ULTRA WIDEBAND HIGH GAIN ANTENNA WITH BAND NOTCH CHARACTERISTICS

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ABSTRACT

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Ultra-wideband (UWB) antennas are one of the most important elements for UWB systems. With the release of the 3.1 - 10.6 GHz band, applications for short-range and high-bandwidth handheld devices are primary research areas in UWB systems. Therefore, the realization of UWB antennas in printed-circuit technologies within relatively small substrate areas is of primary importance. In this project the design of high gain antenna for UWB applications with band notch characteristics has been covered. The design intends to cover entire UWB specified by FCC i.e. 3.1-10.6 GHz with desired band notch capability. Initially an antenna has been designed which operated at a small bandwidth than various bandwidth enhancement techniques have been used to enhance its operating bandwidth. These techniques include corner truncation, partial grounding and inset feeding. Efforts have also been put in to increase the gain of the designed antenna using different substrates and by increasing the radiating area of the antenna while keeping the overall size of antenna compact. A detailed analysis of the obtained antenna parameters has been carried out and efforts are made to obtain best possible antenna efficiency parameters which include bandwidth, gain, return loss and VSWR. The fabrication and lab testing of the designs have been carried out. To prevent interference problems due to existing nearby communication systems operating within ultra wideband (UWB) frequency range, the significance of an efficient band-notched design has increased many folds.

CERTIFICATE

It is certified that the work contained in this thesis entitled **"Ultra Wideband High Gain Antenna with Band Notch Characteristics"** carried out by Capt Faizan Mumtaz, Capt Shoaib Athar and Capt Muhammad Shafique 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

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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
PN	Pseudorandom Noise
HPBW	Half Power Bean Width
FNBW	First Null Beam Width
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
LOS	Line of Sight
SNR	Signal to Noise Ratio
RMSA	Rectangular Microstrip Antenna
VNA	Vector Network Analyzer
CPW	Co Planar Waveguide

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

The ensuing chapter explains the importance of UWB antennae with band notch characteristics, along with the background, problem statement and objectives of the project. It also provides an overview of some fundamental concepts of antenna theory.

1.2 BACKGROUND

Ultra-wideband (UWB) technology has engrossed much interest both in the industry and academic circles due to its low cost, potential to handle high data rate and relatively low power requirements. An UWB antenna is one of the key components for realizing the UWB systems. 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]. We however, note that designing an UWB antenna to deliver high performance is much more challenging than it is when dealing with the conventional narrowband antennas. Typically, it is desirable for a UWB antenna to cover a wide bandwidth spanning the entire range of 3.1-10.6GHz, to produce an omnidirectional radiation pattern, and to have a compact size as well as a simple configuration. Thus size reduction, gain and bandwidth enhancement, with desired band notch characteristics are major considerations for practical applications of micro-strip antennas.

1.3 PROBLEM STATEMENT

In Ultra wide band antenna design the most important and challenging step is to achieve wide bandwidth with high gain and radiation efficiency, which is difficult to achieve on microstrip patch antenna because microstrip patch antennae are inherently low gain and narrow band antennae, yet there are techniques which can be applied in order to obtain desired outcome. Another major challenge is to introduce the band notch characteristics in antenna design while keeping the other performance parameters according to the desired standards.

1.4 PROJECT OBJECTIVES

The objectives of this project are mentioned below:-

a. To design a high gain antenna for UWB applications, which possess band rejection capabilities.
b. To simulate and optimize the design using High Frequency Structure Simulator software (HFSS).
c. To fabricate the proposed antenna and analyze its performance through laboratory tests.
d. Implement new techniques of achieving high bandwidth, frequency notch characteristics and improved gain and radiation pattern to further enhance existing literature.
e. Study previous work done on UWB antennas with band notch characteristics.
f. Optimize various characteristics of designed antenna such as Return loss, Radiation pattern, Gain and Surface current density.

1.5 ANTENNA PARAMETERS

While designing the antenna, its overall performance relies upon numerous parameters which are necessary to realize. An antenna is dependent on various parameters which are as follows:-

a. Bandwidth

The range of frequencies that signal use on the transmission medium is called as the bandwidth. It is an essential parameter of the antenna. An antenna that can transmit and receive signal at maximum bandwidth is always desirable. The units of bandwidth are hertz (Hz).

Bandwidth = Higher frequency – Lower frequency

b. Beam Width

Beam width can be defined as the angle between the direction in which there is maximum intensity of beams and the direction containing half of the maximum intensity of beams [1]. With the decrease of the beam width, the increase in side lobes is observed and it is true for the other way round [1].

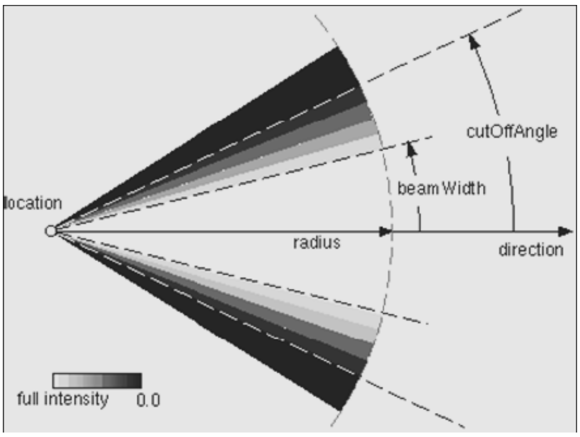


Figure-1.1: Beam width

Beam width can be sub-divided categorically into two parts:-

1) Half power beam width (HPBW)
2) First null beam width (FPBW)

c. Radiation Resistance

Radiation pattern can be outlined as the parameter that represents the accurate radiated power, provided the current is input at the terminal of the antenna [1]. Radiation resistance is dependent on the design of the antenna. The larger the size of antenna, the more will be the radiation resistance observed.

$$R = \text{Power Radiated} / I^2_{rms}$$

d. Radiation Pattern

Radiation pattern is the graphical visualization of an antenna's gain against the angle. It is generally a 2D (two dimensional) pattern, exhibiting the objective of both the azimuth and elevation angles. Radiation pattern for an ideal isotropic antenna is spherical and equally radiates in all directions. Ideally, for point to point communication, the directive antenna's radiation pattern has a single narrow beam [2]. For the microstrip path antenna, the width of the patch is responsible for the radiation pattern.

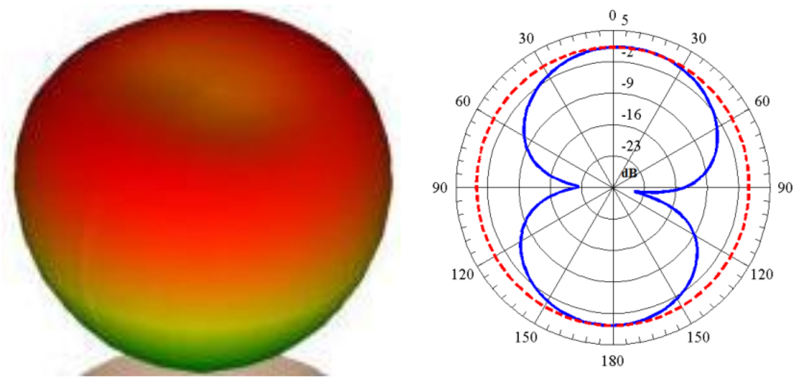


Figure-1.2: 3D and 2D radiation pattern

e. Antenna Gain

Gain is counted as one of the very important parameters of the antenna that shows that the amount of input power transformed to the radio waves in the certain direction for the transmitting side. For the receiving side, antenna gain describes the efficiency of radio waves coming from the certain direction are transformed into optical power. Gain is less than the directivity due to ohmic losses in antenna [4]. Mathematically it can be written as:

$$G = KD$$

G = gain of the antenna

D= directivity

K = efficiency factor (0≤K≤1)

f. Return Loss

The ratio of the power reflected from discontinuity to the power incident upon the impedance discontinuity [3]. Both of the powers are measured in decibels (dB). Return loss = forward power (dB) – reflected power (dB)

$$RL(dB) = -20 \log10 |\Gamma|$$

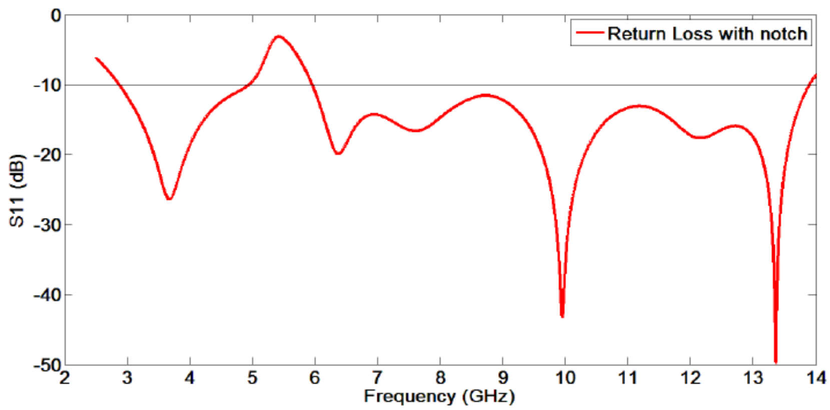


Figure-1.3: Return Loss graph

g. Directivity

The directivity of an antenna described as the concentrating power of an antenna. This means that it is the observance of how effectively an antenna emits radiations in the desirable direction. Mathematically antenna directivity is the ratio of the maximum power density to its average value over a sphere when observed in the far field region [5].

