Mutual Coupling Reduction in UWB MIMO Array Antenna

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Project Title: **Mutual Coupling Reduction in UWB MIMO Array Antenna**

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Course: BETE-51

Abstract: The combination of UWB technology with MIMO technique has uncovered new avenues of research in the field of antenna design. The MIMO system comprises of multiple transmitting and receiving antennas which are closely spaced. The spatial multiplexing, to utilize multipath fading, is associated with the no. of antennas element so the higher the elements counts the greater will be the throughput. This combination provides high data rate/throughput for modern day applications. High gain antennas are possible by designing arrays of MIMO systems. Major hurdle in this type of design is mutual coupling b/w closely carefully spaced antennas which compromise the efficiency of antennas. This can be neutralized by increasing distance between elements but will compromise compactness of antenna systems. Large size antennas are not viable for modern day applications. This has to be refuted by introducing various isolation techniques so that a compact antenna system can be designed which has high gain and greater bandwidth. Isolation improving techniques in this paper include defected ground, stepped slots and linear tapered slots. The purpose of this paper is to open new avenues of research in the field of UWB MIMO Array antenna systems. The writing and sequence of paper is kept simple to act as a guideline for those who want to enter in field of antenna design. With the launch of the 3-10 GHz band, applications for Personal Area Networks (PAN) are major research areas in UWB systems.

CERTIFICATE OF CORRECTNESS AND APPROVAL

It is hereby certified that information in this thesis “**Mutual Coupling Reduction in UWB MIMO Array Antenna**” carried out by 1) Capt. Muhammad Ishtiaq 2) Capt. Imran Ullah Khan 3) Capt. Muhammad Waqas 4) Capt. Shahid Ilyas 5)Capt. Fahad Zia Abbasi with the direction of Assistant Professor Major (Retired) Fazal Ahmed in serenity of our degree program of Bachelor of Telecommunication Engineering is correct and approved.

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Assistant. Professor Major (Retired) Fazal Ahmed

FYP Supervisor

Military College of Signals, NUST

DEDICATION

Dedicated to our teachers for their guidance and supervision, without their help and supervision this project would not have been made possible.

DECLARATION

We hereby declare that content of assignment presented in the project report has not been submitted in another award of qualification or degree anywhere else.

ACKNOWLEDGEMENT

All praises to our Creator for granting us understanding and forte to complete such massive project.

We are grateful to our project supervisor, Assistant Professor Engineer Fazal Ahmed for help and encouragement. We also thank and appreciate our colleagues and the staff of Electrical Engineering for their help in developing the project. We are grateful to our parents also, who stand with us in difficult times and hardship. Without their support and encouragement, we would not be able to accomplished our targets successfully.

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Key to Abbreviations

1.	MIMO	Multiple Input Multiple Output
2.	UWB	Ultra-Wide Band
3.	CST	Computer Simulation Technology
4.	HFSS	High Frequency Structure Simulator
5.	FR4	Flame Retardant 4
6.	NIE	National Institute of Electronics

Chapter 1

1. Introduction. The combination of UWB technology with MIMO technique has uncovered new avenues of research in field of antenna design. The MIMO system comprises of multiple transmitting and receiving antennas which are closely spaced. The spatial multiplexing, to utilize multipath fading, is associated to the no. of element of antenna, such that higher the elements count greater the throughput. This combination provides high data rate/throughput for modern day applications. High gain antennas are possible by designing arrays of MIMO systems. Major hurdle in this type of design is mutual coupling b/w adjacently spaced antennas which compromise the efficiency of antennas. This can be neutralized by increasing distance between elements but will compromise compactness of antenna systems. Large size antennas are not viable for modern day applications. This must be countered by introducing various isolation techniques so that a compact antenna system can be designed which has high gain and greater bandwidth. Isolation improving techniques in this paper include defected ground, stepped slots and linear tapered slots. The stepped slots helped in matching at lower, medium and higher frequencies of UWB Band. Objective is to design an antenna by using three different antenna design techniques: -

(1) UWB Antennas

(2) MIMO Antennas

(3) Array Antennas

Our aim was to integrate various antenna designing techniques to develop an antenna which will have compact size, improved antenna gain, return loss and other antenna efficiency parameters. The involvement of different techniques demanded that the project be completed in various stages thus the project was completed in following five stages.

(1)	Stage-1	Simulation/optimization of UWB patch
(2)	Stage-2	Conversion of antenna to 2 element MIMO with reduced mutual coupling
(3)	Stage-3	Fabrication of antenna
(4)	Stage-4	Testing
(5)	Stage-5	Application

Chapter 2

2. UWB Antenna Design

a. Bandwidth of UWB systems is very high with range of frequency from 3.1 GHz - 10.6 GHz. The UWB sys have short range, have high data rates and low power requirements. The conventional communication systems which send sinusoidal waves are different from UWB systems in which pulses of short duration are transmitted.

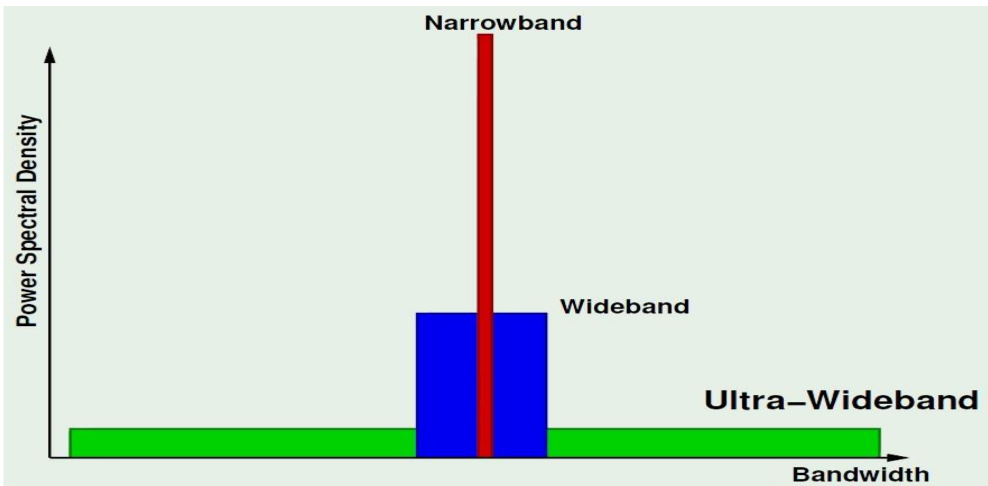

Figure no 1 UWB

b. **Design Specifications**.

