A Compact Slotted Microstrip Multiband Patch Antenna

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

June 2017

ABSTRACT

Our project "Compact Slotted Microstrip Multiband Patch Antenna "aims to incorporate design of a multiband antenna with slotted monopole patch for wireless communication. The designed antenna makes use of open complementary split-ring resonators (OCSRRs) to obtain multiple bands covering **Wi-Max (3.3-3.8GHz)**, **Wi-Fi (4.9-5.9GHz)** and **PAN (2.4-2.48GHz)** however the PIN diodes can be used depending upon their ON and OFF state, acting as a series or parallel RLC circuit to provide reconfigurability. The OCSRRs act as high impedance elements at their resonant frequencies when modeled as parallel circuit. Multiple operative sections can be attained in the monopole patch of the antenna by placing the OCSRRs at calculated distance. The principal operating frequency of the fabricated antenna is proportional to the length of the patch while the additional resonance frequencies are determined by their distance from OCSRRs. Use of coplanar waveguide structure optimized the design by making it easy to fabricate and compact which made it facile to integrate with other devices to meet the modern day communication requirements. All frequency bands exhibit similar radiation characteristics. The final results obtained are consistent with the simulated data and a good return loss with positive gain of the antenna is observed. The antenna can be made reconfigurable by using PIN diode in OFF or ON state to convert operation of antenna from triple band to dual band.

CERTIFICATE

It is herewith certified that the constituents of this thesis entitled “Compact Slotted Microstrip Multiband Patch Antenna” articulated by Rabiya Farooq, Hira Afzal, Abdullah Zafar and Hashir Rashid under the skilled assistance and surveillance of Lec Maryam Rasool have been dedicated sincere sense of effort and therefore found adequately falling under the requirement of the B.E Degree in Electrical (Telecom) Engineering.

Supervisor:

Lec Maryam Rasool

MCS, NUST

____

Dated:

DECLARATION

It is pertinently declared that the contents presented in this treatise carries resemblance to none nor it is being submitted in support of any other award or qualification in the institution itself as well as anywhere outside.

DEDICATED TO

Allah Almighty, All Benevolent and Merciful

Faculty for their constant guidance

And our parents for their boundless encouragement

ACKNOWLEDGEMENT

With the sincere endeavor we would consider it obligatory to pay our heartiest gratitude towards our mentor Lec Maryam Rasool who wisely dedicated her skilled efforts and willingly put her blessed hand in helping us bringing all the tasks to their final representation.

Moreover the fulfillment of this work is credited to the help from other institutions, our friends and family who voluntarily ventured into the process of its completion and eventually giving it a sequential shape.

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Chapter 1

PROJECT INTRODUCTION

1 PROJECT INTRODUCTION

1.1 Background Study

Communication has always been a paramount need of human beings. When there was no mode of proper communication, people used to communicate through fire, smoke, light signals and other means. With the rapid development in technology different communication mechanisms came into existence, antenna being one of them. The history of antennas dates back to 1800s, when German Physicist Heinrich Hertz used them in his experiment for finding electromagnetic waves. Afterwards they were started being used for communication purposes and ever since their structures are modified accordingly for improved communication. Antennas designed at a particular frequency were not capable of operating on multiple frequencies but with development in the field of communication there was a need to design antennas that operate on multiple frequencies. As a solution multiband antenna came into existence which was established using different techniques to cover various bands. The advancement in technology demands communication devices which are smaller in size. Compact antennas fulfil the requirement of small size. The increasing demand of Wireless local area networks (WLANs) and Personal area networks (PANs) necessitates the production of antennas capable of operating on various bands and different standards. Furthermore, the required antennas must be cost effective and compact in order to assimilate them into modern devices. Printed monopole patch antennas propose the solution to above mentioned issues.

1.2 Overview

The Modern technology demands for developing compact, low cost and facile to fabricate antennas that cover the bands widely used for communication. In order to cater for the demands of ever expanding wireless communication industry, we designed a multiband antenna that can be integrated with devices operating on multiple bands of communication. Furthermore the compactness of antenna will allow it to fit in majority of the existing devices.