h. Voltage Standing Wave Ratio (VSWR)

VSWR is the measure of efficiency of how well the impedance load is matched with the source impedance. It is defined as “amount of signal that is reflected back from a connector” [3]. Due to the mismatching, constructive and destructive interference is produced. Constructive interference produces maximum amplitude while destructive interference results in minimum amplitude. Based on this behavior, VSWR can also be defined as “ratio of maximum voltage to the minimum voltage” [7].

i. 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:-

1) Linear polarization
2) Circular polarization
3) Elliptical polarization

j. Efficiency

Efficiency generally describes the effectiveness of the antenna. When antenna is operating at a certain frequency, it measures the electrical losses taking place throughout the antenna. It is expressed as the ratio of the power emitted to the power which enters the antenna.

k. Resolution

The resolution of an antenna is equal to half the beam width between the first appearing nulls. Mathematically it can be expressed as:-

$$\text{Resolution} = \text{FNBW} / 2 = \text{HPBW}$$

CHAPTER TWO

LITERATURE REVIEW

2.1 MICROSTRIP PATCH ANTENNA

2.1.1 Introduction to Microstrip Patch Antenna

For transmitting and receiving high frequency electromagnetic signals a special type of antenna is used known as Microstrip antenna. For broad frequencies ranging from 100 MHz to 100 GHz, these antennae are designed [4]. The patch could be of square or rectangular shape. The dimensions of the patch are length, width and height of substrate which are represented by L, W and h, respectively. Another important parameter of the patch antenna is its dielectric constant (*εr*). Lower the value of *εr*, better will be the performance of the antenna.

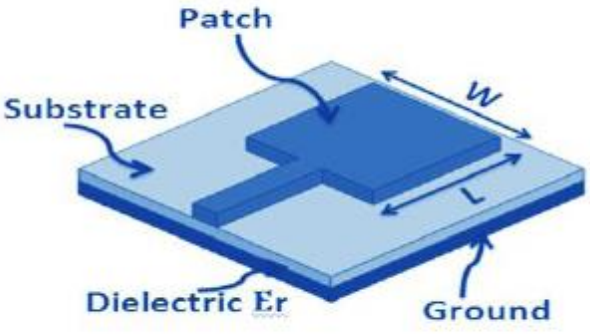


Figure-2.1: Micro Strip Patch Antenna

2.1.2 Advantages of Microstrip Patch Antenna

Advantages of microstrip patch antenna are listed as under:-

a. They are easy to fabricate and are very economical.

b. They are very light weighted.

c. When compared with other antennae, they are found to have low volume.

d. They have low profile planar configuration.

e. They can support both linear and circular polarization.

f. They are able to handle dual and triple frequency operations.

g. Cavity backing is not required.

h. They are found to be mechanically robust when mounted on rough surfaces.

2.1.3 Disadvantages of Microstrip Patch Antenna

Disadvantages of microstrip patch antenna are listed as under:-

a. They have narrow bandwidth.

b. They are said to be less efficient.

c. They have low gain.

d. They emit undesired radiations from feeds and junctions.

e. They have large ohmic losses.

2.2 FEEDING TECHNIQUES

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories i.e. Contacting and Non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line/Coaxial Cable. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch such as aperture coupling and proximity coupling. Several feeding techniques are:-

a. Microstrip Line

The simplest of all the techniques of feeding the microstip antenna is the microstrip line. Conducting material is used in making of a microstrip line. It has a strip-shaped structure and is placed at the corner of the patch.

Relatively, its dimensions are smaller than the patch. To maintain the input impedance of 50Ω, the length and width of the transmission line are set accordingly.

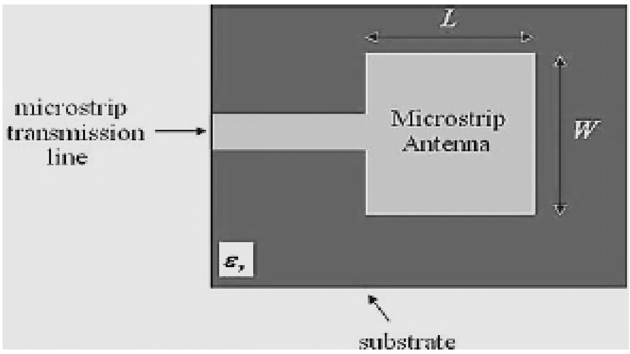


Figure-2.2: Microstrip line feed

b. Coaxial Cable or Probe Feed

Two conductors named as outer and center conductors are used in this design. The patch antenna is placed above the center conductor and the outer conductor is connected to the ground plane. The center conductor acts as a probe feed for coupling electromagnetic waves in and out of the patch. If the substrate's height becomes larger then inductance is introduced by this feeding method.

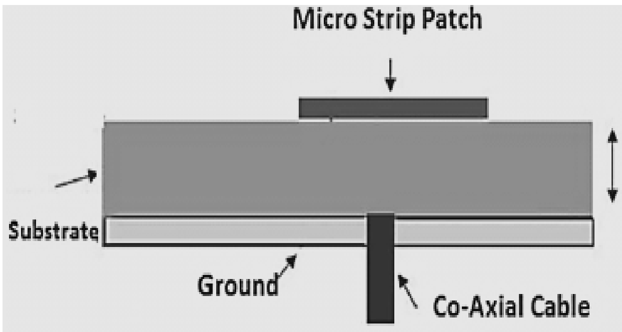


Figure-2.3: Probe Feed

c. Aperture Feed

In this method, to transmit the energy to the antenna, the transmission line is shielded from the antenna by a conducting plane with an opening aperture shown in Figure. The upper substrate should be made of lower permittivity which ensures better radiation results to generate loosely bound fringing field. High value of permittivity of substrate leads to incorrect radiation patterns. Fabricating the antenna using this feeding technique is a hectic task.

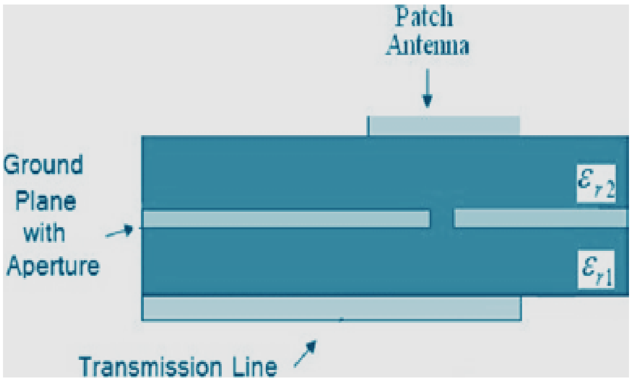


Figure-2.4: Aperture Feed

d. Coupled (Indirect) Feed

All the techniques discussed above can be altered since they do not touch the antenna directly. To eliminate the conductance, which is produced in other feeding methods, couple feed is used which eliminates conductance by introducing capacitance. In the Figure below, the gap leads to capacitance.

