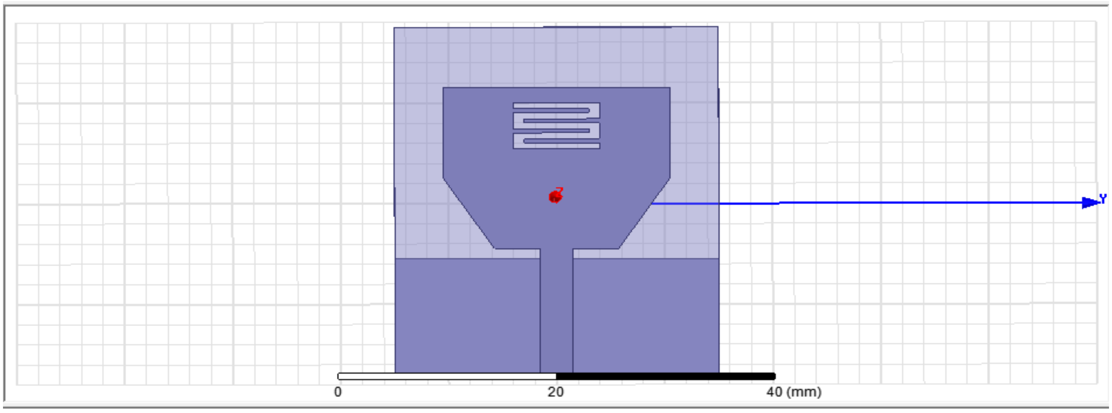


Figure-3.14: Design with reduced Ground Plane

Size of Reduced Ground Plane(mm)	Lower Freq(F_L) GHz	Higher Freq(F_H) GHz	Bandwidth(F_H-F_L) GHz
11.5	3.25	9.19	5.94
12	2.98	10.77	7.79
12.5	3.15	10.62	7.47

