DESIGN OF MULTI-BAND FREQUENCY RECONFIGURABLE MICRO-STRIP PATCH ANTENNA

By

Capt Muhammad Bilal

Capt Syed Aqeel Hussain Shah

Maj Muhammad Tahir Khan

Capt Mumtaz Ahmed

Project Supervisor

Lecturer Maryam Rasool

Submitted to the Faculty of Electrical Engineering, Military College of Signals, National University of Sciences and Technology, Rawalpindi in partial fulfillment for the requirements of a B.E. Degree in Telecommunication Engineering

June 2019

ABSTRACT

Design of Multi-Band Frequency Reconfigurable Microstrip Patch Antenna

This document confers a multi-band frequency reconfigurable micro-strip patch antenna applied to different system applications. The proffered antenna consists of 3x monopole radiators , 3x rectangular tuning strips with a microstrip feed line. With these structures incorporated, the antenna can resonate on 3x different frequencies while maintaining low profile and uncomplicated shape. To verify the results simulated, a sample of this antenna has been designed , fabricated and tested. The simulated and measured (tested) return losses, radiation patterns are depicted. Measured results show that the antenna can be designed to resonate on the frequency bands of around 2.5 GHz for the GPS systems and for the IEEE 802.11b&g WLAN systems, 3 GHz for the WiMAX systems and 5 GHz for the IEEE 802.11a WLAN systems.

CERTIFICATE OF CORRECTNESS AND APPROVAL

It is hereby certified that information in this thesis "**Design of Multi-Band Frequency Reconfigurable Microstrip PatchAntenna**" carried out by (1) Capt. Muhammad Bilal (2) Capt Syed Aqeel Hussain Shah (3) Maj Muhammad Tahir Khan (4) Capt Mumtaz Ahmed under the direction of Lec Maryam Rasool in partial fulfillment of our degree of Bachelor of Telecommunication Engineering is correct and approved.

Approved By

____

Lec Maryam Rasool

Project Supervisor

Military College of Signals, NUST

DECLARATION

We hereby declare that no content and form of work presented in this thesis has been submitted in support of another award of qualification or degree either in this institution or anywhere else.

DEDICATION

This dissertation is dedicated in thank to ALLAH ALMIGHTY our Creator who has blessed us with wisdom, knowledge and understanding and then to our parents for their direction and their endless support. We are thankful to our Faculty for their guidance and supervision, without their help and supervision this project would not have taken the final shape. And a special dedication to those who laid their lives for the nation for the country and those who laid their lives but we do not even know about them, to those who are supposedly are Shaheeds but still in the Indian prison.

Pakistan Zindabad, Armed Forces of Pakistan Paindabad.

ACKNOWLEDGEMENT

The accomplishment of this project would not have been possible without the contribution of different people the names of which cannot be reckoned with. Their assistances are sincerely respected and thankfully recognized. We would like to thank following:

To Allah Almighty who is the most Powerful and Merciful and everything is in His obedience.

Lecturer Maryam Rasool for her support and guidance during the entire project.

Lab Engineer Amara Umar for her assistance and guidance while designing the antenna.

To Pak Army who spared us for 4 years to study.

Table of Contents

ABBREVIATIONS

1.	**HFSS**	>	High Frequency Structure Simulator
2.	**IEEE**	>	Institute of Electrical and Electronics Engineers
3.	**Wi-Fi**	>	Wireless Fidelity
4.	**WiMAX**	>	Worldwide Interoperability for Microwave Access
5.	**MSA**	>	Microstrip Patch Antenna
6.	**dB**	>	Decibel
7.	**MPA**	>	Microstrip Patch Antenna
8.	**CPW**	>	Co-planar Waveguide
9.	**UWB**	>	Ultra-Wide Band

CHAPTER 1

INTRODUCTION

What is the most important component of wireless communication? The answer unanimously is antenna. When using an antenna there is no requirement of laying a wire for or any other physical medium for ranges which are very long. There are hindrances and obstacles while laying a wire or fiber when distances increase and topography changes. If a fault occurs, it is difficult to locate faults and rectify them when weathers are harsh terrains are hilly and rocky. So, what is then solution? Solution is wireless communication. And antenna is the constitutive part of this type of communication. An antenna is solution to all those problems mentioned above. In this modern era of communication advancement, dozens of wireless communication standards have been developed. Now the focus of engineers is how to design multiband antennas that can integrate as many standards such as GPS, WiMAX, WLAN [1] into a single antenna. There are many ways to integrate these standards into a single antenna, one of the ways is Microstrip patch antenna reconfiguration. These antennas can be reconfigured in three ways (1) Frequency reconfiguration (2) Radiation pattern reconfiguration (3) Polarization reconfiguration micro-strip [2] patch antennas are low cost, low profile and easy to fabricate. Here we have chosen frequency reconfiguration mechanism to design **Multi-Band Frequency Reconfigurable Micro-Strip Patch Antenna.**

1.1 Types of Antennas

Antennas can be arranged into 2 types based on characteristics like structure of antenna and radiation pattern of antenna.

1.2 Types of Antenna Based on Structure

It means that how an antenna looks like physically, its spatial description and aesthetics. Some of the types keeping structure in mind are given below

1.2.1 Wire Antenna

A wire antenna bears a [3] wire (which may be long) which is suspended over ground (fig 1.1). Length of wire has no relation with wavelength of radio, but its length is chosen keeping in mind the convenience.

Fig 1.1 A Random Wire Antenna

1.2.2 Loop Antenna

Loop antenna [3] is basically an electrical conductor which has continuous structure which may take form of a circle, rectangle or triangle. A loop antenna be classified as electrically large and small (fig 1.2).

Fig 1.2 A Loop Antenna

1.2.3 Parabolic Antenna

These antennas have a surfaces which are curved and if area of cross section seen it looks like a parabola, the reflectors[3] used are parabolic reflectors(fig 1.2.a).

Fig 1.2.a Parabolic Antenna

1.2.4 Micro-strip Patch Antenna

These antennas are also called printed antennas[3] because these are fabricated on a material called PCB (fig 1.3). These antennas mostly operate on microwave frequencies. A PCB is used to etch different elements of antenna on it. It electrically connects the components of antenna and mechanically supports these components. These low profile antennas are carved with the help of a sheet or patch of metal which is mounted on ground plane.

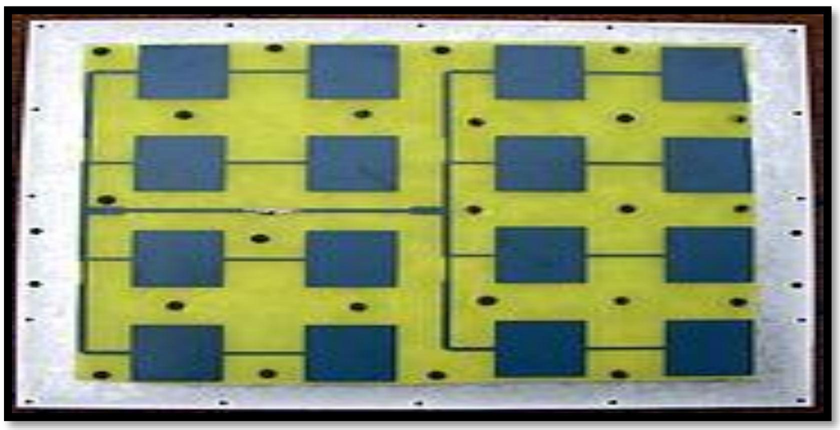

Fig 1.3 An Array Of Micro-Strip Patch Antennas

1.3 Types Of Antennas Based On Radiation Pattern

Keeping in mind how an antenna does radiate we would see some types as well. Some are as given below.

1.3.1 Isotropic Antenna

These are theoretical antennas which are supposed to radiate in all directions[4] equally. These antennas are standards to measure the performance of practical antennas (fig 1.4).

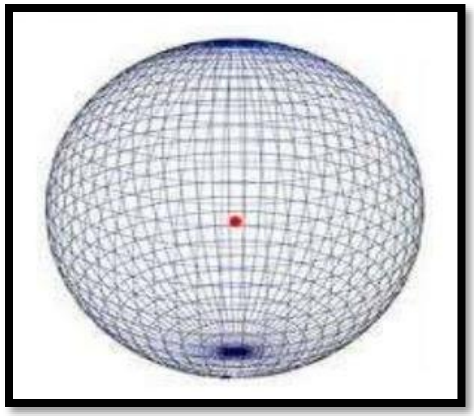

Fig 1.4 Isotropic Radiation Pattern

1.3.2 Directional Antenna

These antennas receive or throw radiation beam in a specific direction as it can be seen in (fig 1.5).

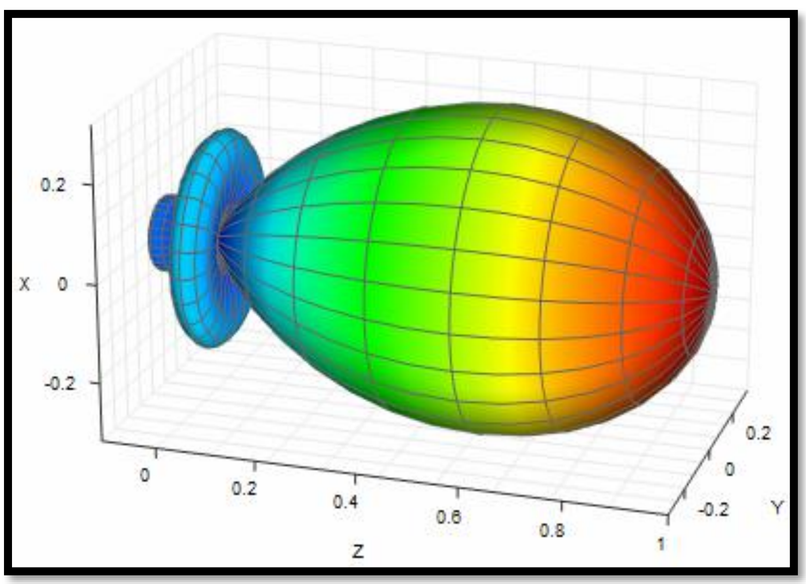

Fig 1.5 Directional Radiation Pattern

1.3.3 Omni-Directional Antennas

These antennas radiate equally in all direction in 2D- plane as depicted in (fig 1.6). Different radiation patterns can been seen in (fig 1.7).

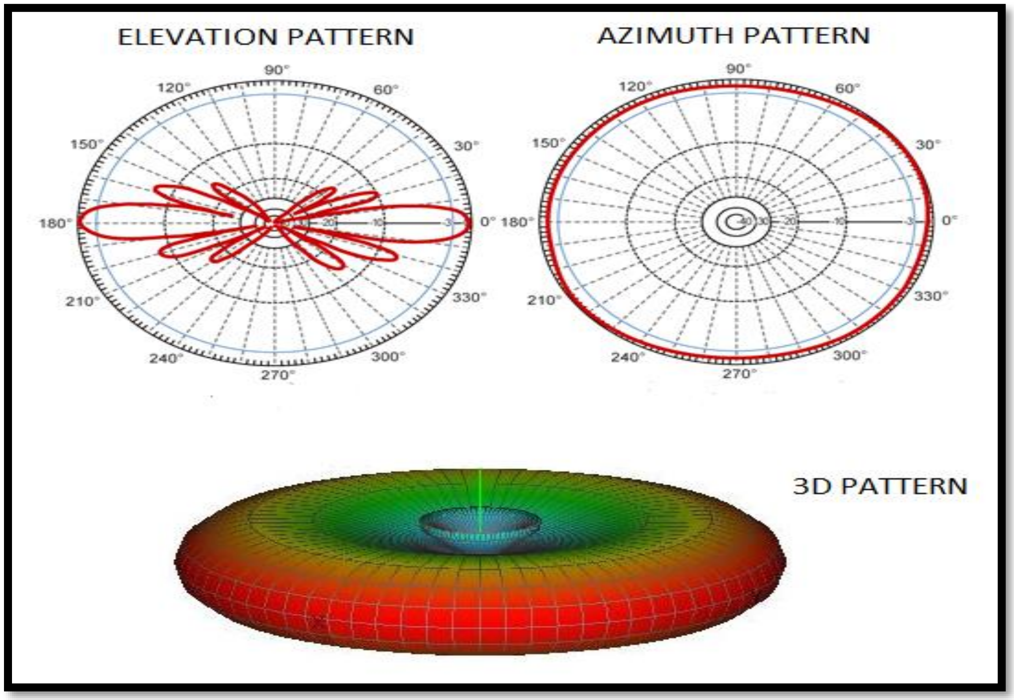

Fig 1.6 Radiation Pattern of Omni-Directional Antenna

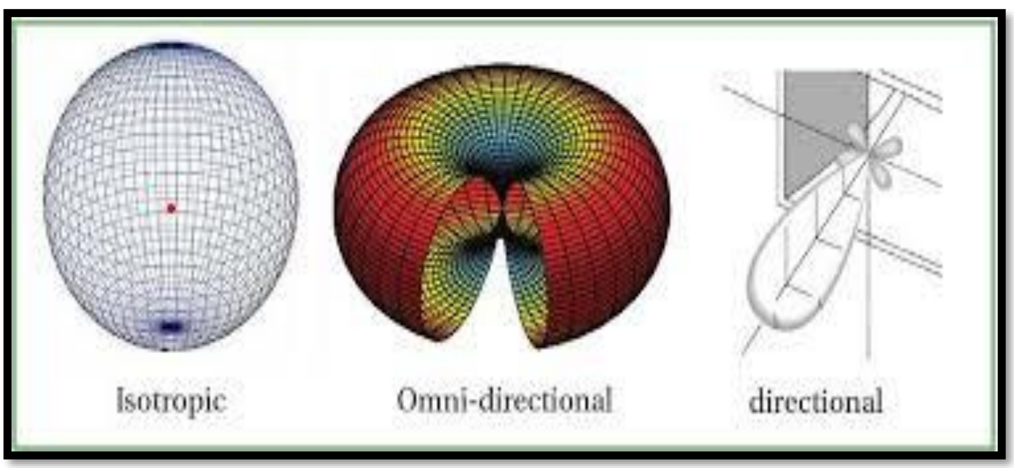

Fig 1.7 Radiation Patterns

1.4 Microstrip Patch Antennas

Our main area of focus will be MPA. Because our project work will be done keeping the basics of MPA in mind.

1.4.1 Components of Micro-Strip Patch Antenna

Substrate

Substrate is material mainly used to mechanically [4] support an antenna. But it has effects on electrical performance of the equipment. In Pakistan FR4 is mostly used as it is readily available beside being inexpensive material.

Ground

It is relatively larger surface of metal on which carved[3] patch of antenna is mounted.

Patch

It is the carved shape on antenna which will be mounted [3] on ground.

Feed

It is mechanism to give [4] power to antenna.

Port

It is the point through which antenna [4] is given feed.

All the given components given above can be seen in (fig 1.8) and (fig 1.9).