(1) UWB antenna with size of 22 x 26 mm^2

(2) FR4 substrate of thickness 1.6 mm

(3) Omnidirectional Directivity

(4) UWB Bandwidth specified between 3.1-10.6 GHz

(5) Return Loss < -10 dB

(6) Transmission Coefficient < -10 dB over the entire band

c. **Initial Design**. To design a UWB antenna a rectangular shaped patch was designed in CST as per the procedures given in the literature. Patch and ground planes were modified to achieve the wide-band matching.

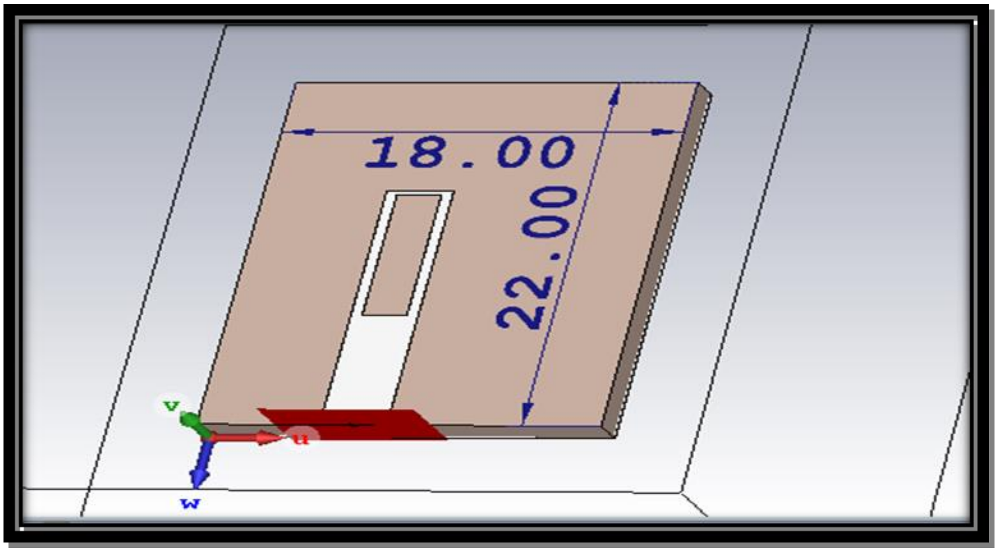

Figure no 2 UWB Anenna Design

d. Analysis of the obtained results. Following results have been achieved:-

(1) **Return Loss**

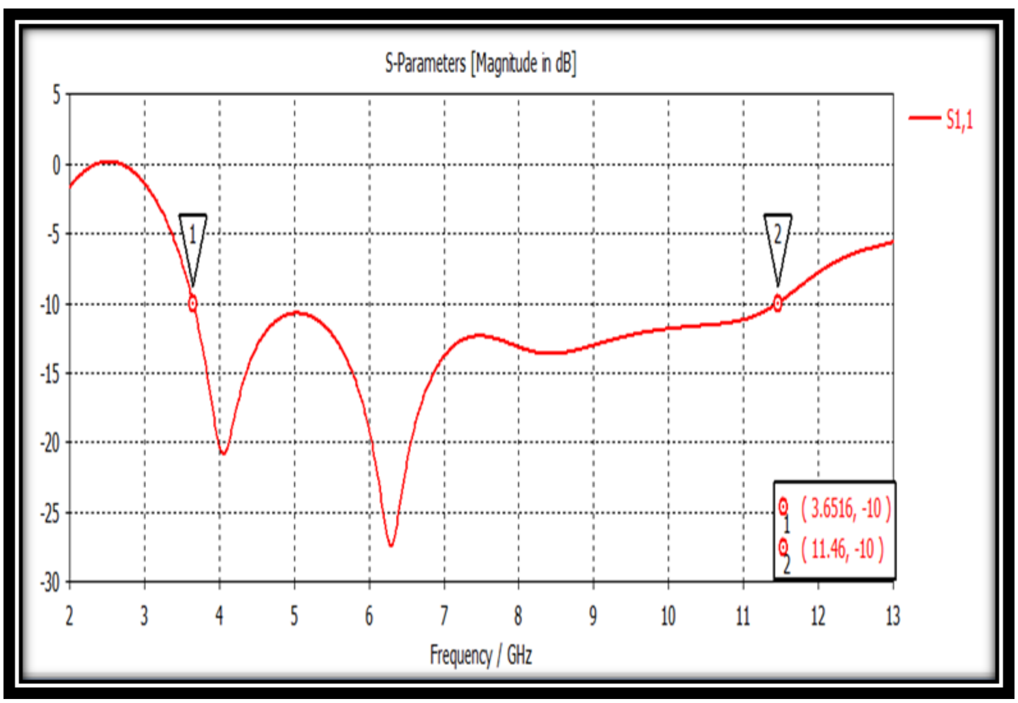

Figure no 3 Return Loss

(2) **Radiation pattern**

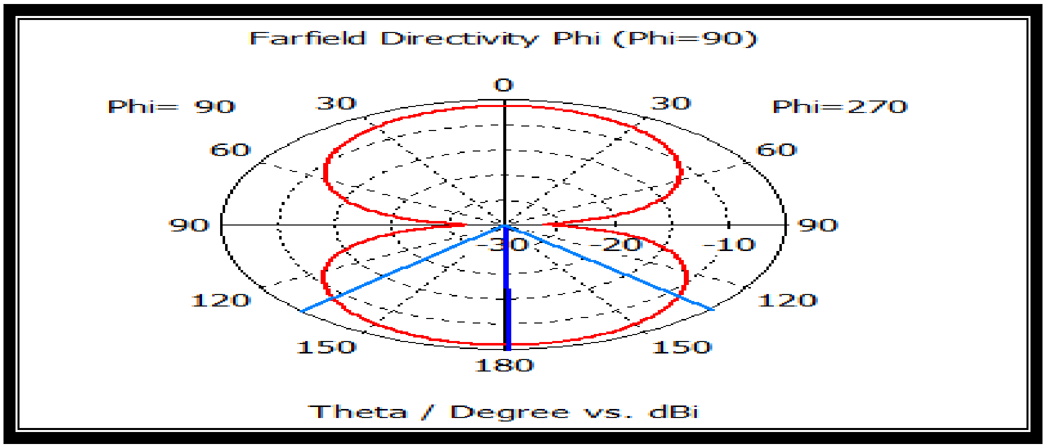

Figure no 4 Radiation Pattern

(3) **3D Polar Plot**

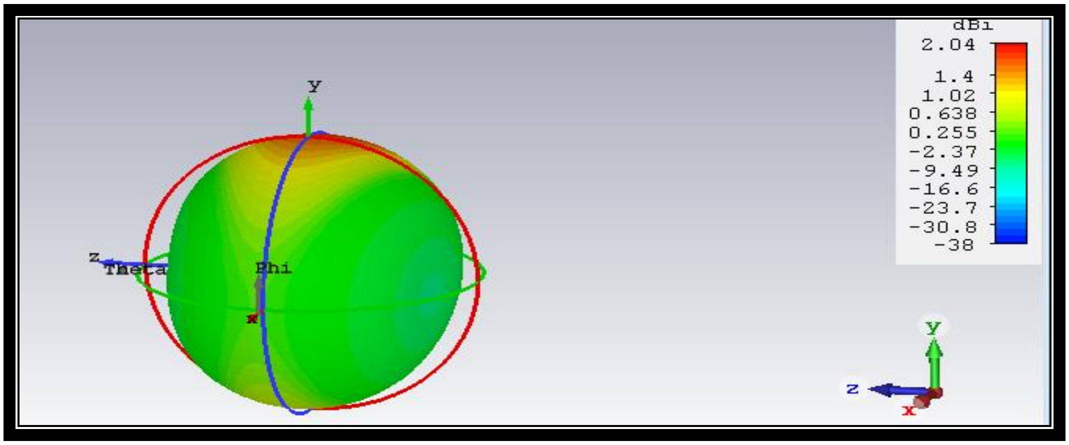

Figure no 5 3D Polar Plot

e. <u>**Analysis Based on CST Results**</u>

(4) UWB antenna is ready to be converted to MIMO antenna

(5) Return loss is less than -10dB for UWB 3.6 - 11.4 Ghz

(6) Antenna has omnidirectional directivity

(7) Gain can be improved by making array of antenna

Chapter 3