Table-3.3: Effect on Bandwidth by reducing Ground plane

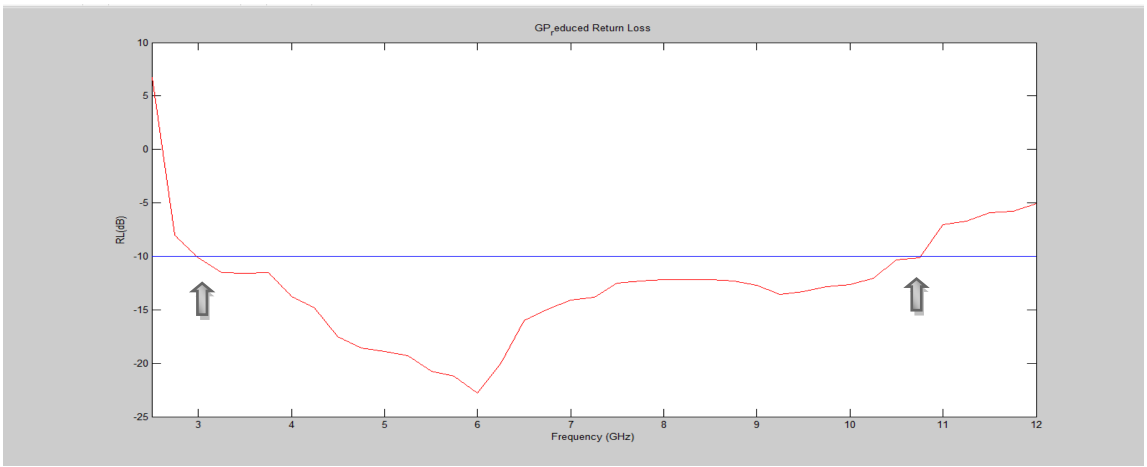


Figure- 3.15(a): Return Loss for Partial Ground Plane

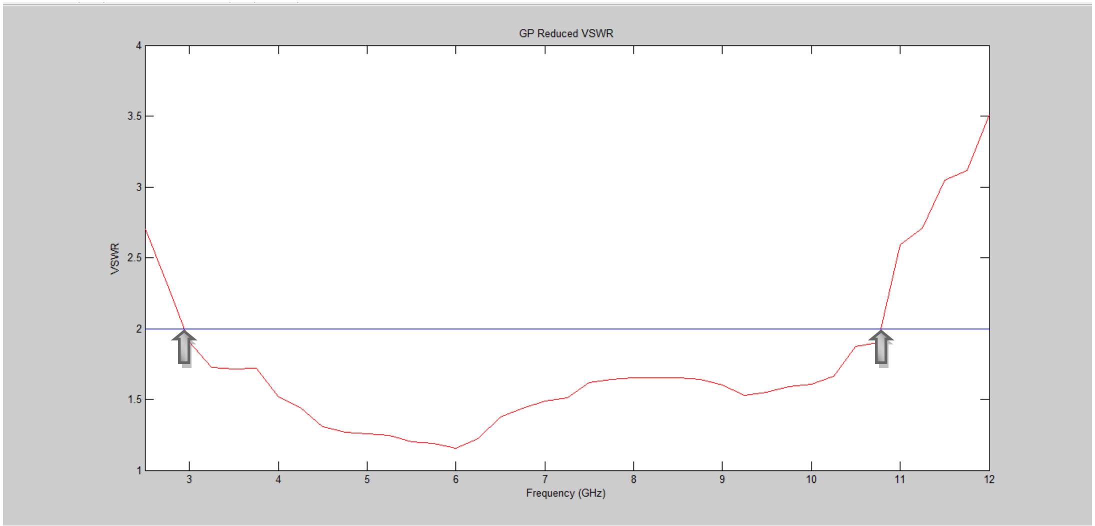


Figure-3.15(b): VSWR for Partial Ground Plane

3.2.4 Slot in Ground Plane

Finally to improve the results for impedance bandwidth a vertical notch is introduced on the partial ground plane to satisfy the 10 dB return loss requirement between the frequency region of 3.1 GHz and 10.6 GHz. The final design and results thus obtained are shown below;

