RECONFIGURABLE ULTRA WIDE BAND MIMO ANTENNA

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CERTIFICATE OF CORRECTIONS & APPROVAL

Certified that work contained in this thesis titled "Reconfigurable UWB MIMO Antenna", carried out by GC Mashood Saleem, GC Muhammad Nouman, GC Ubaid Abbasi, GC Hassan Alam, under the supervision of Dr. Farooq Ahmed Bhatti for partial fulfillment of Degree of Bachelors of Electrical Engineering, in Military College of Signals, National University of Sciences and Technology, Islamabad during the academic year 2016-2020 is correct and approved. The material that has been used from other sources it has been properly acknowledged / referred.

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We are appreciative towards our Creator Allah Subhana-Watala to have helped us during the process of writing our thesis by putting new ideas in our mind and then improving them. Indeed, nothing could have been possible without Your inestimable aid and supervision. All the individuals who have helped us during our thesis did so because of Your will and no one is worthy of praise except You.

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As a final point, we are all very thankful to our loving parents for fulfilling all our necessities that were required to reach this stage.

Dedication

We dedicate this to our loving parents whose support paved a way for us to this wonderful accomplishment.

Abstract

Design of a frequency reconfigurable antenna for mobile devices that operate at ultra wide frequency bands of 2.45(WIFI) 3.1 IMT(2.3 GHz), 3.4 GHz, WLAN 802.11 (2.4 and 5 GHz), 5G sub 6 band (1-6 GHz) and satellite-X band (8-12 GHz). In late time, the interest of Ultra-Wideband (UWB) is expanding in mobile devices, radar innovation and Wireless Personal Area Network (WPAN) applications due to high information rate and channel limit. A few radio wire structures have been proposed to consolidate the high information rate and limit, i.e., Multiple Input Multiple Output (MIMO) based radio wire that give the higher information rate and channel limit. In any case, structuring the reduced reception apparatus, while meeting the business prerequisite of UWB-MIMO framework. One of the most encouraging arrangement is to utilize the organizer microstrip reception apparatuses for accomplishing higher information rates, reduced size, low profile, ease, simple to create, ultra-wide transfer Multi band characteristics have been achieved by variation in length of radiating patch, slots, partial ground and parasitic patches while frequency reconfigurability has been achieved by utilizing RF PIN diodes as switches and switchable frequency bands makes the antenna suitable for wireless devices such as laptop, tablets and future 5G smart-phones. The antenna has been simulated on HFSS 13 and has been fabricated and tested. hence this thesis provides the ultimate solution for the data rate issues in mobile devices by using multiple antenna technique on a same patch. This design is stimulated on HFSS13, tested and fabricated.

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Chapter 1: INTRODUCTION

1.1 What is an Antenna Designed for?

The basic purpose for which antenna is designed is to provide connection between current through a conductor and radio waves travelling in space. Antenna is used for both reception and transmitting purposes.

1.2 Classification of Antenna:

Antennas can be classified into different types depending upon their radiation pattern, shape, and structure. Antennas shapes and structure depends upon the purpose for which they are designed. Considering their shape antennas can be classified as Horn, Vivaldi, Log Periodic, Dipole, Bowtie and Micro strip patch antenna. If we take their radiation pattern into account antennas can be;

a) Omni-directional i.e which has same value of gain in all the directions
b) Directional antenna i.e that has a certain gain in particular direction as compared to other directions.

Figure 1.1 shows the omni directional dipole and high gain directional antenna.

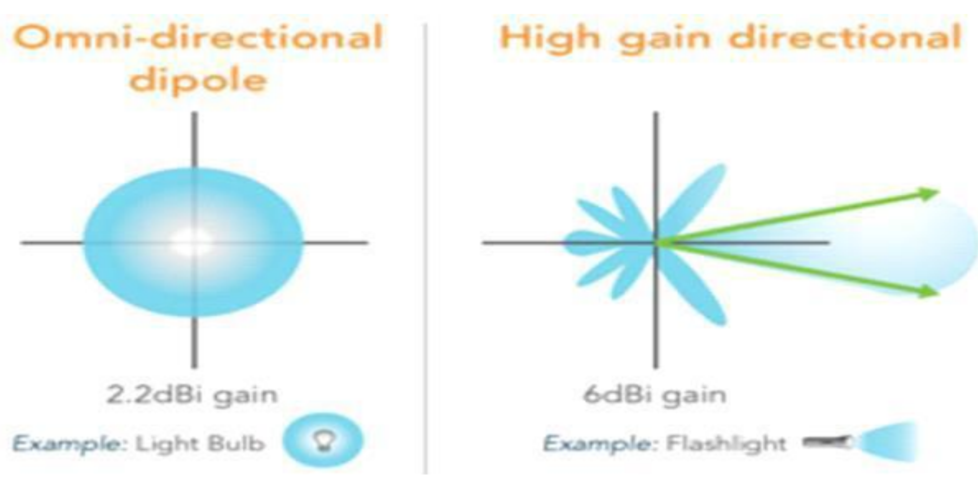

Figure 1.1 Omni Directional and Directional Antenna

1.3 What is Planar Antenna:

Planar antenna is a two-dimensional antenna in which both active and parasitic elements are placed on one plane. It includes the microstrip antenna or the printed circuit board antenna. Patch on the antenna may acquire different shapes e.g. triangular, rectangular, circular. Cost of these antennas are very less, their size is also small and they are versatile hence making them so compatible for the wireless devices especially for the devices operating on more than one frequency.

1.4 What is Micro strip patch antenna:

A simple micro strip patch antenna consist of a patch made up of metal foil etched on the top of PCB surface. Ground is also made up of a metal foil but it is on the back side of the PCB surface. Patch and ground may exist in various shapes. microstrip patch antennas are gaining more and more importance in the modern times because they are economical, have less weight and are compatible. this also makes them perfect for use in mobile devices.

1.5 Construction of patch antenna:

Micro strip technique is used for the construction of patch antenna. A specific dielectric material with a proper thickness serves as substrate. There is a radiating patch on the top of substrate and a ground mostly on the back side of the substrate.

Figure 1.2 shows a basic patch antenna and its components the forming components of antenna are labelled.

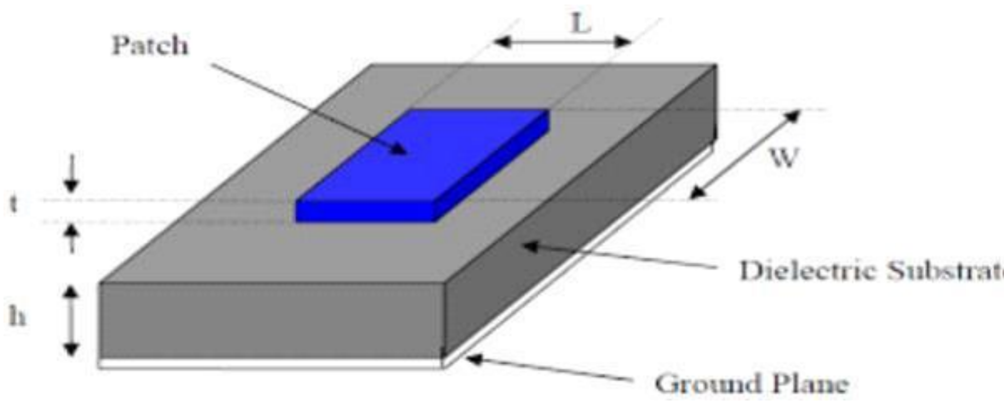

Figure 1.2 A Micro strip patch antenna

1.6 Basic component of patch antenna:

Substrate, patch, and ground these are the three basic components that make up patch antenna.

1.6.1 Patch (Radiating part):

Radiating part may acquire different shape i.e. rectangular, circular, square, elliptical, ring and many others. Most commonly it is in rectangular shape. The patch is optimized depending upon the application for which it is designed.

1.6.2 Substrate:

Substrate is considered to be the support of antenna. Electrical properties of the antenna are affected by the properties of the substrate. Selecting appropriate substrate for the right task is of great importance. There are many factors that should be kept in mind while selecting a proper substrate e.g surface wave excitation, loss tangent and dielectric material, copper losses, temperature and humidity effects.

1.6.3 Ground Plane:

Mostly ground is etched on the back the back side of the substrate. It is made up of a conducting material. If a ground size is reduced to fulfill the requirement it is called the partial ground, it is done in order to increase the operating bandwidth.

1.7 What is Ultra-Wide Band?

Ultra-wide band is a frequency band that ranges from 3.1 to 10.6 GHz. It uses radio waves for short range and wireless communication. It also operates on higher frequencies as it is visible from its operating range.

1.8 Advantages of Ultra-Wide Band:

1.8.1 Improved channel capacity:

The wide range of frequencies available in ultra-wide band improves the channel capacity. Shannon's equation clearly depicts that capacity depends upon SNR, therefore in harsh scenarios with low SNR the UWB communication systems can assure you large channel capacity just because of their larger bandwidth.

1.8.2 Immune to interception:

UWB communication systems have very low transmission powers, this factor play a vital role in making the communication system immune from interception or any kind of detection.

1.8.3 Jamming resistant:

As UWB signals covers the great range of frequencies it gives these signals an edge of high processing gain and this much versatility in frequency range avoids any attempt of jamming

1.8.4 Penetration power:

UWB systems got some superior penetration properties. Lower frequencies present in the UWB with longer wavelengths can penetrate through material.

1.8.5 Simple construction:

Construction of UWB transceiver is far simpler as compared to the construction of narrow band transceivers.

1.8.6 No power amplifier required:

As impulses are already transmitted the low power so there is no need left for the power amplifier in the transmitter.

1.9 Multiple Input and Multiple Output (MIMO):

Multiple Input and Multiple Output as the name suggests is used to increase the capacity of radio linking by using multiple transmitters and receiving antennas. This has also played a vital role to exploit the multipath fading. In earlier times the term MIMO was only used for the antennas having multiple transmitter and receivers, but in modern times this name is also given to the technique in which more than one data signal is sent simultaneously over same channel.

1.10 Advantages of MIMO:

1.10.1 Increased channel capacity:

MIMO technology was basically introduced to increase the capacity of the linkages by deploying multiple antennas on the transmitter and receiver side.

1.10.2 Increased throughput:

MIMO can increase the channel capacity effectively without the need of extra bandwidth. MIMO offers the channelizing of space. MIMO implements the spatial multiplexing technique for this purpose.

1.10.3 Diversity:

MIMO offers the power to differentiate between the signals transmitted over multiple paths, hence allowing to encode the signal more efficiently irrespective of multipath losses.

1.11 Overview of UWB MIMO Technology:

In past century, numerous remote correspondence framework and conventions have been created to meet the necessity of government segments, business and guard associations. To oblige distinctive correspondence framework and conventions the controller specialists have dispensed the constraint in transfer speed, transmission force and range. In 2002 Federal Correspondence Commission (FCC) have presented the ultra-wide band innovation for business applications. It has exceptionally huge transmission capacity 3.1GHz to 10.6GHz and to maintain a strategic distance from obstruction its capacity is kept low. Accordingly, low force and high data transfer capacity are the crucial focal points of UWB framework. UWB frameworks execution restrains due to low force and defenselessness of multipath fading. To build data rate, furthermore, to defeat multipath fading, a MIMO innovation is consolidated with UWB frameworks. Subsequently, UWB-MIMO is a short range, wide band, high data rate and solid correspondence framework. Favorable circumstances of UWB-MIMO framework, for example, moderation of obstruction, high data rate make it reasonable for the applications in high data rate, wireless communication and mobile devices framework and radar framework.

1.11.1 Compact UWB MIMO Antenna with high isolation:

In recent, years the pattern in present day framework and UWB MIMO framework is towards compatibility and scaling down. Antenna is an essential piece of any kind of mobile communication. Printed micro strip antennas are generally utilized in UWB applications because of its small size. High isolation values between antenna elements are mandatory in order to merge MIMO technology with UWB antenna. Expanding research has been dedicated to antenna design that can give ultra-wideband impedance transfer speed and great radiation properties with conservative size and high segregation between reception antenna components.