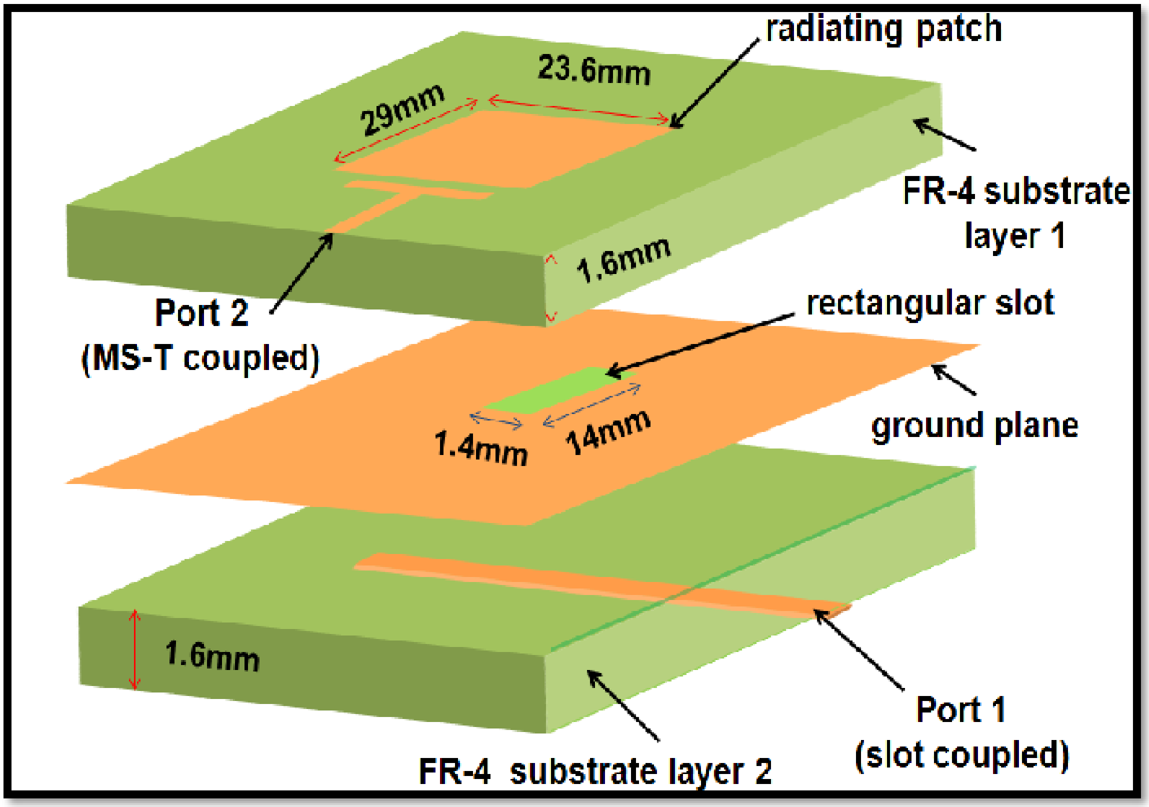

Fig 1.8 Different antenna components

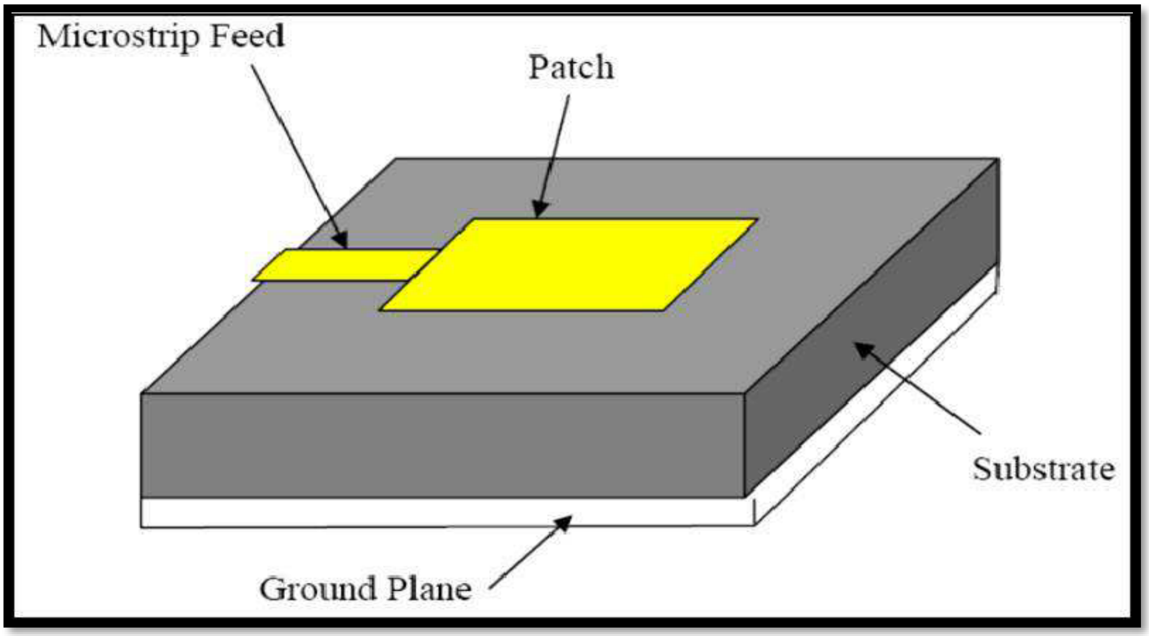

Fig 1.9 Components of microstrip patch antenna

1.4.2 General Shapes Of Patch Antenna

These antennas can have many shapes like rectangular, circular, triangular, semi circle, square and any random shape [5]. Some of the shapes can be glimpses in (fig 1.10).

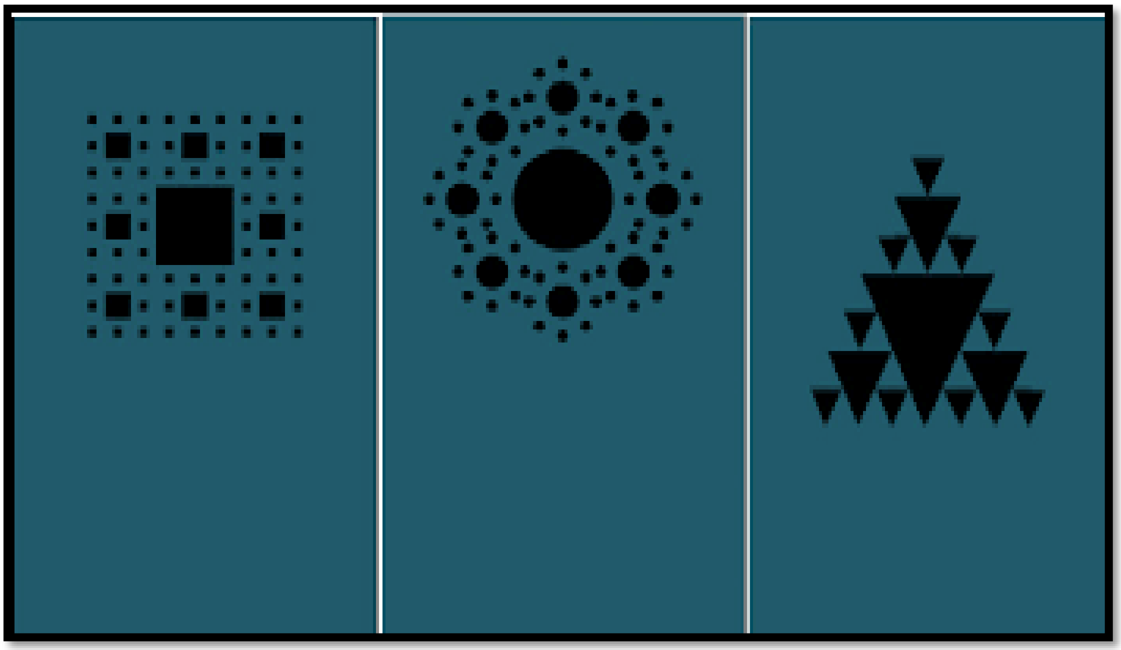

Fig 1.10 Shapes Of Micro-Strip Patch Antenna Array

1.4.3 Advantages of Micro-Strip Patch Antenna

These inexpensive antennas are easy to manufacture and are low profile. Although these antennas are low profile but these antennas have got an ability to create a high gain array. These antennas have diverse polarization ability . These antennas support multi bands and can get multiple feeds and can be carved in various shapes. Micro-strip patch antennas are robust and a centreline feed to these antennas minimizes the undesired modes of excitation. These antennas operate on microwave. They are light weighted and can support dual polarization.

1.4.4 Disadvantages of Micro-Strip Patch Antennas

Micro-strip patch antennas put up with built in conductor and dielectric losses. These antennas carry low efficiency [6]and low gain. These antennas offer a very high level of cross polarization radiation. Such antennas have low capability of power handling and have lower impedance bandwidth. One of the issues is that these antennas radiate from feed and other junctions.

1.5 Dipole Antennas

A dipole antenna has 2x elements (rods) which are identical. Most common example is Rabbit Ears antenna**.**

1.5.1 Shapes of A Dipole Antenna

A dipole antenna can have many shapes . Some of the shapes are shown in figures below

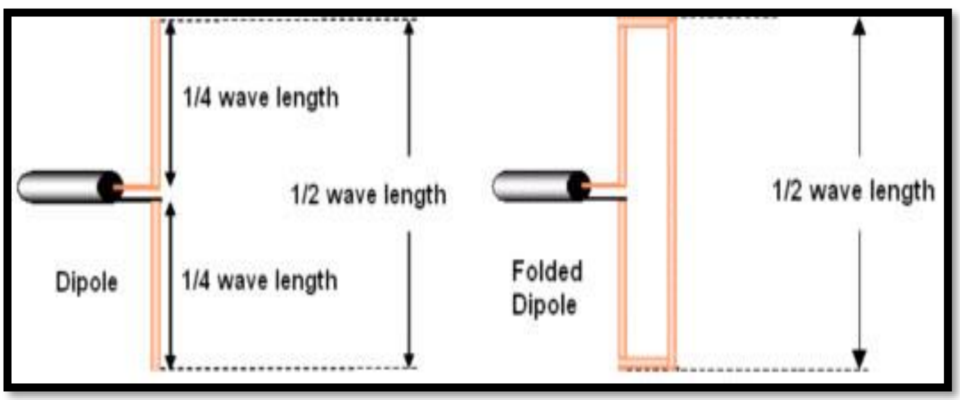

Figure l.10 (a) Figure l.10 (b)

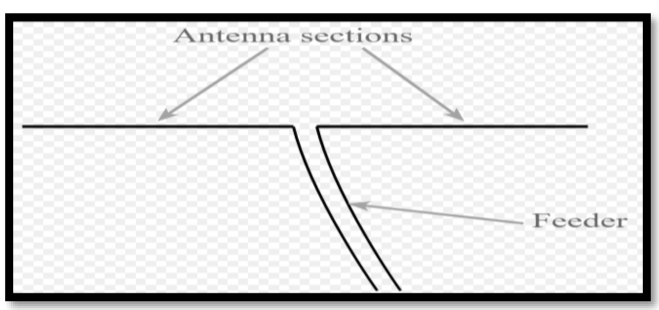

Fig 1.10 (c) A Simple Dipole Antenna

1.6 Modern Trends In Antennas

One of the most important trend is Reconfigurable antennas. There are three ways to achieve reconfigurability.

1.6.1 Reconfigurable Antennas

These antennas have a capability to move from one frequency to other and so as the radiation pattern dynamically. Reconfiguration mechanism is built in the antenna rather and no requirement of external circuits . Change the shape and you get a new frequency. These antennas have a antennas resonating on different frequencies in as a single package for various applications. The reconfiguration capability is used to enhance the antenna performance in a fluid scenarios. These antennas are easy to incorporate with devices used for switching and these antennas have minor size and reduced cost.

1.6.1.1 Frequency Reconfiguration

When an antenna is able switch among the frequencies dynamically, it is reconfiguration of frequency.

1.6.1.2 Radiation Pattern Reconfiguration

When an antenna is able changes the in spherical distribution of pattern that the antenna is radiating. It can be done with the help of rotation mechanism.

1.6.1.3 Polarization Reconfiguration

An antenna that can be switched between vertical and horizontal polarization when a change in polarization is required.

CHAPTER 2

LITERATURE REVIEW

2.1 Reconfigurable Antennas

These antennas have a capability to shift from one frequency to other and change radiation pattern dynamically.

2.2 Techniques to Achieve Reconfigurability

Three main techniques to achieve reconfiguration in antennas are as under.

2.2.1 Frequency Reconfiguration

When an antenna is able to switch among frequencies dynamically, it is reconfiguration of frequency (fig 2.1). The biggest advantage these antennas carry is their flexibility in many applications. So there is requirement of one antenna instead of a number of antennas for different frequency ranges. These antennas are solution to built, price and complexity of systems. Inspite of the fact that it is not possible for frequency reconfigurable antenna to cresonate on all the frequencies at one time but it can be reconfigured as need of the hour (fig 2.2). Reconfigurability can be achieved [6] by use of switching devices. There are bundles design approaches for achieving antenna frequency reconfigurability , some of them are as follows.

- Antennas incorporated with electronics switches (PIN diodes / Varactor Diodes)
- Switching by use of RF MEMS(micro-electrical-mechanical systems) switches
- Materials that are tuneable for substrate (changing the height or permitivity of substrates)

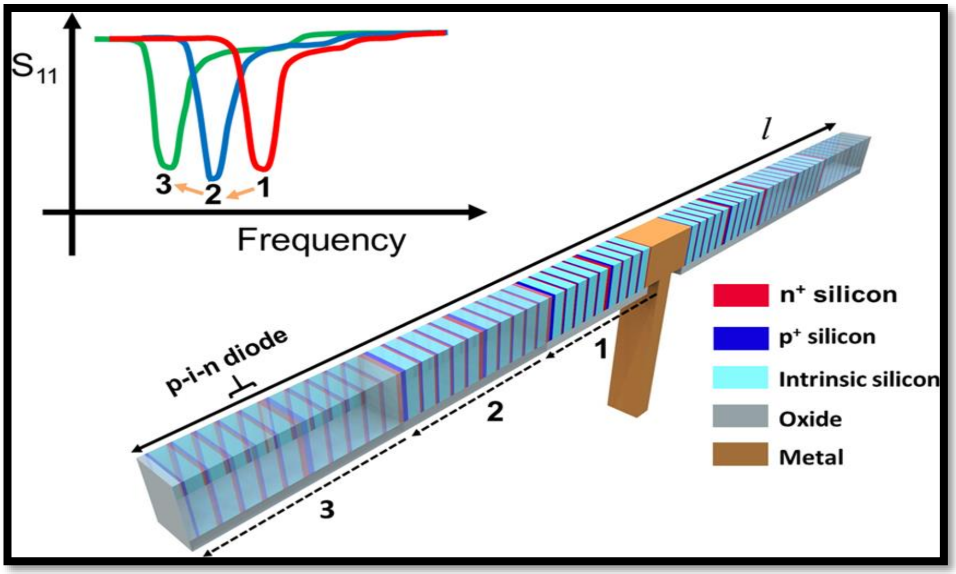

Fig 2.1 Frequency reconfiguration using diodes

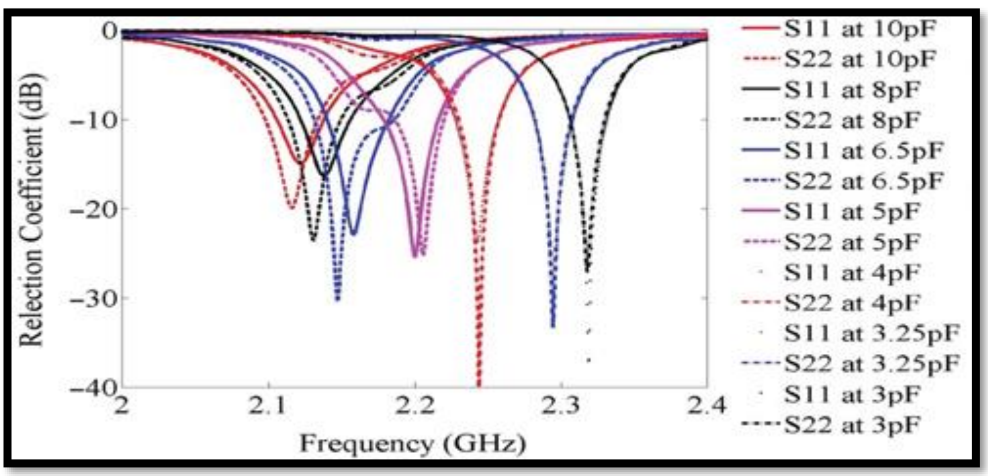

Fig 2.2 Reconfiguration of frequency

2.2.2 Radiation Pattern Reconfiguration

When an antenna is able to change in spherical distribution of pattern that the antenna is radiating (fig 2.3) . It can be done with the help of rotation mechanism or switchable and reactively loaded parasitic elements. In the recent years meta-materials [7] have gained attention owing to their little form factor wide beam steering ranges and their wireless application.