Figure-3.16: Vertical Slot in Ground Plain to improve overall Return Loss

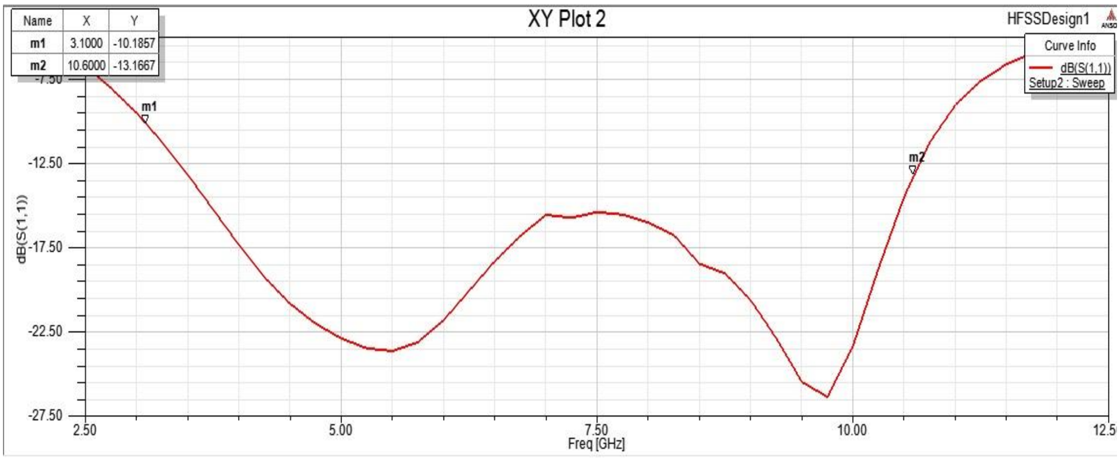


Figure-3.17(a): Return Loss after Vertical Slot in Ground Plane

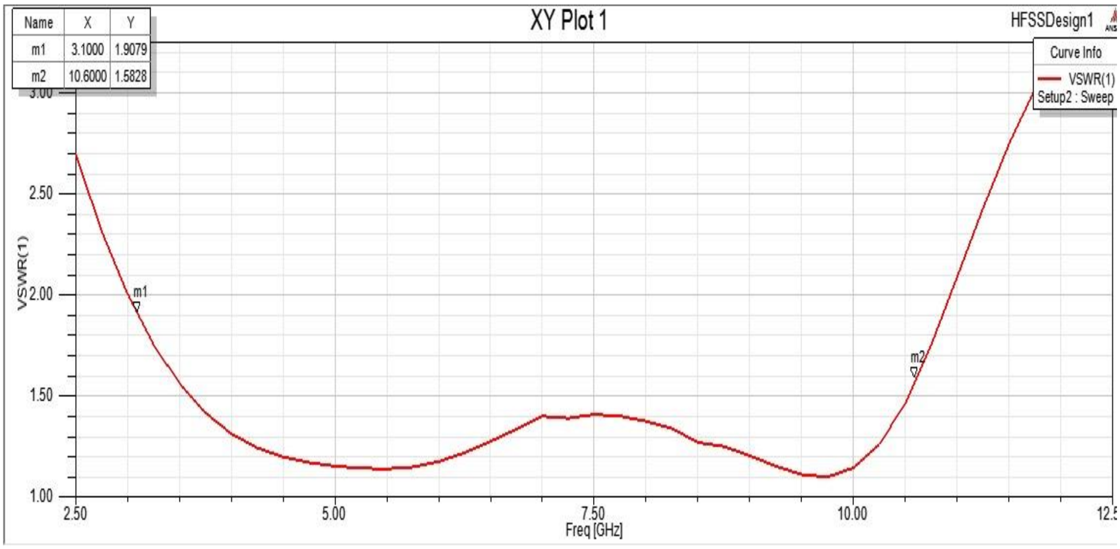


Figure-3.17(b) VSWR after Vertical Slot in Ground Plane

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Results

The Project comprised of designing an ultra wide band antenna on the basis of knowledge of principles of Electromagnetic. The design is miniaturized and conforms to international standards for operational working of a radiating device. Bandwidth enhancement of patch antennae is a process that demands careful and flawless procedures and using one single technique to cover the entire 7.5 GHz of Ultra Wide bandwidth is practically limited. This project has used several bandwidth enhancement techniques in combination and results demonstrate an operational antenna for ultra wide band applications. The final optimized design has been fabricated and tested at SMRIMMS for comparative analysis between simulated and actual results and are found to be in agreement. The results are mentioned in upcoming paragraphs along with the respective figures required.

4.1.1 Return Loss

International criteria for a working radiation device states that it should have return loss or S11 value less than -10 dB for the range of operation specified. From Figure-4.1 it can be clearly seen that both simulated and tested results for hardware design are in good agreement and define the impedance bandwidth as per the required international standards.