1.12 Reconfigurability:

The term reconfigurability refers to altering one or more parameters. This can be brought in any value of the design which leads to the change in properties or characteristics of the design.

1.12.1 Reconfigurability in Antenna:

Reconfigurability in an antenna allows changing the frequency and radiation pattern of the antenna. In order to obtain the desired result and output we can control and optimize this change in properties and characteristics.

1.12.2 Why do we reconfigure?

No doubt that different multiple band antennas can operate at several different frequencies but there is a one major drawback to operate on single wireless standard. Whereas, while working with reconfigurable antennas several standards can be met at the same time. By using the switching operation multiple frequencies can be handled quite efficiently. Frequency on which antenna is operating can be reconfigured as per the desired application. In short a reconfigurable antenna can operate on multiple frequencies.

1.12.3 Advantages of Reconfigurable antennas:

Reconfigurable antennas are of great values in modern times,

1.12.3a Multi Standard operability: Reconfigurable antennas can handle several standards at the same time. This property makes the, very efficient and versatile kind of antennas and we can achieve high isolations between these standards.

1.12.3b Versatility: These antennas are very versatile in nature for example they can be operated at wide bands, narrow bands. They can be used as single element or an array.

1.13 Types of Reconfigurability:

There are numerous parameters which can be altered for the reconfiguration of the antenna. Some common parameters which can be changed for reconfigurability leads to following reconfigurations.

- Frequency Reconfiguration
- Polarization Reconfiguration
- Pattern Reconfiguration

1.13.1 Frequency Reconfiguration:

Varying the geometry of antenna in such a way that it leads to the change in resonant frequency is known as frequency reconfiguration.

Figure 1.3 shows how there occurs a shift in operating frequency after reconfiguration. Operable frequency is shifting to the right side as seen in Figure 1.3.

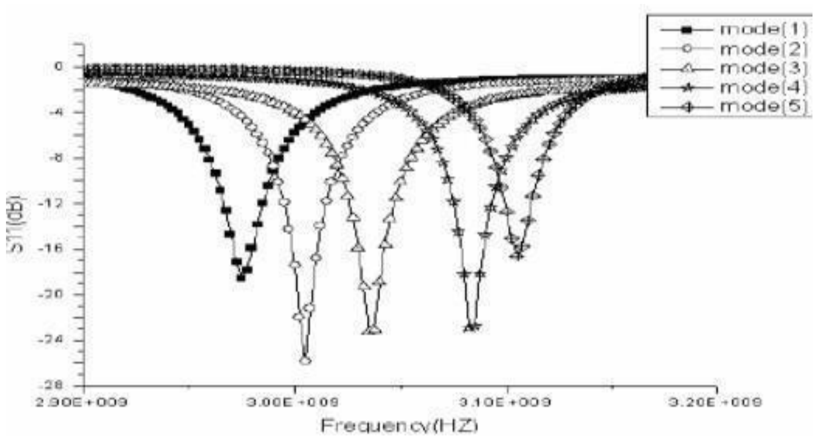

Figure 1.3 Frequency Reconfiguration

1.13.2 Polarization Reconfiguration:

Varying the geometry of antenna in such a way that it leads to the change in polarization pattern of the antenna is known as polarization reconfiguration. it can switch from horizontal to vertical.

Figure 1.4 shows the change in the polarization pattern. Figure 1.4 shows the LHCP and RHCP.

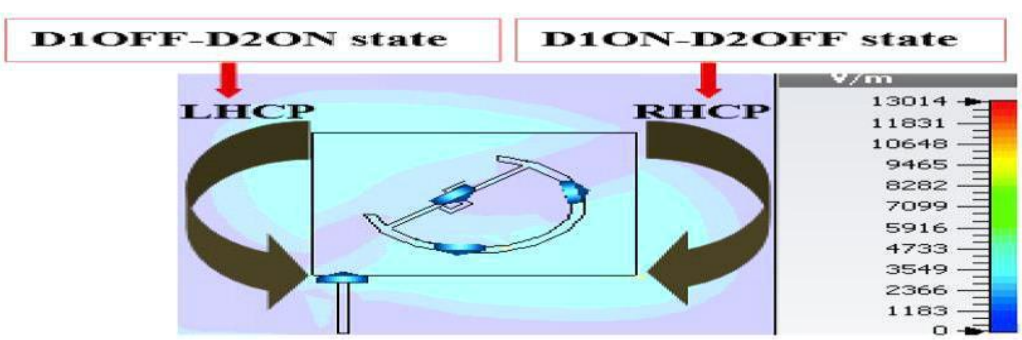

Figure 1.4 Polarization Reconfiguration

1.13.3 Pattern reconfiguration:

It implies to the variance brought into the radiation pattern of antenna. Figure 1.5 shows different pattern after reconfiguration.

Four different radiation patterns are shown in **Figure 1.5**

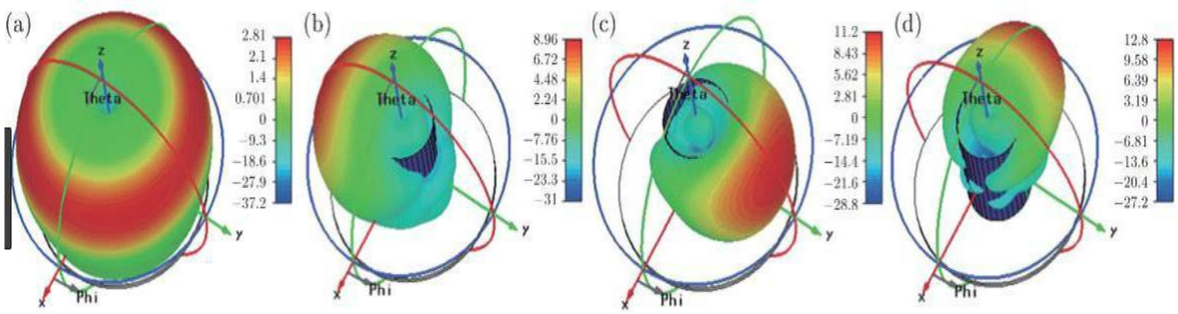

Figure 1.5 Pattern Reconfiguration

Chapter 2: LITERATURE REVIEW

2.1 Introduction of Printed UWB Antenna:

Antenna is known as a sensor or a progress gadget that changes over electromagnetic transmitted vitality to electric signals. It additionally moves electromagnetic waves from guided medium to un guided medium which implies it can transmit and get electromagnetic waves. A wide range of kinds of antennas are accessible in writing and literature, for example, wire antennas, opening antenna, printed antenna and focal point antenna. Micro strip antenna is a significant sort of printed antenna. In a simple micro strip antenna, a simple dielectric is used to separate ground and radiator. Both are conducting metallic layers. Presently micro strip innovation has gotten very mainstream on account of their conservativeness and congruity in metallic devices. Micro strip antennas with complete ground are will in general low transmission capacity and single resonance frequency. These disheartens the utilization of micro strip antenna for UWB frameworks as it requires huge data transfer capacity. By utilizing the transmission capacity improvement procedures these numerous frequencies band can cover to yield a wide bandwidth for UWB framework.

Figure2.1 shows the construction of simple printed micro strip antenna and its component.
Different constructing components of antenna are labelled in Figure 2.1

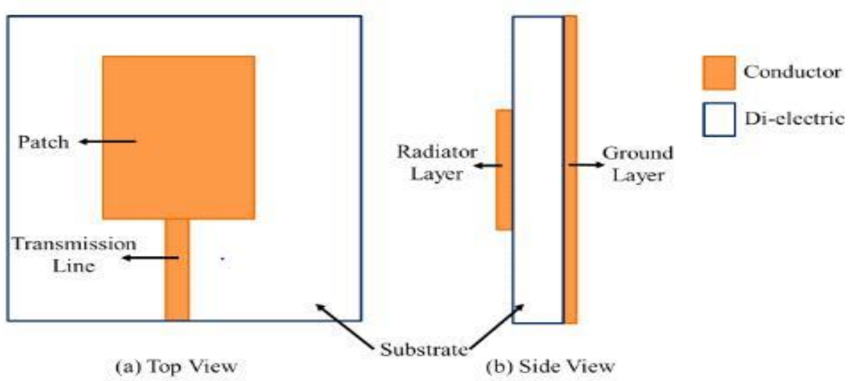

Figure 2.1 Printed Micro strip Antenna

2.2 Different Kinds Micro strip UWB Antennas:

In the following segment different kinds of Micro strip antennas will be discussed after the review of literature,

2.2.1 Vivaldi Antenna:

This antenna is not a strong reflector of waves, the reason for this is its tapered structure. In the absence of reflectors waves travel through the antenna. These travelling waves results in the broad band response. These properties make this antenna useful in the radar applications.

Figure 2.2 shows a fabricated Vivaldi antenna.

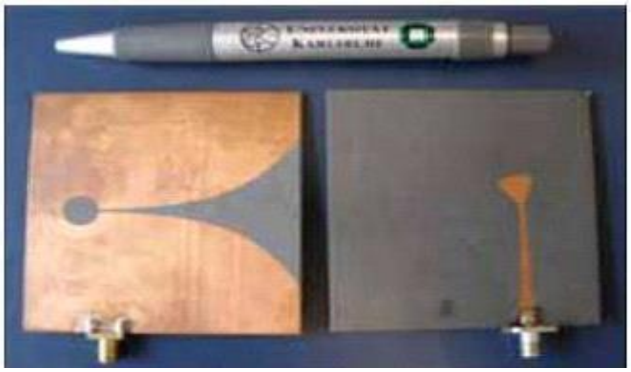

Figure 2.2 Vivaldi Antenna

2.2.2 Spiral Antenna:

This antenna is a true reflection and example of self-balancing antenna. These antennas have non varying values of input impedance over a frequency range.

Figure 2.3 shows an example of spiral antenna.

Figure 2.3 Printed Spiral Antenna

2.2.3 Bowtie Antenna:

This type of antenna has a directional radiation pattern. Its properties and characteristics make it useful in high gain applications. Their radiation pattern is directional.

A fabricated bowtie antenna can be seen in **Figure 2.4.**

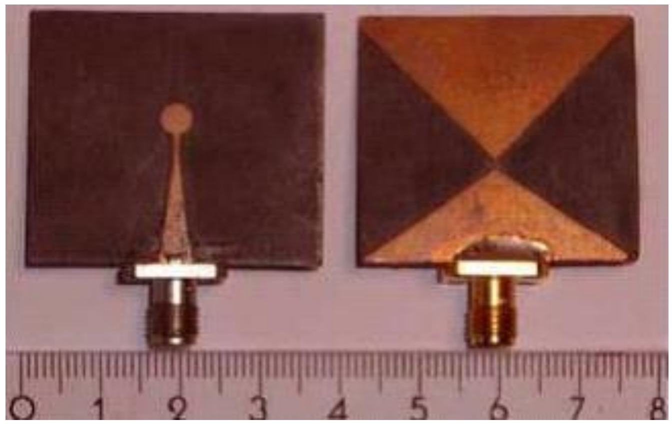

Figure 2.4 Bowtie Antenna

2.2.4 Log-Periodic Antenna:

An array of narrow banded dipole elements which are excited separately forms this type of antenna. This kind of antenna has same advantages and use as of Bowtie antenna. This antenna also has a directional pattern. Its flaws includes its large size and complex feed.

Figure 2.5 shows a fabricated long periodic antenna.

Figure 2.5 Log-Periodic Antenna

2.2.5 Comparison:

Table 2.1 compares types of antennas in terms of its two important properties that are size and radiation type of antenna. Talking in terms of gain and radiation pattern, all the high gain antennas have directional radiation pattern whereas, low gain UWB antennas have Omni directional radiation pattern. While designing the antennas we need to compromise on one thing from size of antenna and input impedance or properties lie gain.