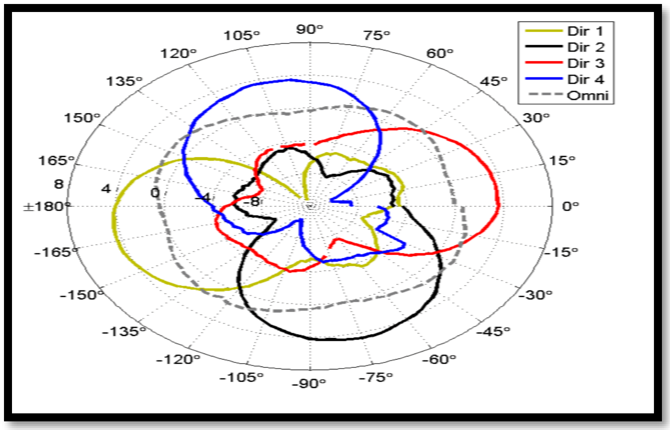

Fig 2.3 Different radiation patterns shown by an antenna

2.2.3 Polarization Reconfiguration

An antenna that can be switched between vertical and horizontal polarization when a change in polarization is required. The capability of changing over among vertical, horizontal and circular polarizations [8] can be used to reduce polarization mismatch losses in moveable devices. Provision of polarization reconfigurability can be done by changing the balance among the different approaches of a multimode structures (fig 2.4).

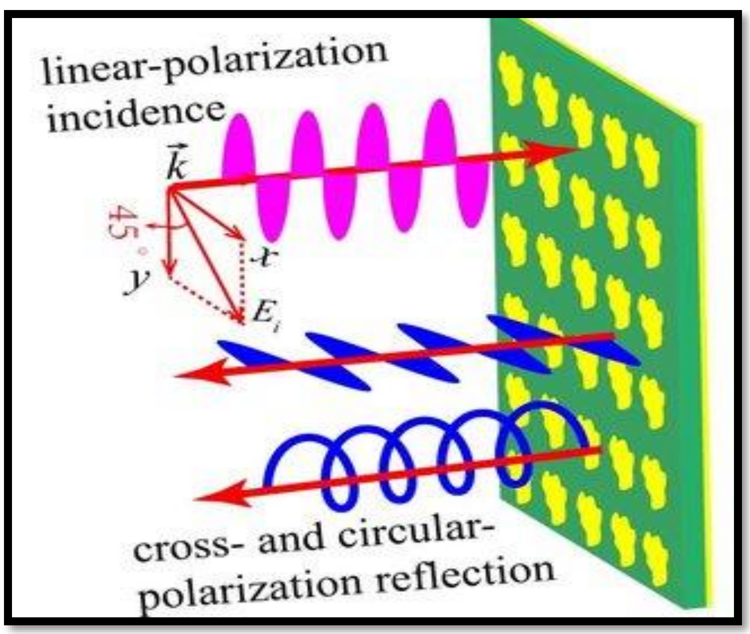

Fig 2.4 Different forms of polarization

2.3 Background

Before commencing the project an intense literature review was carried out , concepts were cleared through different papers read and visit to supervisor. Crux of some of the papers which came through during research are as as given below.

2.3.1 Compact Broadband Microstrip Antenna for Wireless Applications

Ankit Gumasta and Dharmendra Kumar Singh [9] in their research paper proposed a compact size micro-strip antenna that could cover applications ranging from 3 to 7 GHz (fig 2.5). Their proposed work introduced a method that manifested that if the structure on antenna is reduced , there will be increase in the bandwidth and increase in the return loss. Their proposed design was a loaded the monopole CPW fed microstrip patch antenna with symmetric ground plane. The simulation was performed via HFSS (fig 2.6) . The simulation proved that the proposed antenna was applicable in 3 to 7 GHz range of frequencies. The physical shape of antenna is below.

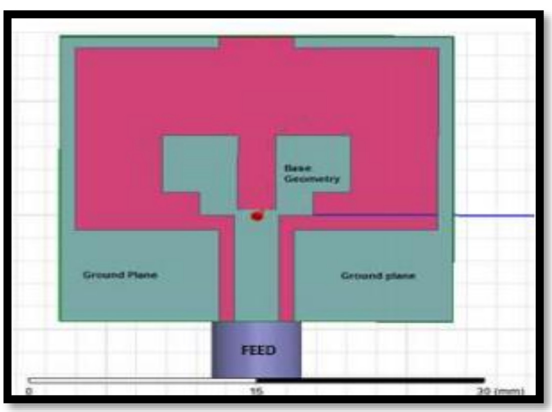

Fig 2.5 Proposed shape on antenna

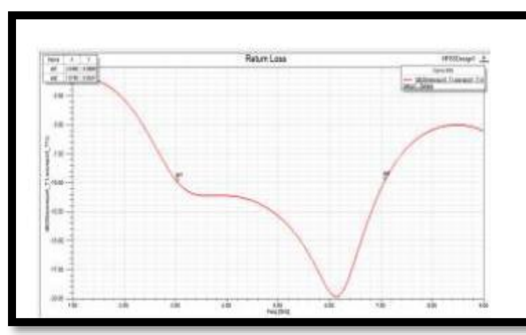

Fig 2.6 Return Loss Vs Frequency

2.3.2 An asymmetric compact multiband slot antenna for GPS, WiMAX and WLAN applications

Jaehoon Choi and Yunnan Jin of Hangyang University [10] presented a paper that proposed an asymmetric compact multiband slot antenna for WLAN, WiMAX and GPS applications. The ground was composed of a rectangular slot a U-shaped slot ,a L-shaped slot to the left of the rectangular slot and 3x stubs . After the proper design four resonant frequency bands were achieved with -10 dB reflection coefficient the 1.57 GHz , 2.4 GHz , 3.5 GHz , and 5.5 GHz frequency respectively. The antenna had a 13 × 32× 0.8 (mm) size in total. Simulated and measured results indicated that the proffered antenna had enough bandwidth as well as good radiation performance in all frequency bands mentioned above. Shown are (figures 2.7 & 2.8).

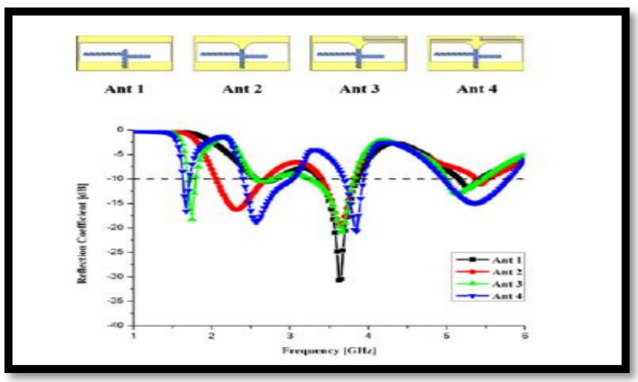

Fig 2.7 Simulated reflection coefficients for various antenna structures

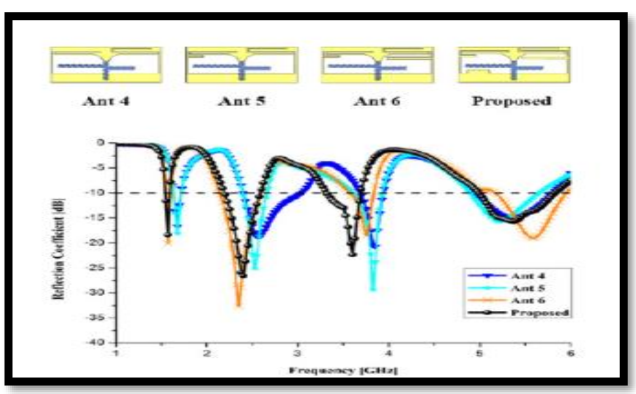

Fig 2.8 Simulated reflection coefficients for various antenna structures

2.3.3 A compact Multi-band planar monopole antenna

Jingjian Huang and Naichang Yuan [11] had written a paper in which they depicted a compact Multi-band planar monopole antenna for applications such as WiMAX , GPS and WLAN. The proffered antenna was made up of 3x monopole radiators, 3x rectangular tuning strips and to feed it microstrip feed line was used. Their antenna could generate 4x resonances at different frequency ranges to cover the bands for applications mentioned before while this antenna maintained low profile yet simply structured. Measured results showed that the antenna could workover the frequency ranges from 1.43 till 1.63 GHz for the GPS system, 2.4 to 2.51 GHz for WLAN systems, 3.28 till 3.77 GHz for the WiMAX system and 5.13 till 6 GHz . This antenna made the basis of our project antenna. The proffered antenna is in the figures (2.9 & 2.10) shown below.

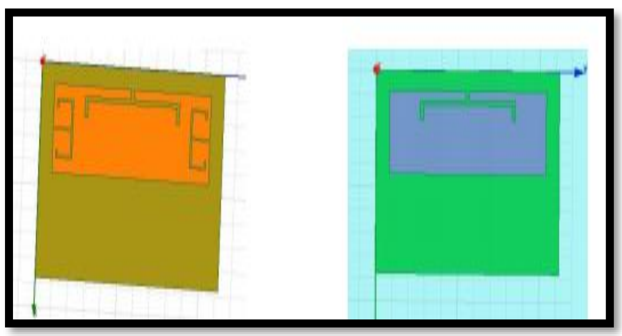

Fig 2.9 Shape Of Proposed Antenna

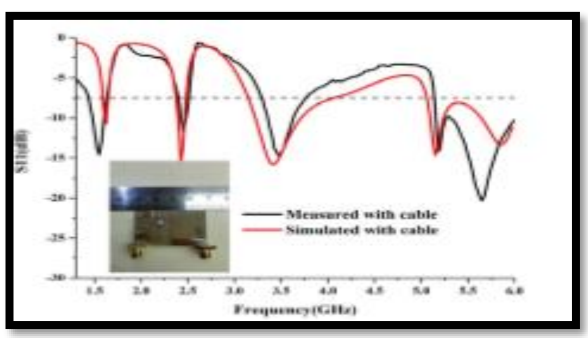

Fig 2.10 Frequency Vs Return Loss

2.3.4 A compact asymmetric coplanar strip (ACS)-fed multi-band [12] antenna for Bluetooth / WLAN / WiMAX applications

A compact asymmetric coplanar strip (ACS)-fed multi-band[12] antenna for WLAN, WiMAX and bluetooth applications was discussed by Naidu and Malhotra in their paper. Theit antenna was a straightforward monopole structure with a mirror- L shaped limb and 2x rectangular resonating strips. It was very tiny in size (13.75 x 26 mm^2 and ground plane is included in it). The mirror-L shaped limb radiated at 2.5 GHz , ACS-fed monopole structure with 2x rectangular strips resonated at 3.3 GHz and 5.75 GHz . They also proposed that if lengths and positions are selected properly , the operation in multibands with wide impedence bandwidth could be gained. Both results (measured and simulated) showed that the antenna had impedance bandwidth of 200 MHz (2.40 till 2.60 GHz) and 2800 MHz (3.2 till 6.0 GHz) and antenna could cover the 2.4 GHz Bluetooth, 2.4/5.2 /5.8 GHz WLAN and 3.5/5.5 GHz WiMAX band. The (figure 2.11 and 2.12) of antenna can be seen below.

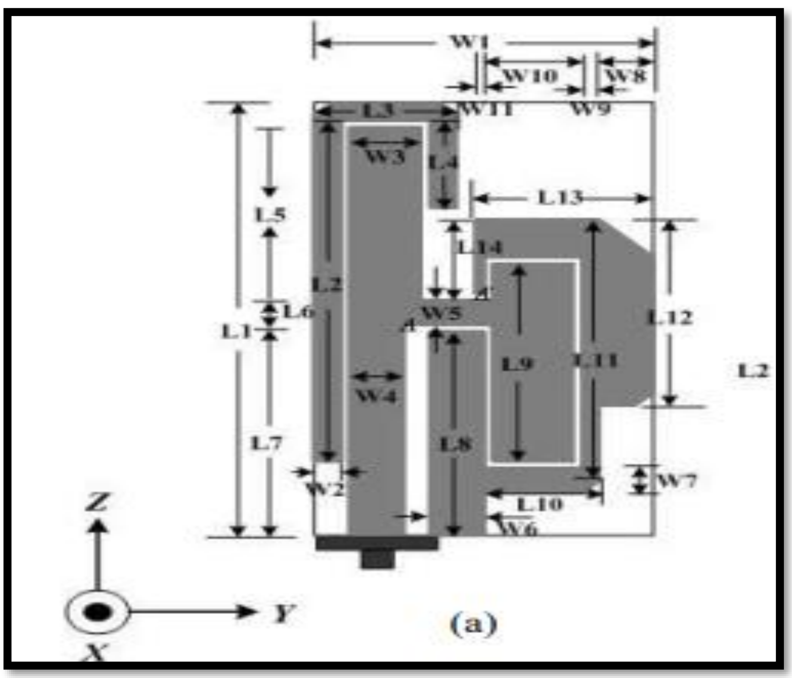

Fig 2.11 Proposed Shape Of Antenna

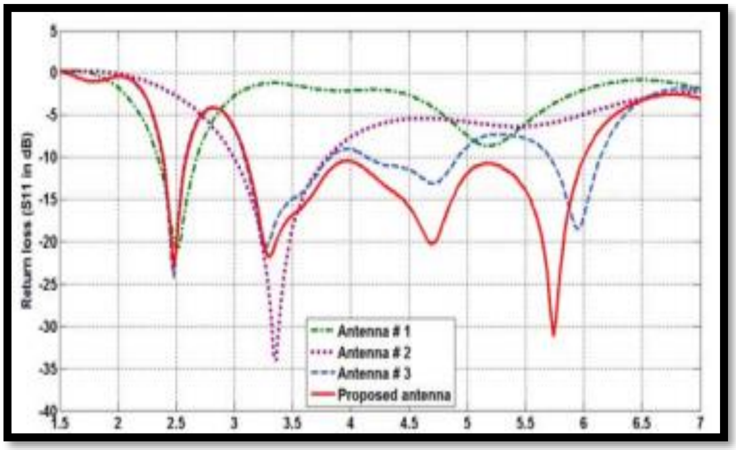

Fig 2.12 Frequency Vs Return Loss

2.3.5 Dual-band antenna with compact radiator for WLAN applications

T.I Yuk and Li Liu [13] of Hong Kong university presented paper in which the antenna mentioned above was presented. The antenna consisted of an E-shaped and L-shaped resonating elements to produce two modes of resonance for dual-band operation (fig 2.13) and (fig 2.14) . The E-element was fed directly by a 50-Ω microstrip line was designed to resonate on a frequency band approaching 5.5 GHz to extend over the two higher bands of the WLAN system. The L-element is coupled-fed through the L-element and made to resonate on a frequency band at 2.44 GHz to extend over the lower band of the WLAN system .