1.3 Problem Statement

Present day technology asks for antennas operating on multiple frequencies. The standard methodology to attain multiband patch antennas consisted of using numerous strips or creation of different electrical paths, all of them showing resonance at different frequencies. Problems with these designs are the enlarged dimensions of antenna, large ground planes required or the difficulty of obtaining desired frequency bands due to design complexity. Such antennas were difficult to assemble and not easy to assimilate with recent devices. As a solution we propose an antenna operating on multiple frequencies that is compact in size and simple enough to fabricate so that it can be integrated with any modern day device.

1.4 Project Approach

We used open complementary split-ring resonators (OCSRRs) to attain multiple operating frequencies within an antenna covering bands of **Wi-Max (3.3-3.8GHz), Wi-Fi (4.9-5.9GHz) and PAN (2.4-2.48GHz)**. The idea is based on the concept that the first band is proportional to the length of the printed antenna and the added bands are determined by loading the printed antenna with a set of resonant LC circuits at measured distance which appear as open circuit at their resonant frequencies giving rise to two effective communication bands. Use of coplanar waveguide structure optimized the design by making it easy to fabricate, single layered and compact which made it facile to integrate with other devices to meet the modern day communication requirements. All frequency bands exhibit similar radiation characteristics. The final results obtained are consistent with the simulated data and a good return loss with positive gain of the antenna is observed. The antenna can be made reconfigurable by using PIN diode in OFF or ON state which enables the antenna top operate at different bands

1.5 Project Objective

This project is mainly based on the concepts of Transmission Line and Waveguides, Wave Propagation and Antennas, Electromagnetic Field Theory, Wireless Communication System and Patch Antenna Designing Techniques, specifically those involving introduction of slots for achieving multi band operation. Through this project we integrated our theoretical knowledge with practicality to gain further insight and refine our skills in all the fields mentioned above.

Our objective was to design and fabricate a compact Microstrip Multiband Patch Wireless Antenna covering bands of WLAN, PAN and Wi-Max by using (OCSRRs) approach .The resultant antenna was compact in size, single layered, cost effective and easy to integrate with modern technology devices.

1.6 Project Requirements

- High Frequency Structure Simulator Version 13.
- Patch Antenna Fabrication Tools.
- Patch Antennas Results Measurement Equipment.
- Advance Design System
- Vector Network Analyser
- Matrix Laboratory
- Microsoft Visio

1.7 Antenna Fundamentals

1.7.1 Substrate

Substrate is an essential part of microstrip patch antennas. It is mostly situated between ground plane and the patch. Different substrates are used depending upon their dielectric constant. Thus for the best results right substrate selection is a must on the basis of cost, efficiency, availability and size.

1.7.2 Ground

Ground Plane is a conducting surface. It is mostly located below the substrate and sometimes on the same plane as the patch (as in coplanar structure).

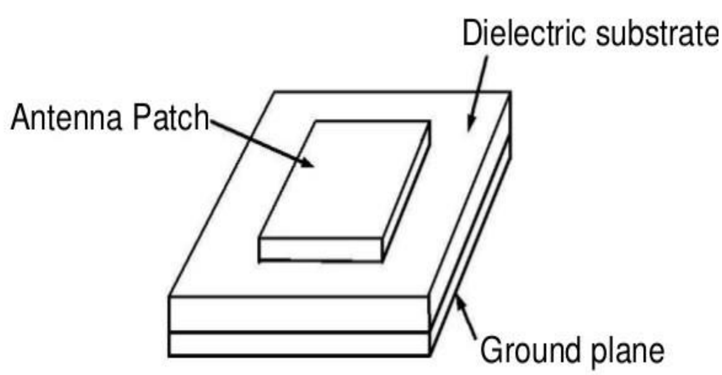

Figure 1: Ground

‘

1.7.3 Patch

Patch is a metal foil of various shapes that is printed on the surface of a Printed Circuit Board (PCB). Dimensions of different shapes of patch largely govern the effective frequencies of the antenna. In our design we used a rectangular patch of well calculated dimensions to achieve our desired bands.

1.7.4 Transmission line

Transmission line provides a path between antenna and transmitter/receiver that carries RF (radio frequency) power from one end to another. It helps to transport the signals received by the antenna with minimum distortion to the components that further decode them without error.