Table 2.1 compares and show the basic characteristic properties of different antennas.

Type of Antenna	Type of Radiation Pattern	Size Compactness
Vivaldi	Directional	Low
Log-Periodic	Directional	Low
Spiral	Bi-Directional	Medium
Bowtie	Bi-Directional	Medium
Slot	Omnidirectional	High
Monopole	Omnidirectional	High

Table 2. 1 Comparison of Printed UWB Antenna Types

2.3 UWB MIMO Antennas:

UWB innovation is very valuable for short range communicational framework because of wide bandwidth. The performance of UWB restrains in multi path fading conditions also, a MIMO innovation is merged with UWB frameworks. Hence an antenna with wide transmission capacity and various components is required. Basic properties of UWB MIMO reception include mutual coupling and diversity gain between multiple elements. As passing time is heading towards reduction of size hence, we have to compromise on one factor either it’s the size or the mutual coupling of antenna elements.

2.3.1 Comparison of Techniques to Reduce Mutual Coupling in UWB-MIMO Antenna:

The main aspect of MIMO around which all of its other properties revolves or are dependent upon is mutual coupling. There are various techniques which are used to increase the isolation between the elements of the antennas.

Table 2.2 clearly shows the comparison between these techniques keeping in view the size of antenna.

MIMO Techniques	Effective For	Size Compactness
Matching and Decoupling	Narrow band MIMO	Small
EBG	Both Narrow and UWB	Medium
Neutralization Line	Both	Small
DGS	UWB	Medium
Spatial and Angular	Both	Small
Inserting Stubs	UWB	Large

Table 2. 2 Comparison of MIMO Antenna Isolation Types

2.4 Frequency Reconfigurable Antennas:

Reconfigurable antennas cover a wide range of frequencies or multiple frequencies. These antennas are design in order to get rid of several antennas which has to be used to operate on different frequencies. By using this technology, we will not need different antennas to cover several frequencies but a single reconfigurable antenna will do the task. This property makes it quite useful in mobile devices and wireless communication because size of antenna has been reduced and it results in good isolation. Therefore, demand of reconfigurable antennas is increasing day by day.

2.5 Techniques of Frequency Reconfiguration:

With the advent of time numerous techniques and structures have been employed in order to achieve frequency reconfiguration. Few structures that can be taken under consideration for achieving the goal of frequency reconfiguration are mentioned below,

- Patch antennas,
- Wire antennas and
- PIFA structures

2.5.1 Patch antennas:

In these antennas switches are used to vary different parameters in order to achieve the goal of reconfiguration and these parameters includes geometry or slots of antennas. Dividing the current path also leads to achieving reconfigurability.

2.5.2 Wire antennas:

In such antennas the only parameter that helps us to attain reconfigurability is the length. It is the only geometrical parameter in the design which can be varied to achieve reconfigurability. Changing the length about quarter of original length we can obtain first resonant frequency.

2.5.3 PIFA structures:

Feed line and ground location is varied in order to attain reconfigurability. These two parameters are varied to attain the desired results. Keeping in view different parameters and aspects like size, compactness, price, bandwidth, radiation pattern, the most suitable and appropriate design is micro strip patch antenna as it has got numerous advantages.

2.6 Switches for reconfigurability:

Deduced from literature, following types of switches are used to attain reconfigurability.

- RF PIN diodes
- Varactor diodes
- PIFA structures
- RF MEMS
- FET based switches
- Reed switches

2.6.1 RF PIN Diodes:

Like switches it operates in two modes. Once turned ON or in ON state it provides connectivity whereas in OFF state it simply disconnects. For this specific reason it is placed in the slot.

Figure 2.6 (a) shows top side of a reconfigurable antenna with an inserted PIN diode.

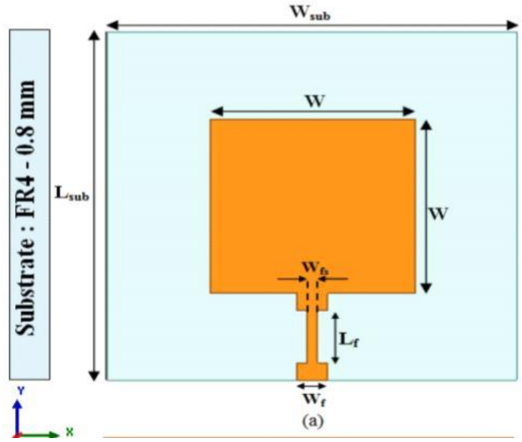

Figure 2.6 (a) A Multiband reconfigurable antenna (top side)

Figure 2.6 (b) shows shift in frequency. The results show that pin diodes have reconfigured the frequency and have achieved three different bands.

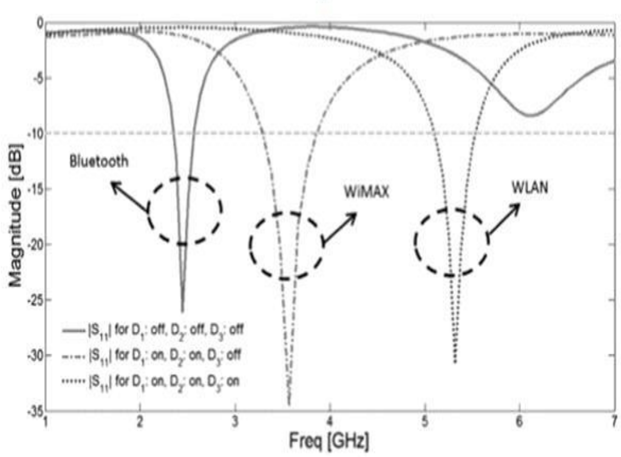

Figure 2.6 (b): S11 parameter of Multiband reconfigurable antenna

2.6.2 Varactor Diodes:

Reconfiguration is achieved by varying the value of capacitance between the two extremes. These diodes have built-in value of capacitance. To attain the desired results the value of capacitance can be varied between the wide ranges of frequencies available between two extremes.

Figure 2.7 (a) shows the geometry of multiband antenna with varactor diodes.

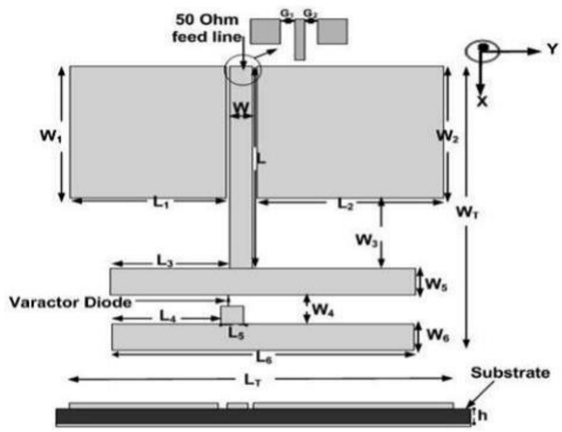

Figure 2.7 (a): Geometry of multiband reconfigurable antenna

Figure 2.7 (b) shows value of return loss at different capacitances of the varactor diodes used for reconfiguration and figure.

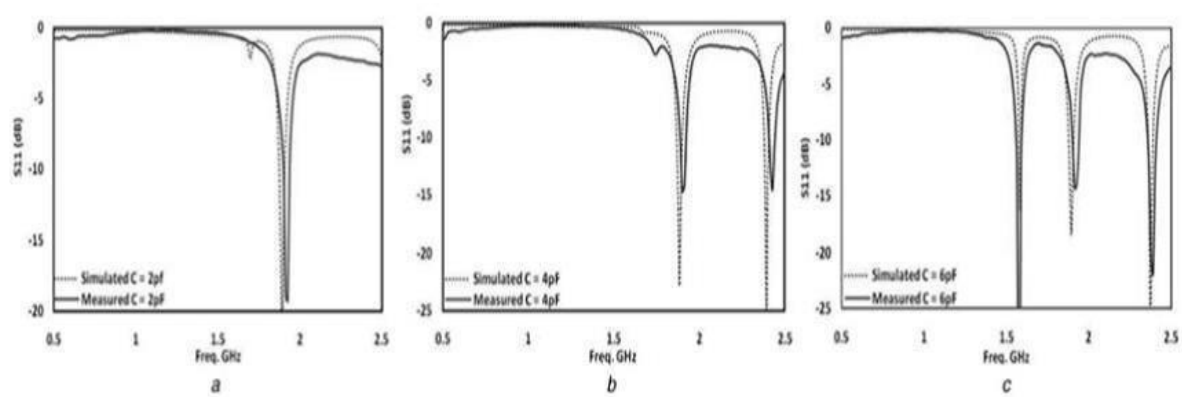

Figure 2.7 (b) Measured return loss for variable values of capacitance 9(a) c=2pF (b) c=4pF (c) c=6pF tri-band operation

2.6.3 PIFA Structure:

Another method which is also used to reconfigure antennas is PIFA. Planar Inverted F structure or PIFA designs are used for attaining multi-band properties. Geometry of PIFA can be seen in figure 2.8.

Figure 2.8 shows the structure of PIFA from different dimensions.

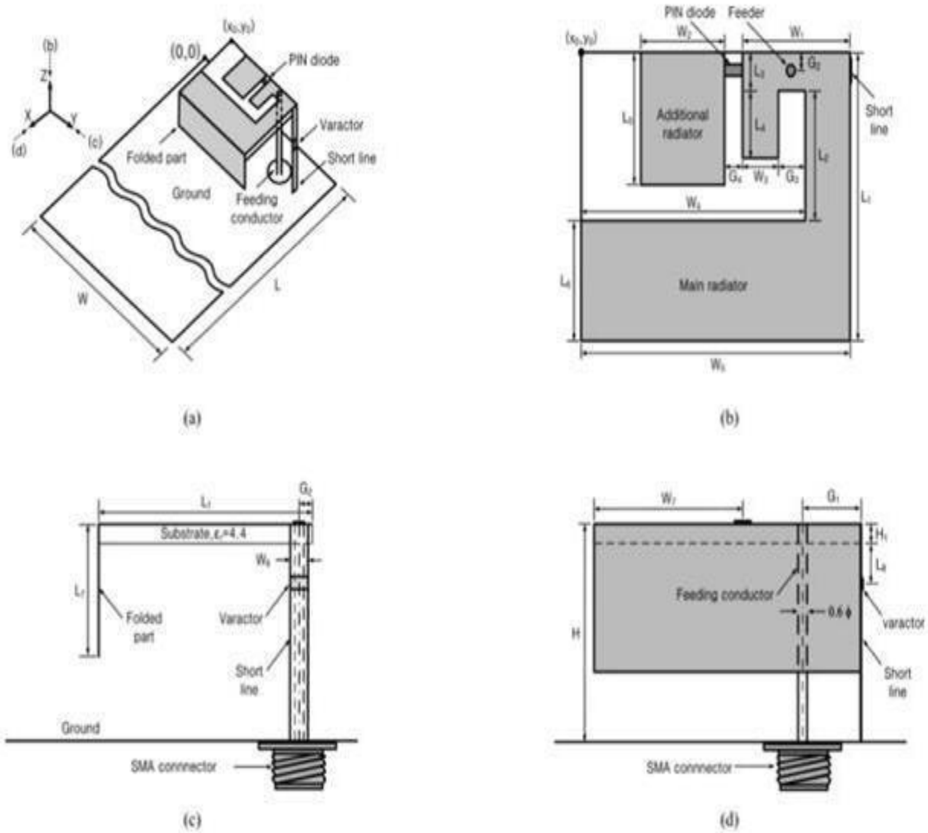

Figure 2.8 Geometry of proposed PIFA from different dimensions

2.6.4 RF MEMS:

A radio frequency micro electromechanical switch offers low force scattering, little size, minimal effort and improved seclusion, when contrasted with other RF switches. That is the explanation; they are utilized in capacitors, inductors, power dividers, and full structures.