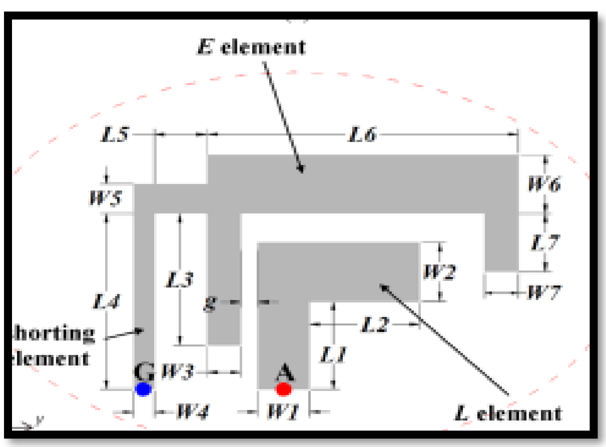

Fig 2.13 Shape Of Proposed Antenna

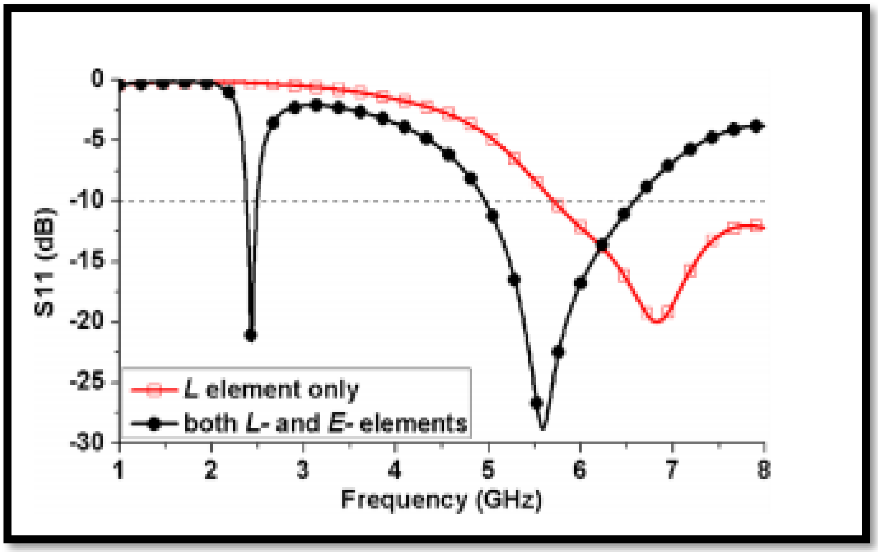

Fig 2.14 Frequency Vs Return Loss

2.3.6 Novel compact ultrawideband (UWB) printed slot antenna with three extra bands for various wireless applications

H. R. Hassani and M. M. Samadi Taheri[6], propsed a paper as mentioned above in the title. Their antenna was low in profile and comprised of octagonal-shaped slot fed by a beveled and stepped rectangular patch for extending over the UWB band (3.1–10.6 GHz) . By connecting three inverted U-shaped strips at the upper part of the slot in the ground , additional triple linear polarized bands can be generated to extend over GPS (1520–1590 MHz), tiny part of GSM (1770–1840 MHz) and Bluetooth (2385–2490 MHz) . These antennas have a steady radiation pattern both at the triple and the all the UWB bands. (figure 2.15) & (figure 2.16) can be seen below.

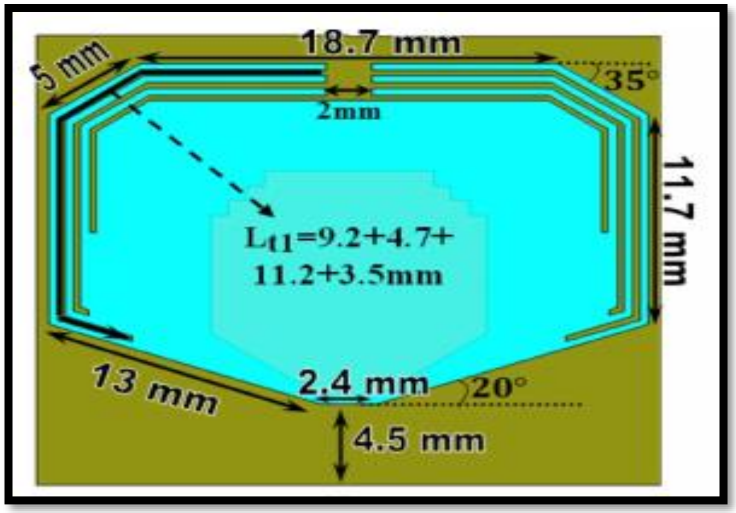

Fig 2.15 Proposed Shape of Antenna

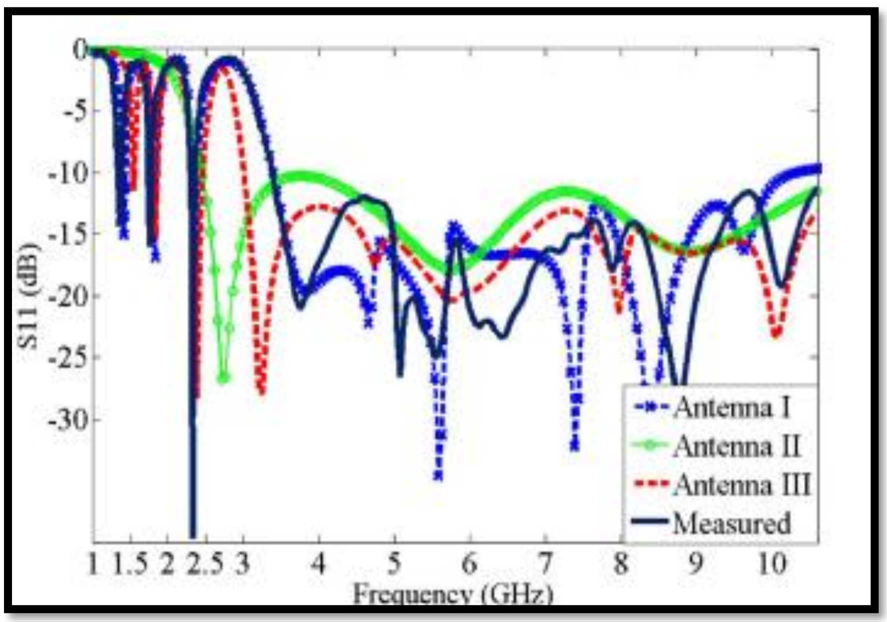

Fig 2.16 Frequency Vs Return Loss

2.4 Problem Statement

In today's era of modern wireless communication, where there is requirement of systems operation on different frequencies working simultaneously like GPS, WLAN and WiMAX to get maximum results. One way is that all systems working on different frequencies should work at different antennas with different multiple power sources. But it is difficult to handle because all antennas are different entities. There arises a need that how all these systems operating on different frequencies can be incorporated into single antenna of small size and lesser cost that can support all these frequencies and also uses no extra power sources . As there will be be only one power source.

2.5 Proposed Solution

The ultimate goal of our FYP is to design a compact reconfigurable antenna that can excite multiple-band operation combining different communication standards simultaneously into a single device. It requires HFSS for simulation.

2.6 Selected Technique

The technique which has been shortlisted by us is frequency reconfiguration. The most important point to choose frequency reconfiguration is that it very easy to achieve. You need only to change the dimensions or shape you will get a new frequency. It is up to one how one exploits that frequency for his use.

CHAPTER 3

ANTENNA DESIGN AND DEVELOPMENT

3.1 Design and Structure

Antenna which we have designed is (28x30) mm in total measurement. Actual size of antenna at which our desired results were achieved was 20x28mm (20mm on x-axis and 28mm on y-axis). The reason which results us to deviate from our original design was the size of chokes. To compensate the size of chokes and their soldering on substrate the increase of 10mm was required. This increase in size of substrate results in increasing the dimensions of our antenna. This increase in antenna dimension was unavoidable due to compulsory usage of chokes. The chokes are acting as an inductor in the circuit which allows only the flow of DC current from them and stops the AC current to pass from them. The detailed working of Pin diode and RF chokes (ADCH-80A) will be discussed later in chapter 4

Our antenna is basically a dipole antenna with L shaped strips and rectangular patches. The dipole is cut from half and presented in in 2-dimensional view as shown in figure 3.1.a and figure 3.1.b.

2x Pin diodes (as shown in fig.3.0.a) have also been incorporated in antenna for switching purpose. The details and dimensions of Pin diode are shown in figure 3.5 as a Diode 1 and figure 3.6 as a Diode 2. We can manipulate with the results just by switching these two diodes as on and off state. On state of these pin diode can be achieved by giving the DC input of 0.7V to the pin diode which makes them as a forward biased. In this state resistance of pin diode is very small which allows all of AC current to pass through the pin diode and thus it results in connecting to different coppers patches together and allows a smooth flow of AC current from complete copper patch without any hindrance. When no DC input of 0.7V is applied then the pin diode will be acting as a reversed biased diode and it is offering a huge resistance to the AC current which stops all AC current components and this diode will be treated as in off state. In this state the copper patch on one side of pin diode gets disconnected from the copper patch on the other side of the pin diode thus resulting a discontinuity in the AC current path. We can have different combinations of these Pin Diode that are discussed below.

1. When both Diode 1 and Diode 2 are in off state. In this combination AC current is only flowing through the copper patch on the left side of the Diode 1 and copper patch on the bottom side of Diode 2. This combination makes smallest copper patch in our antenna design through which AC current is flowing and this smallest portion is only responsible for all the radiations emitted by the antenna.
2. When both Diode 1 and Diode 2 are in on state. This combination makes the largest radiating copper patch through which AC current is flowing. This is the only combination in which complete copper patch is responsible for emitting radiations
3. When Diode 1 is in on state and Diode 2 is in off state. In this combination the Diode 2 is acting as reversed biased thus offering a huge resistance to AC current and ultimately results in stopping the AC current from passing through the Diode 2. Eventually the copper patch to the top of Diode 2 will be disconnected from the remaining copper patch and will not participate in emitting the radiations.
4. When Diode 1 is in off state and Diode 2 is in on state. In this combination complete copper patch from the left side of Diode 1 participate in emitting radiations because the AC current that comes to Diode 1 will be stopped as it is in reverse biased condition and the Diode 2 will permit the AC current to pass through it as it is forward biased. This will result in connecting the copper patch above the Diode 2 to the patch below of the Diode 2. So, the complete copper patch that is to the left of Diode 1 from bottom (current feed) till top (copper patch above the Diode 2) will act as the radiating patch.

The results achieved by the above combinations will be discussed later in Chapter 4

Substrate which we used is FR4. Instead of enormous bad effects on results FR4 substrate is used because of easy access in market and cheap price enforced us to use it in our project fabrication. SMA connectors have been used for AC current feed that are also cheaply available in market.

3x RF chokes (ADCH-80A) as shown in figure 3.0.b, have been used in fabrication of our antenna. RF chokes are the costly equipment because of less availability in the market. These RF chokes (ADCH-80A) helps us in giving the DC current to pin diode from a DC power supply. The mechanism that helps us in this scenario is discussed in next paragraph.

To make the pin diode forward biased the pin diode needs a DC 0.7V from a DC power supply. Since the pin diodes are connected to a DC power supply by some wire. This is the point where problem arises if we directly connect the power supply (0.7V DC) to pin diode through the wire then this length of the wire creates the problem. The AC current was supposed to flow by pin diode from one copper patch to another part of copper patch (connecting two different copper patches together). The AC current now gets a new current path that is from diode to wire and then to power source. Since AC current is flowing through the wire also therefore the complete length will also starts radiating and it also become a part the antenna which is not desired.

To overcome the problem arose by the AC current flowing in wire we used RF chokes (ADCH-80A). The choke acts as an inductor which stops the AC current and allows only DC current to pass from it. The choke is soldered to the copper patch that is connected to +ve leg of pin diode then the wire is soldered to the choke (ADCH-80A) and other end of wire is connected to DC power supply of 0.7V.This scenario is creating the only path (DC power source >wire>choke>diode) for DC current. Thus, blocking the AC current flow to enter into wire. Therefore, the problem of AC current flowing into wire is resolved by using RF chokes and the length of wire would not be acting as a part of antenna.

HFSS was used for simulation of antenna.

Fig 3.0.a Pin Diode

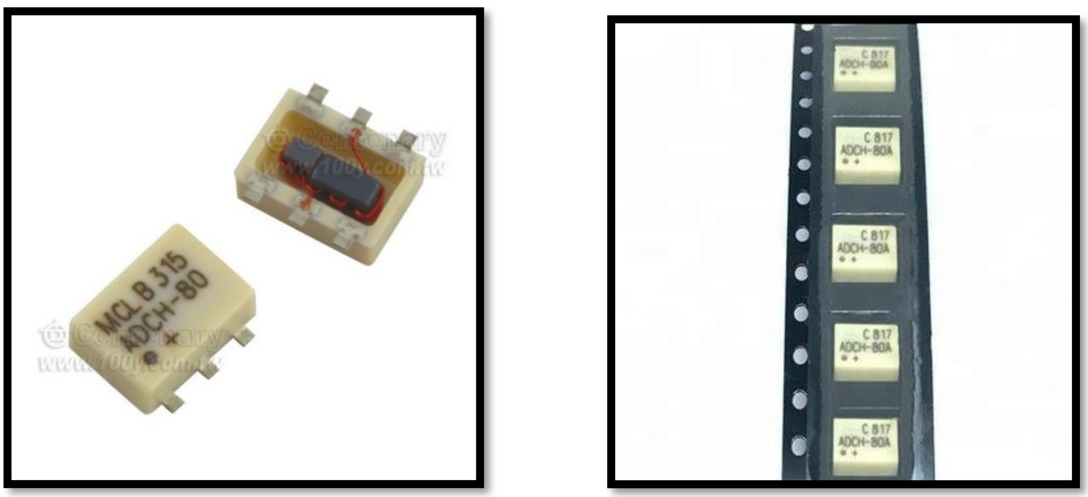

Fig 3.0.b RF Choke (ADCH-80 A)

3.2 Dimensions

Antenna's front, back and side view can be seen in the (fig 3.1). All dimensions can be seen in table 1.

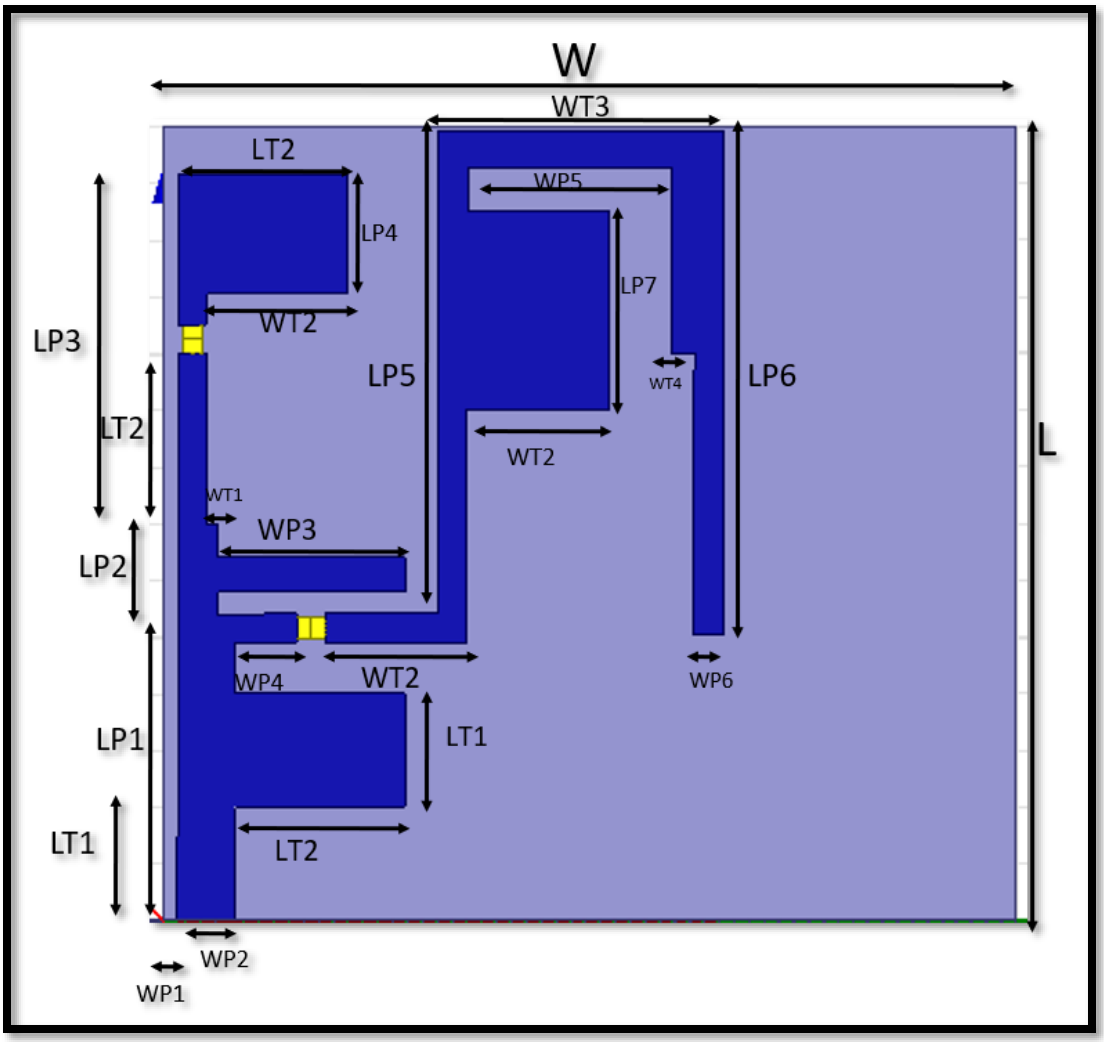

Fig 3.1.a Antenna dimensions (Front view)