3. **MIMO**. Communication performance can be enhanced through manipulating the three-dimensional properties of multi-path channels. The technology has converted the disadvantage of multipath fading into the advantage for communication systems by increasing transmission capacity and reliability. MIMO systems, having many elements of antenna at the transmitter and many elements of antenna at the receiver side, have the prospects for increased capacity in broad multipath environments.

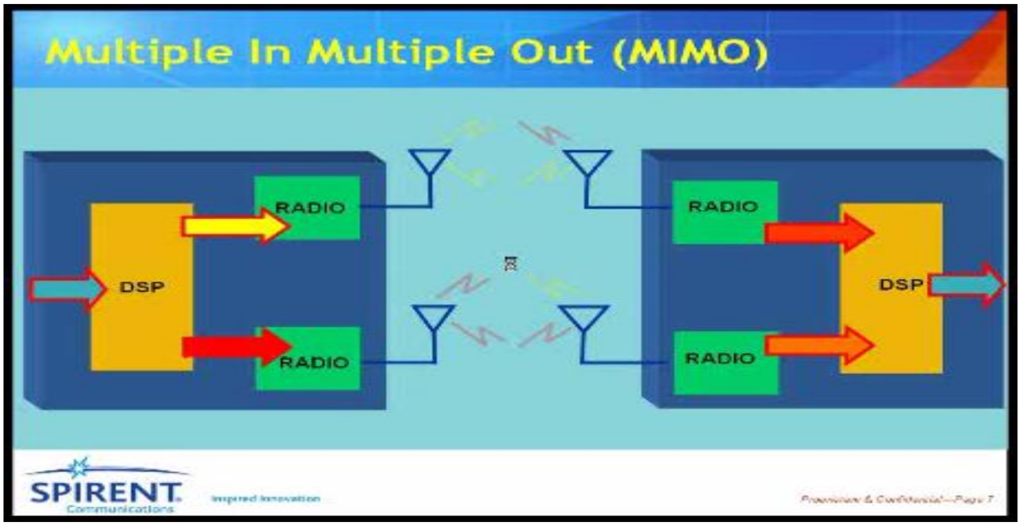

Figure no 6 MIMO

a. **UWB-MIMO Design**. The MIMO antenna comprises of minimum of two elements having low mutual coupling between them. A second element was placed near an UWB patch that is having same ground plane. However, when two elements of MIMO are placed closer to each other they would interfere, thus to reduce mutual coupling we may increase the distance between the elements. In modern day portable applications due to limitation of space the antenna size mus be compact. This issue can be resolved by placing the elements closer but with introduction of some isolation enhancing mechanism. This is done by the introduction of Linear tapered slots (triangular structure) in the ground due to which the antenna elements dont face each other directly. Further reduction is permitted in the gap b/w the elements thus resulting into a smaller design.