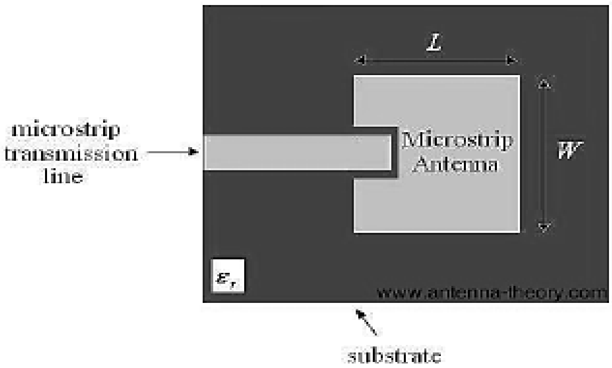


Figure-2.5: Coupled Feed

e. Feed with a Quarter-Wavelength Transmission Line

In this type of feeding, the quarter length with impedance of Z_1 to transmission line having impedance Z_0 is used for matching. Z_{in} is the input impedance in this case and matching with Z_0 is the main goal here. Let the impedance of antenna is Z_A then Z_{in} can be expressed as:-

$$Z_{in} = Z_1^2 / Z_A$$

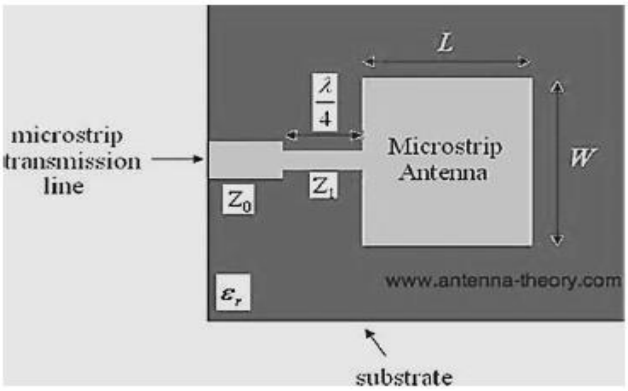


Figure-2.6: Quarter wavelength T.L feed

2.3 TECHNIQUES TO DESIGN ANTENNA

Different antenna designs are used to implement and achieve desirable results. These techniques include:-

a. Partial Grounding

Partial grounding, full grounding and quarter grounding are the techniques used to handle the available bandwidth or to increase the bandwidth factor. Partial grounding technique is used to enhance the bandwidth of the antenna.

b. Corner Truncation

Corner truncation adopts the same nature as of the partial grounding effect. The bandwidth of the antenna increases by truncating the corners of the antenna. Radiation is also affected by corner truncation as it causes the radiating edges to increase which in turn lead to higher bandwidth.

c. Addition of Slots

Gain is observed to be improved, considerably, when slots are introduced near the radiating edges of the antenna.

d. Addition of Slits

Adding the slits helps to transform the non-radiating edges to radiating edges which helps to in the formation of directionally desired radiations. Due to this, the directivity of the antenna increases which in turn increases the bandwidth.

e. Quarter Wave Transformer

In the patch antennae, quarter wave transformer is a very important technique which is used to match the load impedance to the source impedance which, is observed to, result in the increase in the return loss.

2.4 ULTRA WIDEBAND (UWB) TECHNOLOGY

2.4.1 Principles of UWB Technology

a. UWB (Ultra Wide-Band) is a radio communication technology that uses very low energy pulses & it is intended for short-range-cum-high-bandwidth communications by using a huge chunk of the radio spectrum.
b. UWB communications transmit in a way that doesn't interfere with other traditional narrowband and continuous carrier wave systems operating in the same frequency band.
c. And UWB is a Very High-speed alternative to existing wireless technologies such as WLAN, HiperLAN.
d. A February 14, 2002 Report and Order by the FCC (Federal Communication Commission) authorized the unlicensed use of UWB in the range of 3.1 to 10.6 GHz for commercial applications.
e. The approved FCC power spectral density emission limit for UWB emitters operating in the UWB band is -41.3dBm/MHz. This is called Part 15 limit the same limit that applies to unintentional emitters in the UWB band.

f. UWB RF technology transmits Binary data (0/1) over a very wide spectrum of frequencies using low energy and extremely short duration pulses (in the order of Pico-seconds).

g. In a Multi-user environment to minimize interference each device is given a unique PN code (Pseudo-random Noise). And a receiver operating with the desired PN code can decode the transmission.

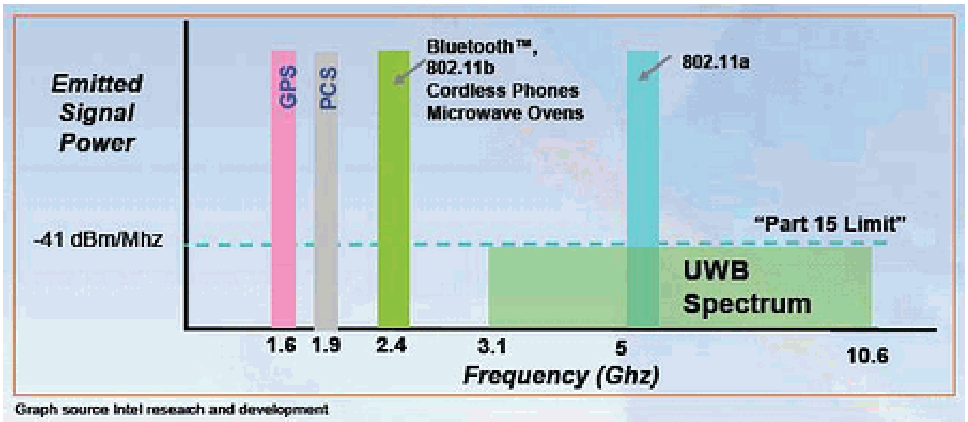


Figure-2.7: Comparison of various communication standards

2.4.2 Advantages of UWB Technology

a. Capacity. It can achieve very high data rate (can reach up to 500 Mbps). Its bandwidth is from 3.1 GHz to 10.6 GHz and each channel is of more than 500 MHz BW.

$$C=B.Log2\ (1+SNR)$$

Where C=Channel Capacity

B=Bandwidth of Channel

b. Low Power & Low Cost. No need of modulation. Un-modulated baseband pulses of very short duration are sent in this communication technology, that's why it is known as a "Carrier free Impulse Baseband Radio". It is an all-Digital System not requiring any kind of analog components such as Mixers/Balanced Modulators for signal modulation. It needs very small Transmitter power for its transmission. And Power is in microwatt range.

c. **Fading Robustness.** Wideband nature of the signal helps it avoiding the problem of time varying amplitude fluctuations. It is also immune to Multipath Delays (introduced due to non-LOS (line of sight) communication where various version of same signal appear at the receiver which have undergone a variety of diffraction, reflection, scattering effects) as time delay introduced is generally more than the signal duration.

d. **Flexibility.** It can dynamically trade-off throughput for distance.

e. **Short Range.** Its normal range of operation is within 10 m, so its power requirement is low and interference with other short range devices is less. It comes under WPAN (Wireless Personal Area Network) protocol.

f. **Security Aspects.** It behaves as a wideband noise source for other NB (Narrow Band) systems operating in that frequency range; but it doesn't affect them because of its low signal power. It only increases the SNR requirement of those systems. By using PN (Pseudo Random) codes UWB system can be made undetectable for hostile receivers.

g. **Multiple Access.** Various Modulation techniques can be employed:-

   1) PPM (Pulse Position Modulation)
   2) BPSK (Binary Phase Shift Keying)
   3) PAM (Pulse Amplitude Modulation)
   4) OOK (On-Off Keying)

   For Multiple access we can use:-

   1) TH-UWB (Time Hopping)
   2) DS-UWB (Direct Sequence)

2.5 PREVIOUS WORK DONE ON UWB ANTENNAE

a. **Bandwidth Enhancement of a Wide Slot UWB Antenna with Notch Band Characteristics.** A CPW-fed monopole antenna of size 28x21x1.6mm^3 is presented with dual band notch characteristics to avoid interference in UWB frequency range. The wide bandwidth is achieved by embedding L-shaped slots in CPW ground and by etching rectangular slot band stop filter is obtained. The notch characteristics are obtained at 5GHz-6GHz for HIPERLAN/2 and IEEE 802.11 a (5.1 GHz-5.9GHz) and C-band (4.4GHz-5.0GHz). The result of the presented antenna shows that the antenna not only has dual band notch characteristics but also has good radiation pattern and wide bandwidth.