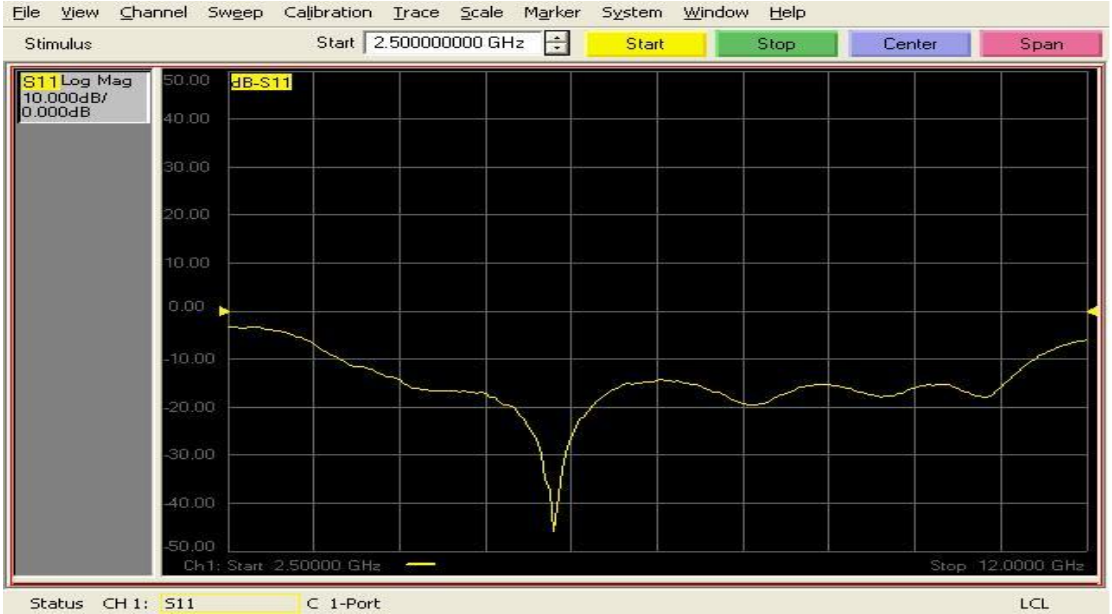


Figure-4.1: VNA Result for Return Loss of Fabricated Design

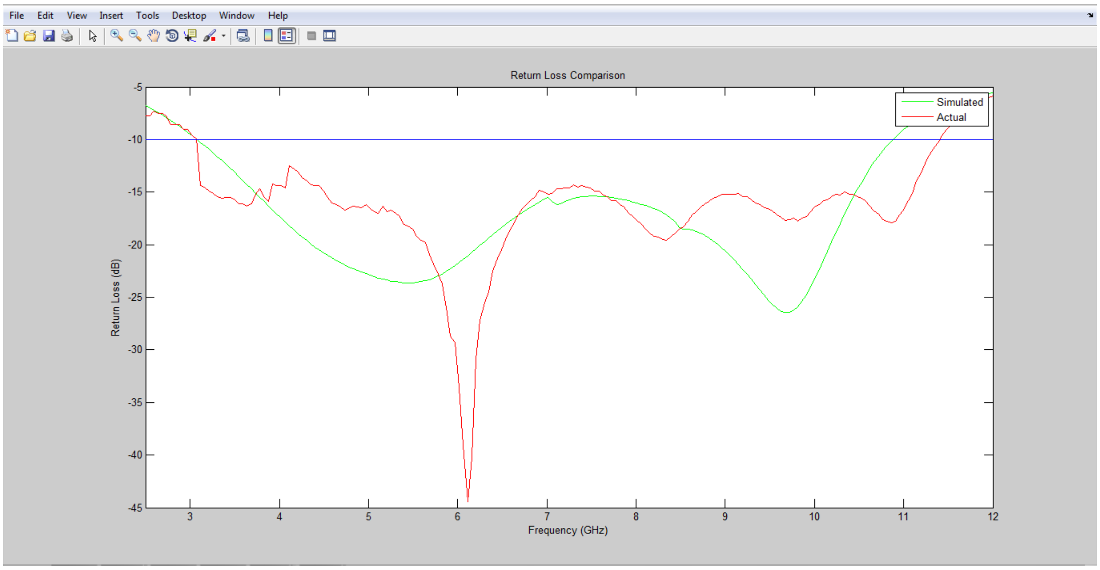


Figure-4.2: Comparison of Simulated and Actual Return Loss

4.1.2 VSWR

VSWR for an antenna is specified to be less than 2 as per the international standards of operating bandwidth. This design reflects good agreement of this performance parameter between simulated results as well as the tested hardware results of VNA. Figure- 4.3 shows the results;