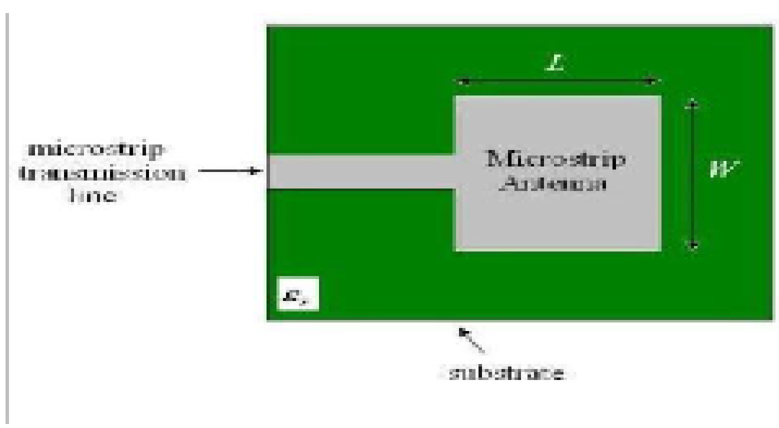

Figure 2: Transmission line

1.7.5 Radiation Pattern

Power radiated from the antenna in the direction leading away from the antenna is called radiation pattern. It is usually observed in the far field region of the antenna. The radiation plots are generated in antenna simulating software like HFSS and are useful for visualizing the directions in which antenna radiates.

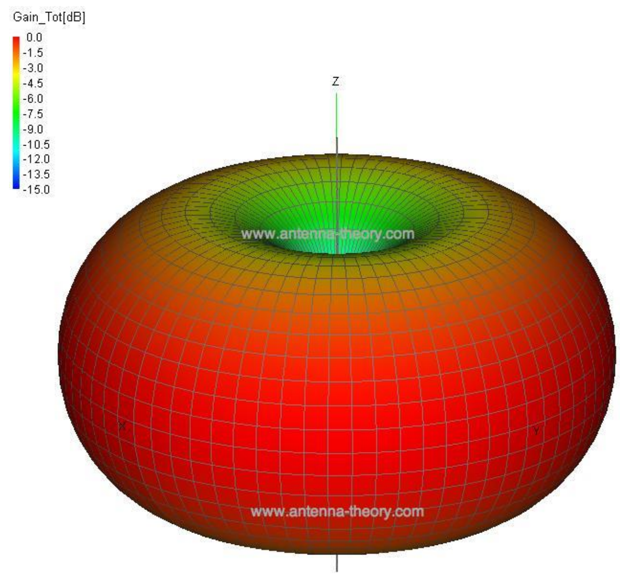

Figure 3: Radiation Pattern

1.7.6 Gain

The gain is a ratio of output power over input power. It shows the ability of antenna to radiate power in a particular direction. The measurement is typically taken in dB (Decibels). The gain of a good antenna should be positive with high numerical value.

1.7.7 Efficiency

The efficiency is defined as a ratio of antenna delivered power to antenna radiated power. A high efficiency is obtained when majority of the power reaches the receiver whereas low efficiency will occur when majority of the power will be absorbed or radiated away as losses due to impedance mismatching. Good antennas should have high efficiency.

1.7.8 Return Loss

Return loss occurs when the signal is comes back instead of reaching the destination due to mismatch of the transmission line. This loss occurs in the form of power being wasted instead of arriving at the desired end. In HFSS S11 plot shows the power reflected back from the antenna, hence is termed as return loss. It is preferred to have return loss of less than -10dB according to IEEE standards.

1.7.9 Bandwidth

An antenna can operate efficiently over a selected range of frequencies that is termed as the bandwidth for that particular antenna. It is defined in terms of Hertz (Hz) and for a particular bandwidth the standing wave ratio (SWR) of an antenna will be less than 2:1.

1.7.10 Directivity

The ability of an antenna to radiate and receive energy effectively from a particular direction is called directivity. Directional antennas can be manipulated to have the radiation beam in the wanted direction whereas Omni-directional antennas radiate equally in all directions.

1.7.11 Surrounding Field

The region surrounding an antenna is called Field. It is further subdivided into two fields.

1.7.11.1 Near Field

It is the region of electromagnetic wave around an antenna due to flow of high frequency current. Reactive near field region immediately surrounds the antenna whereas radiating near field region/Fresnel region occupies the area between far field and reactive near field.