b. **Band Notch Characteristics Using Ground Stubs For Compact UWB Antenna.** A planar monopole UWB antenna is designed by using pair of ground stubs to achieve single notch band characteristics. The proposed antenna has wide bandwidth from 2.7GHz to 12GHz with respect to the return loss which is less than -10 dB. The average peak gain of antenna is around 3.15 dBi and has omni directional radiation pattern. Single band notch characteristics are successfully achieved according to obtained results, which prove that ground stubs work efficiently in order to get single notch characteristics. The features of proposed antenna are suitable for applications in wireless devices.

c. **Compact Printed Ultra WideBand Monopole Antenna with Dual Band Notch Characteristics.** A microstrip fed planar UWB antenna with compact size of 35×14mm2, having dual band notch characteristics is proposed. The bands are notched by embedding an E-slot in radiation patch and U-slot in feeding line. By adjusting the corresponding slot both the notched bands can be controlled.

d. **UWB Antenna with Single or Dual Band Notches for Lower WLAN Band and Upper WLAN Band.** UWB antenna is proposed to overcome interference problem due to near-by communication systems within UWB frequency range. The two antennae having band notch characteristics are presented. The first proposed with single band notch and second is for dual band notch function. The fork shaped UWB antenna with one separated strip is proposed for single band notch and with two strips for dual band notch characteristics.

e. **Qing-Xin Chu and Ying-Ying Yang** have done a thorough study on Compact planar ultra-wideband antenna and also proposed the use of nested C-shaped slots to produce band-notch characteristics in 3.4 GHz band and 5.5 GHz band in order to minimize the interference of the UWB antenna with Wi-MAX and WLAN 2 bands respectively. While etching the slots they have also discussed the mechanism by which the slots provide band-stop filter type response to the antenna performance. They have explained very clearly how the destructive interference for the surface currents makes the antenna non-responsive at those notch frequencies. They have also given the relationship between the notch frequency and the length of the slot to be etched.

f. **D.O. Kim and C.Y. Kim** has proposed a very novel strategy of integrating three notch elements on a primitive antenna to produce triple band-notch characteristics. They have also proposed a method to decrease the cross-coupling among notch elements. Optimized positioning of notch elements to achieve controllability of each rejection band is explained very clearly in this paper. The idea of using CSRRs (Complementary Split Ring Resonators) is described here. This paper also explores the importance of calculating return loss due to each element after embedding them on the primitive antenna. They have also instructed not to embed the notch elements blindly onto the patch antenna without taking into account the mutual coupling problem.

g. Comparison

RESEARCH PAPER	**GAIN ACHIEVED**	**YEAR OF PUBLICATION**
Improvements in a high gain UWB antenna with corrugated edges by Z. Wang and H. Zhang	7 dB	2009
High Gain Printed Ultra Wideband Antenna Concept by Brankovic, V.	7dB	2007
High Gain Compact Strip and Slot UWB Sinuous Antennas by Renato Cicchetti	8dB	2012
High Gain Cavity Backed UWB Antenna with and without Band Notch Feature by Dawar Awan, Shahid Bashir and William Whittow	7.5dB	2014
A printed high gain UWB antenna design using tapered corrugation and grating elements by Pandey and Meshram	8.5dB	2015

CHAPTER THREE

DESIGN AND DEVELOPMENT

3.1 DESIGN PROCESS

3.1.1 Step 1- Implementation of an Existing Design

In first step an UWB antenna design proposed in one of the recent research papers has been implemented and the simulated results are verified as given in the research paper. One of the major discrepancies in the proposed design was its small radiating surface which resulted in a low gain of the antenna.