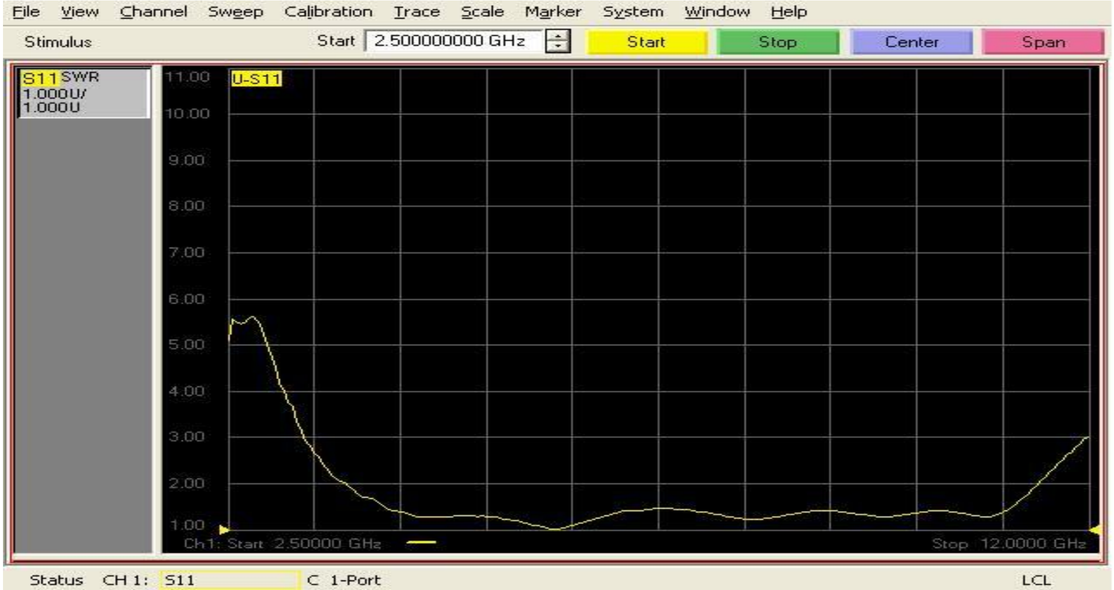


Figure-4.3: VNA Result for VSWR of Fabricated Design

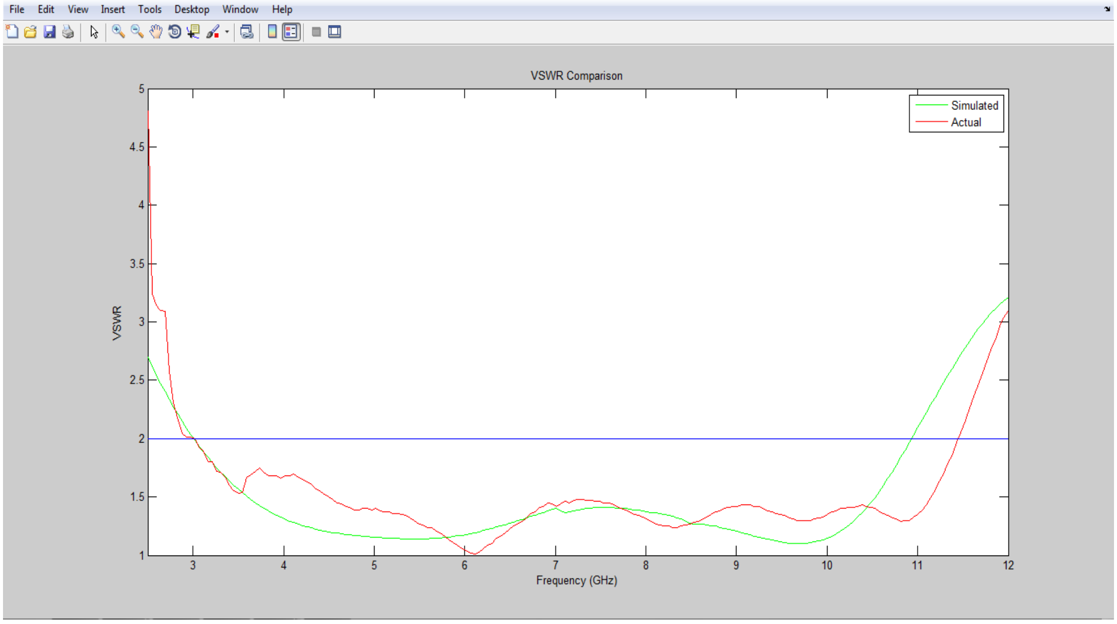


Figure-4.4: Comparison for VSWR Simulated and Actual

4.1.3 Gain

The gain obtained for the design is reflected in Figure-4.5. The working Bandwidth is well covered as far as gain of the design is concerned.