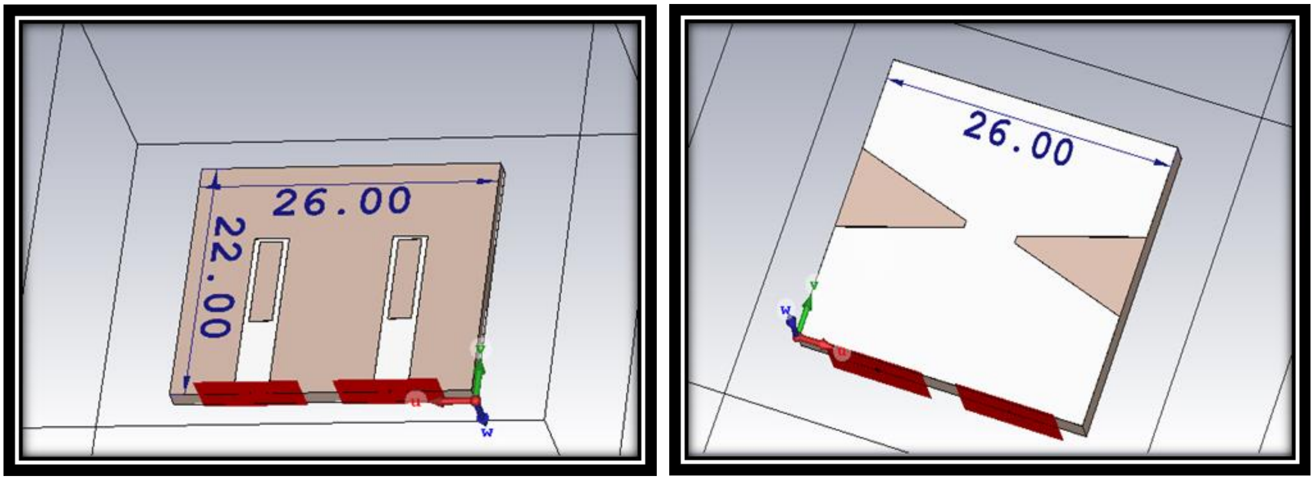

Figure no 7 MIMO UWB Antenna Design

b. **Return Loss**. After adjusting the dimensions, we acquired certain results as per the need of project. Simulated results are as shown.

