A COMPACT MULTIBAND MICROSTRIP PATCH ANTENNA

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ABSTRACT

A COMPACT MULTIBAND MICROSTRIP PATCH ANTENNA

A compact Multi-band Microstrip patch antenna applied to GPS/Bluetooth/WiFi applications is presented in this report. The proposed antenna is composed of derived dipole radiator, a rectangular tuning strip, and a microstrip feed line. With these structures employed, the antenna can generate three different resonances to cover the desired bands while maintaining low profile and simple structure. The simulated and measured return losses, radiation patterns are presented. Measured results in this report show that the antenna can be designed to cover the frequency bands of GPS/Bluetooth/WiFi.

CERTIFICATE

It is hereby certified that the constituents of this project entitled "A Compact Multiband Microstrip Patch Antenna" written by following students

1. GC Muhammad Ammad
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Under the constant assistance and skillful guidance of Lec Maryam Rasool and found satisfactory as per the requirement of the B.E Degree in Electrical (Telcom) Engineering.

Project Supervisor:

Dated: ___ June, 18

____

Lec. Maryam Rasool

MCS, NUST

DECLARATION

We hereby declare that none of the content of our work presented in this thesis has been submitted for some other award of qualification or degree either in this or anywhere else in another institution.

DEDICATED TO

Allah Almighty, the Beneficial and Most Merciful

And Prophet Muhammad (PBUH)

And our parents and faculty for their enormous encouragement

And support for completing this possible.

ACKNOWLEDGEMENT

We are thankful to Allah Almighty for His countless blessings without which nothing can be achieved.

We also pay our heartiest gratitude towards our mentor, Lec Maryam Rasool, for her encouragement, support, professional skills and instructions for bringing the all tasks to their final representation.

We would also like to thank the faculty for being helpful in the development of this project.

We are most thankful to our parents for their love and support in times of difficulty and hardships. Without their kind support this could never have been achieved.

At the end, we would also like to thank Major General Amjad Ahmed Butt HI(M) for being a source of constant motivation, hard work and team work for us.

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LIST OF ABBRIVIATIONS

Abbreviations	**Word in Full**
GPS	Global Positioning System
WIFI	Wireless Fidelity
VSWR	Voltage Standing Wave Ratio
HFSS	High Frequency Structure Simulator
PCB	Printed Circuit Board

CHAPTER 1

INTRODUCTION

An antenna could be an electrical device that reorganizes guided electromagnetic energy during a transmission line in order to radiate electromagnetic energy in free space. Antenna has a large variety in which main antennas are transmitting and receiving antenna use for transmitting and receiving radio waves. Antennas can also be used as an impedance transformer [1]. There are many types of antennas with respect to their function, shape and direction. Antenna is consist of conductor which paved an electrical path between transmitter and receiver, while current starts moving in conductors as a result alternating magnetic fields produced [2].

There many types of antennas including shapes, directions and functions. As far as shapes are concern main types are dipole, monopole, array, loop and aperture etc. Each of them has different characteristics in all aspects [3] [4].

Figure 1: Different Shapes of Antenna

Similarly, antennas with respect to directions are called Omni-directional (isotropic) and directional antennas. Isotropic antennas are those which radiation pattern covers all direction where directional antennas are directed and pointed to one particular direction.

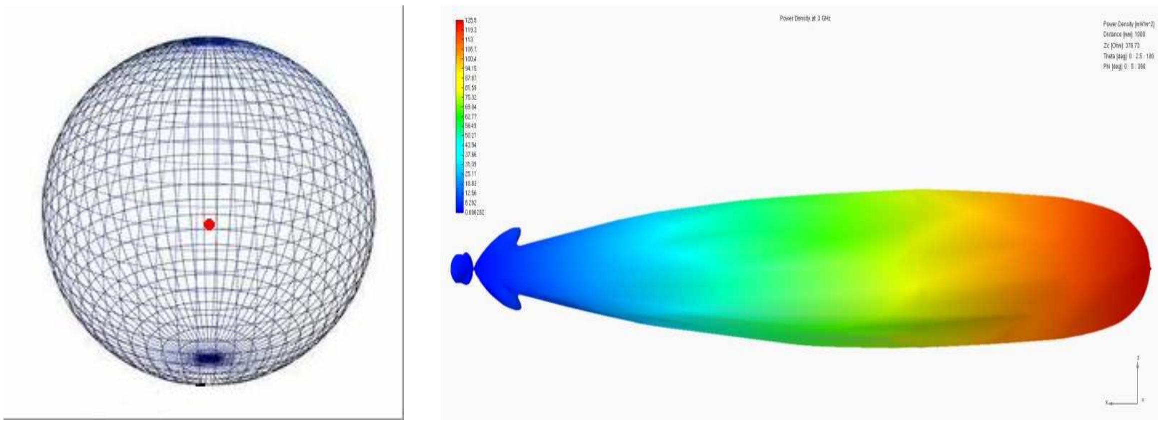
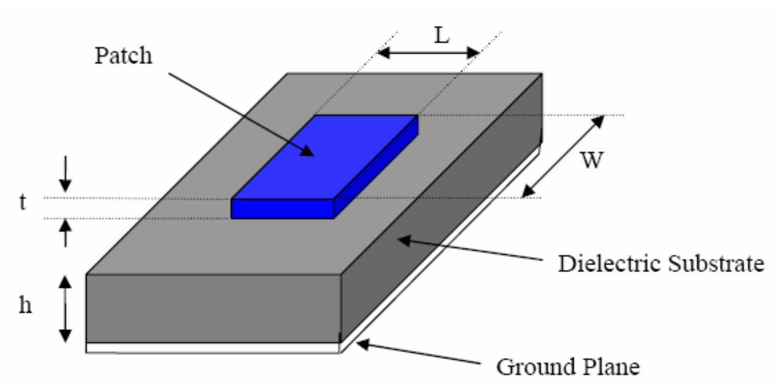


Figure 2: Radiation Patterns of Isotropic and Non isotropic Antenna

And as functions are concerned that will be transmitting antennas or receiving antennas. As far as Microstrip Patch Antenna is concerned antenna is comprised of three main components i.e. patch, substrate and ground. [Fig 3] By these factors we can configure result of any particular antenna by changing their different dimensions.



t= Patch Thickness

L= Patch Length

W= Patch Width

h= Substrate Height

Figure 3: Microstrip Patch Antenna

With the evolution of wireless communications standards, bunch of engineers focus their concentration on a way to propose multiband antennas that may mingled several standards like GPS, Bluetooth, WiFi etc as potential into one wireless terminal device so as to fulfill these needs, varied forms of promising multiband antenna designs are considered. Planar printed slot monopole antennas with varied designs became widespread candidate in multi-frequency applications for its benefits of inexpensive, low visibility, and simple fabrication, while the antenna size is comparatively spacious that isn't appropriate to be inserted in mobile wireless terminals [5].

1.1 Overview

The designed antenna is going to be a patch antenna that subsists of a conductive surface of metal mounted over a partial plate of metal referred to as the ground plane with a substrate dividing the two. So as to attain Multiple Bands, patch antennas are getting more and more widespread because of their low power, lightweight and high rate capability. A compact size is projected minimizing the price, space and energy necessities.

1.2 Problem

The ultimate goal of our FYP is to design an antenna that can excite multiple-band operation combining GPS, Bluetooth and WiFi communications standards simultaneously into a single device. It requires HFSS for simulation. The proposed antenna shows multiple bands of GPS, WiFi and Bluetooth systems.

1.3 Proposed Application

With the fast advancement of the recent wireless communications, like GPS, Bluetooth and wifi, it is sensible to merge systems of various frequency bands into single output to perform different tasks. Moreover, system compactness likes less visibility, less weight and single input (single feed) is additionally fascinating to suit the restricted equipment size of GPS, Bluetooth and wifi devices. Therefore this antenna meets all the necessities [6].

1.4Approach

Following approach followed

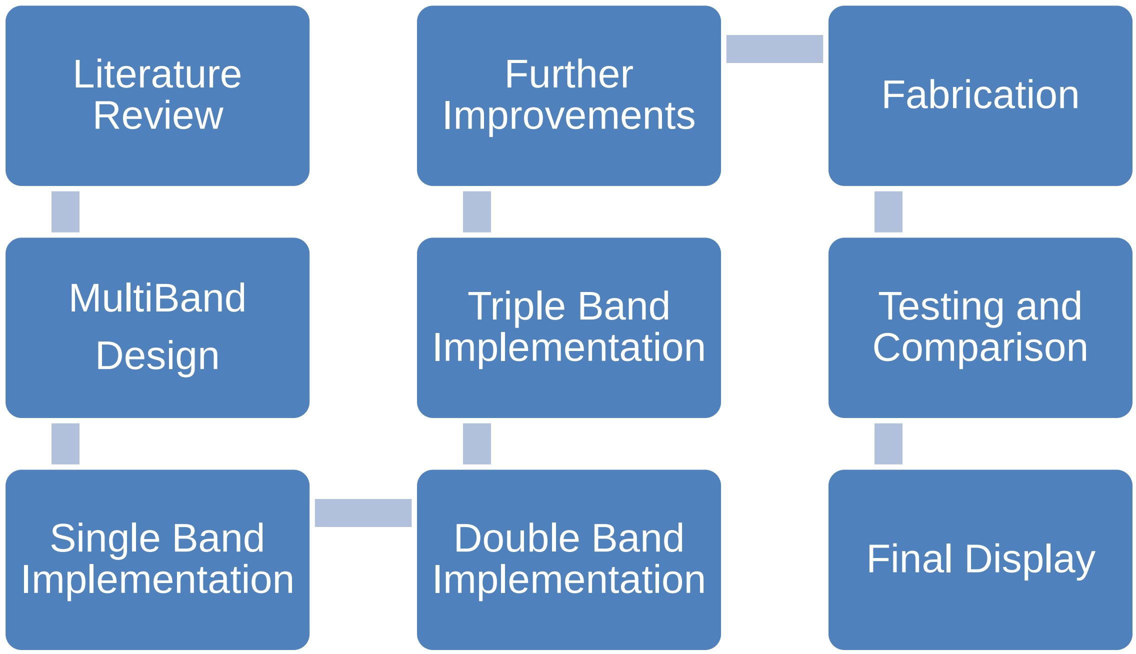


Figure 4: Flow chart of approach

1.5 Objectives

1.5.1 Academic Objectives

- Learning the working of a patch antenna
- Composing the design of a patch antenna
- Analyzing different techniques to achieve multiple bands

1.5.2 Application / End Goal Objectives

The designed antenna support wireless communication device such as GPS, Wi-Fi, Bluetooth and etc.

CHAPTER 2

LITERATURE REVIEW

Over the last few years, analysis has been done for brand new techniques and methods to frame efficient and unfailing systems for microstrip patch antennas. There are few systems that have their edges also has deficiencies, prime focus of our study was on coming techniques.