Figure 2.9 (a) shows the PIFA with on state of MEMS switches

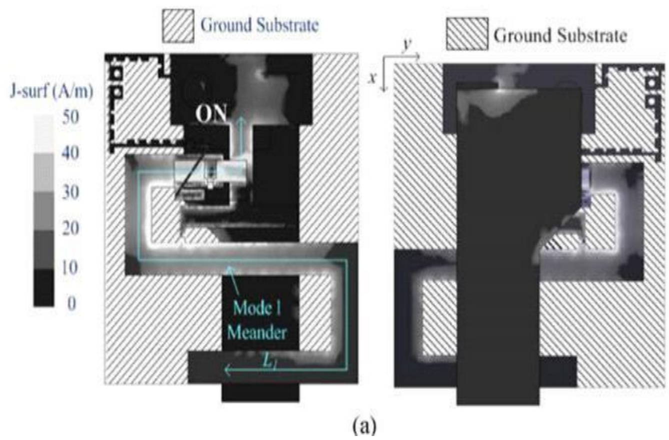

Figure 2.9 (a) Geometry and prototype of PIFA with RF Mems (on state)

Figure 2.9 (b) shows the geometry of PIFA in off state.

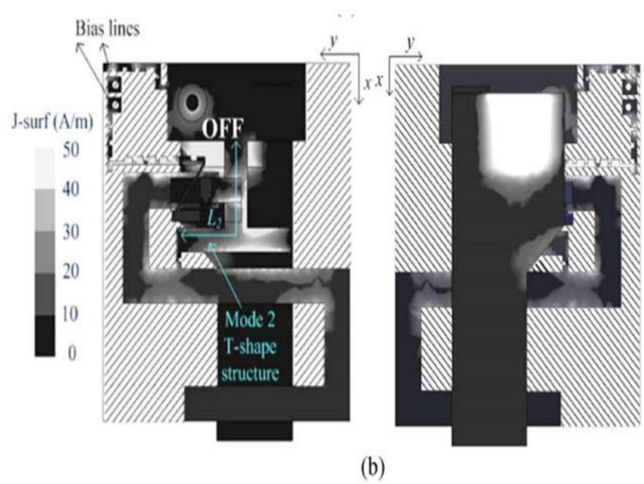

Figure 2.9 (b): Geometry and prototype of PIFA with RF MEMS (off state)

2.6.5 FET Based Switches:

Being operable by digital signals gives these switches a major step ahead as compared to the other switches. This puts forth the Defense straightforward and simple to manufacture, Case and work. They likewise have low insertion losses. It is moreover truly appropriate for miniature sized antennas.

Figure 2.10 (a) shows the geometry of an FET based antenna. Both top and bottom view can be seen.

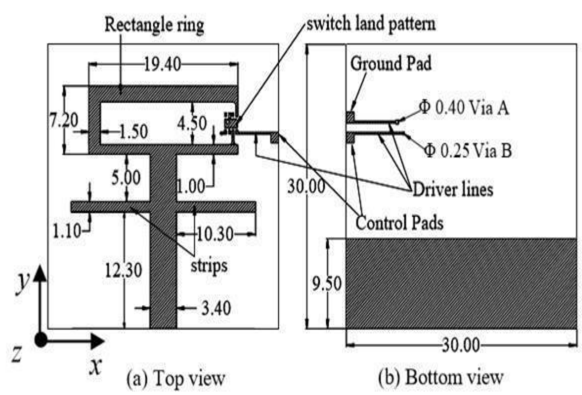

Figure 2.10 (a): An FET- based Antenna

Figure 2.10 (b) shows the shift in frequency after reconfiguration. S11 parameters shows the shift.

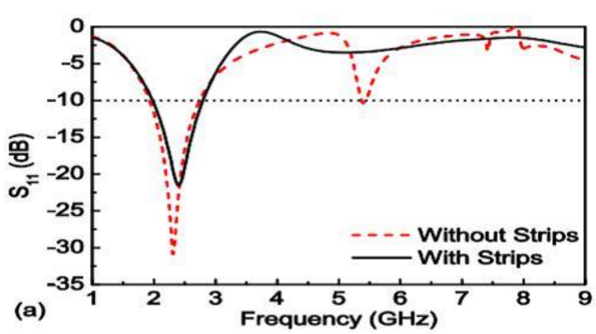

Figure 2.10 (b): S1 parameter

2.6.6 Reed switches:

A reed switch is a unique sort of switch that is constrained by magnetic field. This magnetic field can infiltrate the ground moreover. Its greatest preferred position lies in the way that its controlling circuit can be put at the base of the ground and the antenna radiation execution is not influenced.

Figure 2.11 (a) shows an antenna with reed switches. Comparison between s1 parameters with and without reed switches can be seen in **Figure 2.11 (b).**

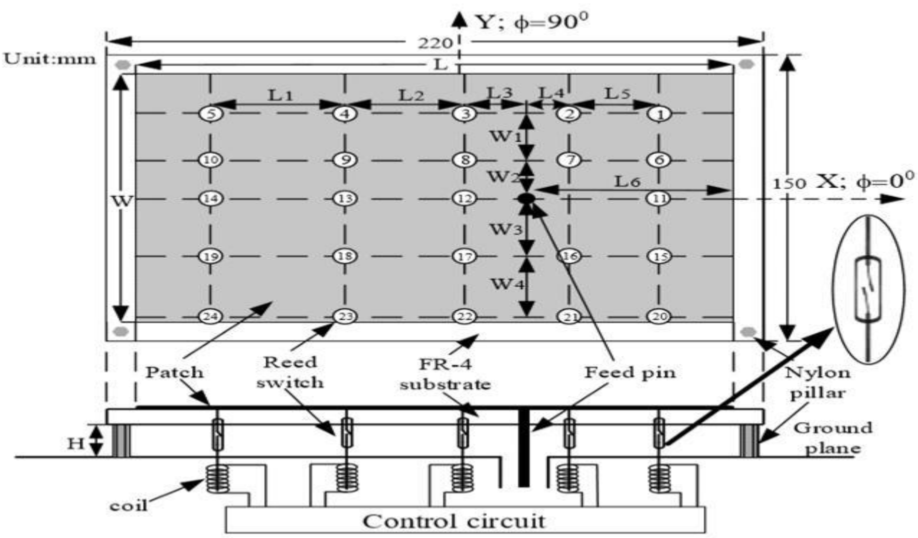

Figure 2.11 (a): An Antenna with Reed switches

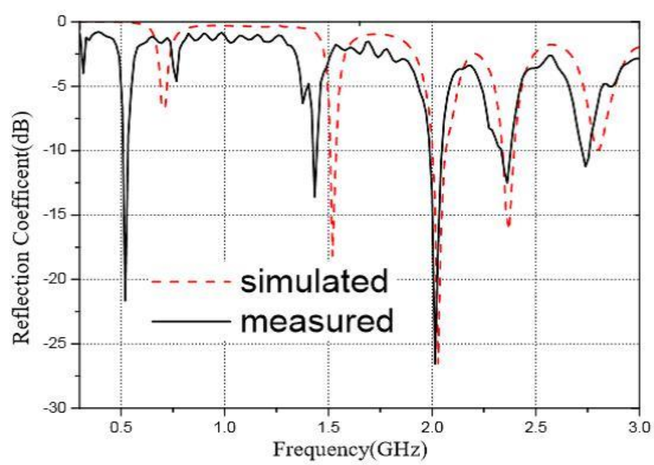

Figure 2.11 (b): Measured vs simulated S11 parameters of antenna with Reed switches

2.7 Thesis Goals:

Our work is unique in a sense that it covers complete UWB along with WIFI band. We have ensured the combination of different bands using a single antenna perfectly for mobile devices. Following are the goal of thesis;

- Design a micro strip patch antenna that operates at 2.45 GHz and UWB for mobile applications and wireless communication.
- Assure reconfigurability for covering wide range of frequencies.
- Ensure high gain and broadside radiation pattern.
- Design a compact size antenna perfect for mobile devices.
- Study parameter alteration effects.
- Performance of switches and their effects.

Chapter 3: Design and Development

3.1 Antenna Design:

After designing so many antennas and discarding them for not giving the accurate result we have designed this final antenna. Design of whole antenna is described step wise underneath.

3.2 UWB Single Element:

Initially a rectangular patch is selected to serve the purpose of radiating element. the patch is 28x29 mm. All the measurements are done using the formulae. Substrate is made up of FR4 with the thickness of 1.6mm.

Figure 3.1 shows the front side of the single element and which is proposed for this thesis.

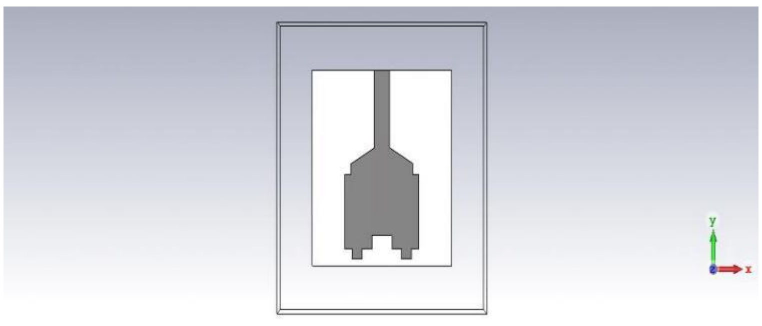

Figure 3.1 Front View

As it can be seen from **Figure 3.2** S-Parameters the S11 is less than -10 dB from 3.4 to 20 GHz indicating that the design operates efficiently from 3.4 to 20 GHz and for this complete operating band, VSWR is less than 2.

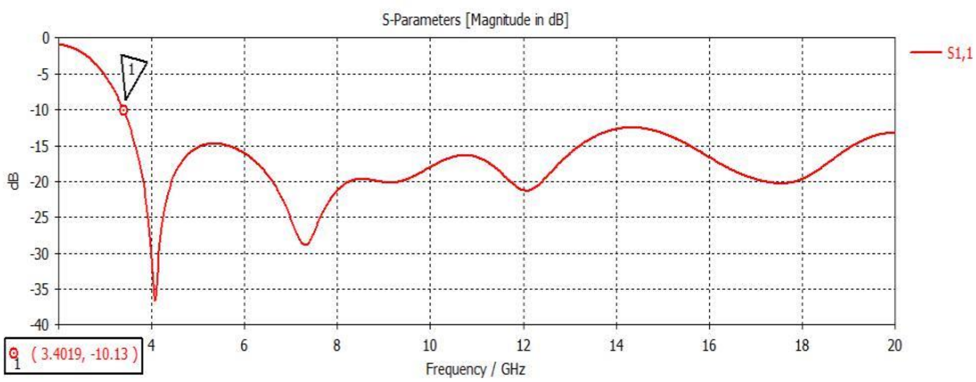

Figure 3.2 S11 (dB) for single element

As seen from **Figure 3.3** radiation efficiency of the antenna which is approximately 80%. For Ultra-wide band it ranges from 50-80%

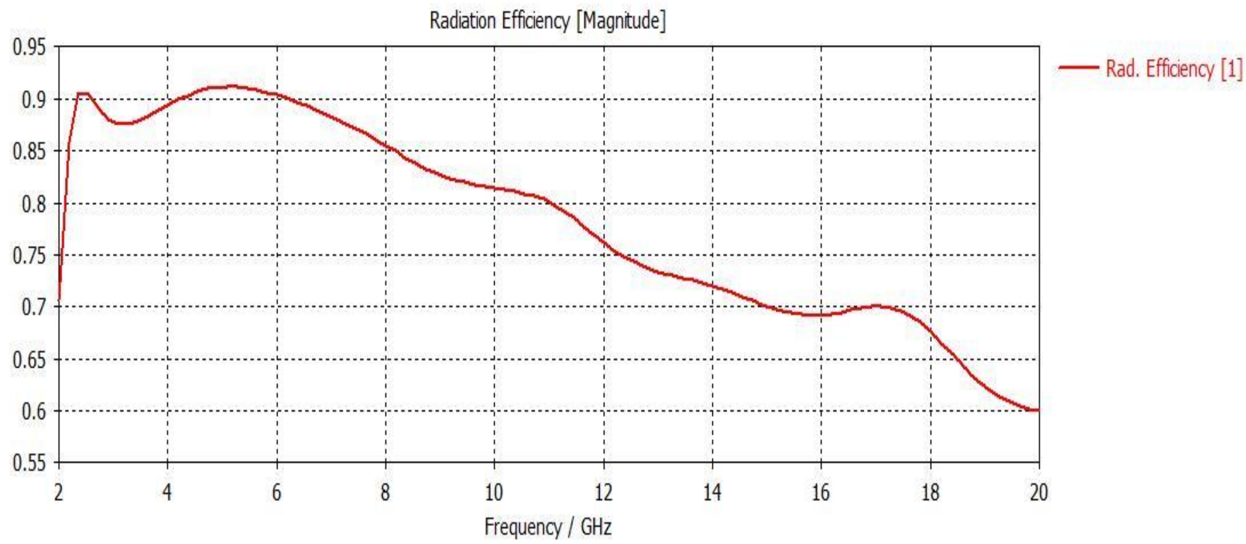

Figure 3.3 Radiation Efficiency for single Element

Figure 3.4 shows the linear increase of gain with the increasing frequency for a single element. gain increases once frequency shifts from 3.1GHz to 10.6GHz.