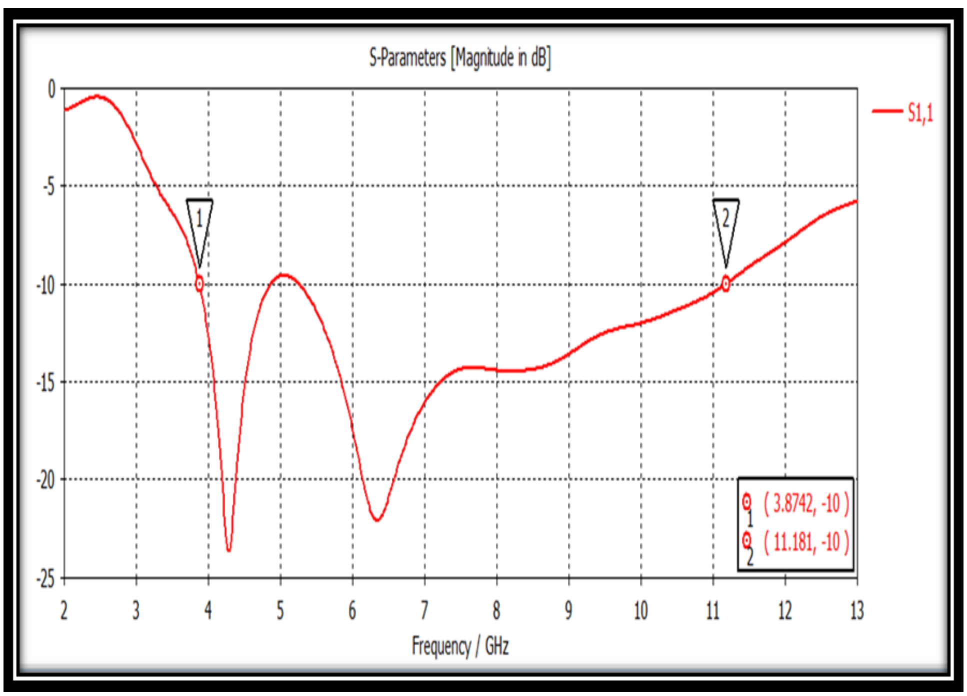

Figure no 8 Return Loss

c. **Transmission Coefficient**

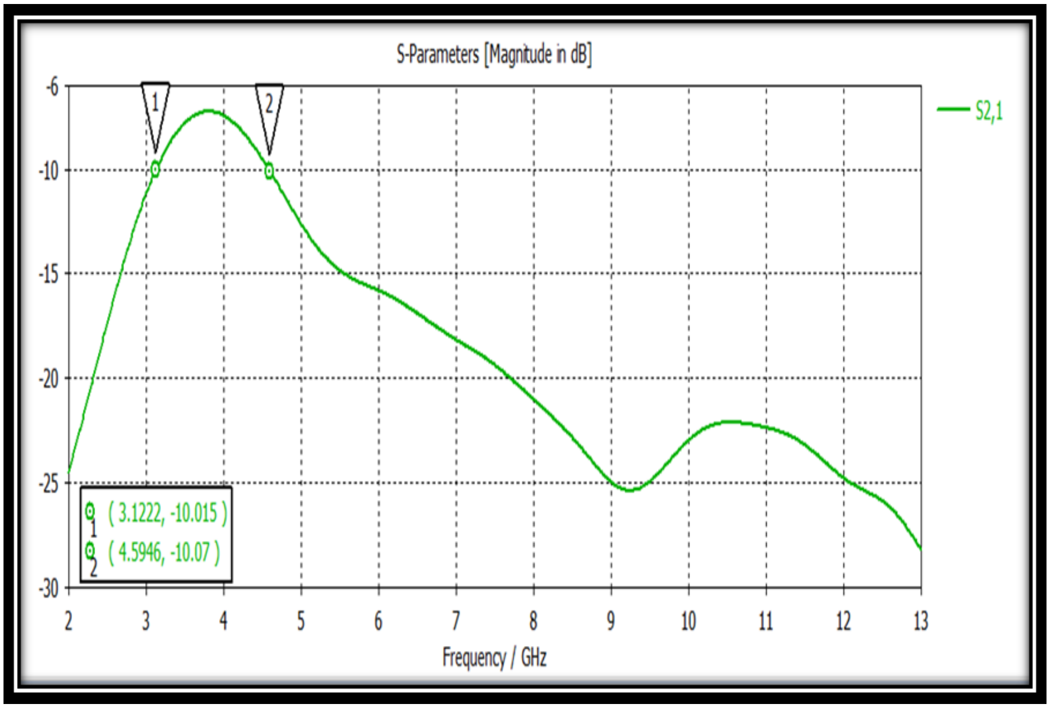

Figure no 9 Transmission Coefficient

f. <u>Analysis Based on Results</u>

(1) UWB antenna is converted to UWB MIMO array antenna

(2) Return loss is less than -10dB for UWB 3.8 - 11.1 GHz

(3) Transmission Coefficient is less than -10dB for UWB 4.5 - 13 GHz

(4) Transmission Coefficient has to be improved from 3.1 – 4.5 GHz

Chapter 4

4. **Mutual Coupling Reduction**. The degradation in transmission coefficient has been observed in the band 3.1 – 4.5 GHz in 1x2 MIMO. Various isolation enhancing and miniaturization techniques have been discussed in literature to get a compact size while retaining the desired results. Final design is simulated by introducing stepped slots in the ground which help in the mutual coupling reduction b/w the antenna element thus resulting to an antenna covering a total space of 22mm × 26mm = 572 mm^2.

The decoupling process is implemented by a simple stepped stub by the introduction of first slot in the ground which mainly decouple in the high band of UWB. The second middle slot further enhances the isolation of medium and high band of UWB. Finally, the third slot decouples the low band of UWB. The current flow is mainly along the stub because the stub suppresses surface currents and extends the current path of different antennas.

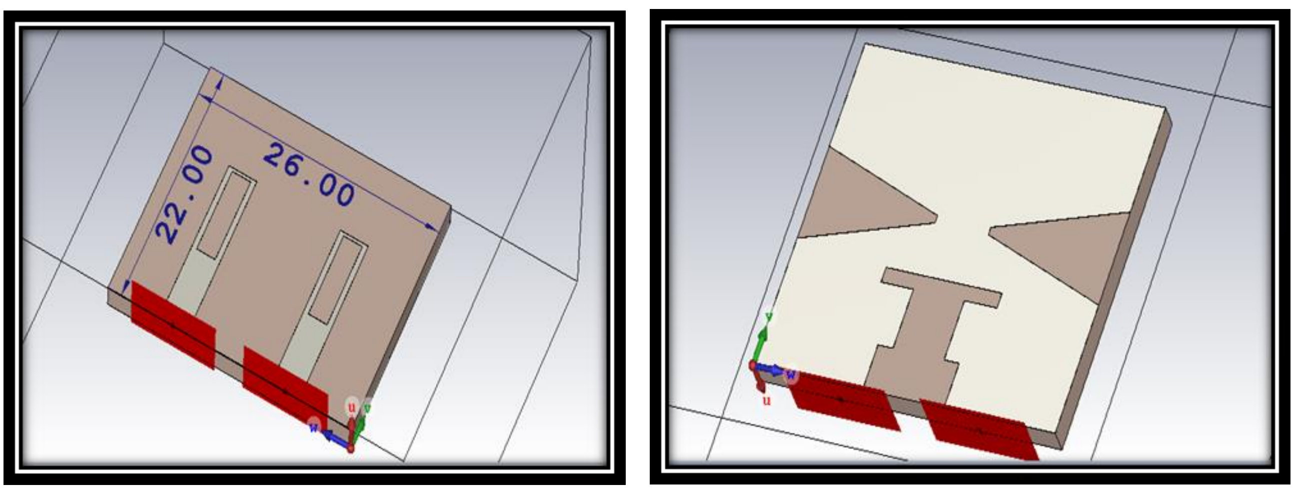

Figure no 10 UWB MIMO Array Design

a. **Isolation Techniques**

(1) Linear Tapered Slots

(2) Stepped Stubs

(3) Defected ground structures

a. **<u>Return Loss</u>.** The return loss of 2 element array is shown in Figure no 11 below. It shows that antenna works between 3.1 GHz to 13 GHz Band. It radiates best at 6.2 GHz with s11 -46.2 dB and at 11.1 GHz where s11 is -44.3 dB.