2.1 Techniques for Achieving Multiple Bands

There are number of methods and ways for achieving a system operating on multiple bands. Although some of them are most popular and commonly used. Particularly for the microstrip patch antennas different techniques will be achieved by changing the shape and dimensions of patch of the antenna [5] [7].

2.1.1 Different shapes of Patch

Patch antenna is known as microstrip patch antenna is the mostly used technique used in wireless communication devices due to its many features such as low visibility, inexpensive, easily integrate with electronic circuits of various feed types, light in weight, ease of fabrication etc. Every shape of patch and slot has its own properties which can be further improved by other various techniques. The main applications of patch antennas are of microwave frequencies because of their short wavelengths and low profile making them important in many commercial applications [8].

Whereas, slots are used in frequency range from 300 MHz to 25 GHz. They are also used as an array fed by waveguide. The slot behaves like a resonant radiator. Slots can have numerous effects on different parameters of patch antenna such as gain, radiation pattern, return loss, bandwidth and size of an antenna.

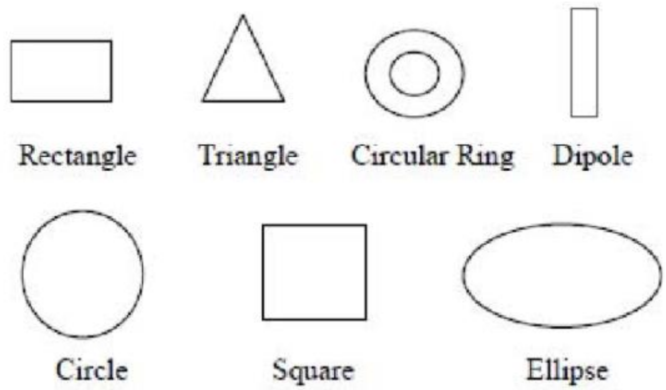


Figure 5: Different Shapes of Patch

Above these the mostly used patch shapes are as follow:

2.1.1.1 Rectangular Patch

Rectangular Patch antenna is the major type of patch antennas and which is widely used. Antenna consists of rectangular sheet of metal above the ground plane disjoined by dielectric substrate connected with the transmission line. Rectangular patches are used to work on a large range of frequencies from 1 – 40 GHz [5] [6] [9].

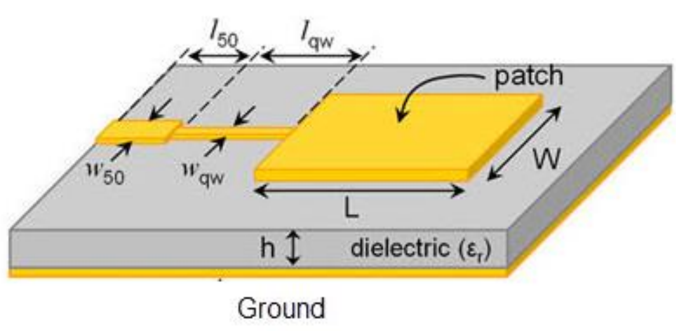


Figure 6: Rectangular Patch Antenna

2.1.1.2 Triangular Patch

By changing the shape of patch to triangle an antenna can attain a good directivity as well as bandwidth. Further results can be improved by introducing different slots to the antenna. The equilateral triangle patch antenna is designed at frequency of 5.8 GHz for the various wireless applications and other scientific and medical purposes. The reason to choose triangular patch over the rectangular is that it takes less metalized area as compared to other shapes. Rectangular patch is best for lower frequency but as t he frequency increases by more than 5 GHz triangular patch produces best results [5] [9].

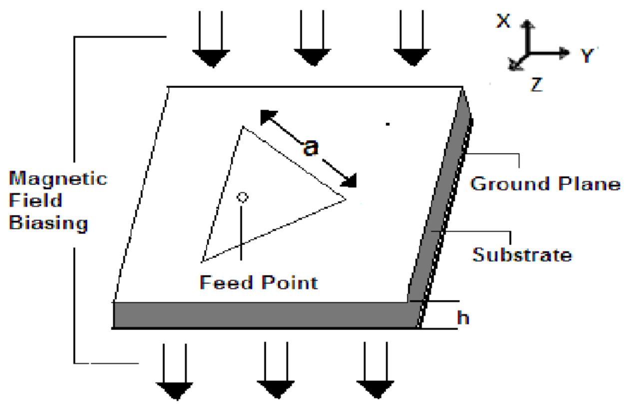


Figure 7: Triangular Patch Antenna

2.1.1.3 Circular Patch

Circular patch antennas are also mainly used in wireless commercial applications. The methods supported by circular patch are associated with patch, ground plane and circular cavity between two. In circular patch the available freedom is to control radius of the patch. The only way to analyze the circular patch is to use cavity mode. The three useful modes of circular patch are TM11, TM21 and TM31 [9] [10].

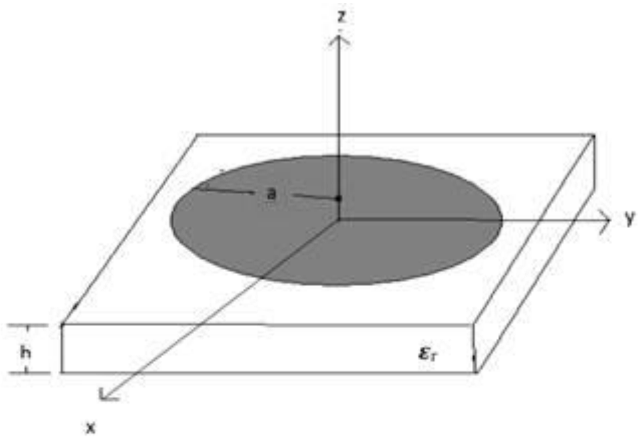


Figure 8: Circular Patch Antenna

2.1.2 Slotted Patch

Similarly by introducing different shapes of slots to the ground plane and the patch will affect different antenna's properties such as bandwidth enhancement and compactness of antenna. By cutting the slots current redistribute on the metal sheet and as a result multiband achieved.

2.1.2.1 U Shaped Slot

It is one of the mostly used slot technique. By introducing U shape slot in the patch bandwidth of an antenna can be increased to 30%. It gives the operating frequency from 5 GHz and above. It reduces size of an antenna and increased the gain simultaneously [11] [12].

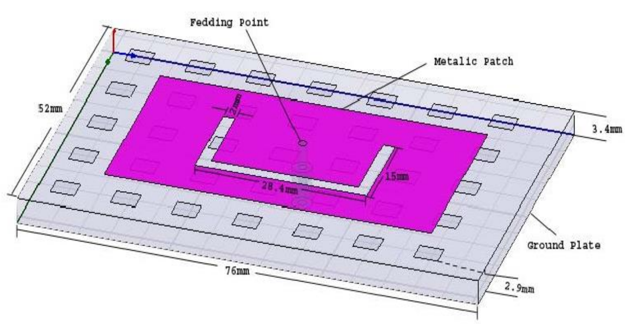


Figure 9: U Slot Patch Antenna

2.1.2.2 E Shaped Slot

E shaped slot is basically comprised of 3 parallel and 1 perpendicular slots. The main advantage of this slot is that by introducing it in patch VSWR <=2 and bandwidth and gain also increases. The most achievable result using E slot is from 8 GHz to 14 GHz. In contrast, E shaped slot have highest bandwidth then U shaped and H shaped slot [13] [14].

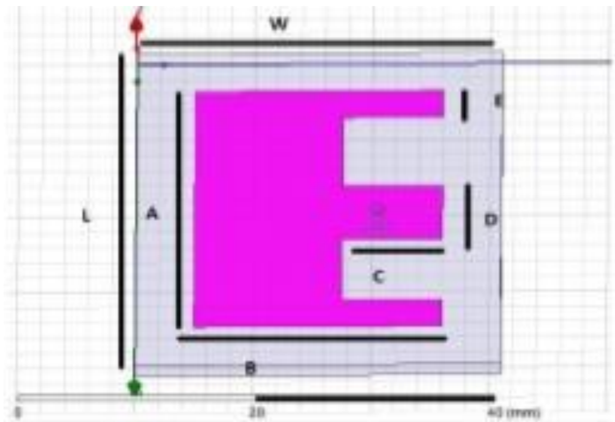


Figure 10: E Slot Patch Antenna

2.1.2.3 S Shaped Slot

The S shaped slot is also commonly used to enhance the gain and bandwidth. The dimension of slot relay upon the length, height and width of the notch. In this particularly slot the maximum efficiency that could be achieved is 92 % [13] [14].

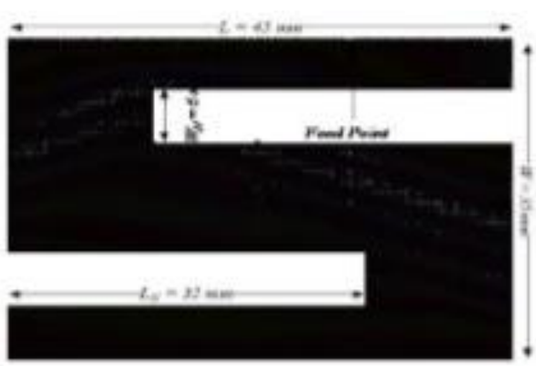


Figure 11: S Slot Patch Antenna

2.1.2.4 H Shaped Slot

The H shaped slot increases the gain but reduces VSWR. By using H slot operating frequency of Bluetooth can be achieved that is 2.4 GHz as it covers the frequency range from 1.5 GHz to 6 GHz. So by covering the frequencies of Bluetooth, WiFi and GPS it is used in most of the wireless devices. By adding a slot at the end of the rectangular aperture, field becomes nearly consistent along the aperture and as a result the coupling increases [14] [15].

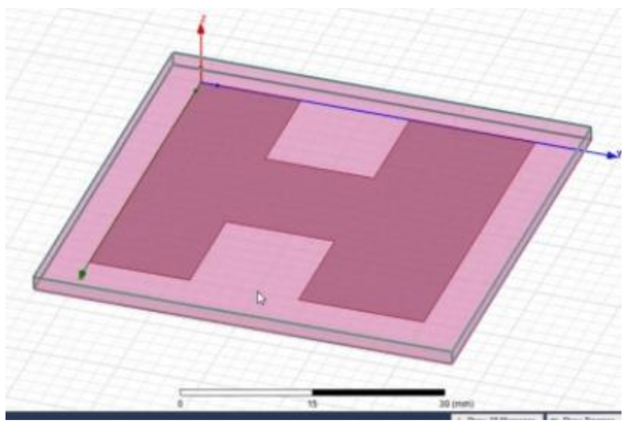


Figure 12: H Slot Patch Antenna

2.1.2 Modified Ground Plane

In the style of microstrip patch antenna, the patch and the size and shape of the ground plane should be decided carefully for desired results. Moreover because of the feeding structure it will be optimized to attain completely different bandwidths [5]. However, the antennas encompass a radiator and ground plane is basically an unstable design, electrical currents in these antennas are passed out each on the radiating element and on the ground plane, and therefore the radiation from the ground plane is ineluctable. Therefore, the working performance of the printed patch antenna is significantly suffering from the dimensions of the ground plane in terms of operating different information measures like bandwidth, gain and radiation patterns. Moreover, because of lateral size or uneven shape of the radiator, the planar monopole antennas undergo high cross-polarization level within the radiation patterns [16] [17].