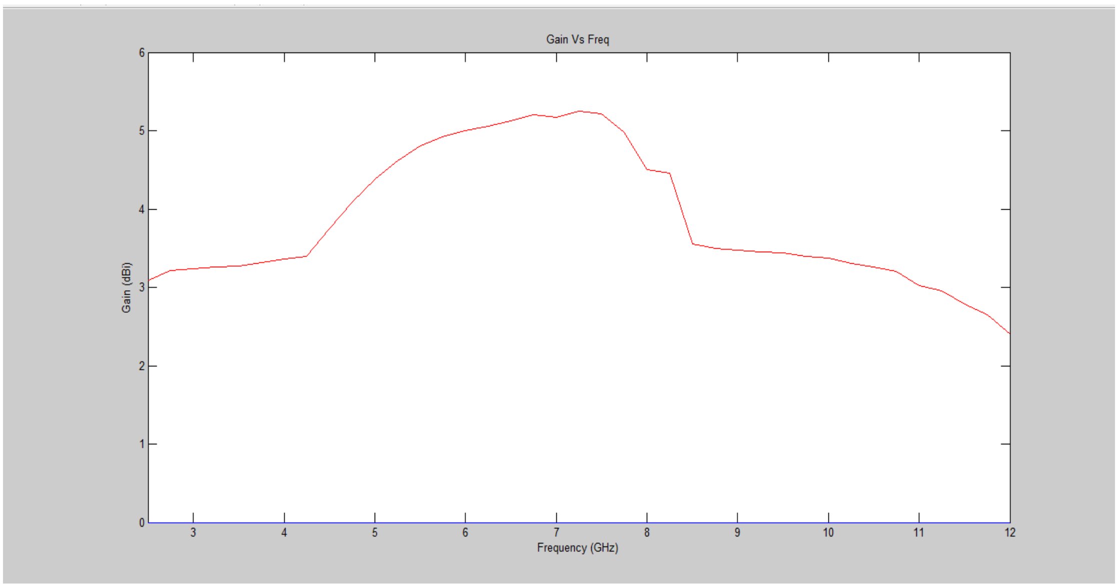


Figure-4.5: Simulated Gain of Final Design

4.1.4 Input Impedance

The input impedance of designed is shown in Figure-4.6. The impedance matching of real and imaginary components reflects that for entire bandwidth good matching exists for the device.