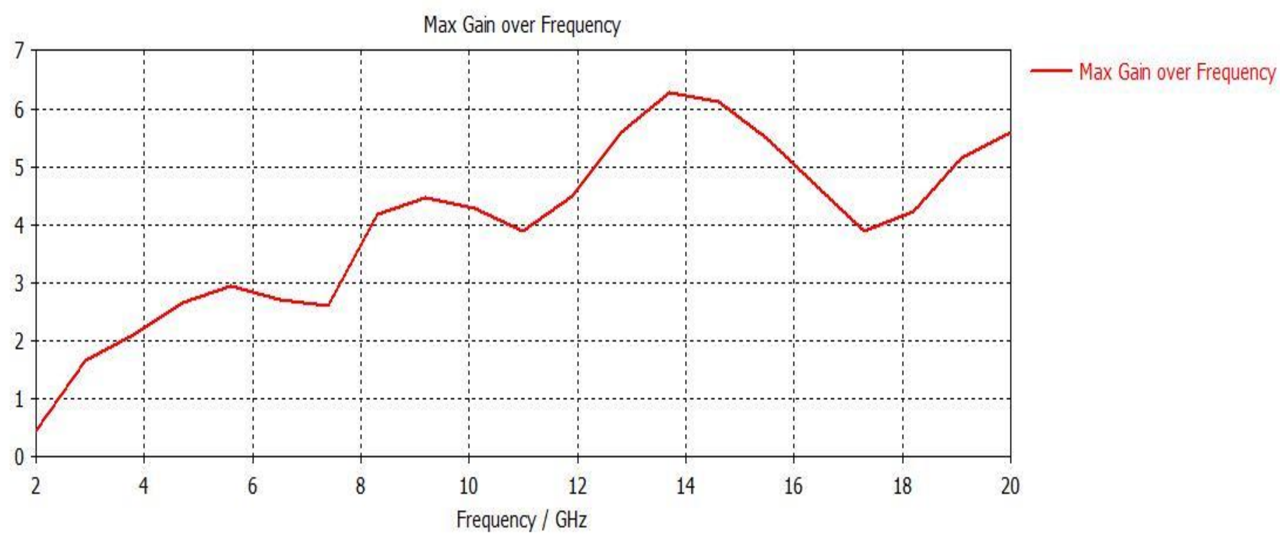

Figure 3.4 Peak Gain (dB)

3.3 Band Notch Single Element:

A slot of U shape is introduced into the design of a single element monopole. Several simulations were done in order to attain the desired results. To make band notch effective we must make sure that s11 parameter should be more than -5db. In order to get the notch at 5.3 GHz different shapes were tried but U-shaped suits it the best.

After trying different shapes, the best proposed design for introducing a notch is displayed in **Figure 3.5.**

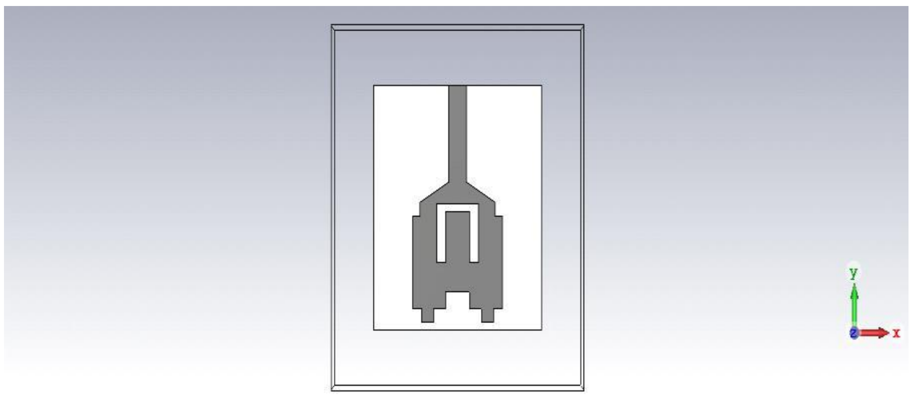

Figure 3.5 Front View

From Figure 3.6 S11 parameter at 5.3 GHz rises above -5db and is approximately -2.94db which truely indicates that a notch is introduced and the U-shaped slot have served the purpose. Now our antenna is operating from 3.1 GHz to 20 GHz except for 5.3 GHz.

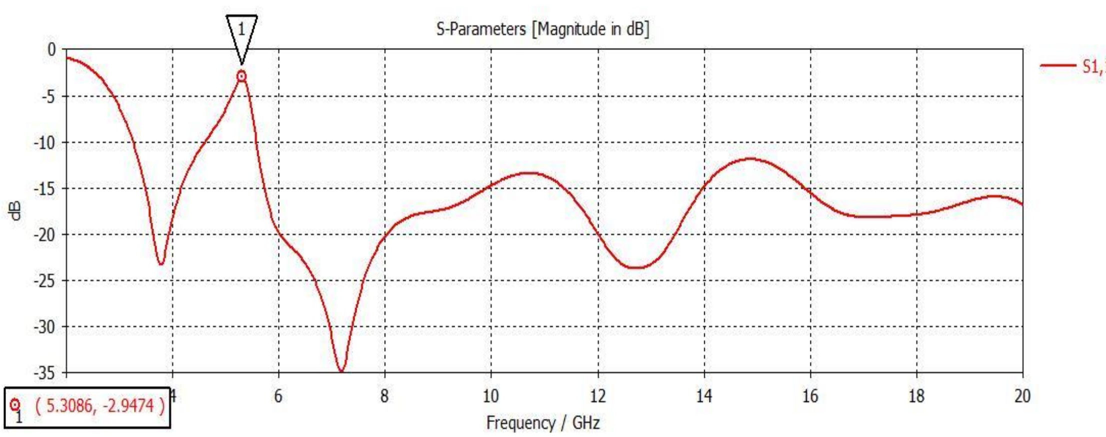

Figure 3.6 S11 (dB) for a notch introduced

It can be seen from **Figure 3.7** that the radiation efficiency of the antenna still stays 80% except for the notch part that has been introduced.

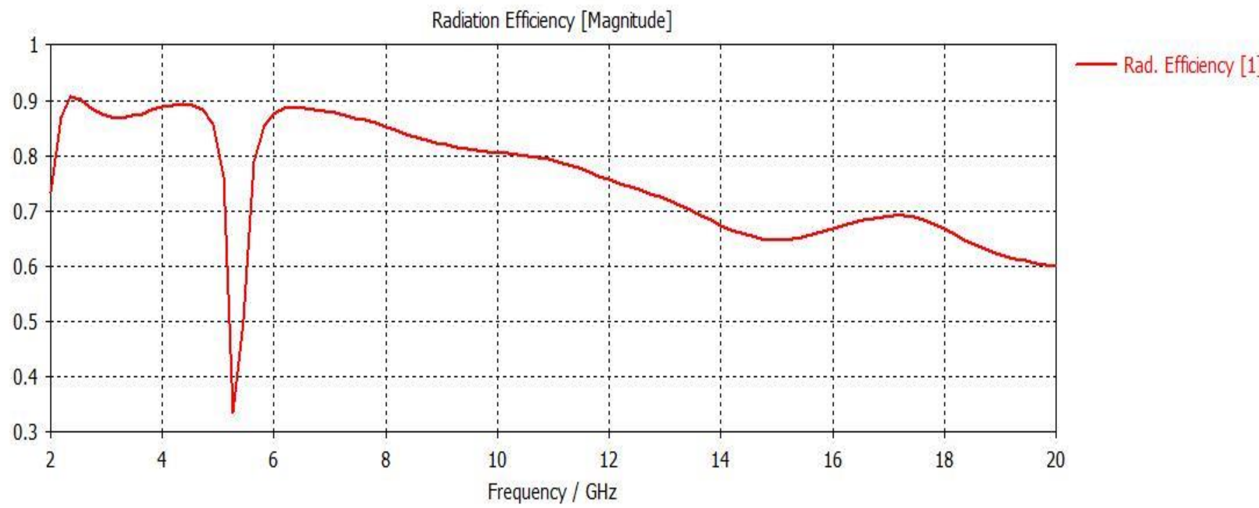

Figure 3.7 Radiation Efficiency

3.4 Reconfigurable Band Notch:

After successfully introducing the notch at the frequency of 5.3 GHz the next step is to reconfigure this single element notch. For reconfiguration purpose we insert a RF Pin diode in the middle of U shape as shown in the **Figure 3.8**

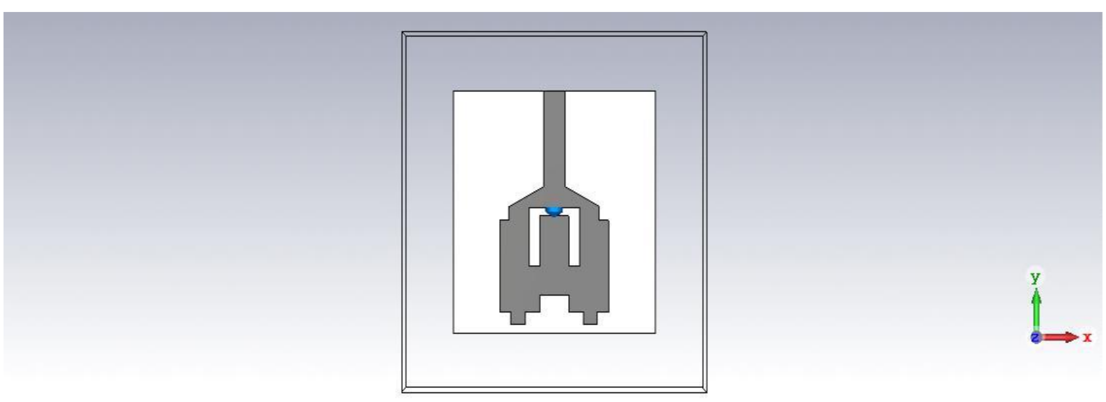

Figure 3.8 Front View

There are two possible states for a PIN Diode either it can be forward biased or reverse biased. the design was simulated and checked in both forward and reverse biased conditions and it has given the following results.

For Reserved Biased Condition

It can be seen clearly from **Figure 3.9** that for reverse bias the s1 parameter from 4.1 to 4.3 GHz is above -5db hence in order to get a notch on this frequency we will simple reverse bias the pin diode and notch will be shifted to left side.