a. Designed antenna has a small size of 12 x 18 mm^2

b. FR4 substrate of thickness 1.6 mm

c. Gain < 3 dB

d. Return Loss < -10 dB

e. VSWR < 2

f. Impedance matching at 50 Ω

g. Covers bandwidth specified for UWB i.e. 3.1-10.6 GHz

h. Feeding technique used is microstrip line feed

i. Material used for the radiating patch and the transmission line is copper

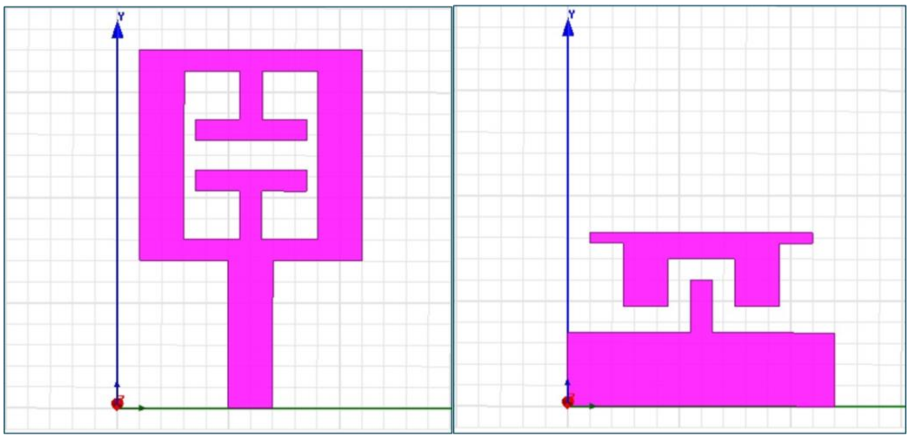


Figure-3.1: Design of Antenna

3.1.2 Results

a. Return Loss

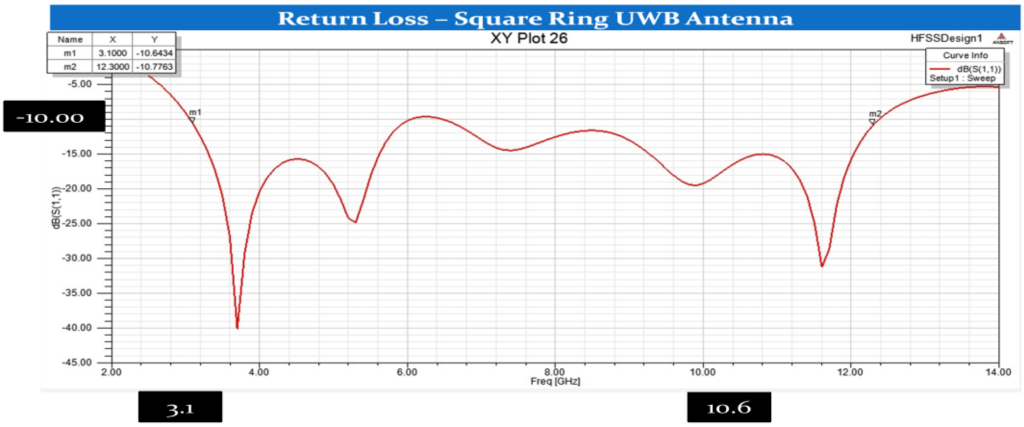


Figure-3.2: Return Loss vs. Frequency

b. VSWR

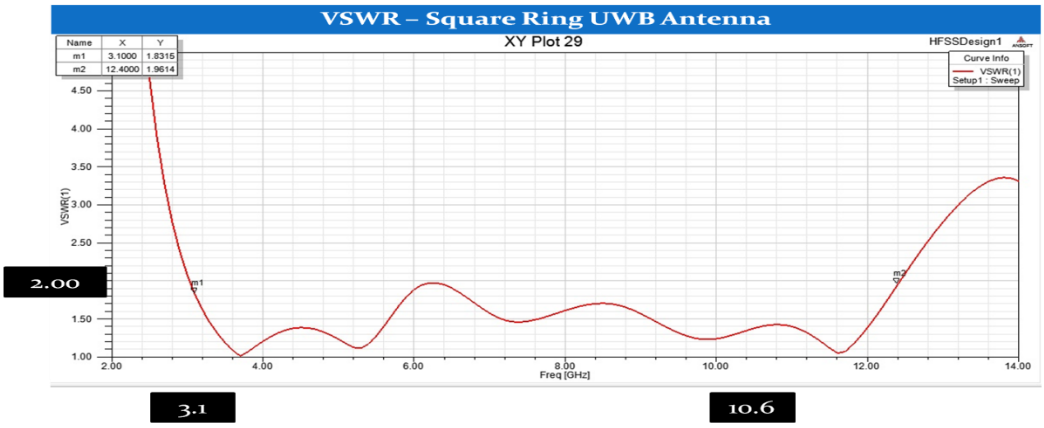


Figure-3.3: VSWR vs. Frequency

c. Gain

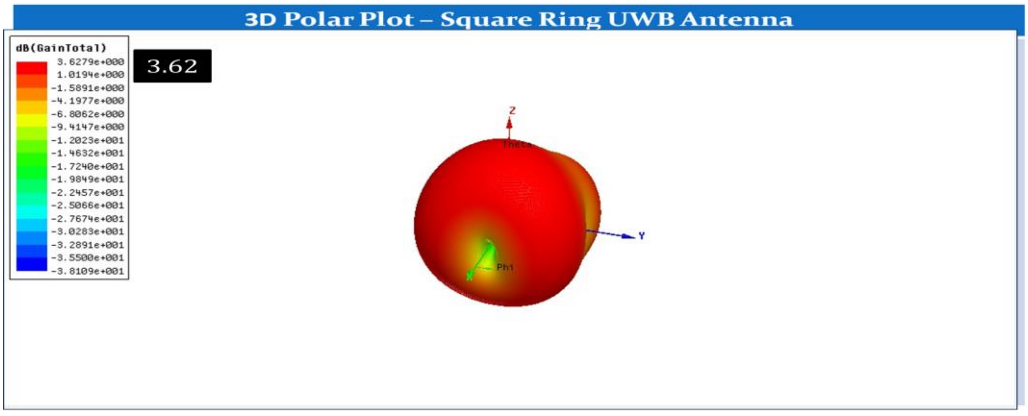


Figure-3.4: 3D Gain plot of Antenna

3.1.3 Step 2- Initial Design and Modifications

In second step initially a simple patch antenna is designed fulfilling FCC design requirements of return loss, VSWR, radiation pattern, surface current density, impedance matching and gain. Then various techniques have been applied to realize an UWB high gain antenna. The dimensions of an initial design were calculated basing on the geometric mean of UWB frequency range i.e. 5.78 Ghz. Then bandwidth enhancement techniques like corner truncation, partial grounding and inset feeding have been implemented to make the antenna operate on complete UWB bandwidth. The substrate used for simulating and fabricating this antenna is FR-4.

Initial Design:-

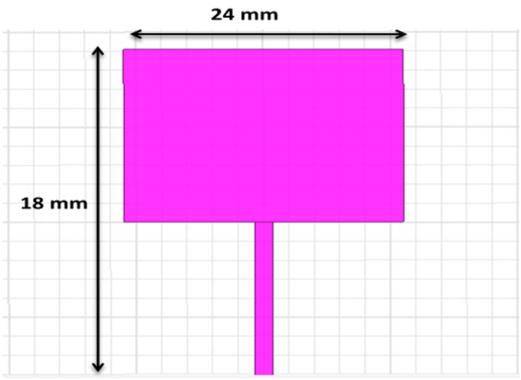


Figure-3.5: Initial Antenna Design

Design after implementing Bandwidth and gain enhancement techniques:-

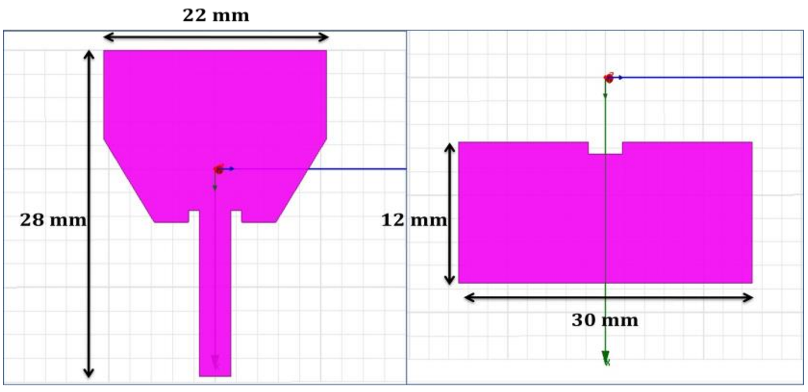


Figure-3.6: Modified Antenna Design

3.1.4 Results

a. Return Loss

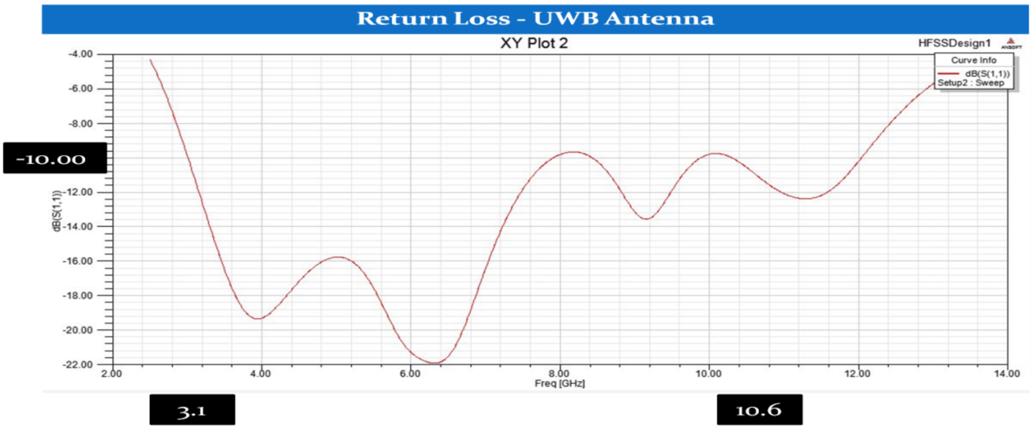


Figure-3.7: Return Loss vs. Frequency

b. VSWR

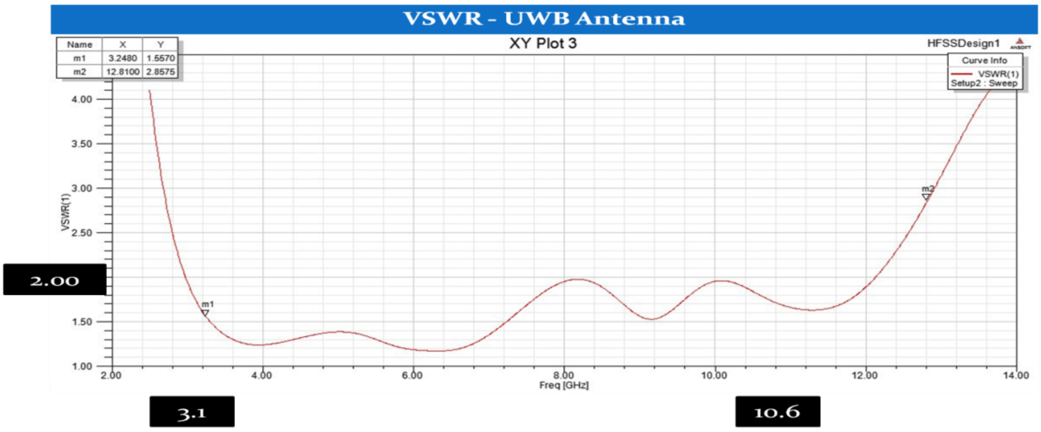


Figure-3.8: VSWR vs. Frequency

c. Gain

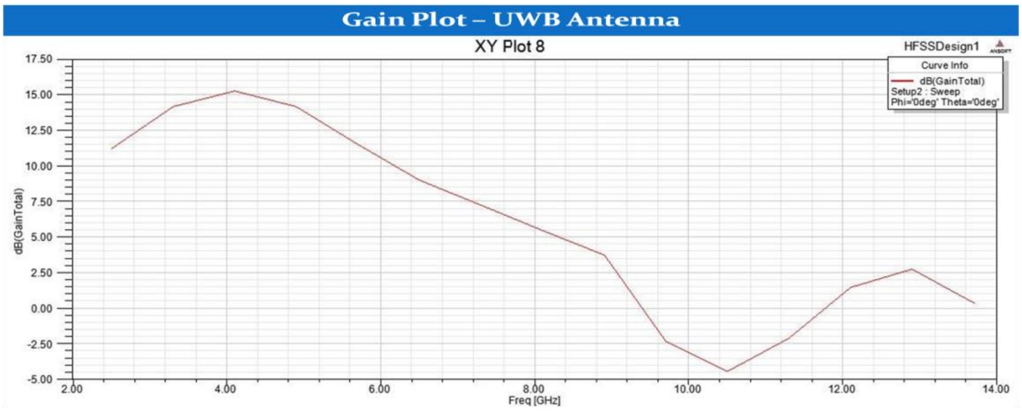


Figure-3.9: Gain vs. Frequency

d. Bandwidth Enhancements

Bandwidth enhancement is achieved by truncating the patch antenna diagonally at the lower edges. Cutting corners of RMSA will induce more discontinuity in the flow of wave and increasing reflections which ultimately results in improved bandwidth [13]. Also the capacitive coupling between the patch antenna and the ground plane is tuned to achieve a wider impedance bandwidth through partial grounding [14]. Moreover inset feeding technique is used to further improve impedance matching.