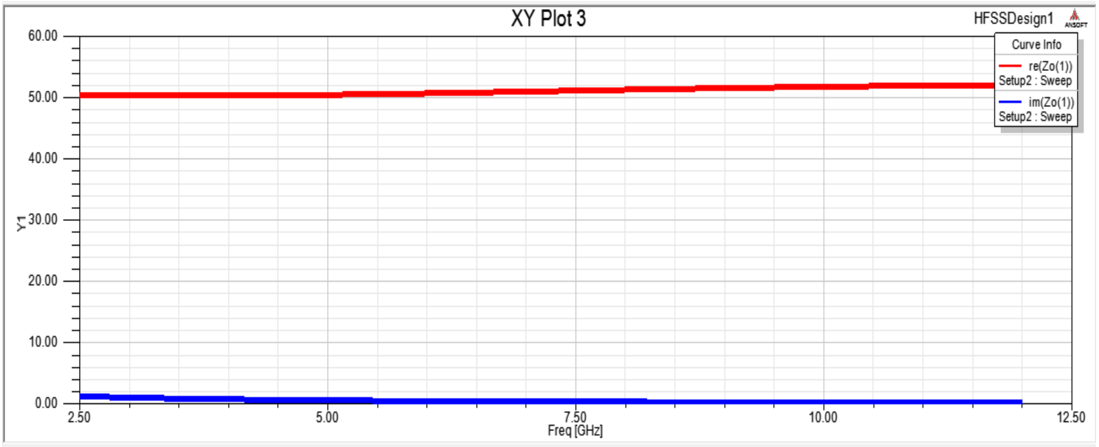


Figure-4.6: Impedance Matching at Input

4.1.5 Radiation Pattern

It is observed that, the antenna exhibits an omni directional pattern in the *H*–plane and a quasi omni directional pattern in the *E*–plane. Figure-4.7(a),(b),(c)) shows variation of the antenna gain versus frequency at 3.5, 5.5 and 6.5 GHz