1.7.11.2 Far Field

It is the outermost region surrounding the radiating near field. It extends beyond infinity and is the region where waves mostly travel. All antenna parameters are measured in this region because here the complete field radiates and the angular distribution is independent of the distance from the antenna. Because of increased distance from the antenna, it can be approximated as point source .

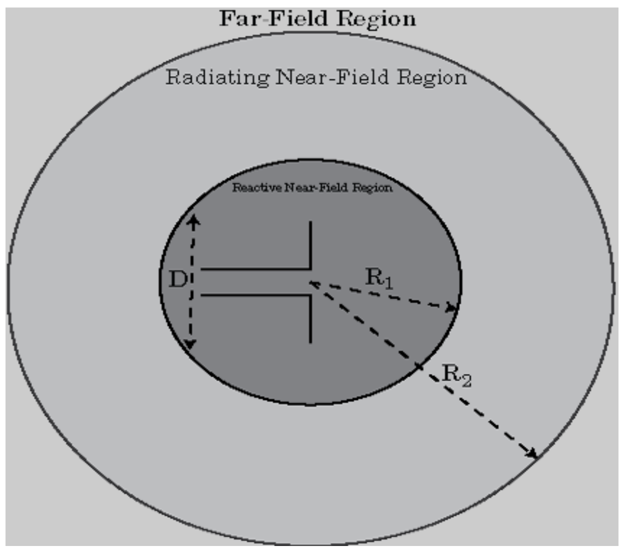

Figure 4: Far Field

1.7.12 Polarization

The direction of back and forth motion of electromagnetic waves in space is called polarization. It is the property that defines the time changing direction and magnitude of the electric field vector.

Polarization phenomena is characterized into following types

1. Linear Polarization
- Horizontal Polarization
- Vertical Polarization
2. Circular Polarization
3. Elliptical Polarization

Chapter 2

LITERATURE REVIEW

2 LITERATURE REVIEW

2.1 Existing Techniques

Over the past years many attempts have been made to design antennas operating on multiple frequencies for various purposes. Each of them uses different techniques to achieve different operating bands. However each of the approach has its own benefits as well as deficiencies.

In 2012, a paper published by IJSCE "**[1]**" proposed a design for multiband antenna operating on Wi-Max and WLAN by implementing defecting ground plane technique that introduces multiple frequencies by making U and T shaped defects on ground plane. For this to work ground and patch must not be on the same plane which increases it's thickness and makes it hard to fabricate.

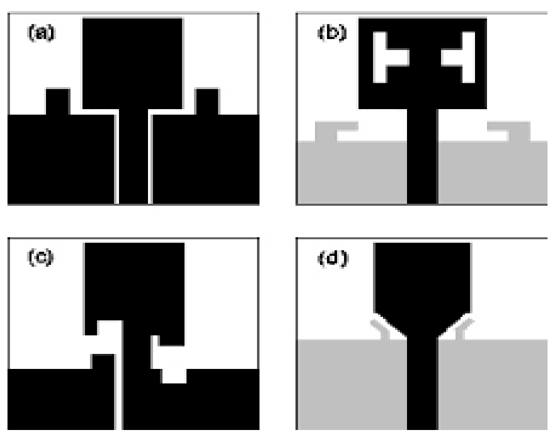

Figure 5: Micostrip Patch Antenna with defected Ground Plane and broad band dual frequency slot

In a paper published by IEEE "**[2]**" a printed monopole patch antenna is amplified with the addition of two arms, resonating at multiple frequencies giving a broad response of upper band. This increases the dimensions of the monopole and asks for larger ground planes [7].