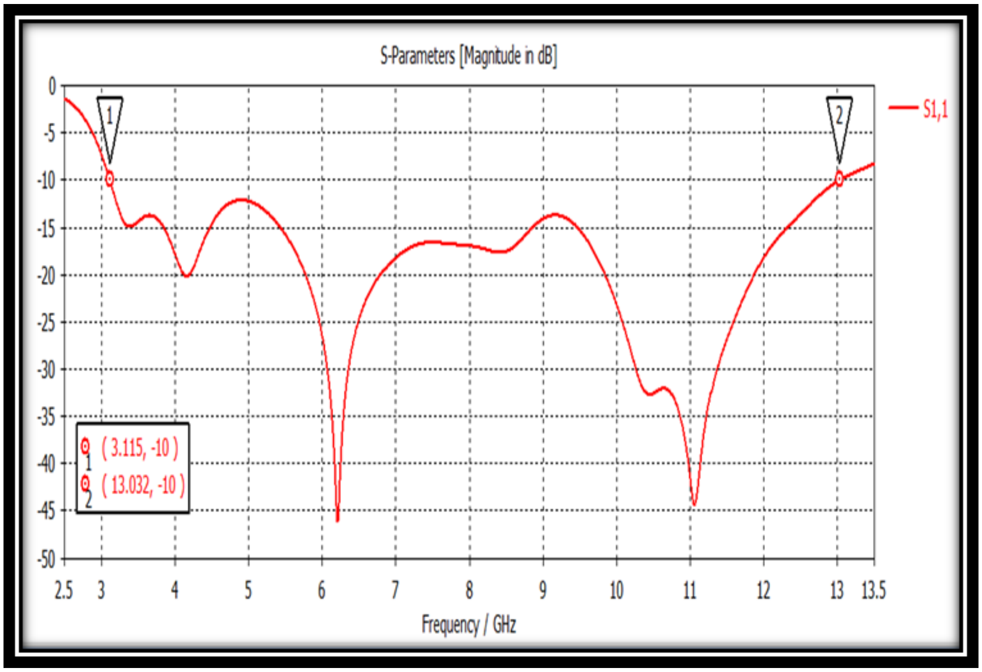

Figure no 11 Return Loss UWB MIMO Array

b. **<u>Transmission Coefficient</u>.** The values of transmission coefficient depict the isolation parameters and reduction of mutual coupling b/w the elements of antenna. Values of s21 is < -13.6 dB for the entire UWB band whereas maximum decoupling is achieved at 9.6 GHz where its value is -43.69 dB.

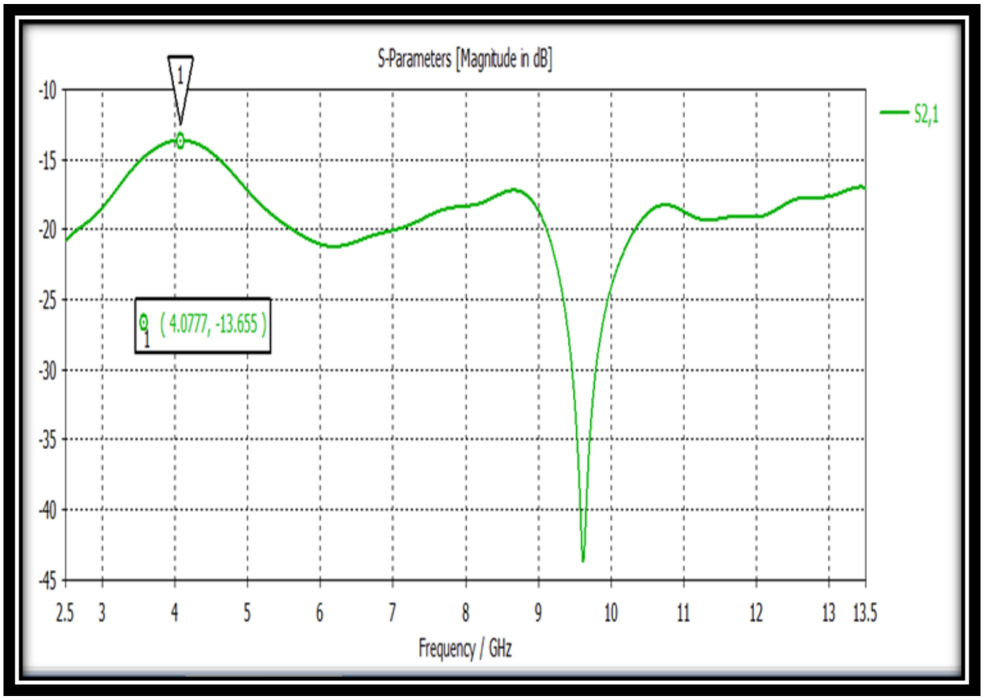

Figure no 12 Transmission Coefficient UWB MIMO Array

c. <u>**3D Polar Plot**</u>. The 3D polar plot shows a gain of 3.22 dBi at 6.5 Ghz. It is useful for visualizing in which direction the antenna radiates. The polar plot shows that the antenna radiation is an omni directional.

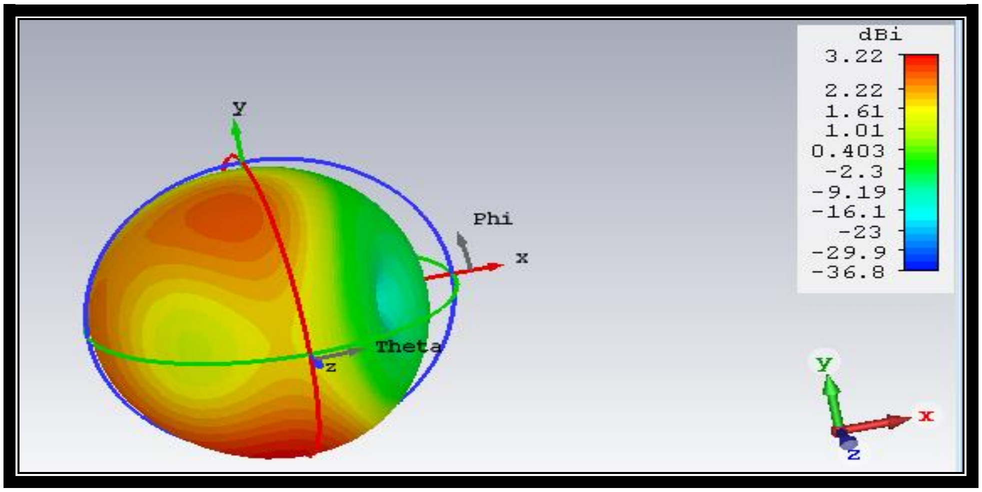

Figure no 13 3D Polar Plot UWB MIMO Array

d. **Radiation Pattern**.