As the printed antenna performance is documented to be relayed about the ground plane, this side has been actively researched. Radiation from the ground plane is imminent because the electrical currents are divided on each of the radiator and on the ground plane. By limiting a notch from the radiator, it might be potential to scale back the ground plane impact on the functioning of a small written patch antenna [18].

Modified ground Plane has two categories; Partial Ground Plane within which overall measurement of ground plane is changed another kind is Slotted Ground Plane in which addition of slots to the ground plane is there and may be anywhere within the plane which sometimes helps in minimization of cross polarization.

Modified ground plane has many advantages. It enhances input electric resistance characteristics. High cross polarization in between ground plane and feed line will be minimized by changing ground plane, sometimes by introducing slots in ground plane [19] [20].

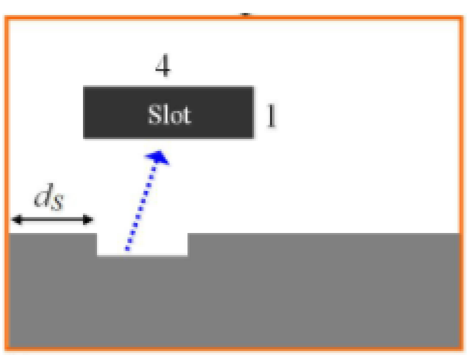


Figure 13: Slotted Ground

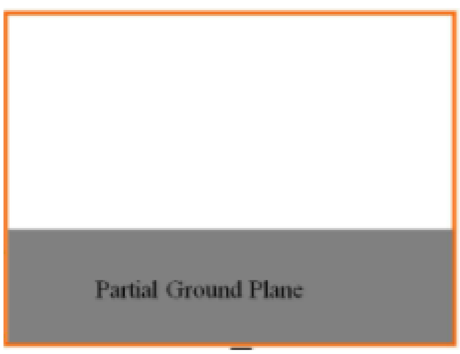


Figure 14: Partial Ground

2.2 Summary

After reviewing the existing literature we have selected the following parameters to be used for our project because of the mentioned advantages.

Parameter	General Trend	Advantages
Material	**FR4 Epoxy**	**Low cost**
Substrate Thickness	**~1.0 mm**	**Compact**
Feed	**Microstrip**	**Ease of Fabrication/ Design**
Ground	**Partial**	**Enhanced Bandwidth**

Figure 15: General Trends for Proposed Antenna

2.2.1 Material

The material used as a substrate is FR4 epoxy because it is easily available and is of low cost.

2.2.2 Substrate Thickness

Keeping the compactness of the antenna in mind, thickness of the substrate is approximately 1.0 mm.

2.2.3 Feed

Microstrip feed is used because it provides ease in the process of fabrication.

2.2.4 Ground

As far as ground technique is concerned partial ground is used as it results in enhanced bandwidth.

CHAPTER 3

ANTENNA DEVELOPMENT AND DESIGN

3.1 Software

The initial design and simulation of antenna is done on efficient software. The designed antenna is tested on software that then offers the simulated results. The accessible software for work testing and simulation is HFSS and CST studio. For fewer complicated antennas each has similar characteristics and the main distinction emanates within the more skillfulness over software system.

3.1.1 High Frequency Structural Simulator (HFSS) 13.0

HFSS 13.0 is the recent version of the high frequency simulation software system by Ansys. It is an advert electromagnetic structural simulator and problem solver. HFSS could be a great tool for designing of antenna, filters and etc. It is user friendly platform for creating and test the working of different types of antennas. Antenna of any shape and design will simply be simulated because the design used in our project are short and brief and not so complex therefore there would not be a lot of working load on the software interface [21] [22].

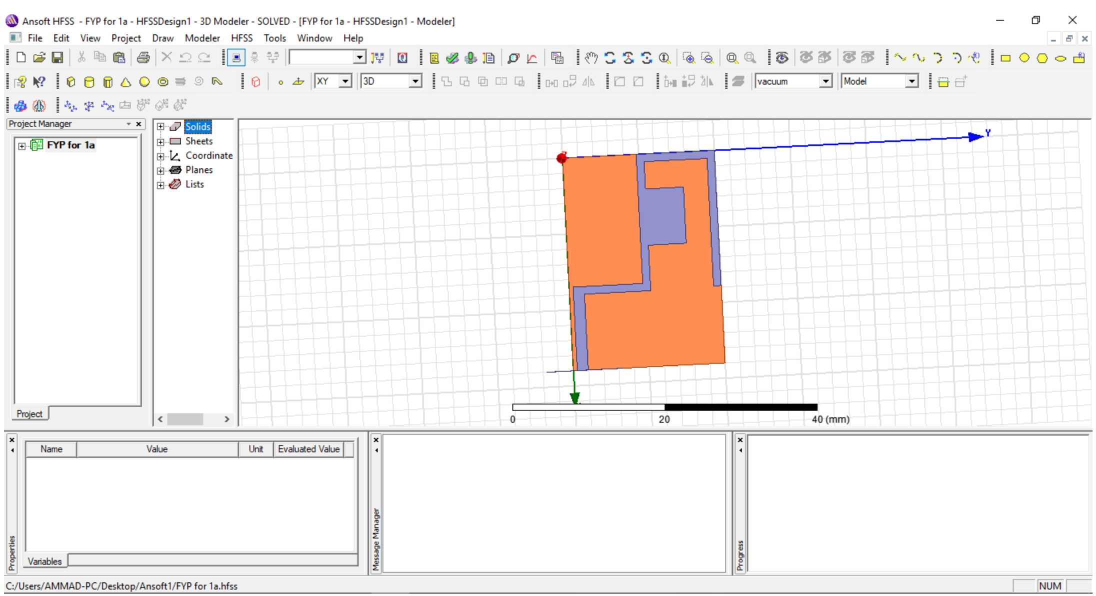


Figure 16: HFSS Interface 13.0

3.1.2 Fabrication

The framed antenna will be finished in laboratory on PCB and the decided substrate is FR4 epoxy. High precision fabricator used to induce accurate outcomes as even a small mistake will have an effect on the result radically.

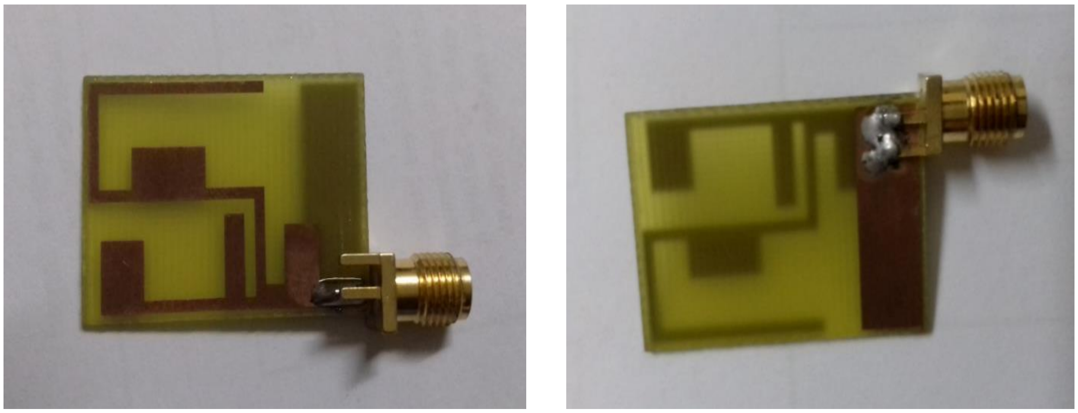


Figure 17: Patch Antenna after Fabrication

3.1.3 Results Measurements

The outcomes epitomize the measure of antenna particularly so to ensure to meet the reproduced and pointed outcomes. Normal parameters that portray are gain, return loss, radiation pattern etc. These parameters are estimated when the fabrication is completed of the planned antenna to make sure that the antenna results are similar those which are tested. Any mistake amid this stage reflects the design defect and compels the planner to return on back to the past stage.

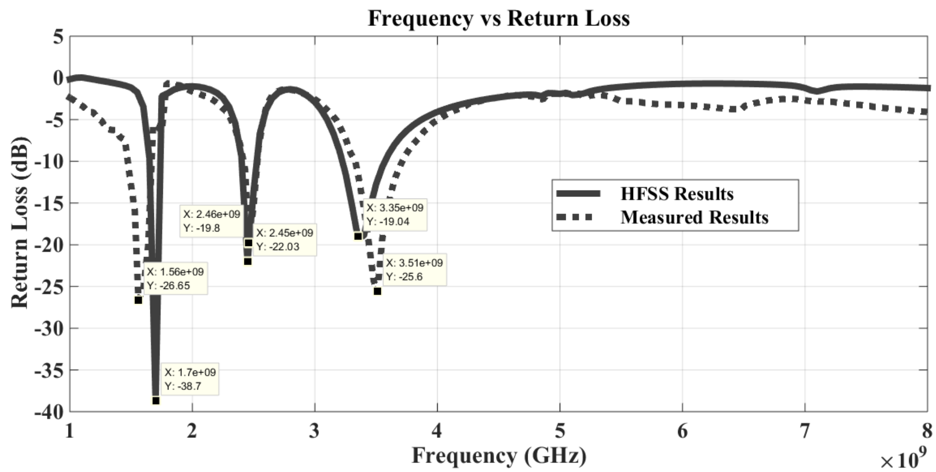


Figure 18: Comparison between Simulated and measured results of a patch antenna

3.2 HFSS Design

The considered strategies within the literature review were thoroughly inspected to carry out the antenna to its final stage. The ways and methods described within the literature review section were so confined for implementation and experimentation. Techniques with the less difficult outcomes can take into account for the best possible results.

3.2.1 Design of Microstrip Patch Antenna

Different techniques used to implement the multiple band microstrip patch antenna were separately enforced and there results were recorded. Designs with undesired outcomes were neglected.

Currently we are dealing and working on two designs and therefore the design with the most effective results are going to be carried forward.