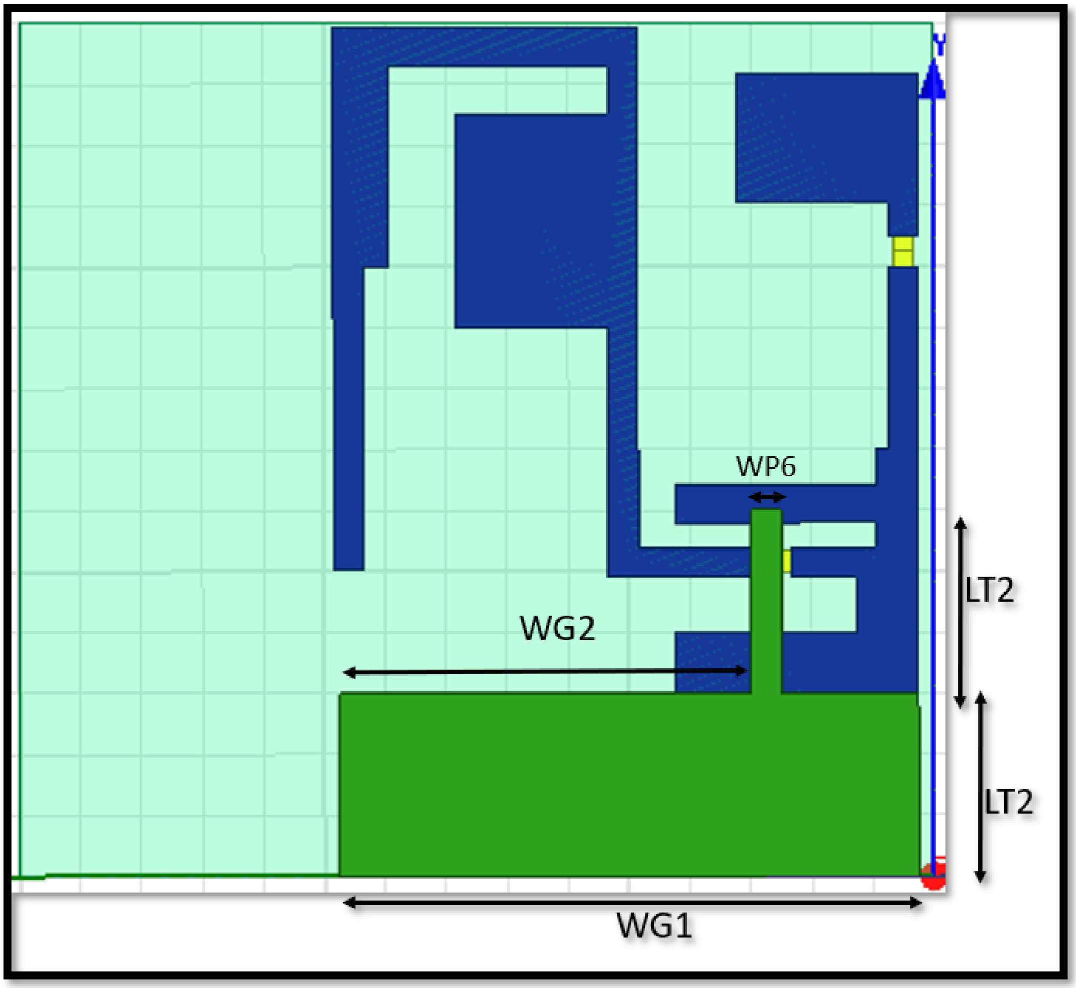

Fig 3.1.b Antenna dimensions (Back view)

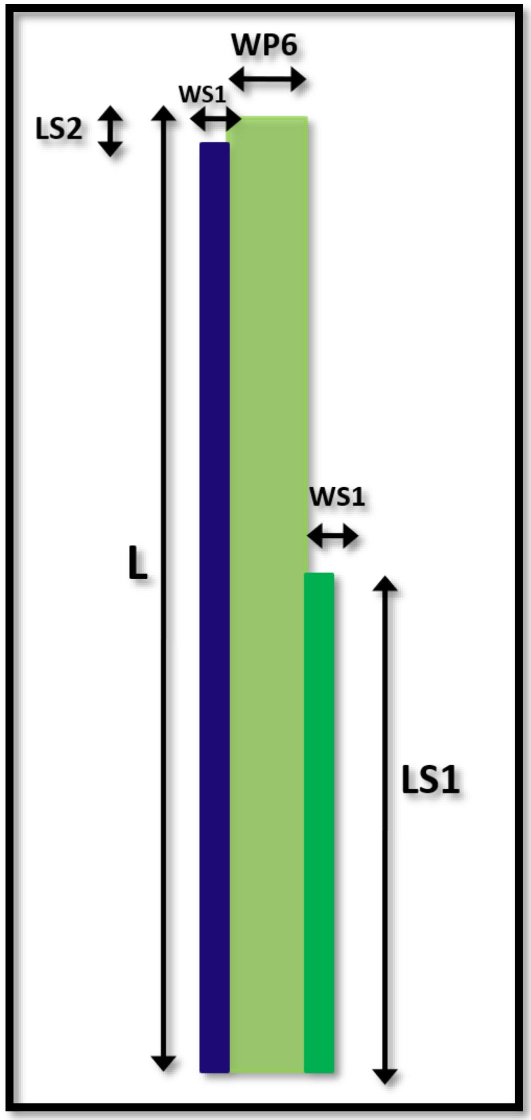

Fig 3.1 Antenna dimensions (Side view)

LP1	10.8mm
LP2	3.2mm
LP3	12.3mm
LP4	4.2mm
LP5	17.05mm
LP6	17.8mm
LP7	7mm
L	28mm
W	30mm
WP1	0.5mm
WP2	2mm
WP3	6.6mm
WP4	2.2mm
WP5	7.2mm

WP6	1mm
WT1	0.4mm
WT2	5mm
WT3	10mm
WT4	0.8mm
WG1	19mm
WG2	13.5mm
LT1	4mm
LT2	6mm
WD2	0.7mm
WS1	0.01mm
LS1	12mm
LS2	0.15mm

Table 1: Antenna Dimensions in mm

3.3 HFSS Design

(Figures 3.2) and (fig 3.3) show patch and ground of the antenna.

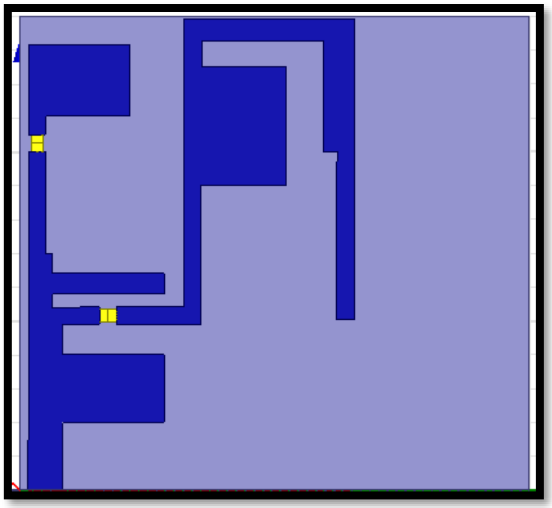

Fig 3.2: Patch

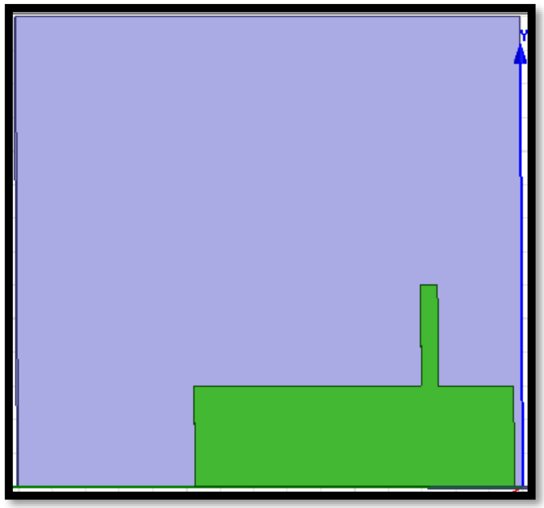

Fig 3.3: Ground

(Fig 3.4) shows more detailed antenna. While (figures 3.5 and 3.6) show positions of diodes.

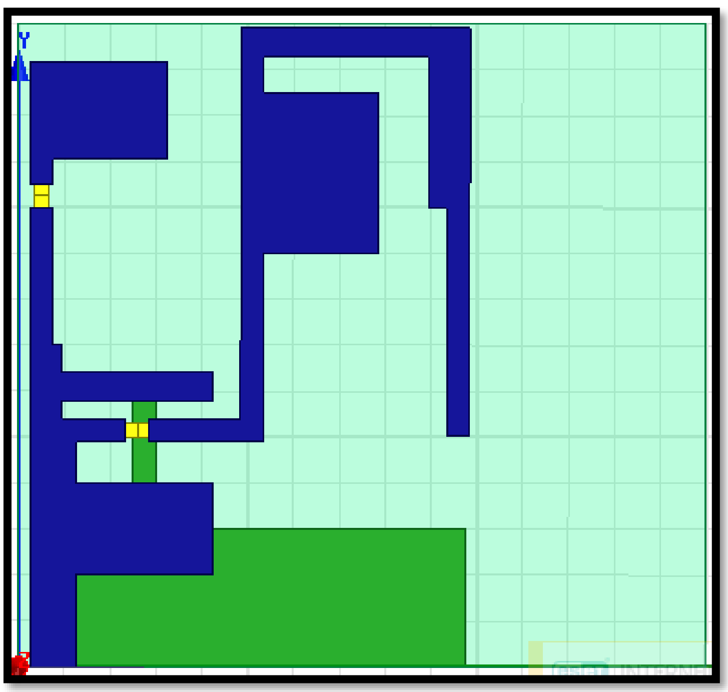

Fig 3.4 Patch and ground

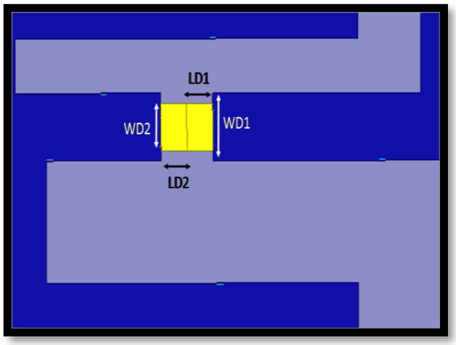

Fig 3.5 Diode 1

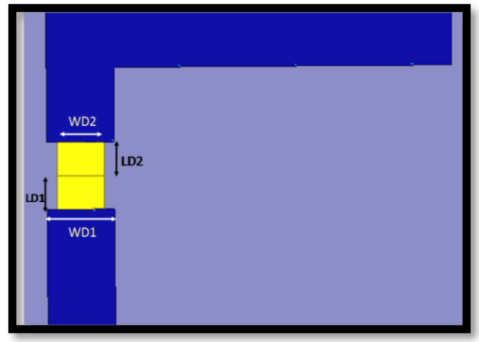

Fig 3.6 Diode 2

3.4 Fabricated Design

Fabricated antenna can be seen in (fig 3.7) .

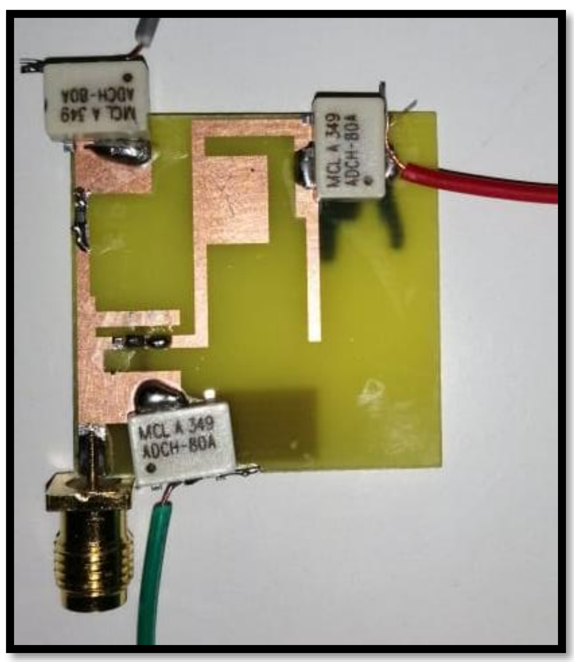

Fig 3.7 Fabricated antenna

CHAPTER 4

ANTENNA MEASUREMENTS AND RESULTS

+ve leg of pin diode is connected to the copper patch which is located to the left of the Diode 1 position and the -ve leg of pin diode is connected to the copper patch which is right of the Diode 1 position. Similarly, +ve leg of another pin diode is connected to the copper patch which is located below of the Diode 2 position and -ve leg of pin diode is connected to the copper patch which is located above of the Diode 2 position.

As discussed earlier 3 RF chokes (ADCH-80A) are used to stops the flow of AC current into connection wires. Choke 1 is connected to the rectangular copper patch which is located below of Diode 1. Choke 2 is connected to the rectangular copper patch located above the Diode 2. Choke 3 is connected to the right most L shaped copper strip. The connection of the chokes will remain same for all scenarios (Single band, Dual band and Triple band).

4.1 S (1,1) Plots

S (1,1) plots of three different scenarios are discussed below

1. S (1,1) plot for single band has been shown (fig 4.1) below which shows maximum dip at 3.76 GHz. To achieve the single band the combination of pin diode (Diode 1 and Diode 2) is used. In this case Diode 1 is in on state and the Diode 2 is in off state. Diode 1 is forward biased thus connecting the copper patches that lies to right and left of the Diode 1. The Diode 2 is reversed biased and no current is flowing through it. The copper patch that lies above the diode 2 is disconnected from rest of the patch thus it will not participate in emitting radiations.

   Orientation of Diode 1 will be same as discussed in start of the chapter. In this case orientation of Diode 2 will be reversed, +ve leg of pin diode is connected to the patch above the Diode 2and -ve leg of pin diode is connected to the patch below of the Diode 2. To make Diode 1 forward biased +ve of DC power source is connected to choke 1 while choke 2 choke 3 are connected to -ve of DC power source. Therefore, by this setting we got Diode 1 as forward biased and Diode 2 as reversed biased.