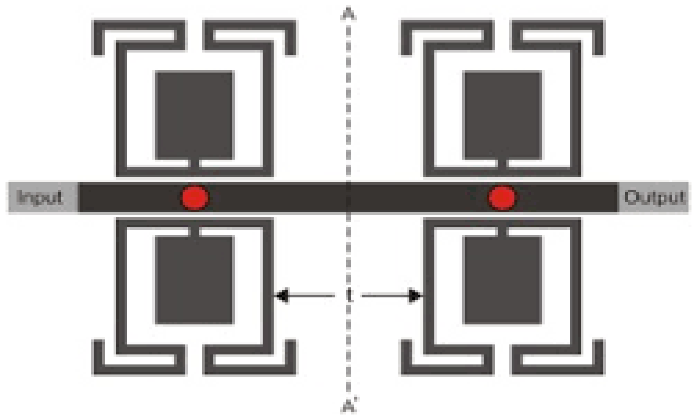

Figure 6: Dual band monopole patch antenna with stagger tuned arms

In 2003, IEEE published a paper "**[3]**" in which an antenna comprising of two T-shaped monopoles of variable sizes which are stacked together to produce two resonating modes for the dual-band operations was articulated. The antenna can be easily given an input of 50 ohm micro strip line. However increasing the resonant frequencies will require more T-shaped monopoles which will increase the dimensions of resultant antenna. Moreover separate ground plane increases the thickness of the desired antenna [8].

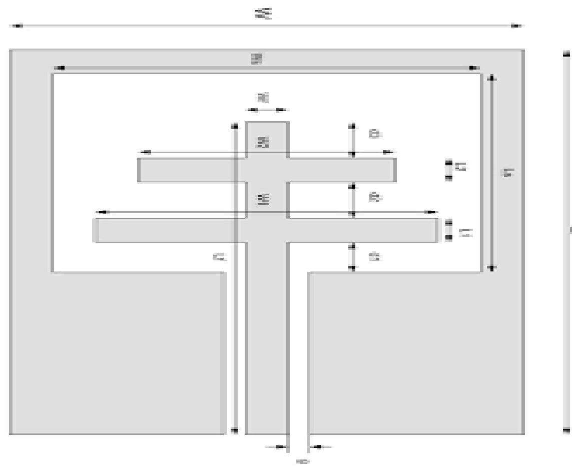

Figure 7: Double T Monopole Patch antenna for 2.4/5.2GHz

In another paper published by IEEE "**[4]**" an antenna arrangement with two S-shaped random parallel lines of distinct sizes, capable of generating different resonant modes is proposed. By adding bulging strips to two S-shaped arms of monopole antennas, much broader mode of impedance matching can be achieved. But this S-shaped structure is not only complex enough to fabricate but also increases the dimensions of antenna. Moreover we cannot introduce another resonant frequency without complicating the design further .

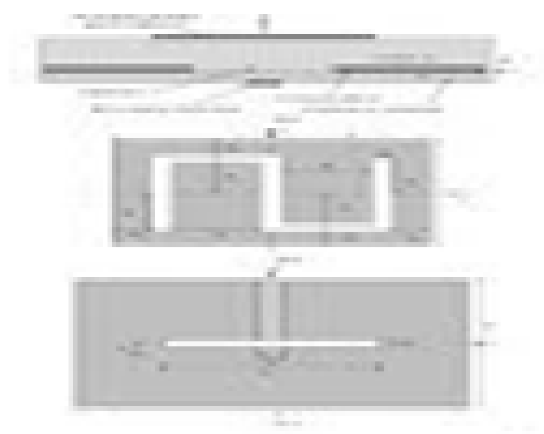

Figure 8: Dual S-shaped monopole patch antenna for Multiband and Wideband

In 2005, a paper published by IEEE "[5]" brought into light a distinct technique that could be used to achieve several resonanting frequencies within an antenna. This paper discussed the Split Ring Resonators (SSRs) and Complementary Split Ring Resonators

(CSSRs) along with their equivalent LC circuits. These comparisons can be used to achieve a desired multiband monopole antenna.

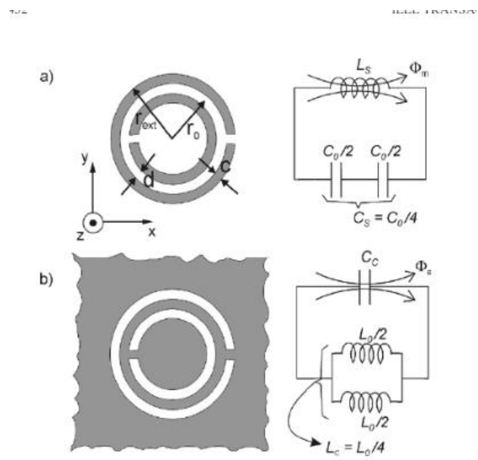

Figure 9: Equivalent LC circuit for Complementary Split Ring Resonators (CSSRs) and Split Ring Resonators (SSRs)