3.2.1.1 Antenna operating on single band: Rectangular patch with partial ground

This is the design of rectangular patch which is getting feed by a microstrip feed line and the partial ground plane. The substrate used is FR4 epoxy

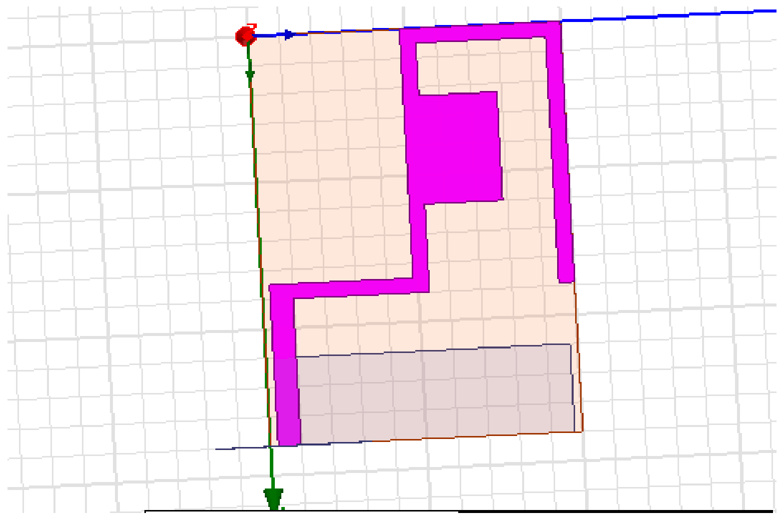


Figure 19: HFSS Design 1

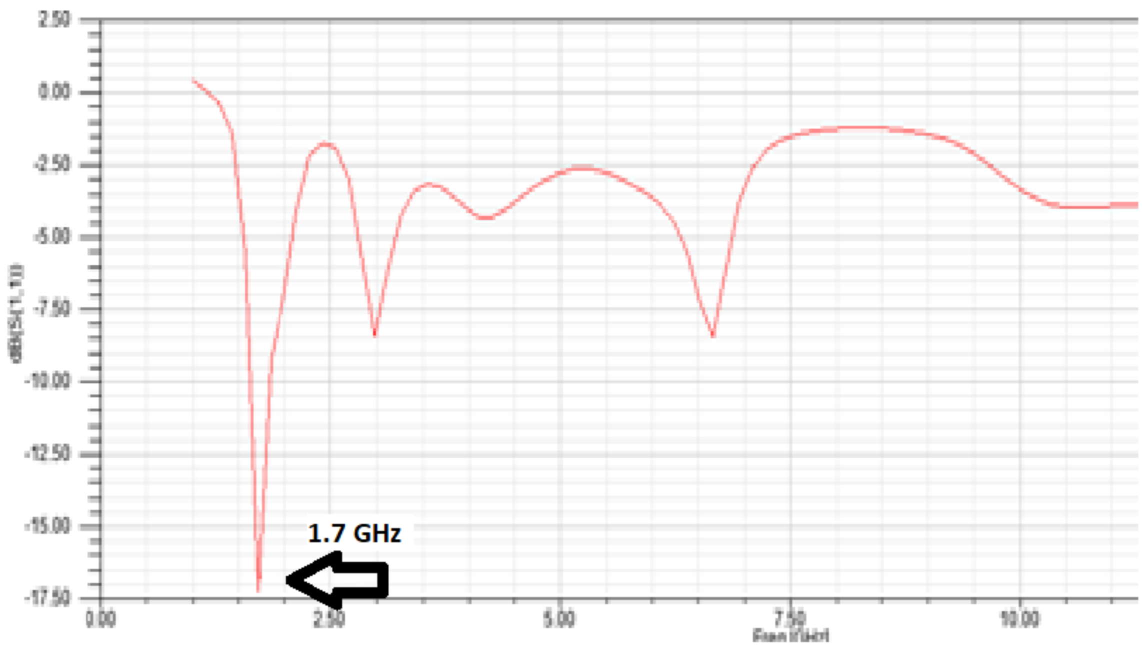


Figure 20: Return loss plot of design 1

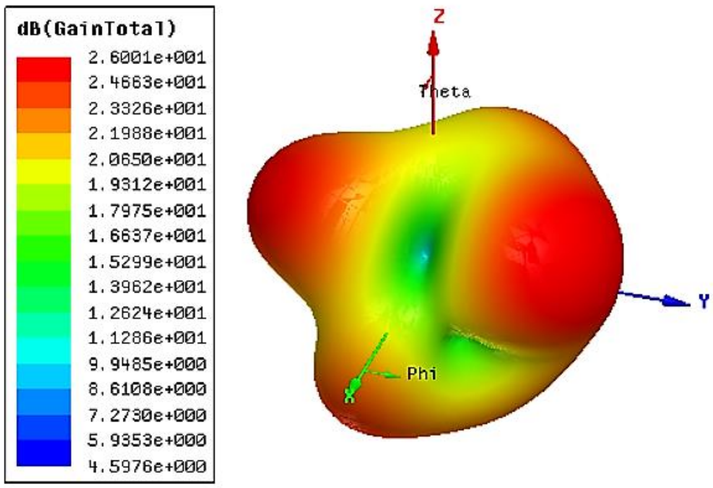


Figure 21: 3D polar plot of design 1

The 3D polar plot shows that the designed antenna has positive gain.

3.2.1.2 Antenna operating on dual band: Improved rectangular patch and partial ground

In this previous design has improved by introducing small patch and patch is getting feed by a microstrip feed line and the partial ground plane. The substrate used is FR4 epoxy.

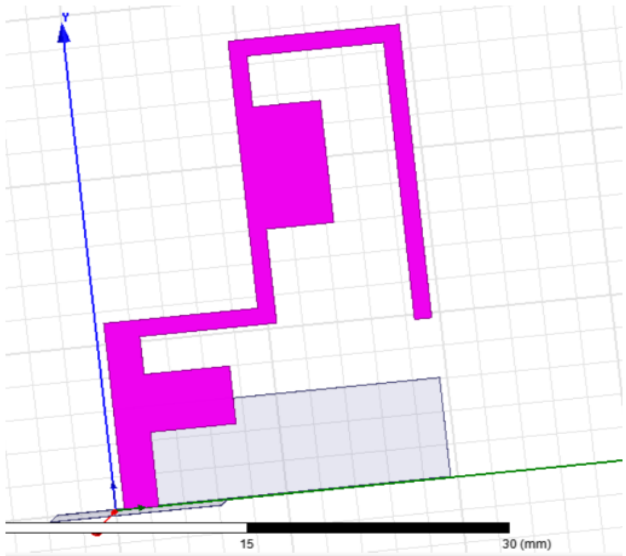


Figure 22: HFSS design 2

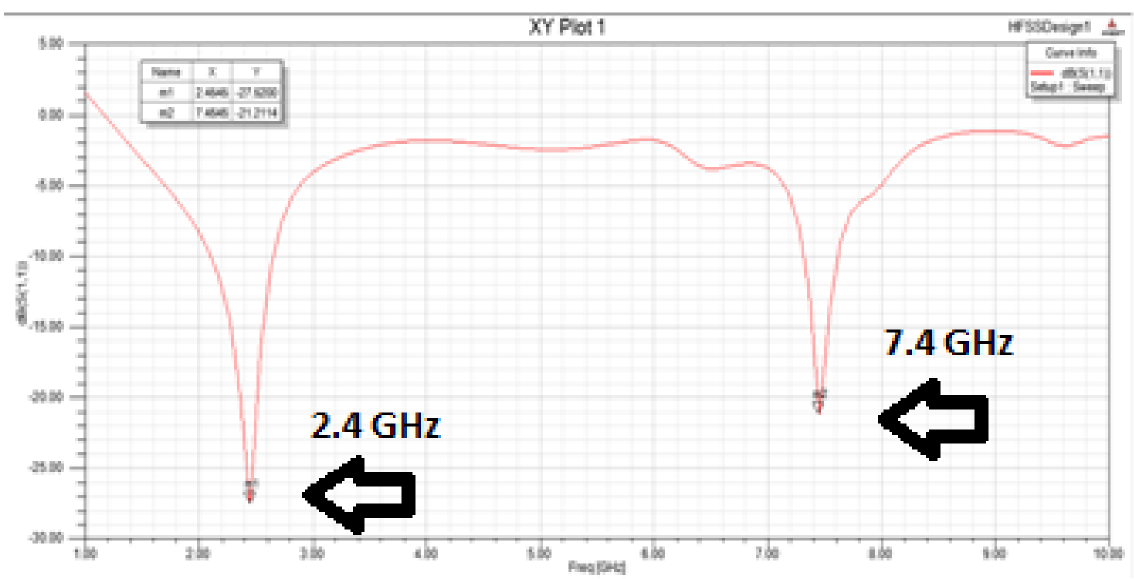


Figure 23: Return loss plot of design 2

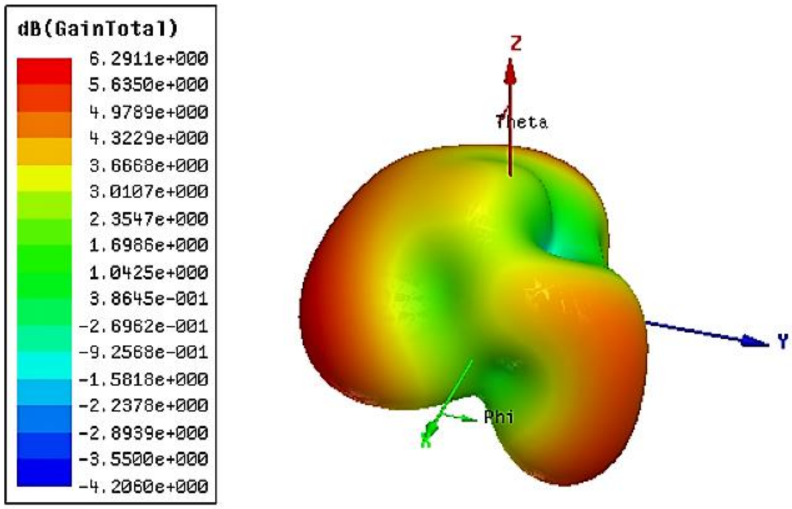


Figure 24: 3D polar plot of design 2

3.2.1.3 Antenna operating on triple band: Improved Rectangular patch with partial ground

In this we have improved design which we demonstrated previously by changing and altering the different dimensions of the antenna in order to achieve desired results.