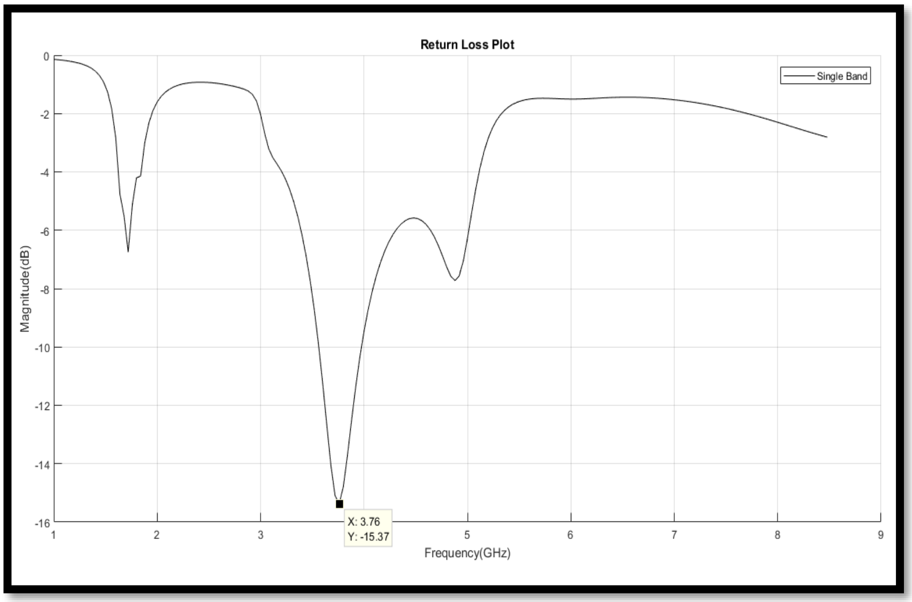

Fig 4.1: Single band at 3.76 GHz

2. Below (fig 4.2) is the plot showing dual band showing dips at 2.81 GHz and 4.78 GHz. These results are achieved by combination of pin diodes that are Diode 1 and Diode 2. In this scenario both the Diode 1 and the Diode 2 are in off state. Both the diodes will be acting as reversed biased. The copper patch to left of the Diode 1 and copper patch below of the Diode 2 are responsible for emitting radiations. In this case patch size used is smallest. Since both the diodes are reversed biased therefore these diodes restrict the flow of AC current only to the smallest copper patch. The copper patch to the right side the Diode 1 and the copper patch above the Diode 1 will not take part in radiating any energy. Therefore, these patches will not be part of the antenna.

   The orientation of the pin diodes will same as discussed earlier at the start of this chapter. To make Diode 1 and Diode 2 reversed biased +ve of the DC power source is connected to the choke 2 and choke 3 while -ve of the DC power source is connected to the choke 1.

Remember the DC power source used would be 0.7V. It should not exceed 0.8V otherwise it will be going to burn the pin diode.

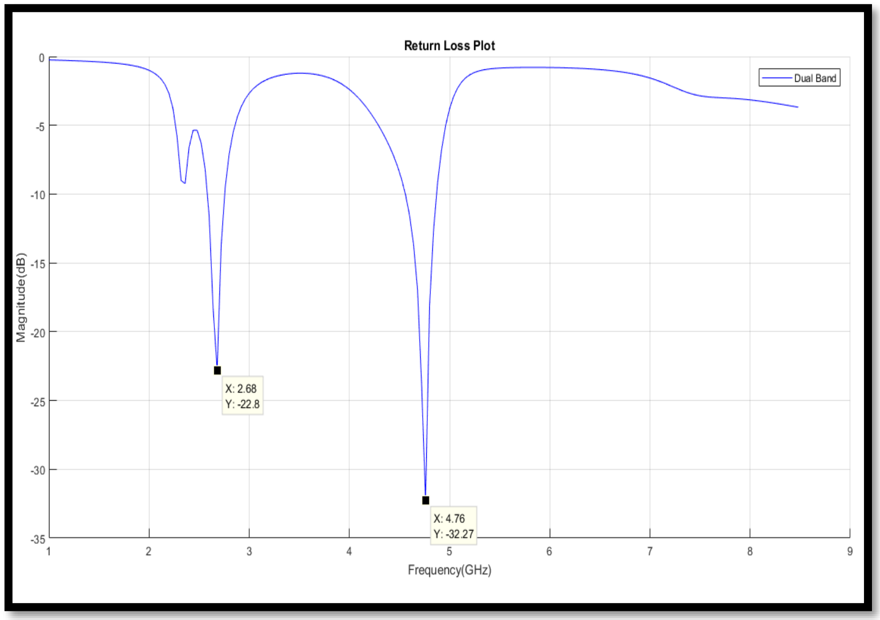

Fig 4.2 Dual band at 2.68 GHz and 4.76 GHz

3. Triple band S (1,1) plot can be seen below at frequencies 2.68 GHz, 3.36GHz and 4.84 GHz (fig 4.3).

   To achieve the triple band the combination of pin diode (Diode 1 and Diode 2) is used. In this case Diode 1 and Diode 2 both are acting as forward biased. Thus, resulting in connecting all the copper patches together. Therefore, in this case complete copper patch is responsible for radiating the energy.

   The Orientation of Diode 1 and Diode 2 will be same as discussed in start of the chapter. +ve of DC power source is connected to choke 1 while the choke 2 and choke 3 are connected to -ve of DC power source. Therefore, by this setting we can get both the pin diodes in forward biased condition at a same time.

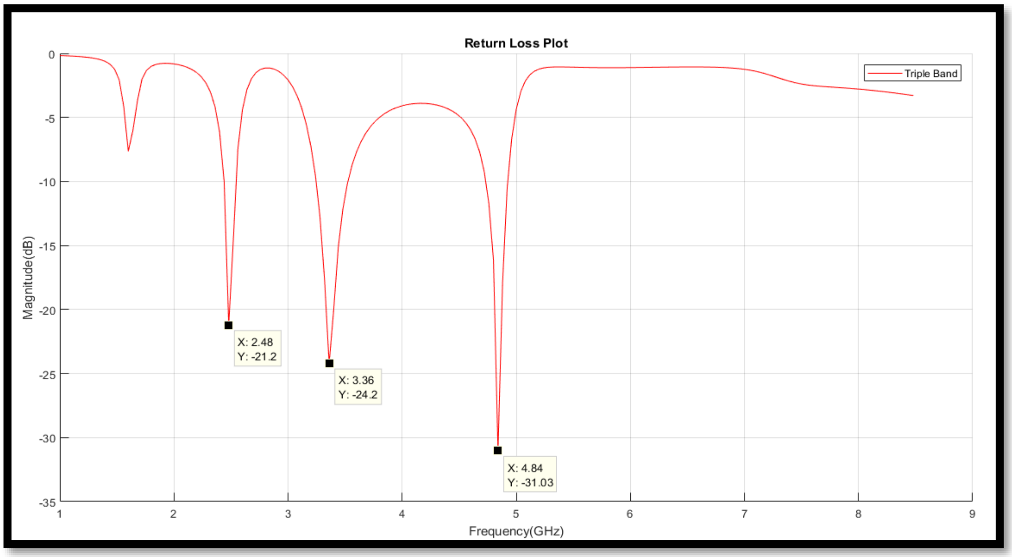

Fig 4.3 Triple band at 2.68 GHz, 3.36GHz and 4.84 GHz

Combined return loss at all frequencies can be seen in (fig 4.4). in this figure the results of single band , dual band and triple band are combined together.

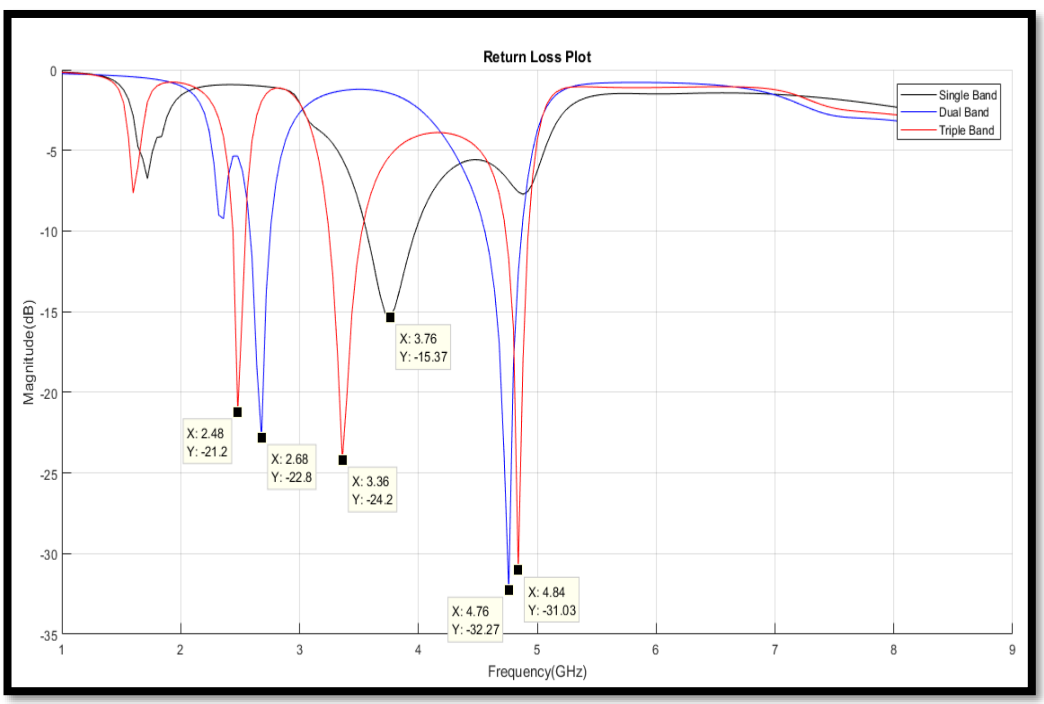

Fig 4.4 Combined return loss plot at all frequencies

4.2 Gain

Maximum gain in single band was achieved at 2.69 GHz (fig 4.5). whereas the gain plot at 3.81 GHz can be seen in (fig 4.6).

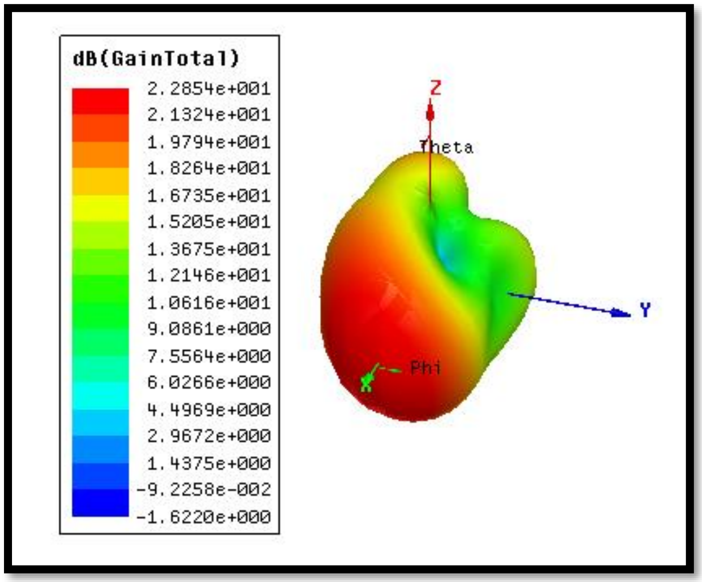

Fig 4.5 Single band gain on 2.69 GHz

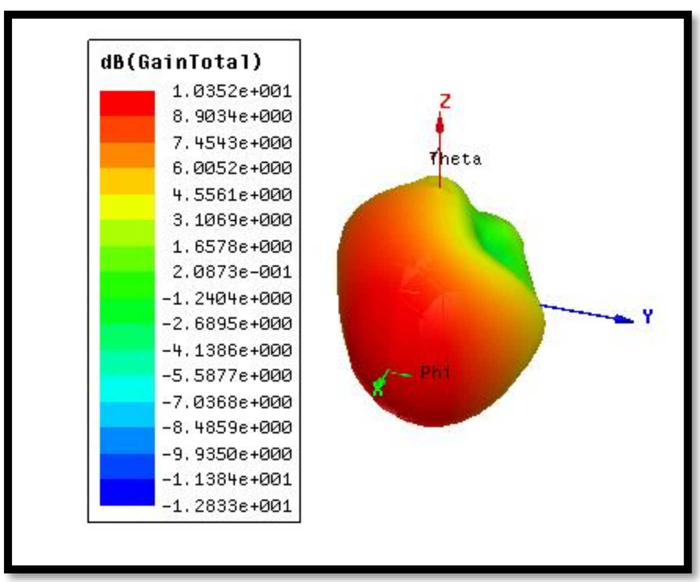

Fig 4.6 Single band gain at 3.81 GHz

There is slight difference in gain at single band and dual band at 2.69 Ghz which can be seen in figure given below (fig 4.7) .

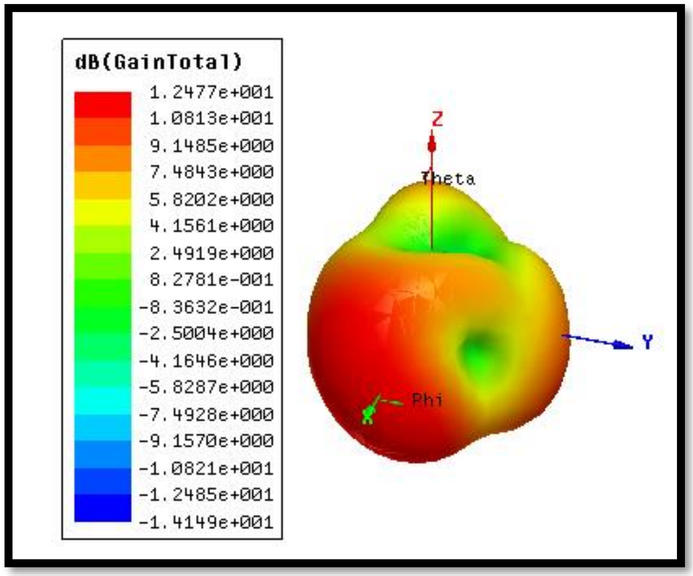

Fig 4.7 Dual band gain on 2.68 GHz

Gain at frequency 4.81 GHz at dual band given below (fig 4.8).

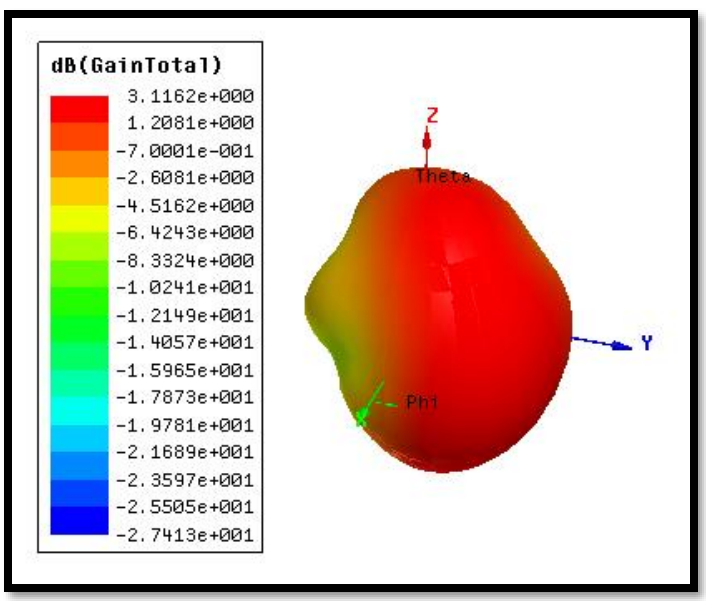

Fig 4.8 Gain dual band 4.81 GHz

Triple band gain at 2.55 GHz is given below (fig 4.9).