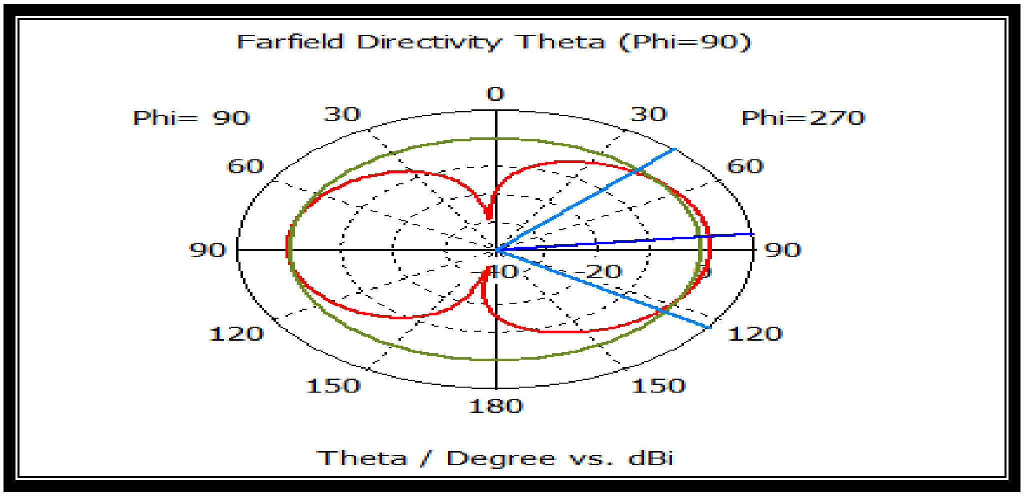

Figure no 14 Radiation Pattern UWB MIMO Array

e. **Gain**

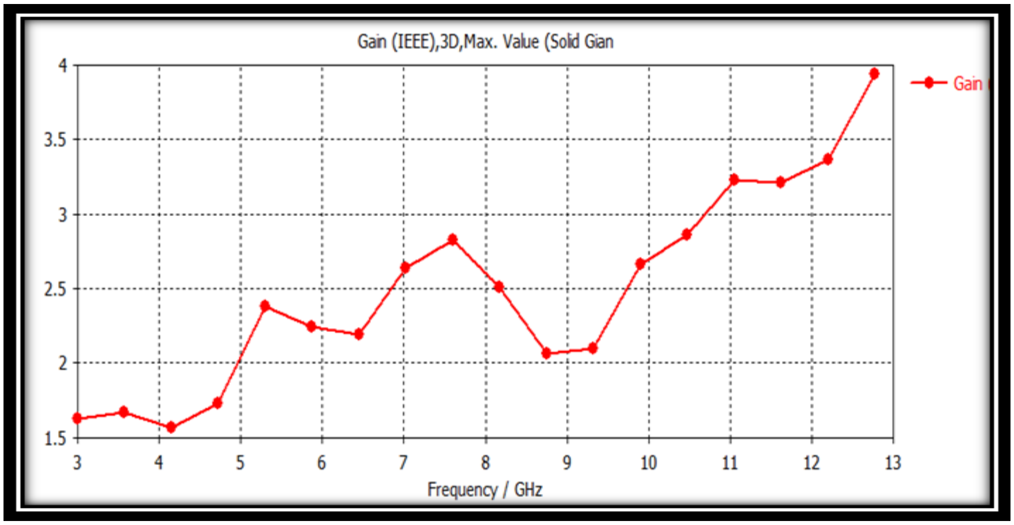

Figure no 15 Gain of UWB MIMO Array

f. **Analysis Based on Results**

(1) Enhancements in band can further be done to increase the bandwidth.

(2) Isolation techniques have provided good reduction of mutual coupling.

(3) Return loss and gain are within the desired specifications.

Chapter 5

5. Miscellaneous Tasks

a. Project Completion Timeline

Month	Task
Jun 17	Literature Review
Jul-Aug 17	Proficient learning of CST Software
Sep-Nov 17	Simulating UWB antenna
Dec 17-Feb 18	MIMO and Array Design
Mar 18	Fabrication of Antenna
Apr 18	Testing and Debugging of Antenna Hardware

Table 1

b. **Fabrication**. Antenna was fabricated on a FR4. Its di-electric permitivity is 4.4. The substrate thickness was 1.6 mm. FR4 substrates are the foremost selection for many applications. It is low cost and has exceptional properties, which makes it ideal for different modern day electronic mechanisms. As more and more microwave systems aimed at consumer markets are developed, there is a considerable interest in minimizing the cost of these systems. The fabrication was done from NIE Islamabad for accurate results so that they are closer to the simulated results on CST.