Switches can be used in antennas to make them reconfigurable. Pin diodes can be used as switches to jump between different bands of frequencies. They can also be used to block a particular band for a specific application. Switching of polarization can be achieved with the help of pin diodes as described in a paper "**[6]**" published in RADIOENGINEERING Vol. 24. By turning the switches on and off around the slits, the direction of current is altered, hence reconfiguring the polarization and electric field of antenna. Therefore, polarization produced by the antenna can be modified to three different types; linear polarization, left-hand circular polarization and right-hand circular polarization.

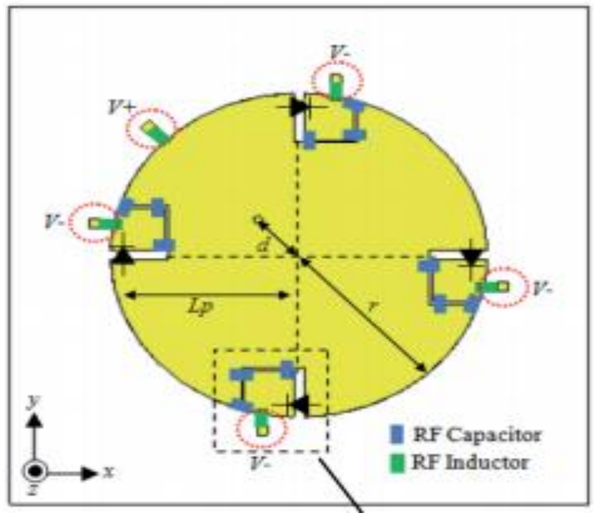

Figure 10: Reconfigurable Patch antenna with Fixed Resonant Frequency for polarization diversity

In a paper "**[9]**" published in IEEE conference, an antenna has been proposed that used four PIN diodes to control the radiation direction by selecting the appropriate radiator and switching the strips between being a director or reflector.

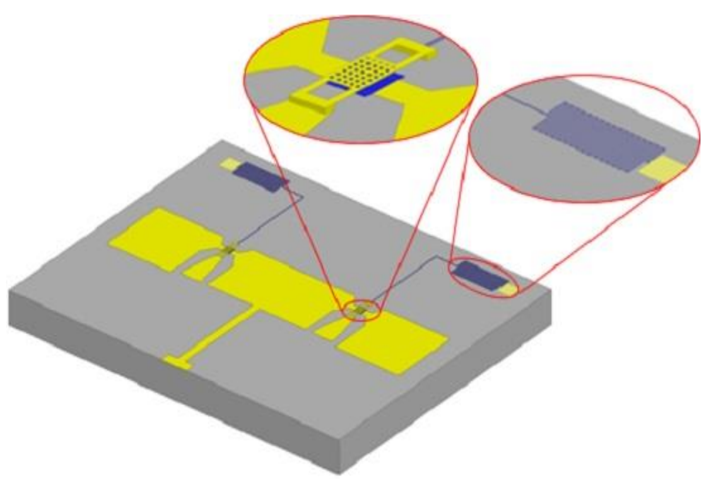

Figure 11: Wideband Reconfigurable antenna with Radial Radiators on Truncated Ground

Moreover diodes can also switch the feeding input of the antenna to achieve pattern reconfiguration as described in a paper “**[10]**”.

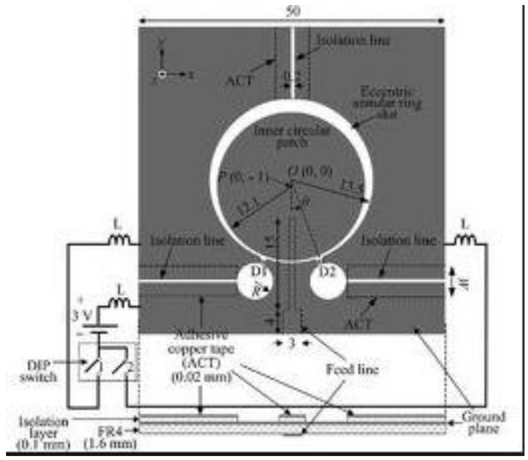

Figure 12: Pattern Reconfigurable antenna with high gain

In addition PIN diodes can be used to switch frequency bands depending upon their state when placed at appropriate locations. So that multiband antennas can be operated on desired chosen frequency bands according to the applications. This approach was implemented in “**A Novel Multiband Frequency Reconfigurable PIFA Antenna”** published in International Conference on Advanced Technologies for Communications (ATC) 2016 [11].