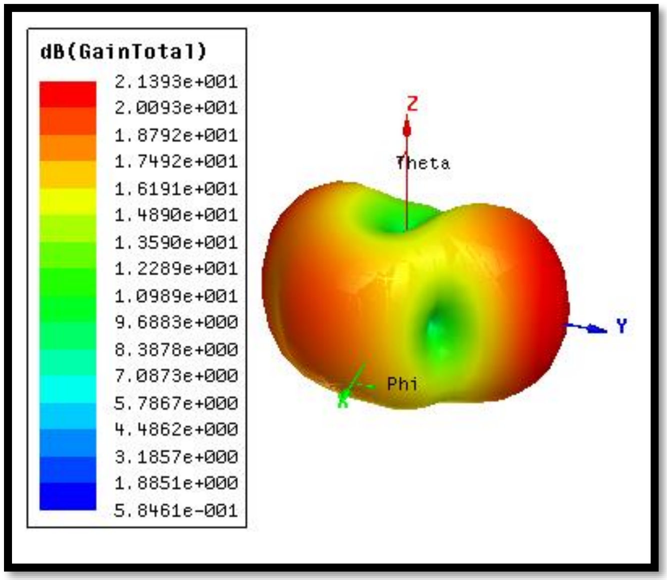

Fig 4.9 Triple band gain on 2.55 GHz

Gain shown below is at 5.4 GHz for triple band (fig 4.10).

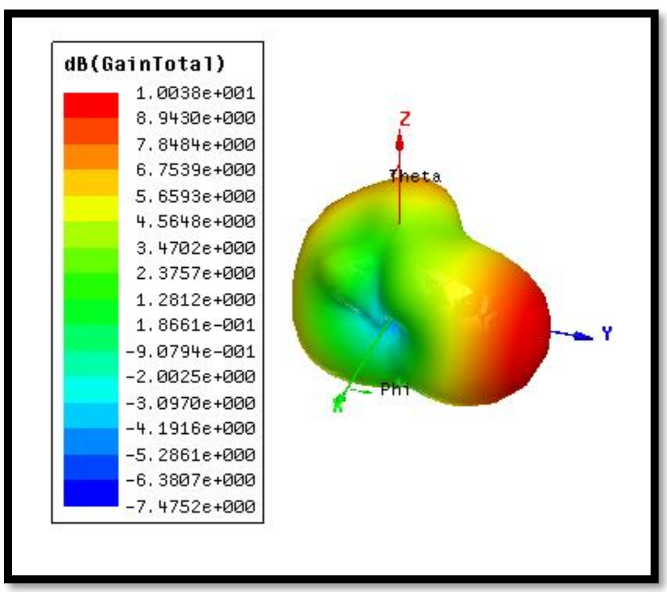

Fig 4.10 Triple band gain on 3.4 GHz

Gain on 4.81 GHz for triple band is shown below (fig 4.11)

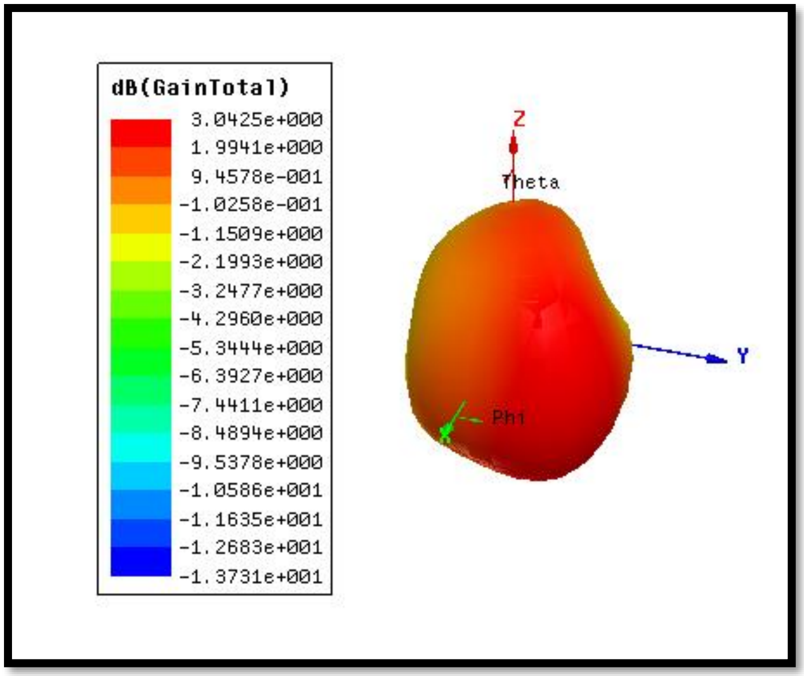

Fig 4.11 Triple band gain 4.81 GHz

4.3 Current Plots

Since determining the diode position is a very difficult job. So, it took a lot of our time just to determine the position of the diodes. Position of diodes is determined by analyzing the different current plots of the complete patch. After looking for suitable positions from where the energy radiation gets less effect the diode positions were marked and a gap of 1mm was left so that on that locations the pin diodes can easily be soldered. Current plots of the complete patch at different frequencies 2.56GHz, 3.40 GHz and 4.81GHz can be seen in the fig 4.12, fig 4.13, fig 4.14 respectively given in which there in no diode used.

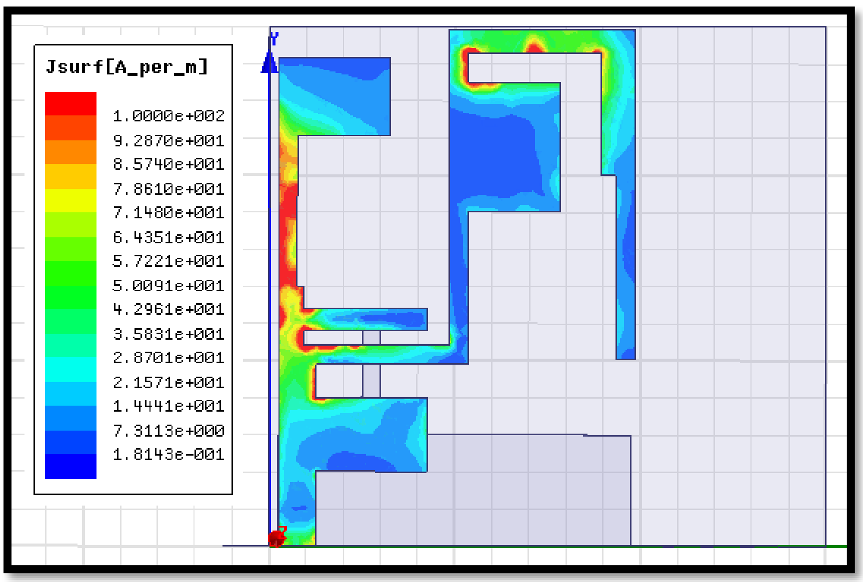

Fig 4.12 Current plot of complete patch without diodes at 2.55 GHz

The red area in the fig is showing that a 100 A/m current is flowing through that locations on the patch. If you see the legend it shows as you move down toward the blue color the amount of current in amperes per meter is reducing accordingly to the values which are given against each color.

Fig 4.12 is showing that the maximum radiations are coming from the area which is marked red in color as shown in figure. One can easily see that the L shaped strips are taking part in radiating energy whereas the rectangular component are not much effective in radiating energy because lesser amount of current is flowing through it.

Similarly, fig 4.13 and fig 4.14 are showing the amount of current in amperes per meter flowing through the copper patch at 3.40 GHz and 4.81 GHz respectively. In the figures the area marked with red color is showing that it the area which is responsible for the maximum radiations and the area which is shown in blue color is responsible for the minimum amount of radiations.

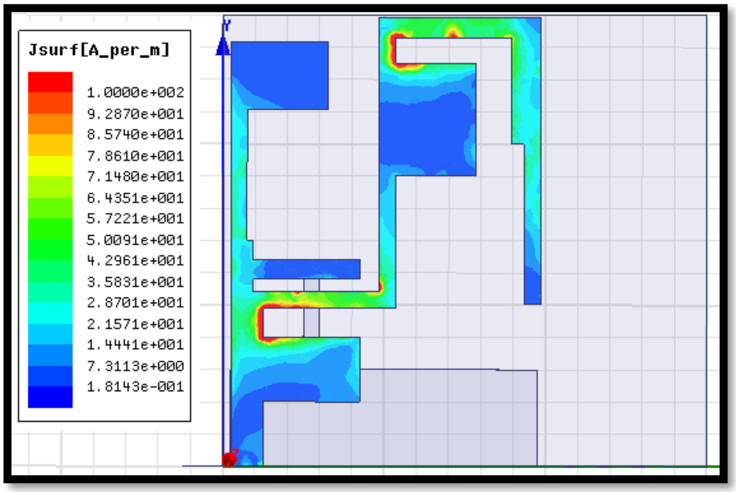

Fig 4.13 Complete patch current plot without diodes at 3.40 GHz

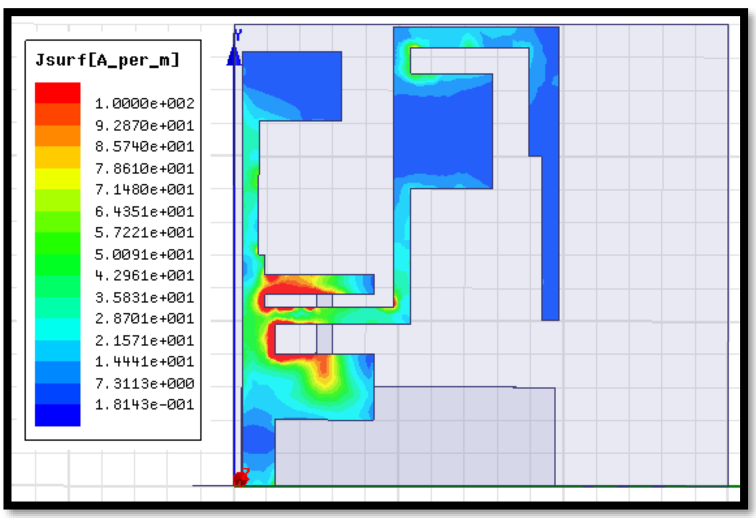

Fig 4.14 Complete patch current plot without diodes at 4.81GHz

After completing the thorough analysis, the positions of the pin diodes are selected. By analyzing the current plots different position were marked and slot of 1mm was kept at that marked locations. After different hit and trial methods and making the diode simulation the final positions of the pin diode were obtained which are marked as Diode 1 and Diode 2 as shown in fig 3.5 and fig 3.6 respectively.

Current plots for all the bands under consideration have been given below after inserting the diode at their proper locations.

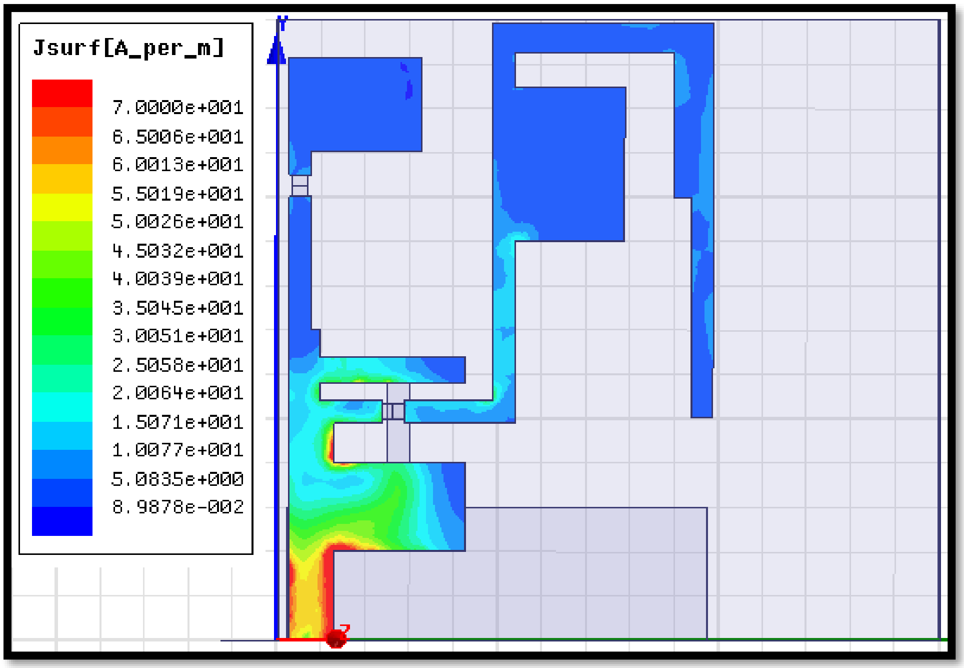

Fig 4.15 Single band current plot on 3.76 GHz

Here in the figure above that area shown in red showing more radiations then then orange and in sequence comes yellow , green , sky blue and the blue. So the area radiating red is the one radiating at frequency 3.76 GHz.

In fig 4.15 copper patch which is near to current feed is responsible for the maximum radiations while the upper sides of copper patch are less participating in radiating the energy.

In the fig 4.16 and fig 4.17 it can be seen that in addition to red area in single band other area is also red . and there is change in area of radiation for dual band at 2.69 GHz and 4.67 GHz.

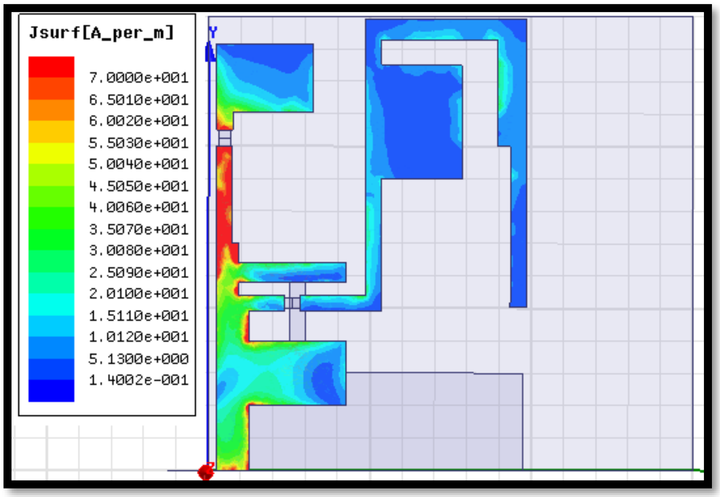

Fig 4.16 Dual band current plot on 2.69 GHz

In fig 4.17 horizontal strips which is left of the Diode 1 and rectangular patch which lies below of the Diode 1 are responsible for radiating the maximum energy while the other parts of the copper patch participate very less in radiating the energy.

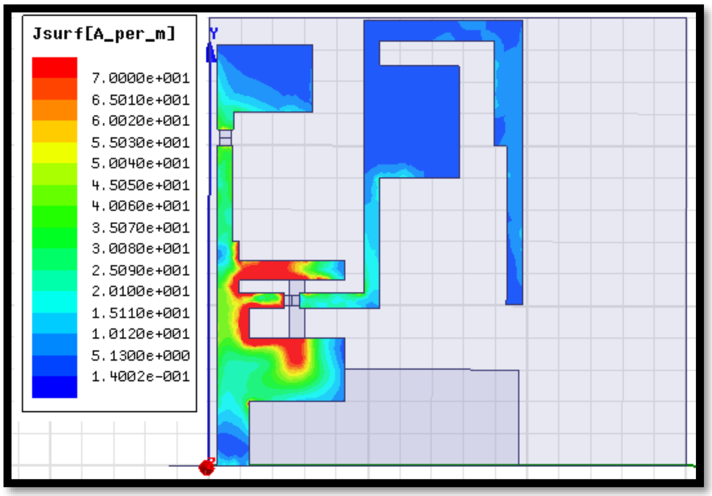

Fig 4.17 Dual band current plot on 4.67 GHz

Down here in the fig 4.18, fig 4.19 and fig 4.20 show that which parts of antenna are more active on triple band for 2.55 GHz, 3.40 GHz and 4.76 GHz respectively.