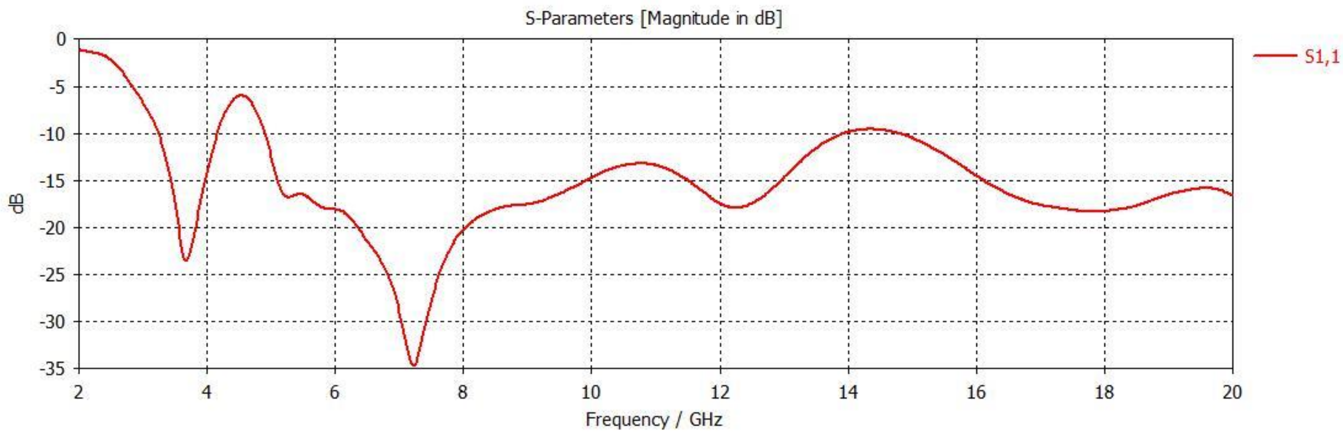

Figure 3.9 S11 (dB) for reverse bias

For Forward Biased Condition

As seen in **Figure 3.10** Once the Pin diode is set forward bias all the notches are removed and despite of the U-shaped slot the antenna operates from 3.1 to 10.6 GHz. The antenna is reconfigured and operates at UWB.

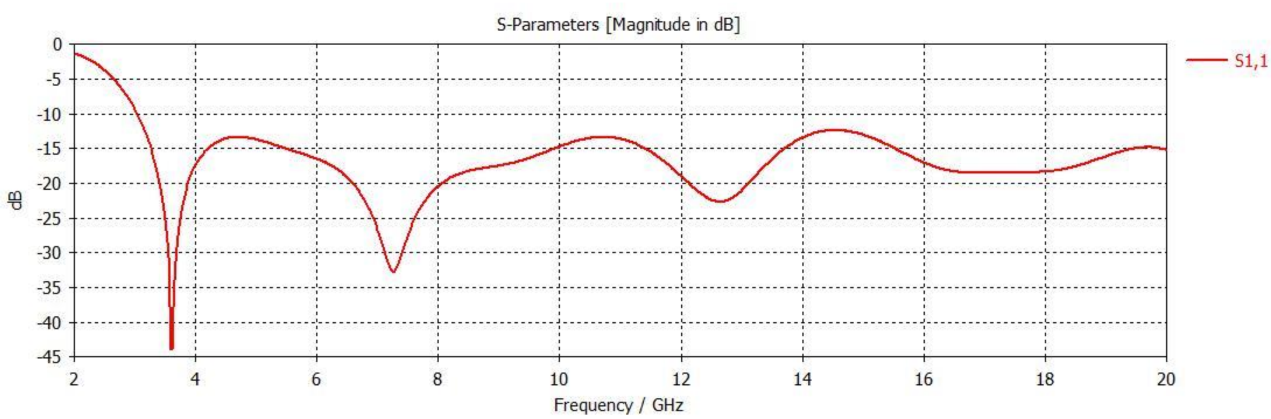

Figure 3.10 S11 (dB) for forward bias

3.5 Two Element UWB MIMO:

Single element reconfigurable design has been achieved successfully, where we first introduced a notch and then removed it using PIN diodes. In order to achieve high data rate we will be moving forward to achieve MIMO first we will be working on two element MIMO. after simulating several arrangements of two elements we got our desired result from the following arrangement.

Figure 3.11 shows the front of the proposed design once we have made it two element MIMO.

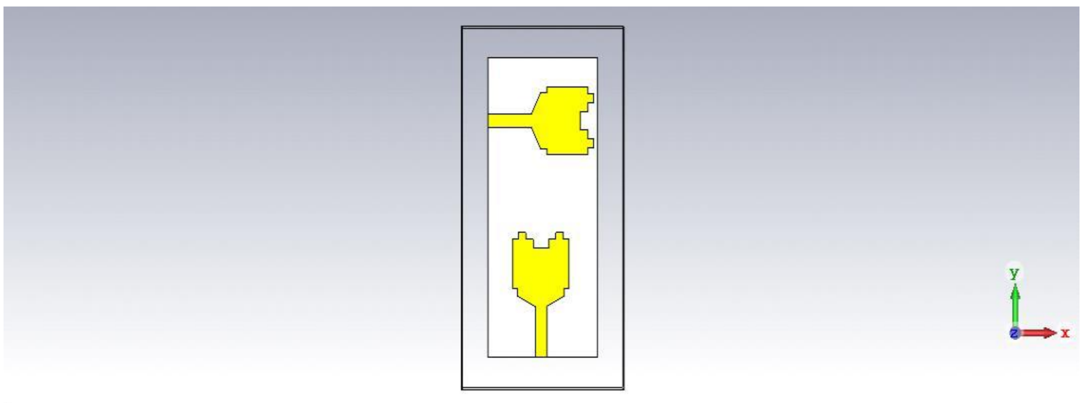

Figure 3.11 Front View

As shown in **Figure 3.12** Red line shows S11 parameter for the first element and orange line shows S22 parameter for the second radiating element. It is quite obvious from the figure that this two-element design operates at UWB as it is below -10db.

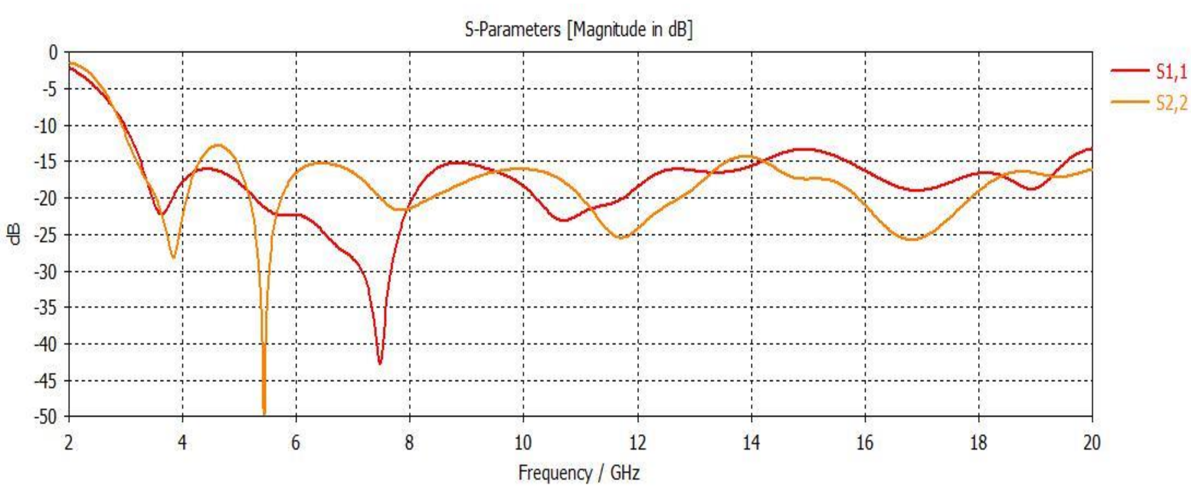

Figure 3.12 S11, and S22 (dB) for two element MIMO

3.6 Two element Band Notch UWB Antenna:

Following the same procedure now we will introduce the notches in the same way as we did in the single element. Introducing a U-shaped slot will introduce a notch**. Figure 3.13** shows the front side of the design with notch introduced.

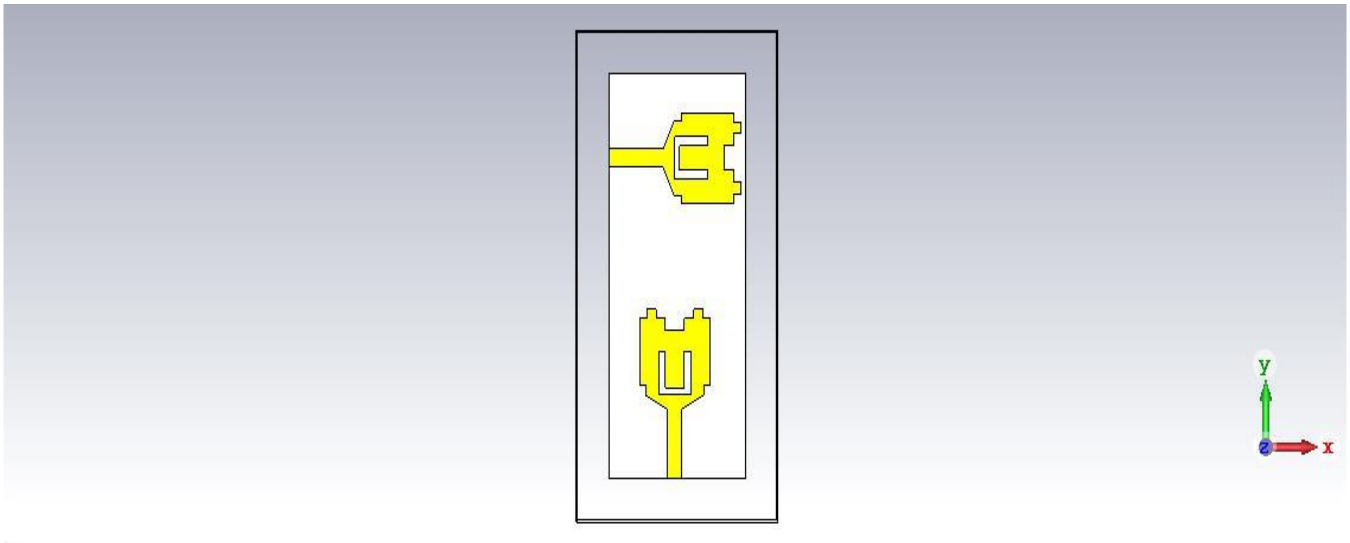

Figure 3.13 Front View

As shown in **Figure 3.14** that S11 is less than -10 dB from 2.88 to 20 GHz with a band notch at 5.3 GHz. hence, we have successfully introduced a notch in the design.

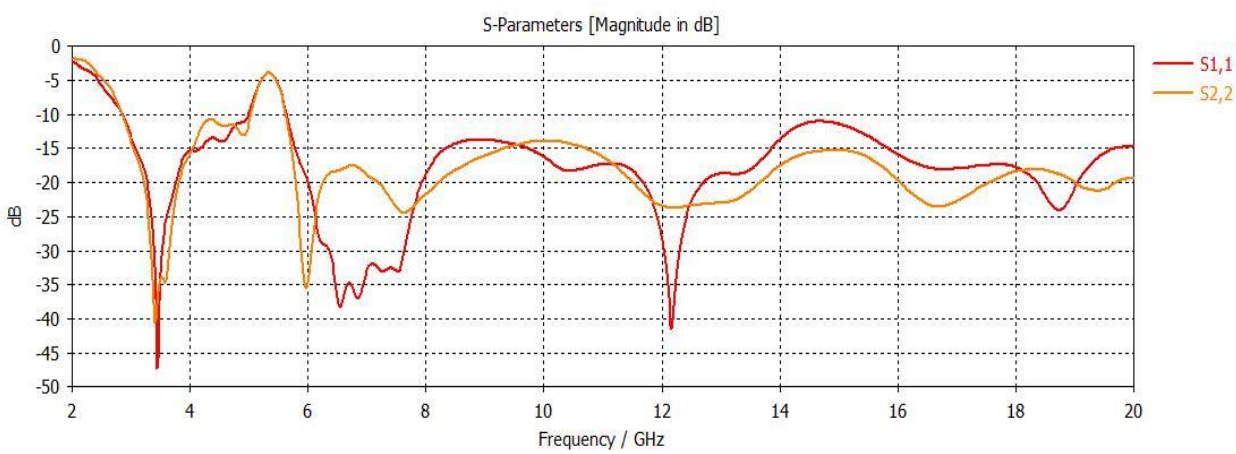

Figure 3.14 S11, and S22 (dB) for two elements

3.7 Reconfigurable Two element Band Notch UWB Antenna:

After introducing the notch, we have to reconfigure it. For reconfiguring it we introduce the PIN diodes in the U-shaped slot**. Figure 3.15** shows the front side of the design with pin diodes inserted.