Techniques	Lower Freq(F_L) GHz	Higher Freq(F_H) GHz	Bandwidth(F_H-F_L) GHz
Initial Design	5.80	5.95	0.15
Edge Truncation	4.63	6.92	4.63
Partial Grounding	3.67	10.13	6.46
Feeding Methods	3.03	11.06	8.03

e. Analysis based on HFSS Results

1) Return loss is above -10dB at certain frequencies
2) Gain deteriorates at higher frequencies
3) Use of techniques to add band notch characteristics reduces the gain

f. Requirements for Final Design

1) Return loss improvement
2) Gain stability using various techniques
3) Addition of band notch characteristics
4) Fabrication of final design and lab testing

3.1.5 Step 3- Final Design

In next step notches have been introduced in the design in order to achieve desired band notch capability. Final design has been realized after several modifications and performing a number of simulations to obtain the desired results. Different design specifications have been implemented using parametric analysis and the one giving the optimal results has been selected for fabrication. Final design consists of a rectangular patch with four corner studs and two L shaped slots in the ground plane. Corner truncation and partial grounding is performed on the final design for bandwidth enhancement. The substrate used for simulating and fabricating this antenna is FR-4 with relative permittivity and dielectric loss tangent of 4.4 and 0.02 respectively. The size of the substrate is compact with dimensions of 30x30mm^2 having height of 1.6mm. To achieve good impedance matching with the load we require 50Ω input impedance for which the length and width of the transmission line are kept to be 14mm and 3mm, respectively. The design with optimum results is then fabricated and tested as per simulations at SMRIMMS NUST.