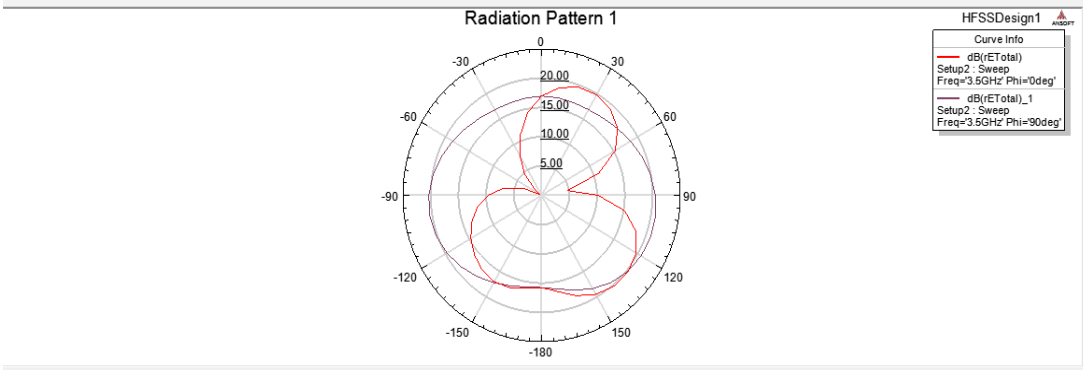


Figure-4.7(a): Radiation Pattern at 3.5 GHz

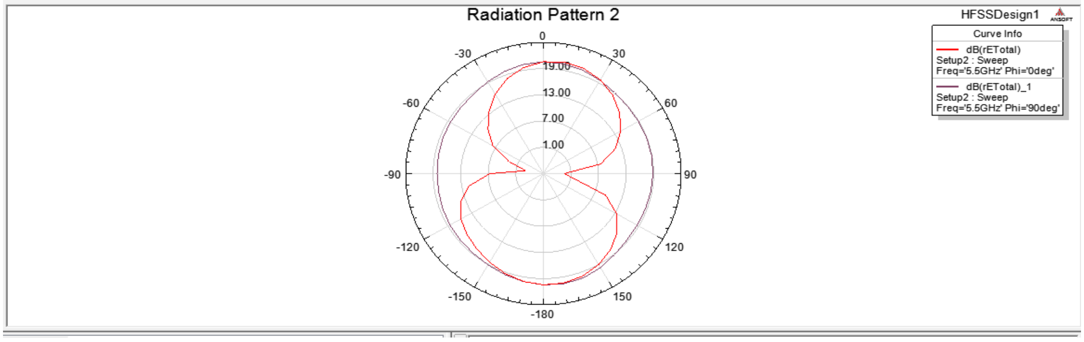


Figure-4.7(b): Radiation Pattern at 5.5 GHz

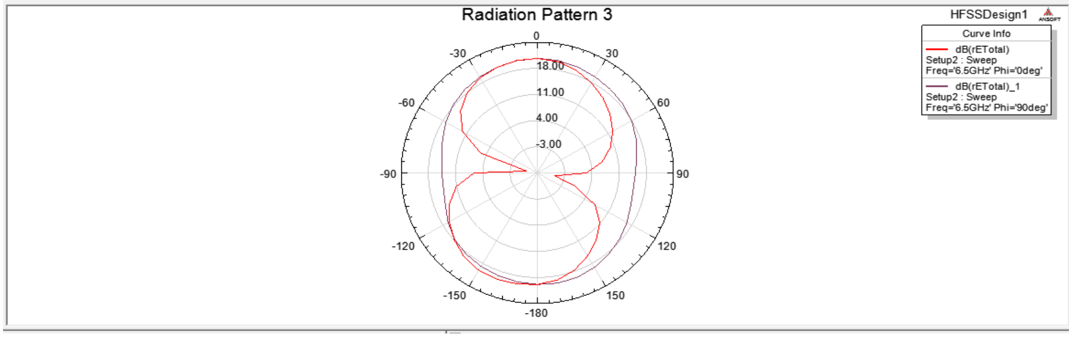


Figure-4.7(c): Radiation Pattern at 6.5 GHz

4.1.6 Group Delay

Group delay is another important criterion to determine the performance of UWB antenna. The antenna should be able to transmit the electrical pulse with minimal distortion. The calculated group delay of the proposed antenna is portrayed in Figure- 19. The variation is less than 0.4 ns over the frequency band from 2.5 to 12 GHz. It shows that the antenna has low-impulse distortion and is suitable for UWB applications.

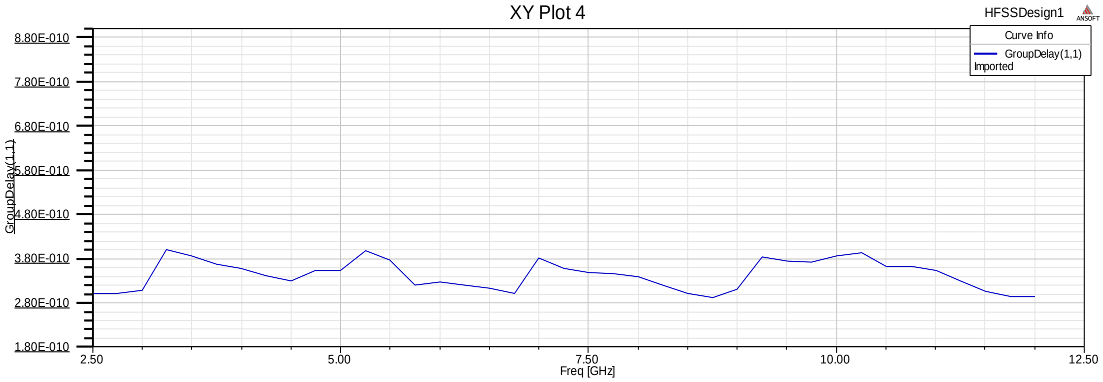


Figure-4.8: Group Delay

CHAPTER FIVE

Recommendation for Future and Conclusion

5.1 Recommendations for Future Work

So far in this project the results obtained are much satisfactory. As in everything there is room of improvement and melioration, therefore, still, several changes can bring positive output in this project.

To avoid interference with other bands notch can be placed in design as required.

Improving the gain by use of better substrate material can also be considered.

Bandwidth can further be enhanced using different feeding technique such as CPW etc.

5.2 Conclusion

In this report, Meandered slot UWB antennae are proposed which operate on the entire Ultra wideband range (i.e. 3.10GHz to 10.6GHz). UWB is achieved by adding a meandered slot to patch, edge truncation and ground plain reduction. The proposed antenna has huge fractional bandwidths of over 120%, is simple, easy to fabricate, cheap, compact in size and can be used in multiple UWB applications including UWB wireless communication systems and Radars. The simulations were performed using High Frequency Structure Simulator. The proposed antennae were then fabricated on low cost FR4 substrate for verification of the simulated results which appear to be in good agreement.

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