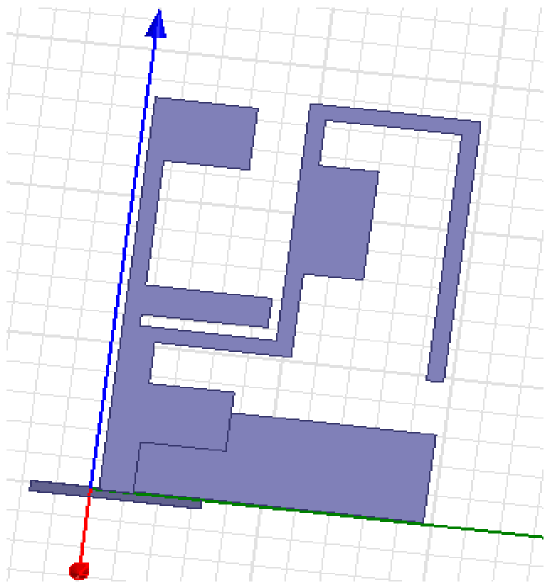


Figure 25: HFSS Design 3

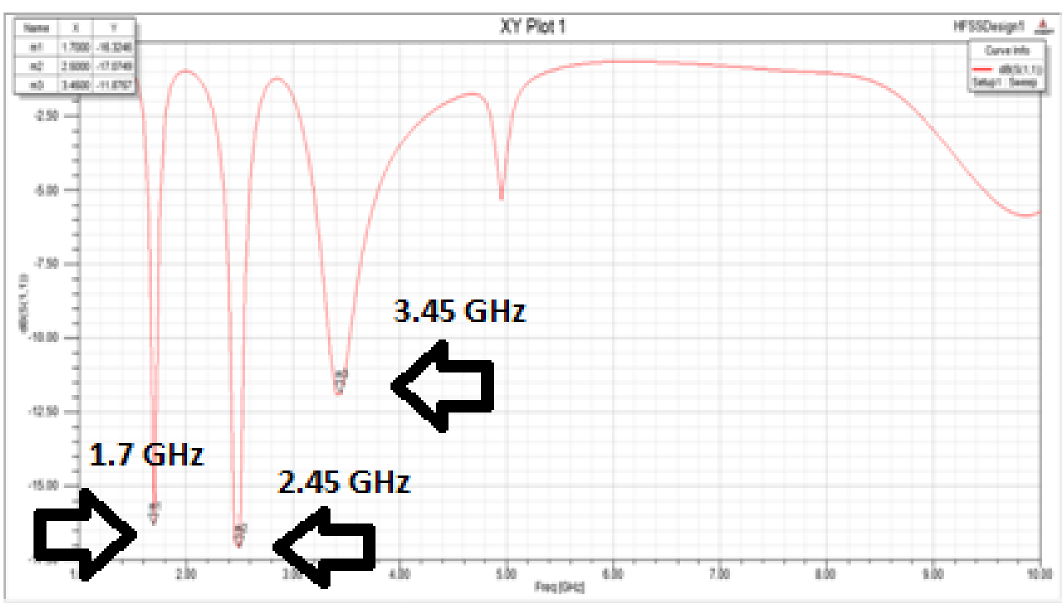


Figure 26: Return loss plot of design 3

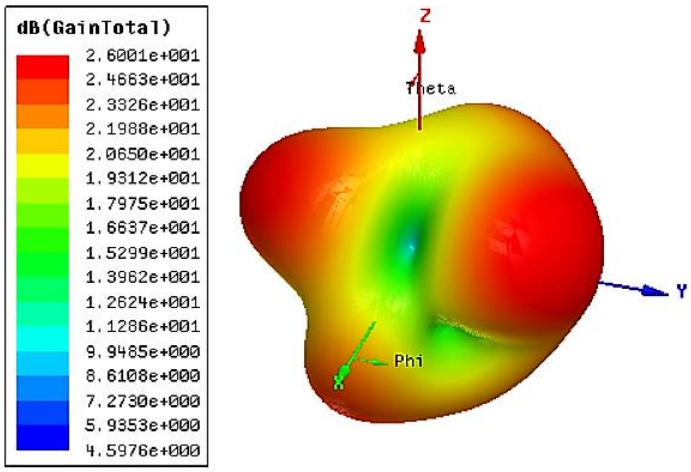


Figure 27(a): 3D polar plot of design 3

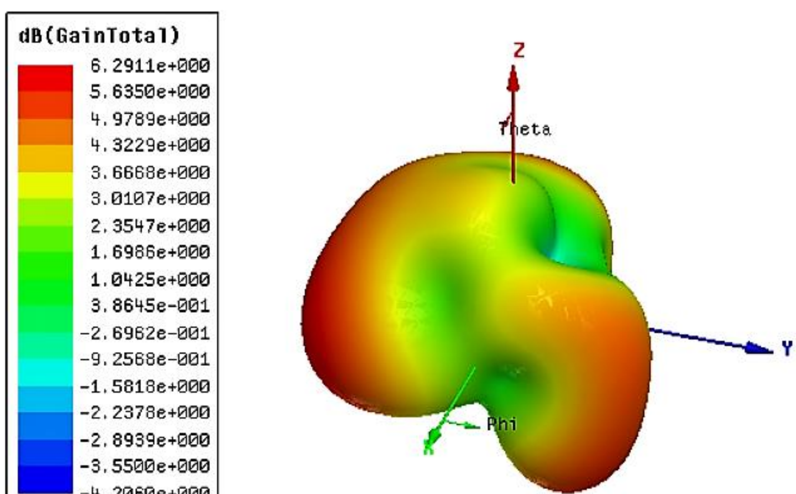


Figure 27(b): 3D polar plot of design 3

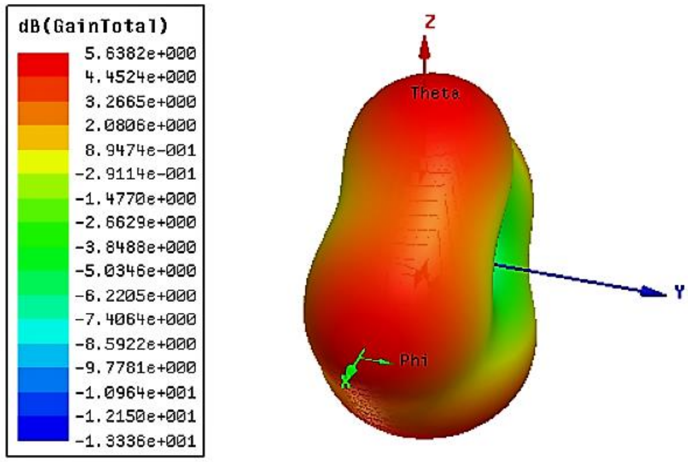


Figure 27(c): 3D polar plot of design 3

3.3 Calculations

3.3.1 Calculation of designed antenna

Following are the dimensions of designed antenna.

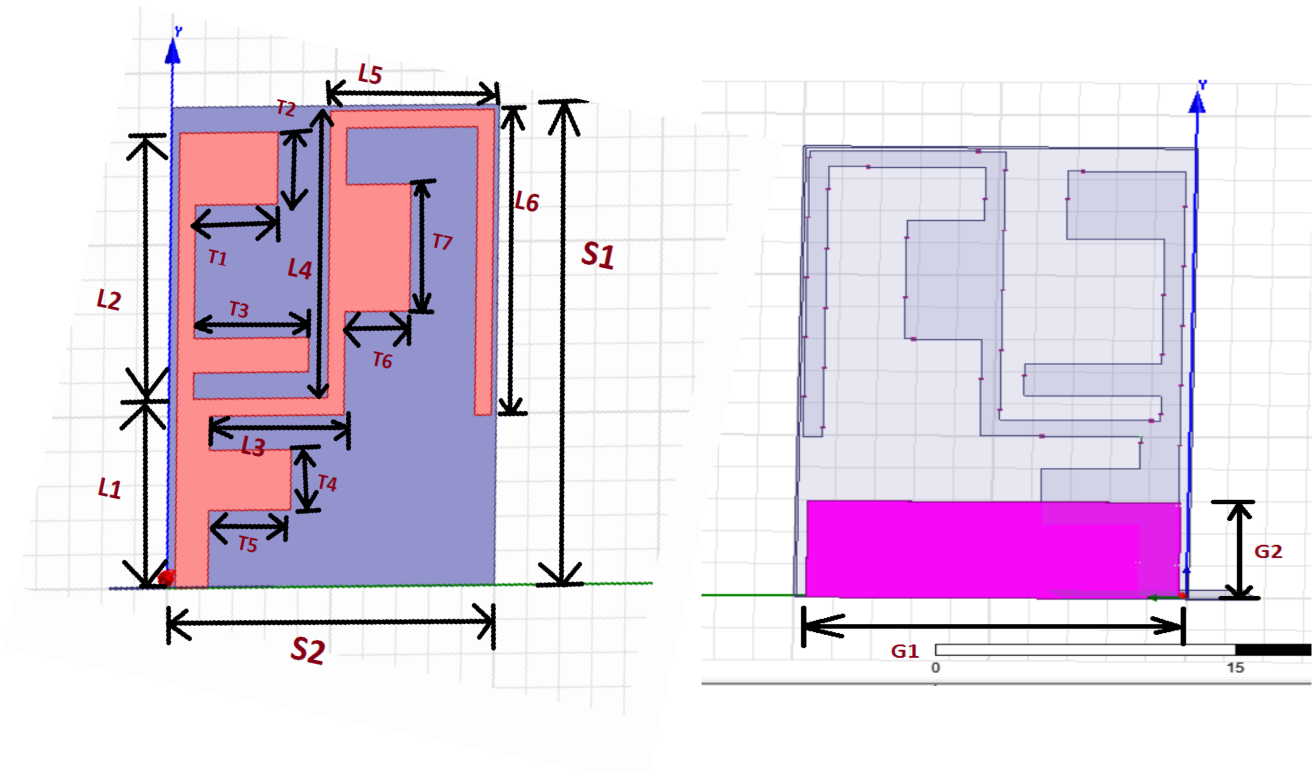


Figure 28: Labeling the Dimensions

Length Measurement of Antenna	Width Measurement of Antenna
S1 = 28 mm	**S2 =** 21 mm
L6 = 17.8 mm	**G1 =** 19 mm
L4 = 16.4 mm	**L5 =** 9 mm
L2 = 15.5 mm	**L3 =** 8.2 mm
L1 = 11 mm	**T3 =** 7 mm
T7 = 7.4 mm	**T1 =** 5 mm
G2 = 6 mm	**T6 =** 3.95 mm
T4 = 5 mm	**T5 =** 3.5 mm
T2 = 4.2 mm	