Final Design:-

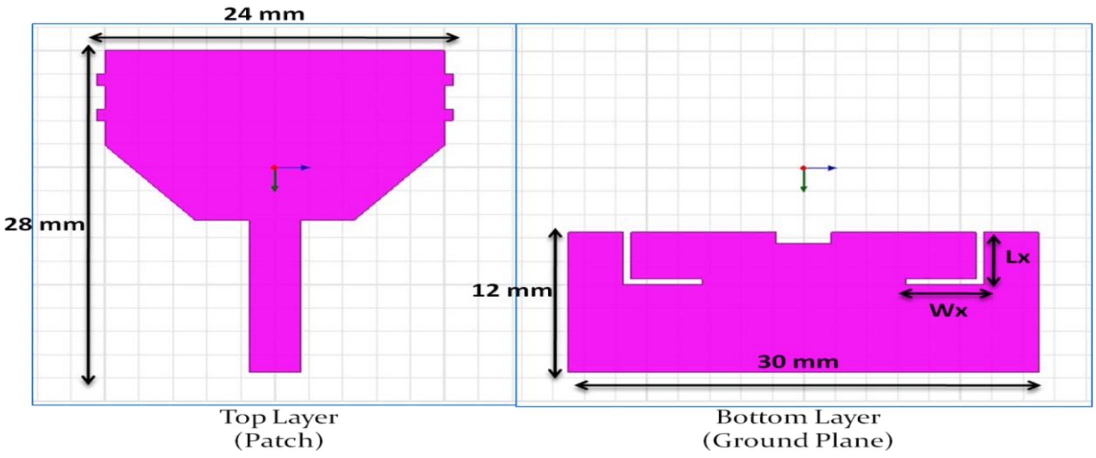


Figure-3.10: Final Antenna Design

3.1.6 Results

a. Return Loss

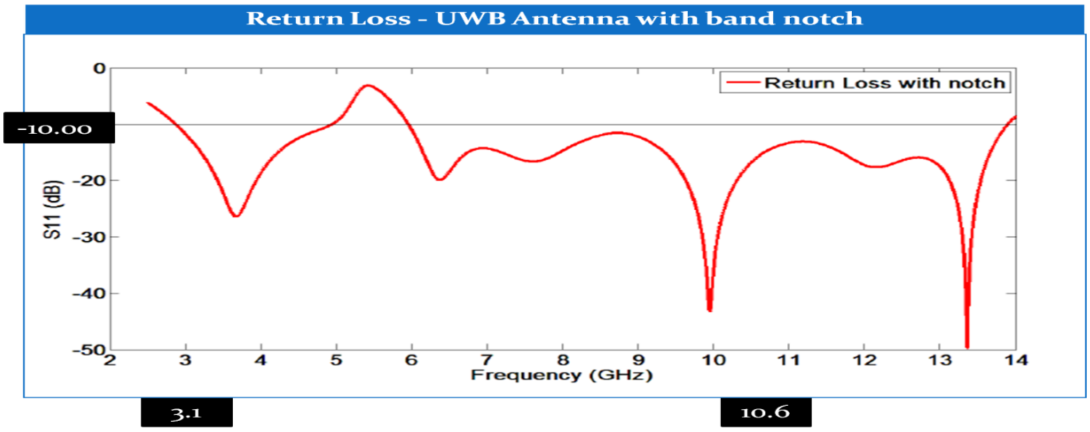


Figure-3.11: Return Loss vs. Frequency of Final Design

b. VSWR

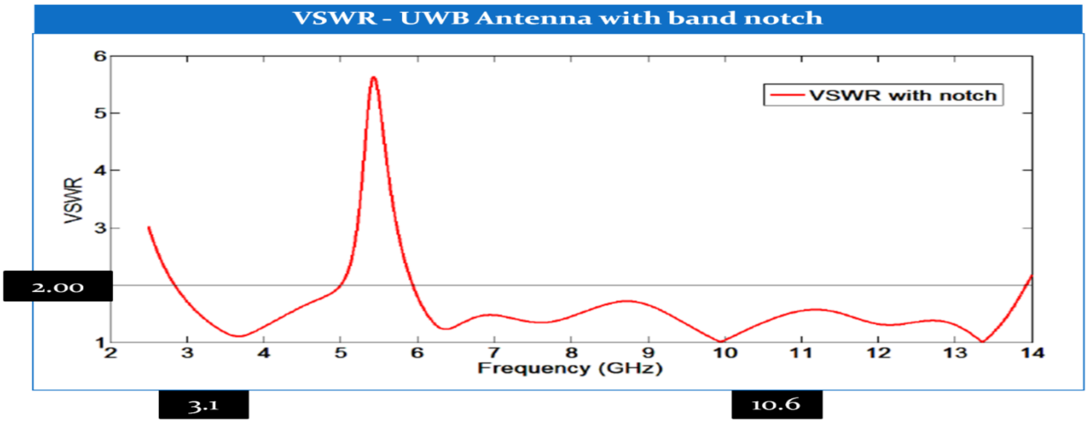


Figure-3.12: VSWR vs. Frequency of Final Design

c. Gain

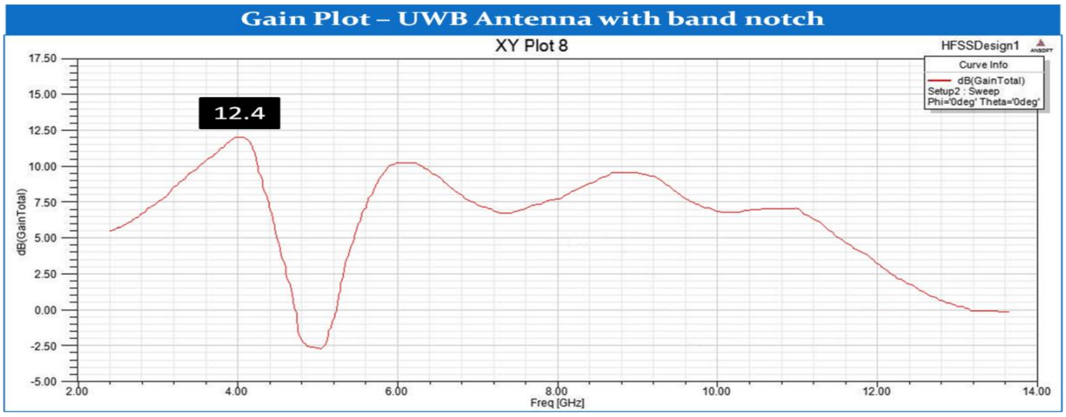


Figure-3.13: Gain vs. Frequency of Final Design

CHAPTER FOUR

PROJECT ANALYSIS AND EVALUATION

4.1 ANALYSIS

The proposed antenna is designed to cover entire UWB specified by FCC i.e. 3.1-10.6 GHz with desired band notch capability. The notch characteristics are obtained at 5GHz-6GHz for HIPERLAN/2 and IEEE 802.11a (5.1 GHz-5.9GHz) and C-band (4.4GHz-5.0GHz). Designed antenna has compact size of 28 x 24 mm^2 with four corner studs on the radiating patch and two L shaped slots in the ground plane. The proposed antenna structure is simulated in order to obtain the return loss, gain and the radiation efficiency of the antenna, using the commercial electromagnetic simulator HFSS. Furthermore, parametric studies on the VSWR have been carried out in order to obtain the optimal dimensions for the proposed antenna. Since Microstrip Patch Antennae are inherently narrow band and low gain, so a major challenge was to realize the Ultra Wideband and enhance the gain of the antenna to the desired standards. These challenges were met using various bandwidth and gain enhancement techniques like corner truncation, partial grounding and increasing the radiating surface of the antenna. The proposed antenna works for all the UWB applications. A detailed analysis of the obtained antenna parameters has been carried out and efforts are made to obtain best possible antenna efficiency parameters which include bandwidth, gain, return loss and VSWR. The project involved the implementation of the knowledge of principles of antenna theory and software skills (HFSS and CST) to design a low cost and light weight UWB antenna with band notch characteristics and has its uses in satellite designing, medical applications and military systems.

4.2 PARAMETRIC ANALYSIS

For optimal performance of the proposed antenna, parametric analysis has also been carried out by varying different dimensions and choosing the one giving best results. The Length and width of the L shaped slots in the ground plane is defined by two parameters Lx and Wx respectively. Both the parameters are varied and effects on the notch frequencies have been noted and finally such dimensions are selected which produced the desired band notch characteristics.

a. Effect of Varying ‘Lx’

Figure 4.1 shows the VSWR graphs of the proposed antenna by varying the slot length parameter Lx and fixing the other parameters. It is observed that varying parameter Lx has a direct impact on the frequency band which is notched from the antenna operating bandwidth. Moreover it is analyzed that with Lx=5mm, the desired band is rejected. In case when Lx= 4mm, the lower band of the WLAN, i.e. 5.15GHz, is not notched. On the other hand when Lx=6mm the upper band of the desired range is not rejected. Therefore, Lx=5mm is taken for further study.

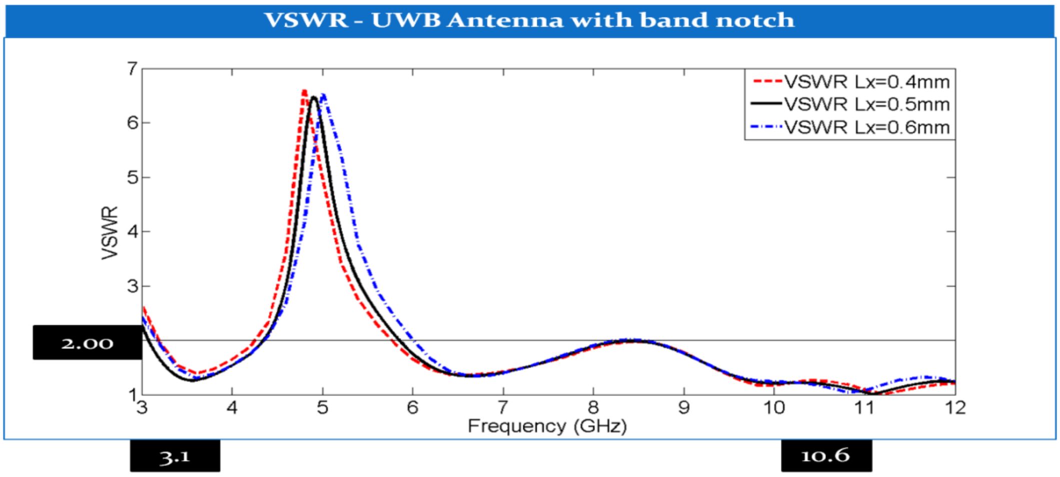


Figure-4.1: Optimized VSWR vs. Frequency Varying Lx

b. Effect of Varying ‘Wx’

In Figure 4.2, the results of the VSWR versus frequency plot when ‘Wx’ is varied are shown. From the graph it can be observed that the optimum results are achieved when Wx=5mm. With Wx=4mm and 6mm, the lower band of the WLAN band is not notched. Therefore, Wx=5mm is taken for further study.

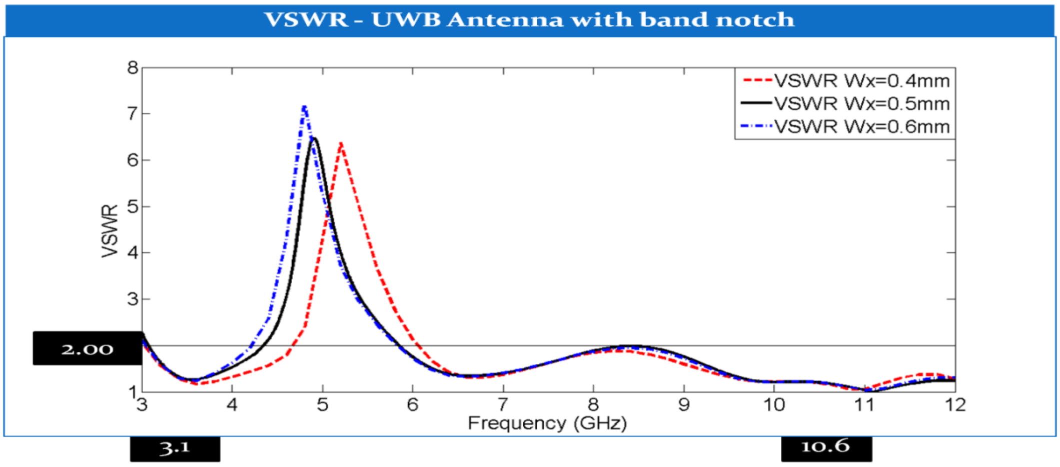


Figure-4.2: Optimized VSWR vs. Frequency Varying Wx

4.3 MEASURED RESULTS

Final design has been fabricated and measured results of the project are shown below. These results are in conformity with the simulated results as the proposed antenna is operating on the entire UWB bandwidth except the notched frequencies, since the return loss in the measured results is less than -10dB and VSWR is less than 2.

a. Return Loss

FCC criteria for a working radiation device states that it should have return loss or S11 value less than -10 dB for the entire range of operation specified. From Figure-4.3 it can be clearly seen that tested results for hardware design are in good agreement and define the impedance bandwidth as per the required international standards.