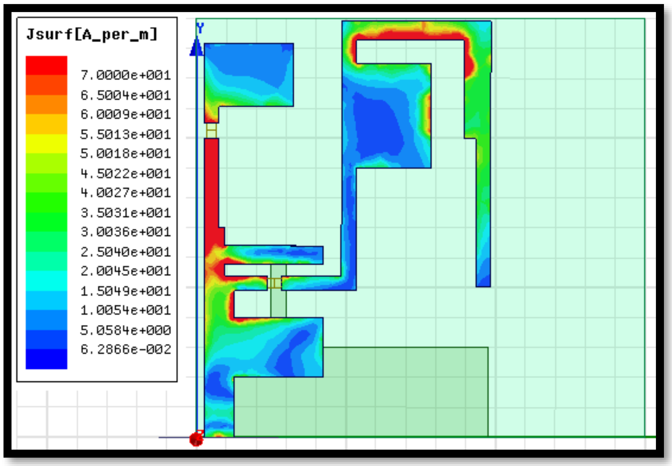

Fig 4.18 Triple band current plot on 2.55GHz

In fig 4.18 L shaped strips are majority participants in radiating the energy while the rectangular patch and other parts of copper patch are less participating in radiating the energy. Same is case in fig 4.19 in which L shaped strips are participating maximum in radiating the energy than other parts of the copper patch.

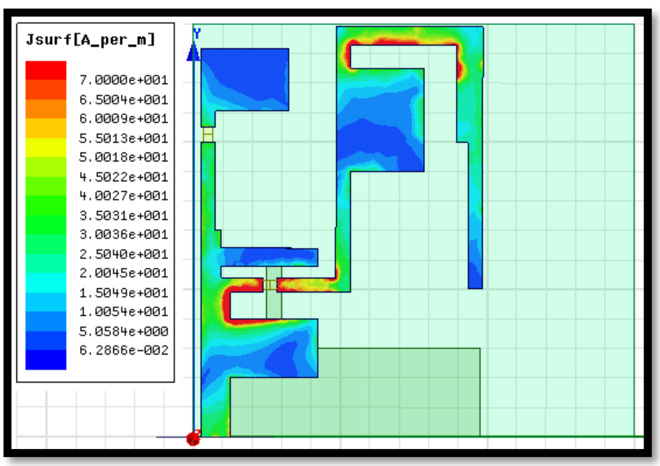

Fig 4.19 Triple band current plot on 3.40 GHz

As both the pin diodes, Diode 1 and Diode 2 are in on state and complete copper patch is located to the right side of the Diode 1 not participating much in radiating the energy. While most of the energy is radiated from the left side of the Diode 1, specially the majority participant in radiating the energy are the horizontal strips and the rectangular patch which lies below of the Diode 1.

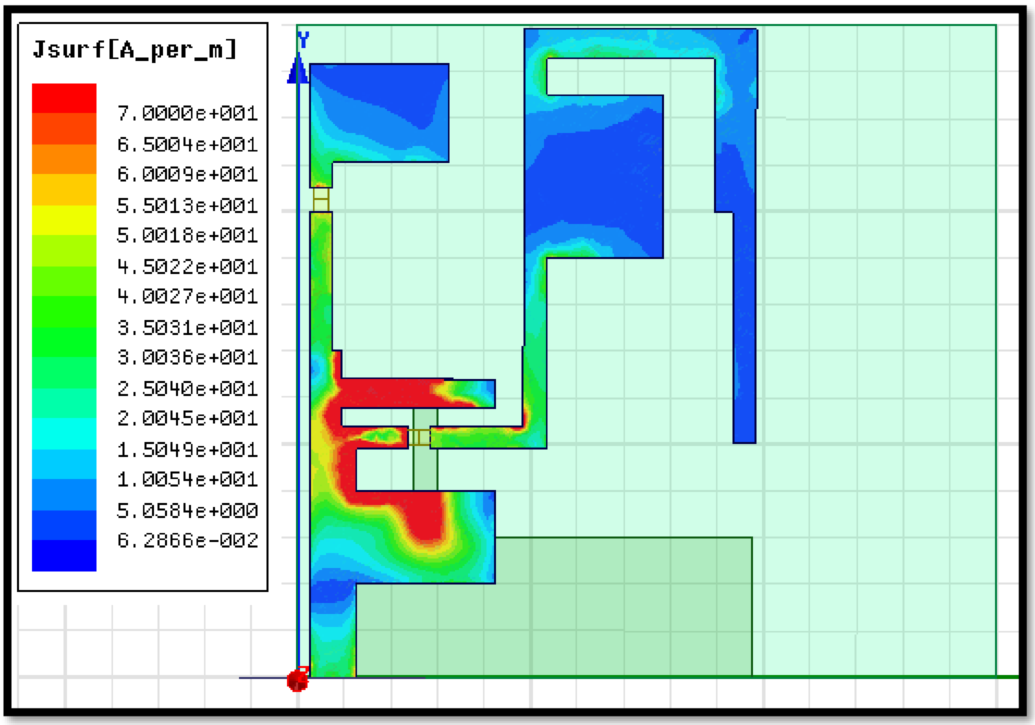

Fig 4.20 Triple band current plot on 4.80 GHz

4.4 Results comparison (simulated results vs measured results)

The design of the project is simulated in HFSS and the results are measured after fabrication of antenna by virtual network analyzer. Fig 4.21 show comparison of measured and simulated results of the single band. Maximum dip of Return loss occure on frquency 3.76 GHz with a value of -15.37 dB during simulatio. But after fabrication measured results shows a shift in frequecy. During measurement maximum dip of return loss occure on frquency 4.08 GHz with a value of -15.1 dB.

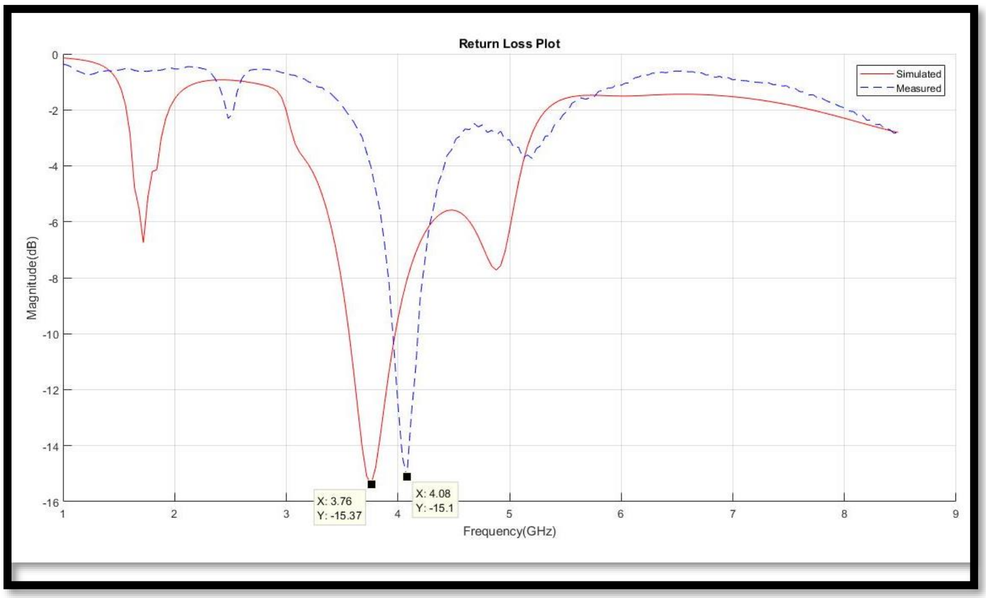

Fig 4.21: Single band return loss

Fig 4.22 shows the comparison of dual band measured and simulated results. In simulated results the value of return loss for frequency of 2.68 GHz is -22.8 dB and for frequency of 4.76GHz is -32.27 dB. While after the fabrication our measured results show a shift in frequency. In measured results the value of return loss for frequency of 2.92 GHz is -15.8 dB and for frequency of 5.04GHz is -19.7 dB.

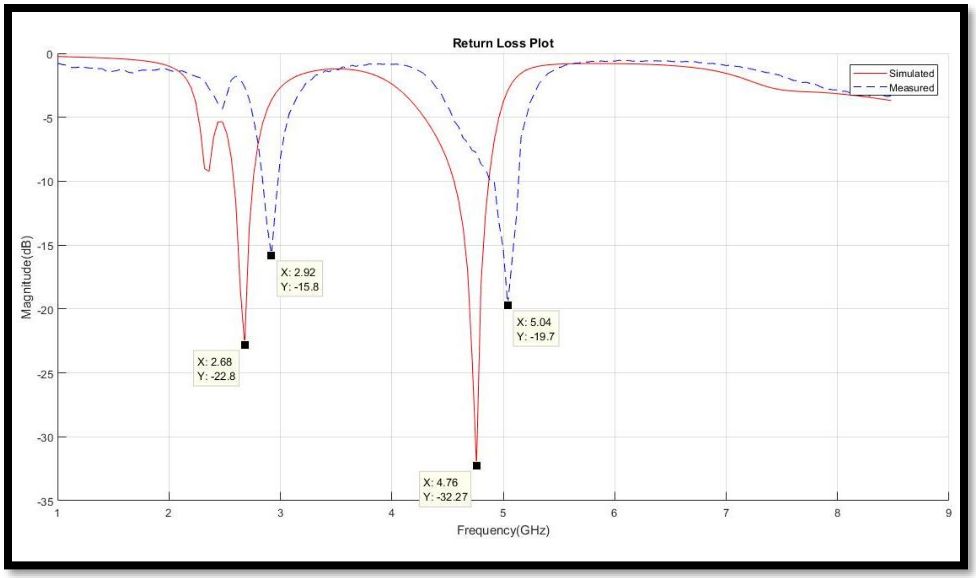

Fig 4.22 Dual band return loss

Fig 4.23 shows the comparison of triple band measured and simulated results. In simulated results the value of return loss for frequency of 2.48 GHz is -21.2 dB, for frequency of 3.36 GHz is -24.2 dB and for frequency of 4.84 GHz is 31.03 dB. While after the fabrication our measured results show a shift in frequency. In measured results the value of return loss for frequency of 2.72 GHz is -13.1 dB, for frequency of 3.76 GHz is -20.2 dB and for frequency of 5 GHz is -24.3 dB.

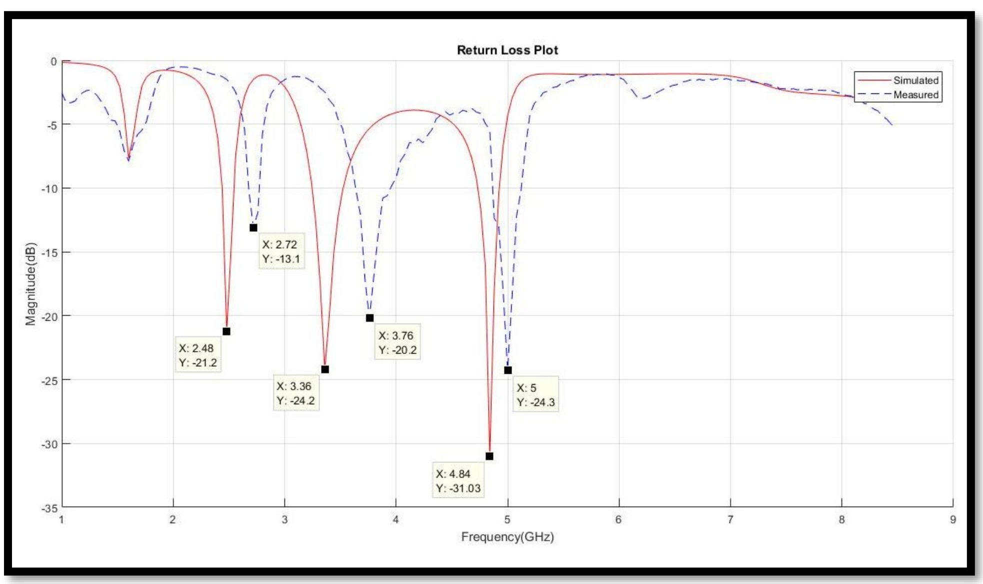

Fig 4.23 Triple band return loss

The results of single bad, dual band and triple band were measured by the virtual network anlyzer. The image taken during taking the measurments is shown in fig 4.24.

Fig 4.24 Results Measurements

CHAPTER 5

Future work And Conclusion

5.1 Future Work

Inspite of the fact that the antenna is giving desired results but still there is deviation is simulated results and results after fabrication. A room for improvement is is there to get better results . In future a lot of improvement can be carried out in following ways:

- The size of antenna can be reduced hence enhancing the compactness of antenna
- More bands can be incorporated in the antenna so more applications could be run on one antenna
- Substrate of antenna can be changed so better results can be achieved as there will be less loss
- A lot of work is required in switching
- Improving the gain can be a big area to work with
- Enhancing the directivity can be an area of consideration in future

5.2 Conclusion

A frequency reconfigurable multiband micro-strip patch antenna has been designed working around 3x different frequencies. Desired bands have been achieved and switching among the bands had been successful by using diodes. SMA connector was used to feed the antenna and chokes were used. The antenna can be brought in utilization for GPS, WLAN and WiMAX applications. And antenna has been tested successfully by running application on it. The desired goals and results have been achieved.

CHAPTER 6

REFRENCES

1. L. Dang, Z. Y. Lei, Y. J. Xie, G. L. Ning, J. Fan, "A Compact Microstrip Slot Triple-band Antennas for WLAN/WiMax Applications", *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 1178-1181, Dec. 2010
2. J. H. Lu, B. J. Huang, "Planar Compact Slot Antenna With Multi-band Operation for IEEE 802.16m Application", *IEEE Trans. Antennas Propag.*, vol. 61, no. 3, pp. 1411-1414, March. 2013
3. W. Hu, Y. Z. Yin, F. Peng, Y. Xi, "Compact Triband Square-Slot Antenna With Symmetrical L-strips for WLAN/WiMax Applications", *IEEE Antennas Wireless Propag. Lett.*, vol. 10, pp. 462-465, May. 2011
4. B. Li, "Triple-Band Antenna With U-Shaped Open Stub Fed By Asymmetric Coplanar Strip For Wlan/Wimax Applications", *Progress In Electromagnetics Research Letters*, vol. 37, pp. 123-131, Jan. 2013.
5. J. H. Lu, Y. S. Cai, "Planar Compact Multi-Band C-Shape Monopole Antenna With Inverted L-Shape Parasitic Strip For Wimax Application", *Progress In Electromagnetics ResearchC*, vol. 20, pp. 17-29, Feb. 2011
6. X. Q. Zhang, Y. C. Jiao, W. H. Wang, "Miniature Triple-Band CPW-Fed Monopole For Wlan/Wimax Applications", *Progress In Electromagnetics ResearchLetters*, vol. 37, pp. 97-105, April. 2012.
7. Arny Adila Salwa Ali and Sharlene Thiagarajah, “A Review on MIMO Antennas Employing Diversity Techniques,” Proceedings of the International Conference on Electrical Engineering andInformatics Institute Technology Bandung, Indonesia, June 17-19,2007
8. Muhammad Afsar Uddin, Fatama Akter, Md. Jahangir Alam,“High Bandwidth F-Shaped Microstrip Patch Antenna for C-band “International Journal of Advanced

Research in Computer and Communication Engineering, Vol. 6, Issue 3, pp-144,2017

9. Ankit Gumasta , Dharmendra Kumar Singh A Compact Broadband Microstrip Antenna for Wireless Applications of 3 to 7 GHz International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 5, Issue 10, October 2016
10. W. Hu, Y. Z. Yin, F. Peng, Y. Xi, “An Asymmetric Compact Multiband Slot Antenna For GPS, WIMAX and WLAN applications” IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 462-465, May. 2011
11. Lierong Wu, Jingjian Huang, and Naichang Yuan “A Compact Multi-Band Planar Monopole Antenna” College of Electrical Science and Engineering, National University of Defense Technology Hunan province, Changsha 410073, China
12. P. V. Naidu and A. Malhotra, “Design & Analysis Miniaturized Asymmetric for Multi-band WLAN/WiMax Applications,” Progress In Electromagnetics Research C, Vol. 57, pp. 159-171, June. 2015
13. X. L. Sun, L. Liu, S. W. Cheung, and T. I. Yuk, “Dual-Band Antenna With Compact Radiator For 2.4/5.2/5.8 GHz WLAN applications,” IEEE Trans. Antennas Propag., vol. 60, no. 12, pp. 5924–5931, Dec. 2012.