CHAPTER 4

ANTENNA FABRICATION AND RESULTS

4.1 Antenna Measurement and Results

4.1.1 S11 Plot

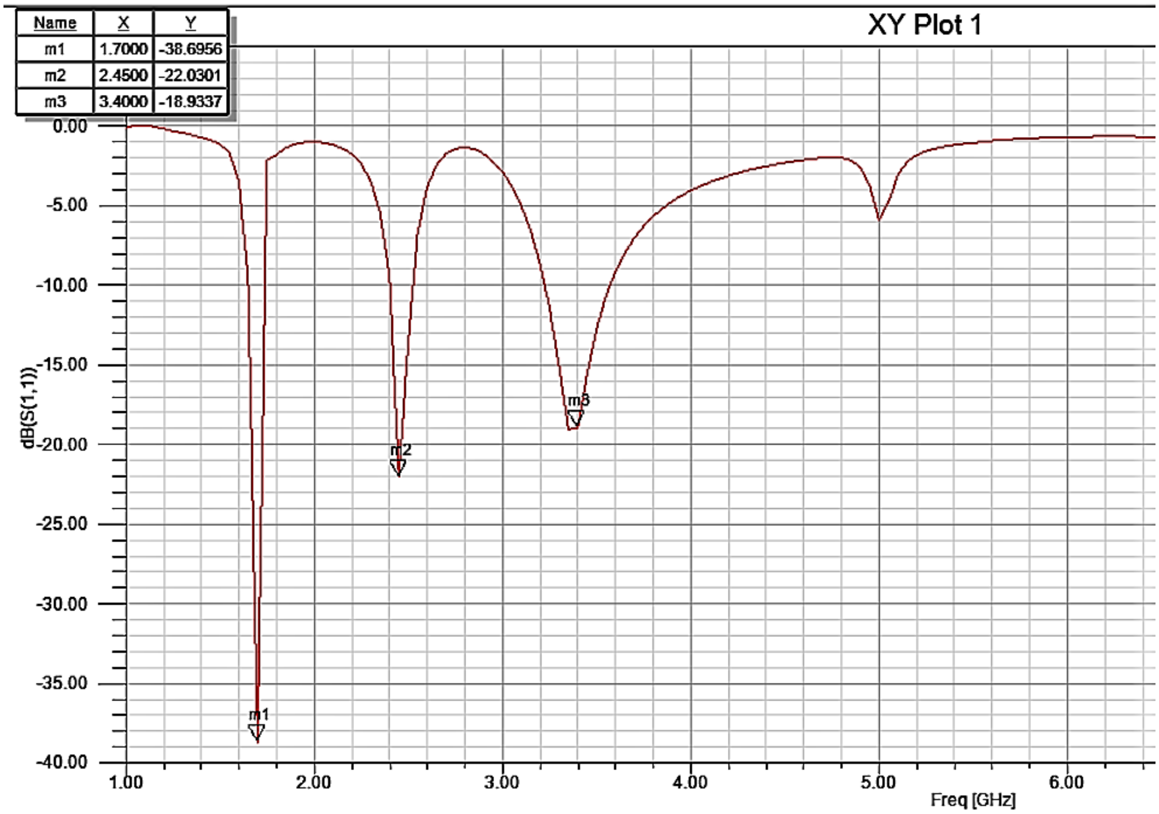


Figure 29: S11 Plot

Here S11 plot show three different frequencies having the return loss more than -10 dB that means they all are operating frequency of antenna. The longest dip is of 1.7 GHz frequency with a return loss of approximately of -38 dB. Followed by second dip is of 2.45 GHz frequency with a return loss of approximately of -22 dB and last dip is of 3.4 GHz frequency having a return loss of approximately -19 dB.

4.1.2 Radiation Patterns

Radiation Pattern indicates that where antenna is transmitting and receiving the power. Each frequency has its own radiation pattern in terms of Gain dB Plot.

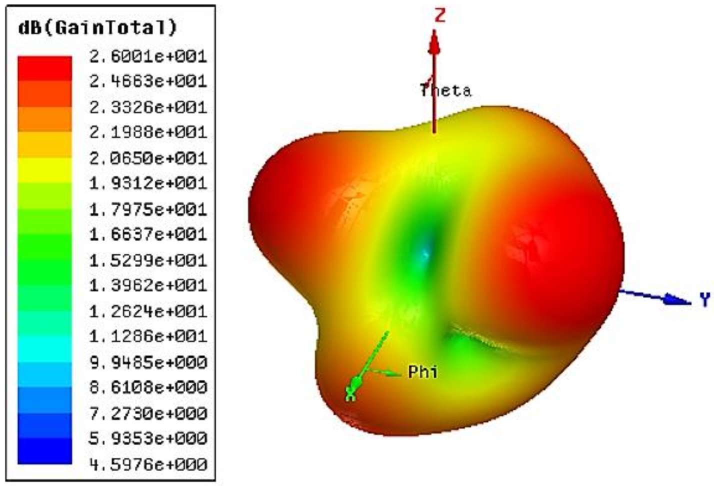


Figure 30: 3D Gain Plot of 1.7 GHz

It has a good and considerable radiation pattern as compared to others as it radiates equally in all axis.

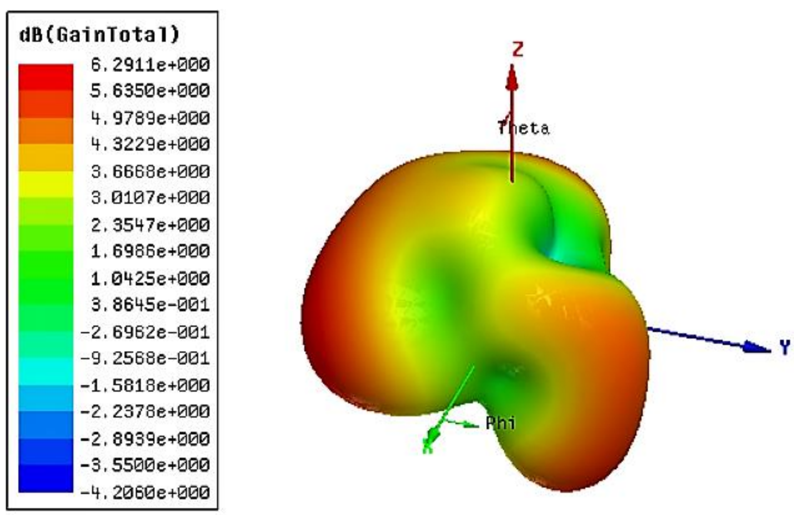


Figure 31: 3D Gain Plot of 2.45 GHz

This band gives the gain of approx. 6 dB on the edges. It more radiates in XZ plane.

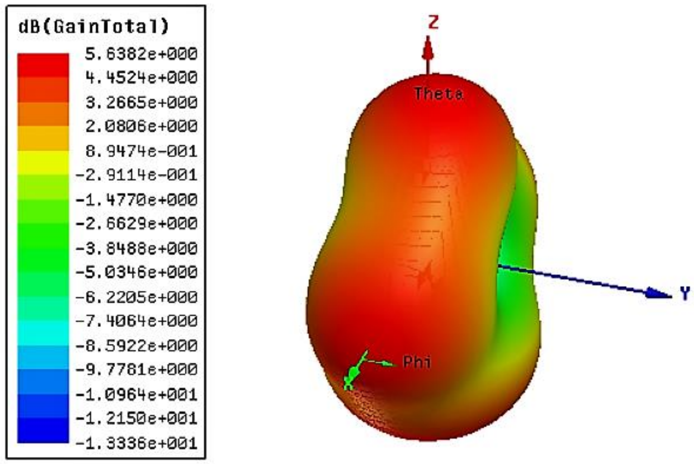


Figure32: 3D Gain Plot of 3.45 GHz

It has a maximum gain of approx. of 5.5 dB. It has a more gain in XZ plane.

4.1.3 Bandwidth

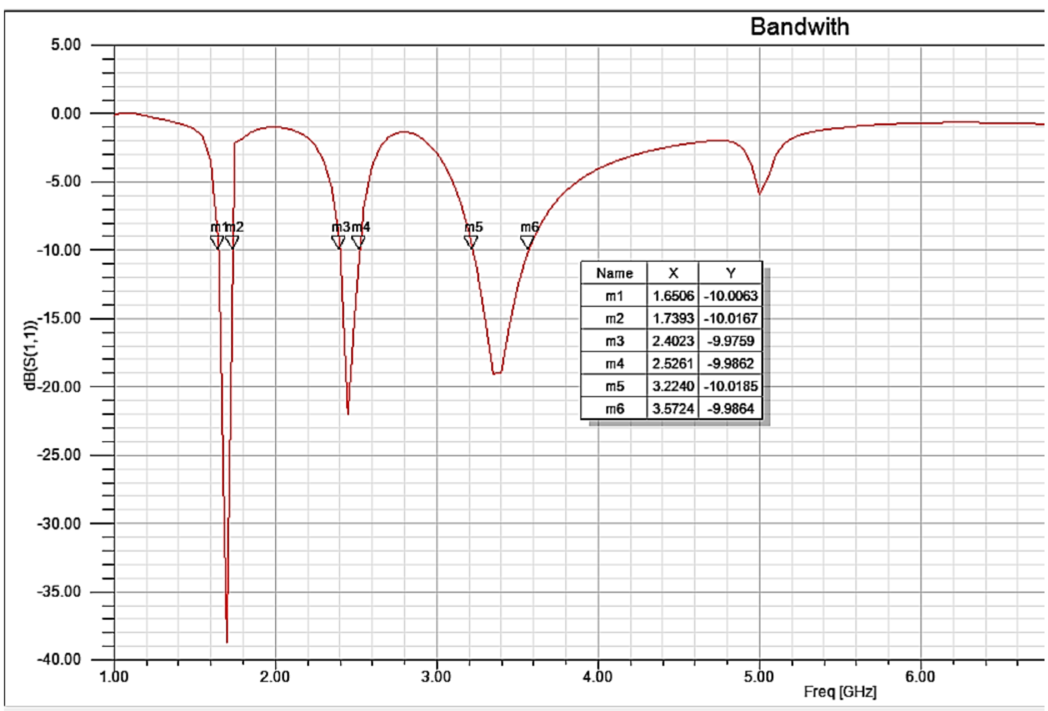


Figure 33: Bandwidth Plot

Following are the bandwidths of respective bands

Frequency Band	Bandwidth
1.58 GHz	88.7 MHz
2.45 GHz	12.38 MHz
3.45 GHz	34.84 MHz

4.1.4 Surface Current Plot

The plot shows that at which part of antenna is responsible to generate that particular frequency we will see the plot for all three bands below;