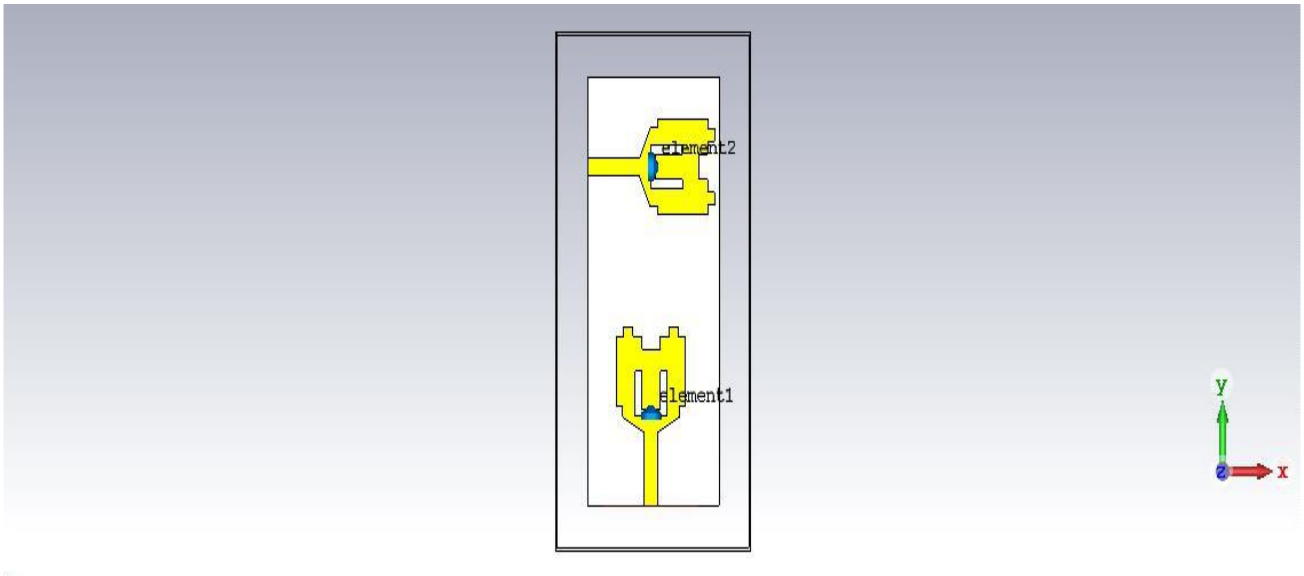

Figure 3.15 Front View

There are two possible states of a PIN diode it can be either

- Forward Bias
- Reverse bias

Simulations were done for both cases. Results were almost same as for the single element. Once the diodes were reverse biased our notch shifted towards left side. Once we set the diodes in forward biased state the notch was removed completely and our antenna was operating from 3GHz to 20 GHz.

For Forward Biased Condition

It can be seen from **Figure 3.16 (a)** that When PIN diodes are forward biased all the notches are removed and our antenna operates on the operating frequency range from 2.8 GHz to 20 GHz.

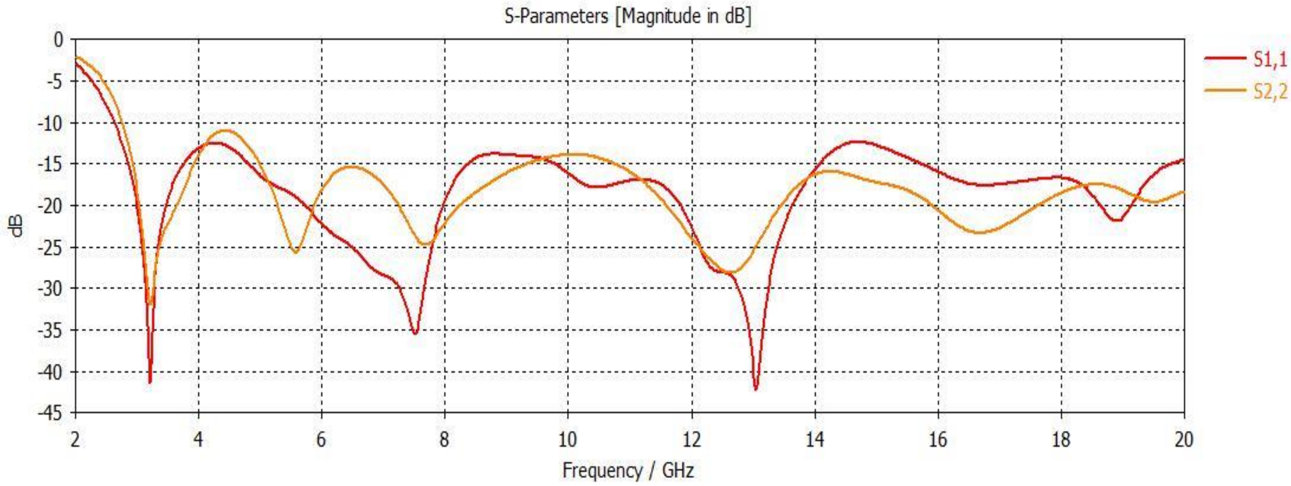

Figure3.16 (a) S11, and S22 (dB)

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Figure 3.16 (b) shows the isolation between antenna elements is less than 20 dB.

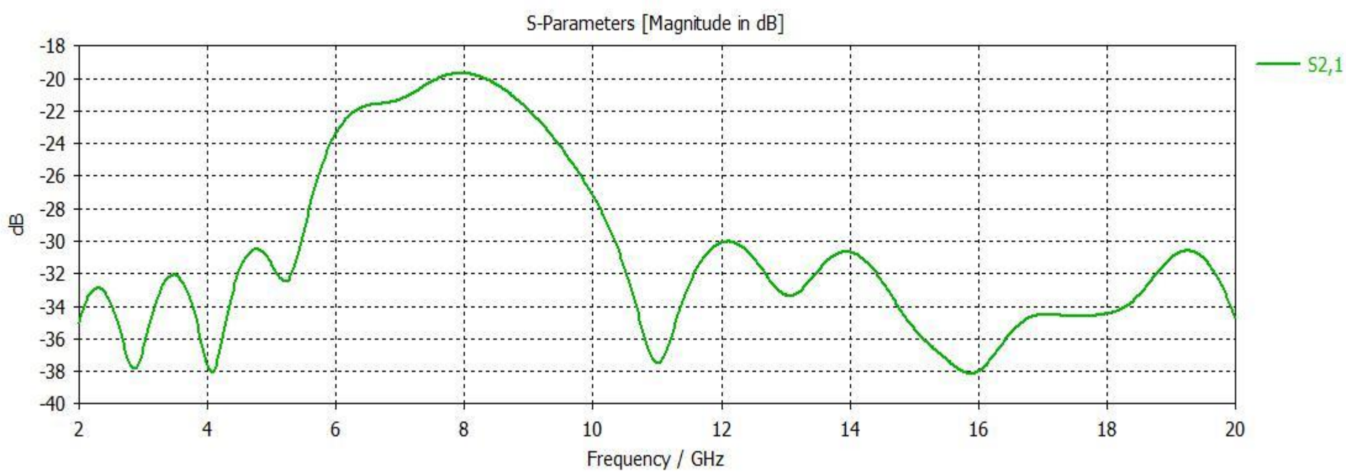

Figure 3.16 (b) Isolation between elements.

Figure 3.16 (c*)* shows that *i*n case of forward bias the maximum radiation efficiency is 83%, while the minimum radiation efficiency is 48%.

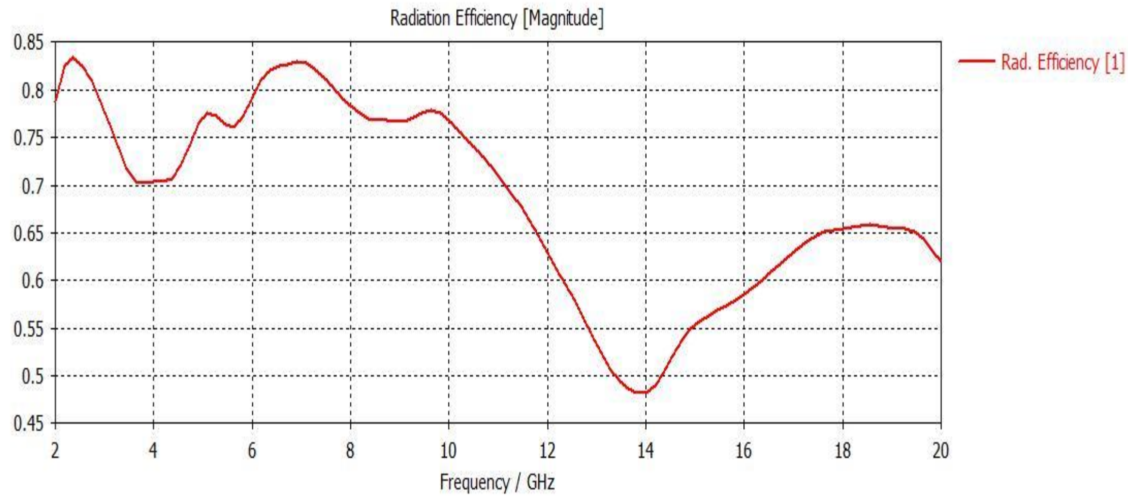

Figure 3.16 (c) Radiation efficiency

Figure 3.16 (d) shows the gain is increasing linearly with the increase in frequency once we move from 3.1GHz to 10.6 GHz

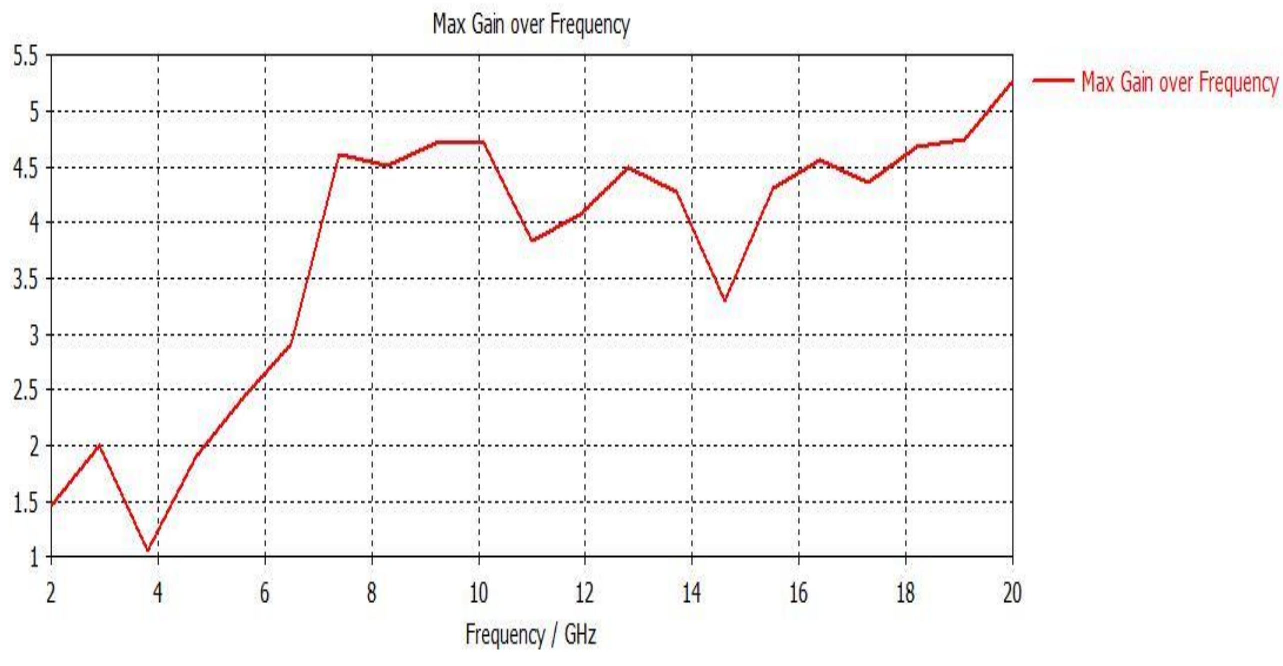

Figure 3.16 (d) Gain over frequency graph

For Reversed Biased Condition

Figure 3.17 (a) shows the s parameter for reverse bias condition. In reverse biased scenario the notch is gain shifted towards the left side. S11 and S22 is less than -10 dB from 2.84 to 20 GHz with a band notch at 4.64 GHz.