Figure no 16 Single Element Front and Back View

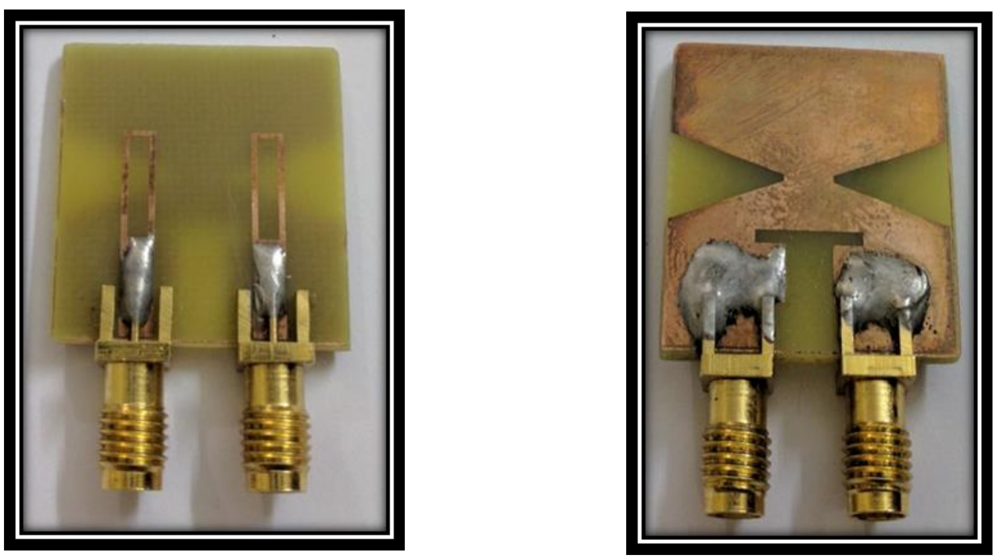

Figure no 17 UWB MIMO Front and Back View

c. **<u>Applications of Antenna</u>**. UWB MIMO antennas provides high data rate for wide range of applications.

(1) High Data Rate Home Network Applications

(2) Ground penetration radar (GPR)

(3) Search and rescue radar to detect human avalanche/earthquake victims

(4) Wireless applications like wireless monitors, camcorders and printers

(5) Medical applications

d. **<u>Application Implemented</u>**. The fabricated antenna was used in a dual band router and an external Wi-Fi adapter connected to a laptop. The connection quality and signal strength were 100% within 5 meter range.

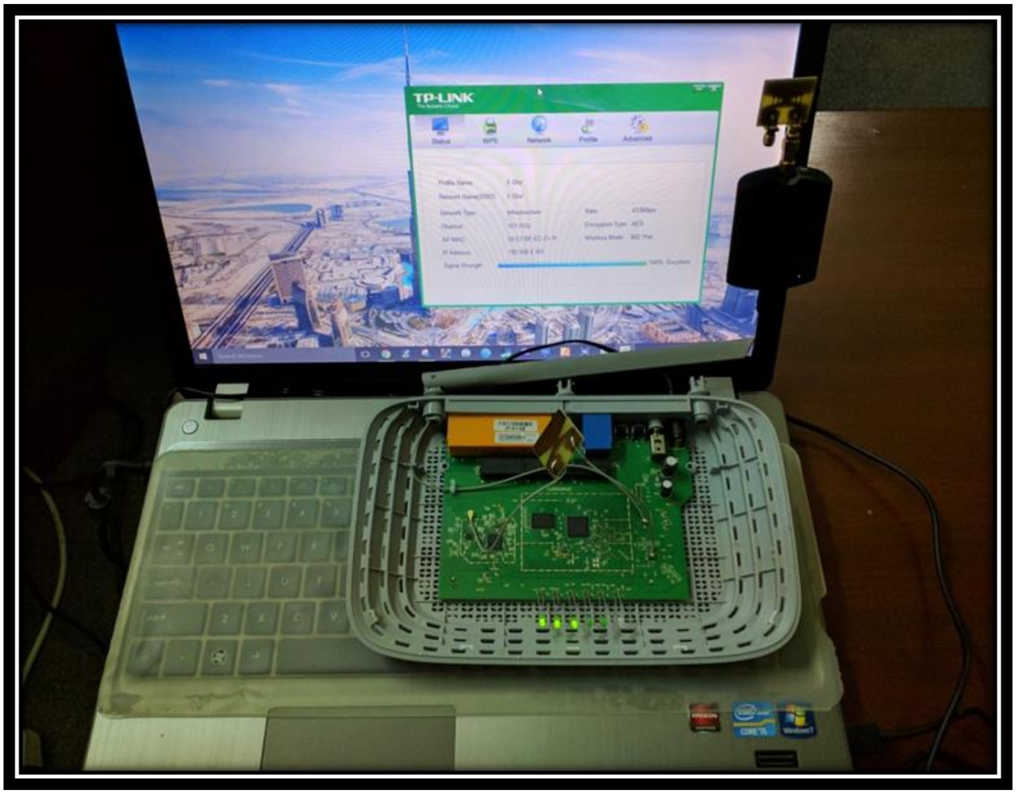

Figure no 18 Application of Antenna

e. **Resources Utilized**. The softwares and lab facilities utilized are:

(1) CST Microwave (Computer Simulation Technology)

(2) Ansoft HFSS

(3) ADS

(4) NIE (National Institute of Electronics)

6. References

a. Microstrip-Antennas: The Analysis and Design of Microstrip Antennas and Arrays by David M. Pozar, Daniel H. Schaubert

b. Al-Hadi, A.A., Ilvonen, J., Valkonen, R., and Viikari, V.: 'Eight-element antenna array for diversity and mimo mobile terminal in LTE-3500 MHz band', Microwave. Opt. Technol. Lett., 2014, 56, (6),

c. S. Zhang, Z. N. Ying, J. Xiong, and S. L. He, "Ultrawideband MIMO/ diversity antennas with a tree-like structure to enhance wideband isolation," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 1279–1282, 2009.

d. Kim, j, Ju, j., Eom, S., Song, M., and Kim, N.: 'Four-channel MIMO antenna for WLAN using hybrid structure', Electron. Lett., 2013, 49, (14)

e. Liu, L., Cheung, S., and Yuk, T.: 'Compact MIMO antenna for portable devices in UWB applications', IEEE Trans. Antennas Propag., 2013, 61, (8), pp. 4257–4264