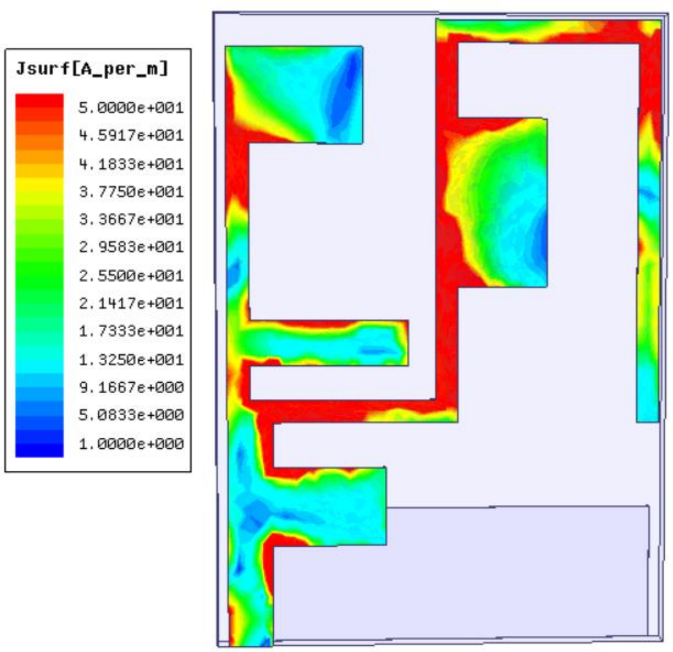


Figure 34: Surface Current Plot of 1.7GHz

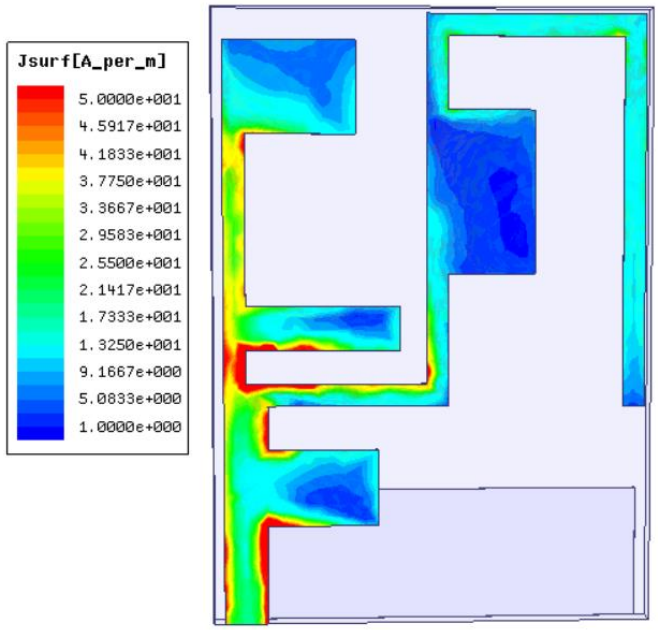


Figure 35: Surface Current Plot of 2.45 GHz

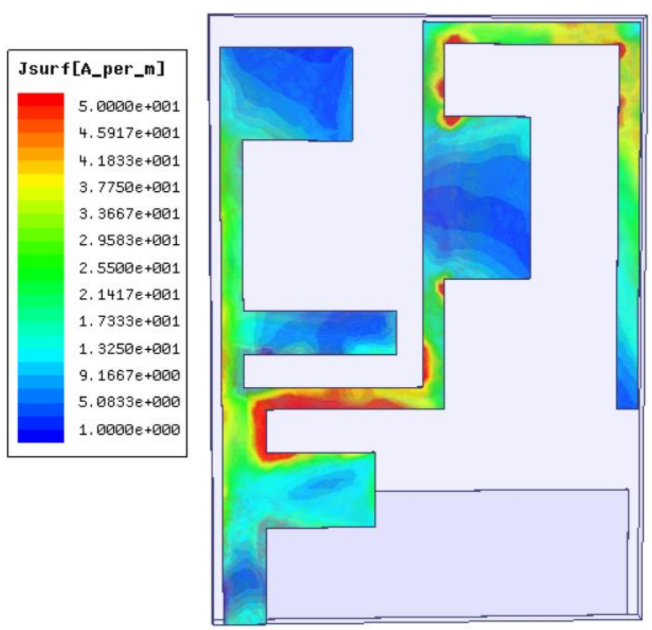


Figure 36: Surface Current Plot of 3.45 GHz

4.1.5 2D Radiation Pattern

2D Radiation pattern shows the power radiated by an antenna as a function of direction away from the antenna.

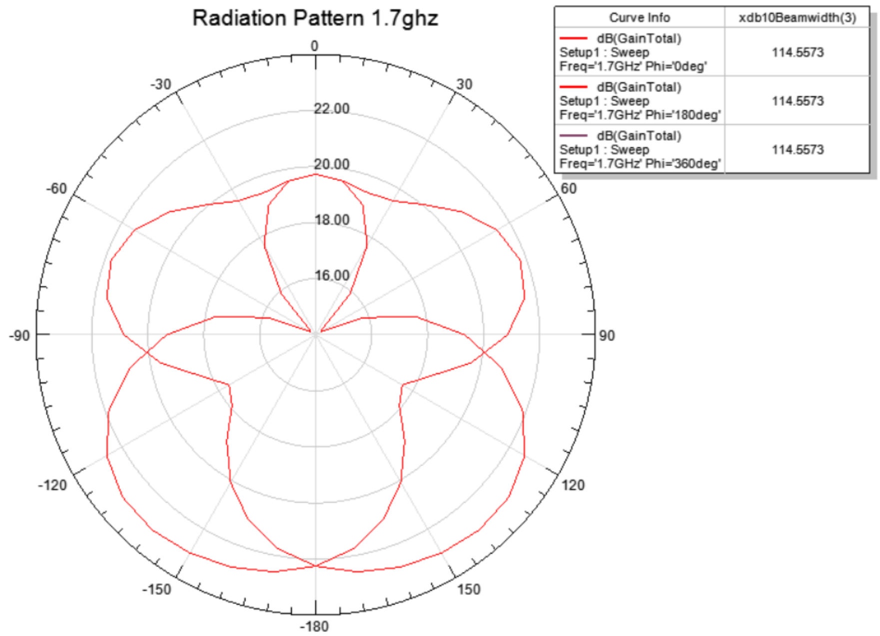


Figure 37: Radiation Pattern of 1.7 GHz

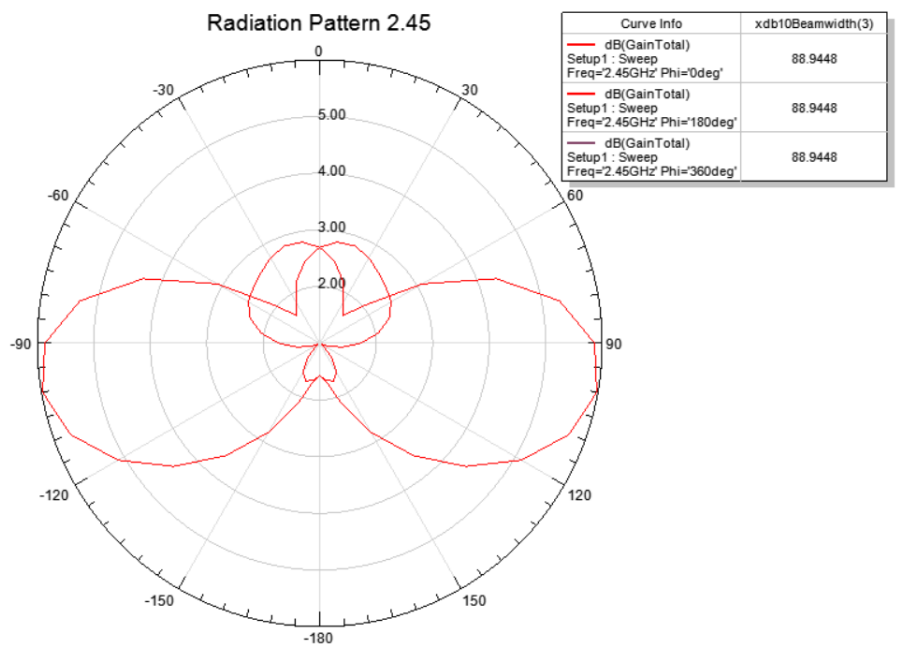


Figure 38: Radiation Pattern of 2.45 GHz

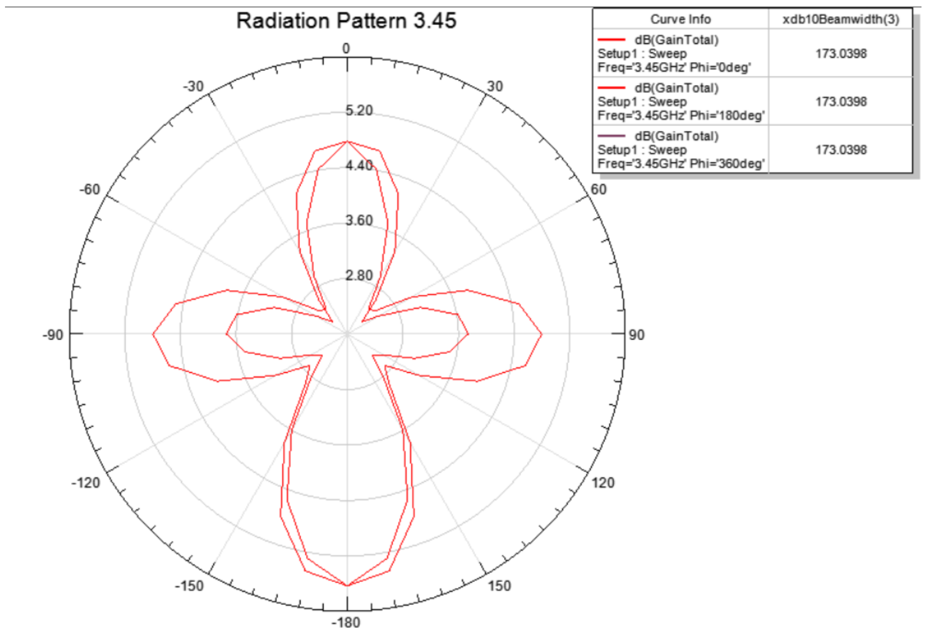


Figure 39: Radiation Pattern of 3.45 GHz

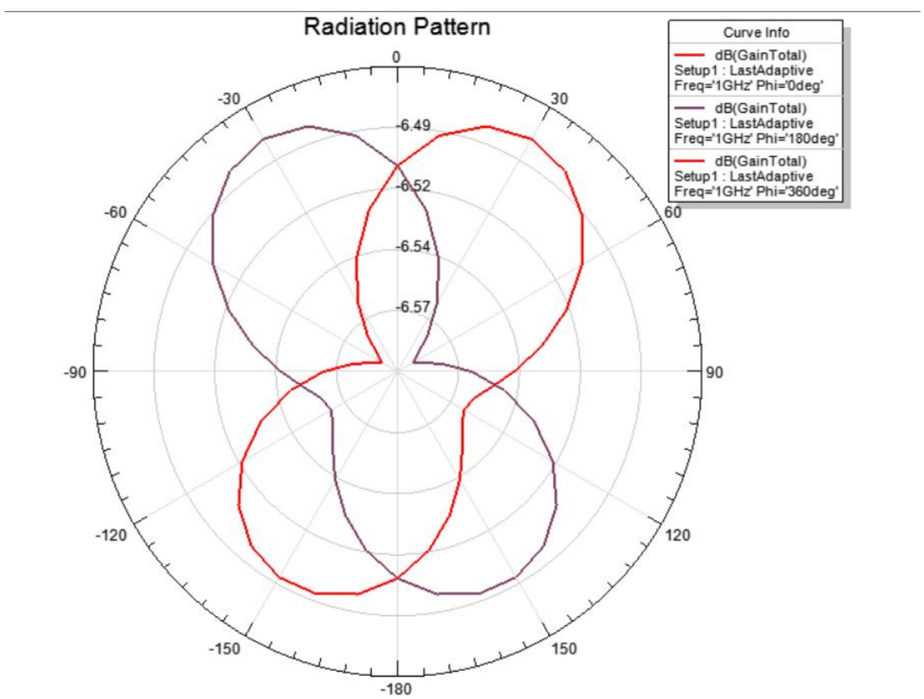


Figure 40: Radiation Pattern

4.2 Antenna Fabrication

Designed antenna is fabricated from National Institute of Electronics (NIE).