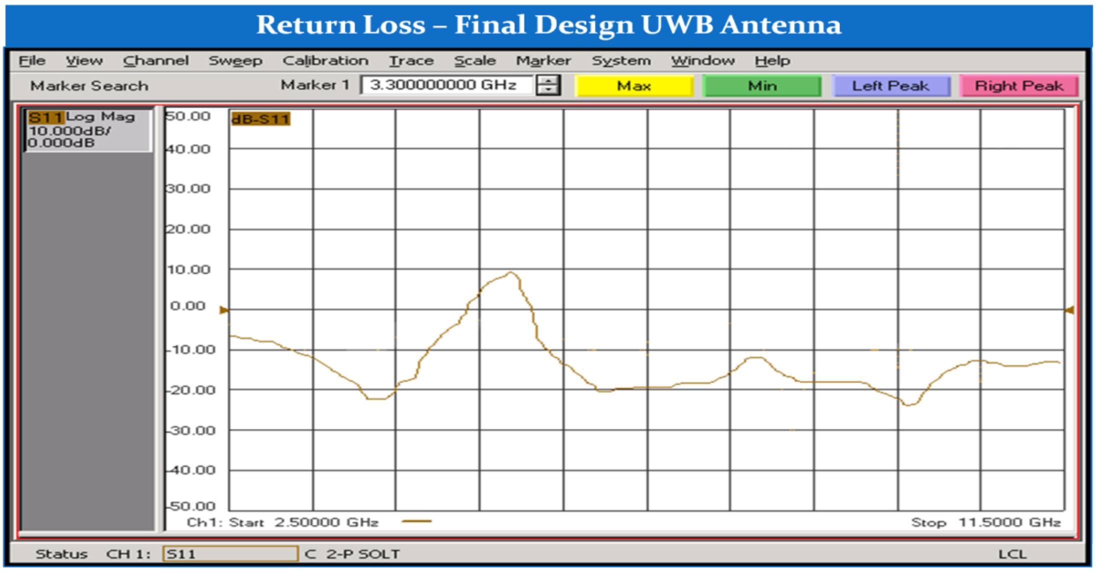


Figure-4.3: Measured Return Loss vs. Frequency of Fabricated Design

b. 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. The measured VSWR for the fabricated design is less than 2 for the entire UWB range except the frequencies which are notched from the antenna operating bandwidth.

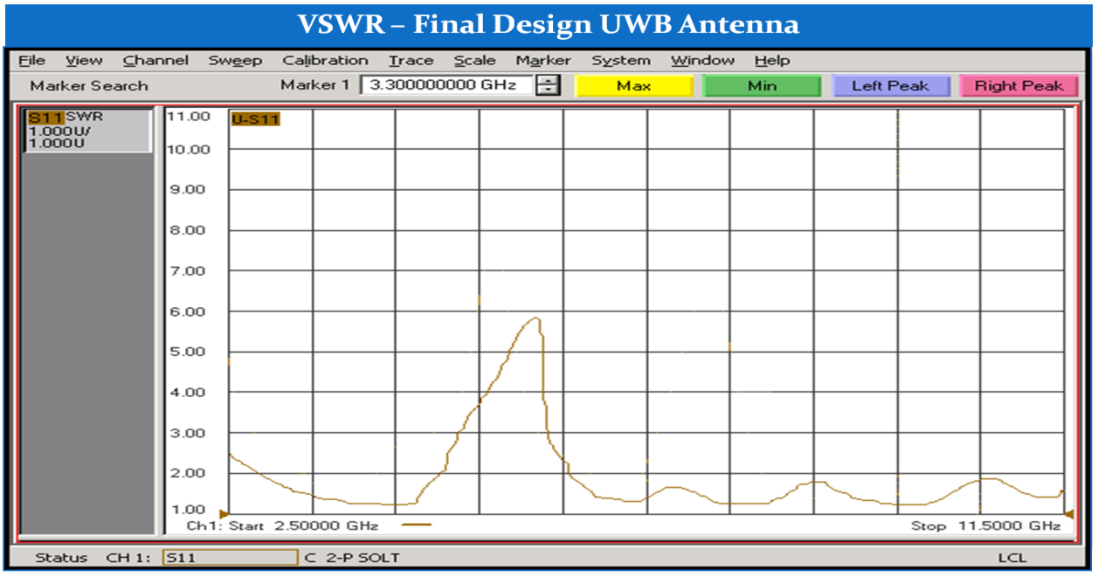
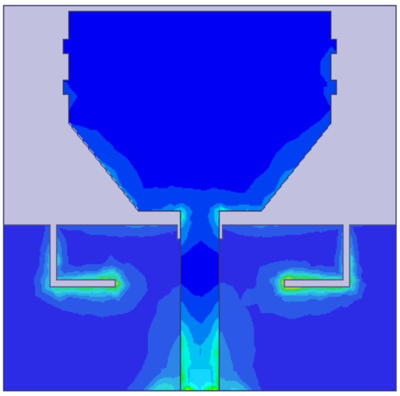


Figure-4.4: Measured VSWR vs. Frequency of Fabricated Design

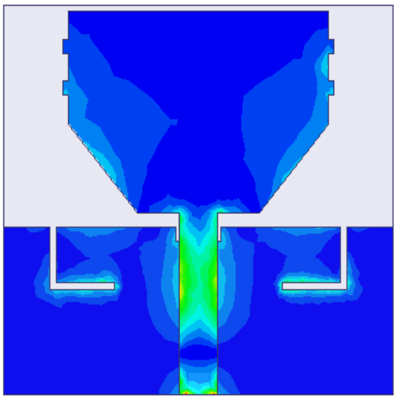
c. Current Distribution

Figure 4.5 (a-d) depicts the surface current distribution of the notching technique applied to the antenna at different frequencies i.e. 3.5GHz, 5.5GHz, 7.5GHz and 9.5GHz respectively. From the Figure it can be observed that the current distribution is relatively normal at 3.5GHz, 7.5GHz and 9.5GHz. However, the surface current density appears to be concentrated around the L-shape slot at 5.5GHz which verifies that antenna is not operating on 5.5GHz.

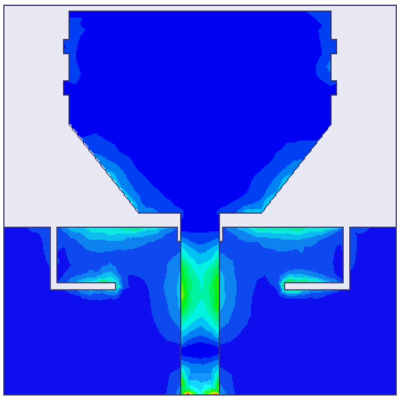


(a)

(b)



(c)



(d)

Figure-4.5: Current Distribution (a) 3.5GHz (b) 5.5GHz (c) 7.5GHz (d) 9.5GHz

CHAPTER FIVE

FUTURE WORK AND CONCLUSION

5.1 RECOMMENDATIONS FOR FUTURE WORK

Although the antenna design proposed in this project is presented after integrating various antenna design techniques and design dimensions are set after a lot of deliberations and detailed parametric analysis, still following recommendations can be taken into consideration as enhancements in this project to bring more positive outcomes:-

a. The gain and efficiency of the antenna can be improved by applying some new techniques like introducing slots in radiating patch etc.
b. Different feeding techniques can also be used to operate the antenna in the UWB range. These techniques include inset feed, aperture couple feed, proximity coupled feed, coaxial probe etc.
c. The fractional bandwidth can be increased by varying the size of corners truncated and the ground plane.
d. Another antenna can be designed which could cover the Bluetooth range i.e. from 2.40GHz to 2.48GHz as well as the UWB range.
e. Improving the gain by use of better substrate material can also be considered.
f. A staircase antenna with slotted-cum-Defected Ground Structure might prove helpful in making the design compact and improving the bandwidth
g. To avoid interference with other bands, notches can be implemented in design at some other frequencies.
h. The antenna can be made more compact in size.

5.2 CONCLUSION

In this project a high gain UWB antenna is proposed which operates on the entire Ultra wideband range (i.e. 3.10GHz to 10.6GHz) and efficiently rejects the WLAN band (i.e. 5.15GHz to 5.825GHz) which is reported to interfere with other UWB applications. UWB is achieved by using corner truncation and partial grounding and the WLAN band is notched by embedding L-shaped slots in the ground plane. Gain stability is obtained by increasing the size of the radiating patch and introducing four corner studs in the antenna geometry. The proposed antenna has huge fractional bandwidth and is simple, easy to fabricate, cheap, compact in size and can be used for multiple UWB applications including UWB wireless communication systems and Radars. The simulations were performed using High Frequency Structure Simulator. The proposed antenna was then fabricated on low cost FR4 substrate for verification of the simulated results, which appears to be in good agreement with measured results. Stable radiation patterns and consistent gain in the UWB band were obtained. The simulation results and other measurement results of the designed antenna show a good agreement in terms of the VSWR, antenna gain, and radiation pattern.

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