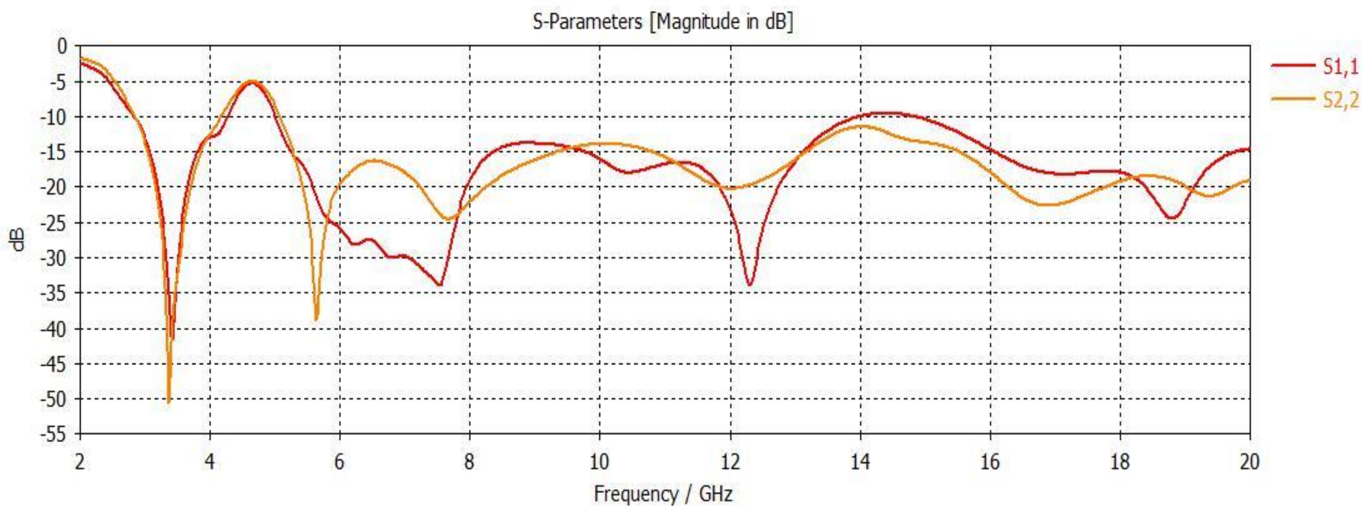

Figure 3.17 (a) S11, and S22 (dB)

Figure 3.17 (b) shows the isolation between antenna elements is less than 20 db.

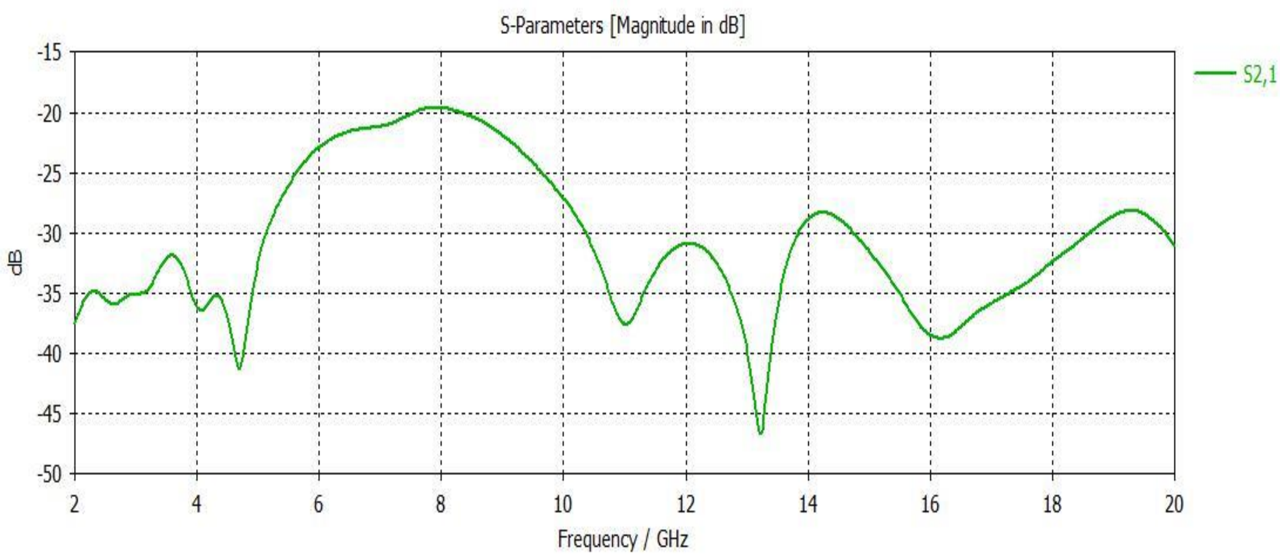

Figure 3.17 (b) Isolation

Figure 3.17 (c) shows the maximum radiation efficiency is 85%, while the minimum radiation efficiency is 52%. The efficiency at the band notch frequency is about 35%

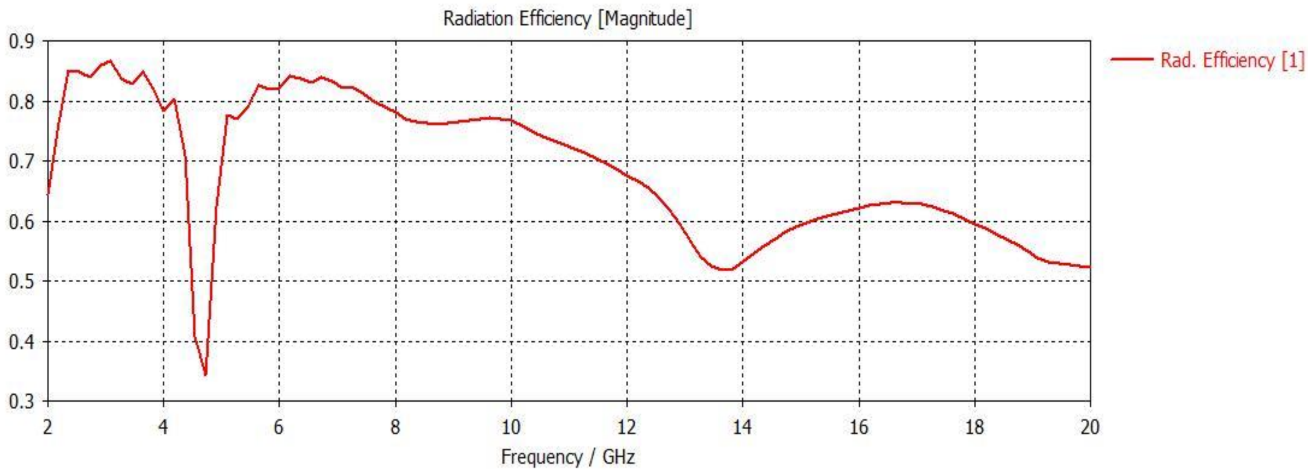

Figure 3.17 (c) Radiation efficiency

Figure 3.17 (d) shows that the gain is increasing with the increase in frequency. At the notch band, the gain is equal to -1.7db

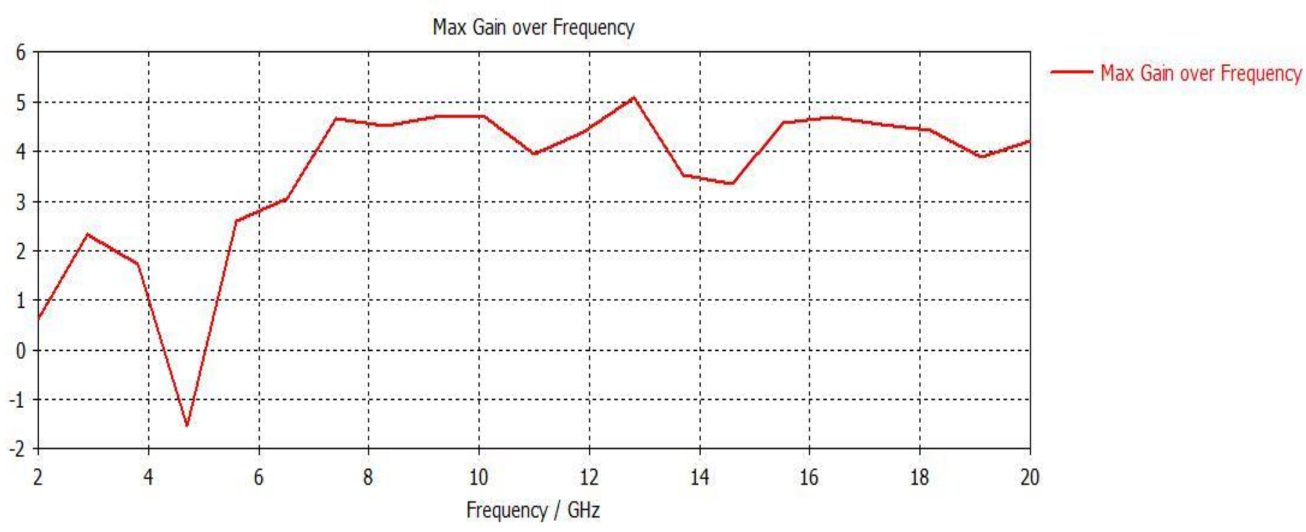

Figure 3.17 (d) Gain

Chapter 4: Conclusion and Future

4.1 Conclusion

Ultra-wide band technology incorporated with MIMO is very much in demand in these days. This compound has found its application in WPAN as well. Devices equipped with such antennas are very much smaller in size. Printed antennas are perfect due to their planar structure for those devices which are space limited. Designing an antenna which can operate on complete UWB and also maintains high isolation value between the radiating components is a difficult task, these tasks have been fulfilled in these antennas quite effectively.

The proposed antenna is so less in size and isolation value is very high. After comparing different results of the proposed antenna like impedance bandwidth and the value of isolation between the radiating part and also the size of the antenna. We compared the advantages of the proposed antenna with the existing antennas, it can clearly be seen that this antenna is compact, very simple and easy to fabricate.

4.2 Future Works

UWB MIMO is a field in which there is a lot of research work going on now days. Adding a touch up of reconfigurability opens a totally new dimension in mobile communication and wireless communication. Compound of these three will lead us to the following things/

- In order to avoid interference between the bands, these antennas have the power to reject some bands as a part of reconfiguration.
- There is a need to have a mathematical expression and formulae for this compound technology of UWB MIMO that will lead to simple processing.

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RECONFIGURABLE ULTRA WIDE BAND MIMO ANTENNA

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GC Ubaid Abbasi

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