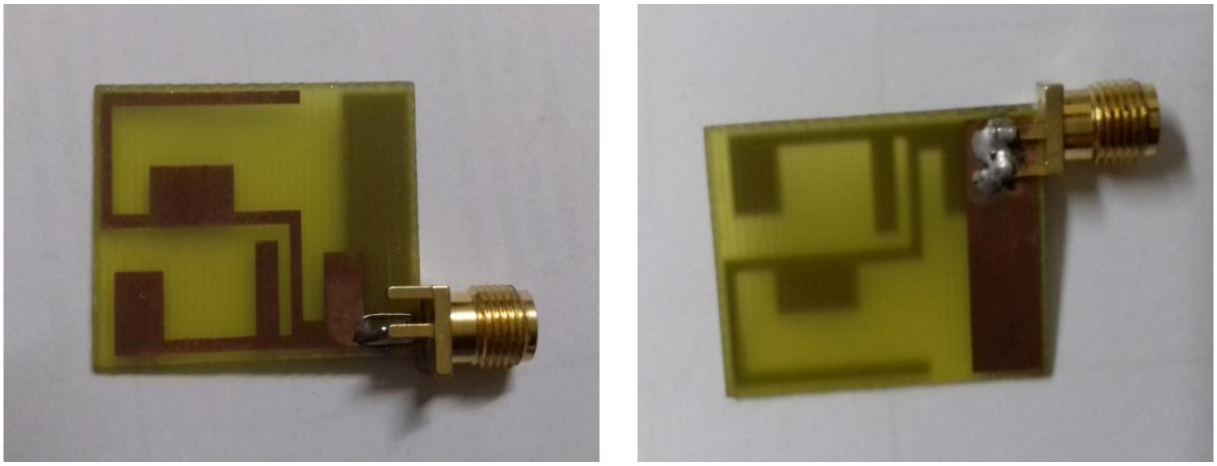


Figure 41: Front and Back view of Fabricated Antenna

As far as measurements and results are concerned we get our antenna results from NIE and the achieving results are same as of stimulated design.

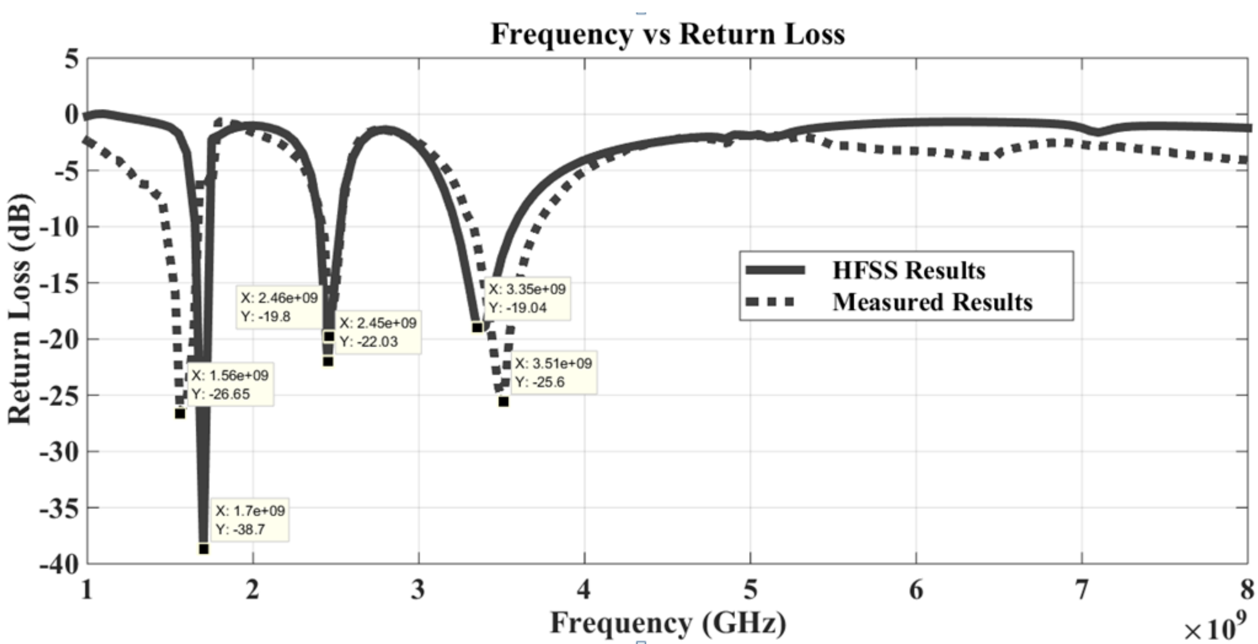


Figure 42: Comparison between actual and simulated results

4.3 Application

Keeping in view the operating frequencies of antenna that are 1.58, 2.45 and 3.45GHz.

Following are the applications of designed antenna respectively,

- GPS Devices
- Bluetooth Devices
- WiFi Devices
- WiMAX Devices

4.4 Hardware Implementation

We integrated our designed antenna with WiFi router mainly,

Firstly we took a router with its own antenna;

Figure 43: Router with its own Antenna

Then we replace the router's antenna with our designed antenna;

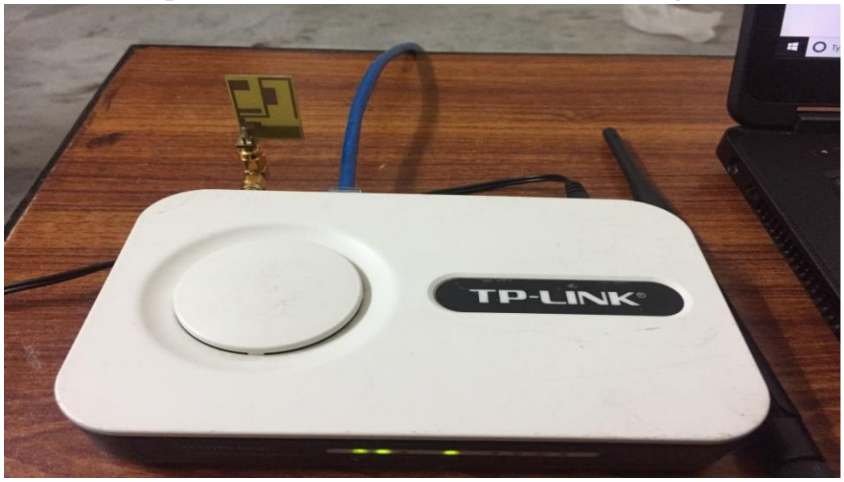


Figure 44: Router with Designed Antenna

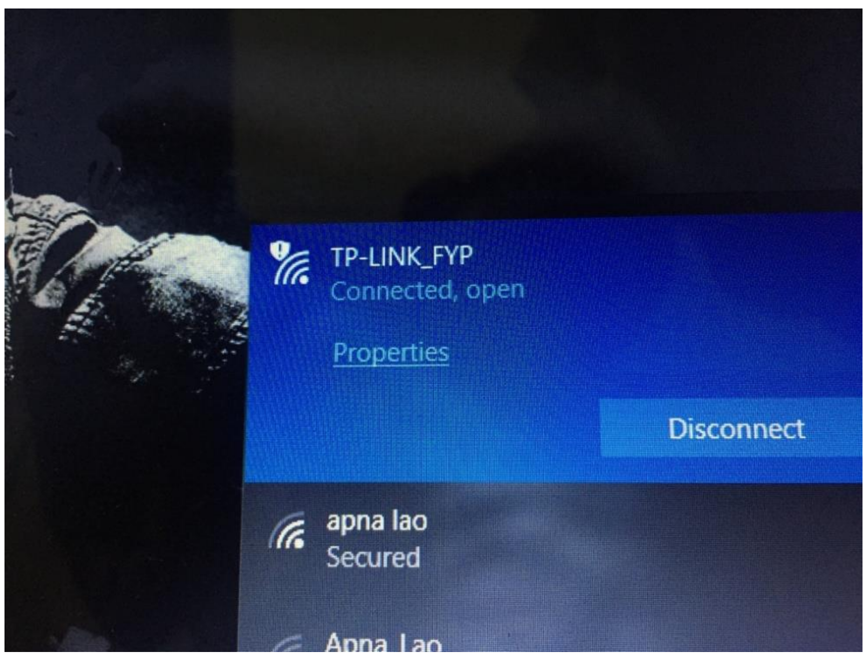


Figure 45: Connectivity showed using Designed Antenna

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

The designed and fabricated antenna can operate on three different commercial frequency bands that are of GPS, Wi-Fi and Bluetooth. The main aim of the antenna is to integrate with a device which requires multiple tasks related to these frequencies so that only one compact antenna will be used making the device itself portable and compact.

5.2 Future Work

- We can more enhance the compactness of antenna by making the changes in dimensions.
- More bands can be achieved by introducing different slots.
- Antenna can be made reconfigurable so that antenna can be dynamically changing its radiation properties.

CHAPTER 6

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APPENDIX- A

A COMPACT MULTIBAND MICROSTRIP PATCH ANTENNA

Extended Title: A Compact Multiband Microstrip Patch Antenna for Wireless Communication
Brief Description of The Project / Thesis with Salient Specifications: Microstrip patch antennas possess a number of unique and interesting properties which make them very attractive for many commercial applications. Some of the key properties of microstrip patch antennas are low profile, light weight, compactness, easy to fabricate and to integrate with many modern day mobile devices. We will be designing a microstrip patch antenna operating at multiple bands.
Scope of Work: The work done will be able to cater the demand of ever growing wireless communications industry. The designed multiband antenna can be used in devices operating on multiple bands for communication. The proposed antenna will be compact in size and will be able to target applications like Bluetooth, WiFi, and GPS etc. Also the compactness of antenna will allow it to fit in majority of the existing devices.
Academic Objectives : • Transmission lines and Waveguides • Wave Propagation and Antennas
Application / End Goal Objectives : The main goal of this application is to work with multiple communication devices so that a single antenna can be used instead of different antennas to provide necessary communication. The compact size will allow space conservation that will allow the antenna to fit into modern day gadgets that are relatively smaller in size.

Previous Work Done on The Subject : We have used HFSS for implementing of different shapes like horn, monopole, dipole antenna, circular and Rectangular Waveguides etc
Material Resources Required: • High Frequency Structure Simulator Version 13 • Patch Antenna Fabrication Tools • Patch Antennas Results Measurement Equipment
No of Students Required : Four **Group Members:** • GC Ammad • GC Ahmad Raza • GC Zain • GC Manzoor
Special Skills Required: ➢ High Command on HFSS ➢ Have a strong grip on the topics relating antenna ➢ Antenna fabrication