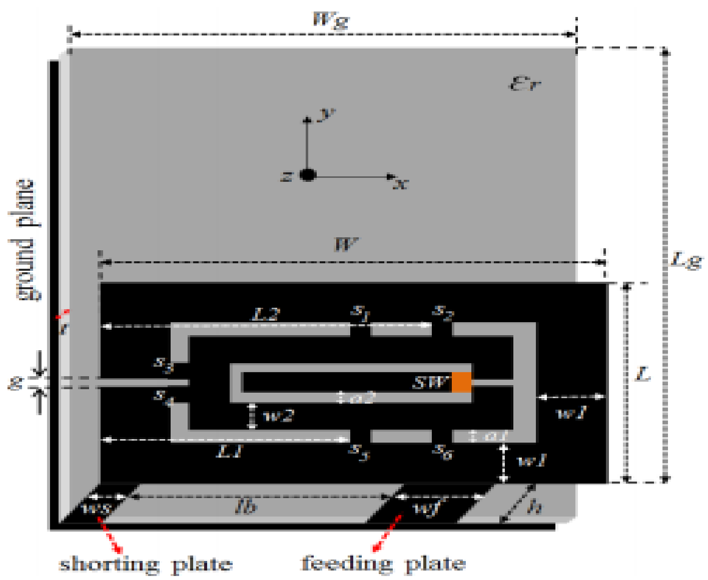

Figure 13: Multiband reconfigurable PIFA antenna

A summary of all the existing techniques is shown in the table:

Antenna Type	Operational Bands	Drawbacks
U and T shaped patch	Wi-Max WLAN	• Increased thickness • Complex fabrication
Stagger-Tuned arms with different resonant frequencies	multi-band WLAN	• Increased Size • Large Ground Plane
Double Stacked T-shaped	WLAN (2.4-5-GHz) for laptop	• Increased Dimensions
Double S-Shaped Monopole	Wi-Max WLAN	• Increased Complexity

Table 1: Existing Techniques

2.2 Use of Background Study

The documents we used were about designing multiband antennas. They gave us an insight about many techniques which can be used to achieve multiple resonant frequencies but not all of them made our design compact, optimized, easy to fabricate and cost effective in order to meet the modern day requirements of wireless communication. This literature survey helped us optimize the parameters of our antenna.

Chapter 3

PROJECT DESIGN

3 PROJECT DESIGN

3.1 Design Requirements

Following are the requirements that our antenna design satisfied:

- Compact Size
- Covers Wi-Max, Wi-Fi and PAN
- Improved Gain
- Simple Structure
- Easy Fabrication
- Facile to assimilate with contemporary devices

3.2 Design Specifications

In our project we made a low cost, easy to fabricate and compact antenna which would meet all modern day communication requirements. Our antenna has optimized parameters like gain, bandwidth, return loss, directivity and radiation pattern. We used HFSS for design and simulation of our project. After the desired simulation results were achieved then we moved on to the hardware part i.e. fabrication of antenna. In the end we tested and compared both results.

3.3 HFSS Design

In order to fulfill the design requirements we choose open complimentary split ring resonators (OCSRRs) approach to achieve multiple operating frequencies in the bands of Wi-Max, Wi-Fi and PAN. Open Complementary Split-Ring Resonators (OCSRRs) are incorporated inside a standard monopole patch in order to contrivance innovative printed monopole antennas operating on multiple frequencies. Monopole is the radiating element; hence, the radiation pattern, polarization, and gain are similar to those of a conventional printed antenna. The antenna obtained is compact and easy to fabricate with cost effective production.

The proposed antenna uses coplanar waveguide structure and is loaded with an OCSRR at calculated distances from the transmission line. The OCSRR can be modeled as a series- parallel resonator circuit due to the two current paths as follows:

- Central inductive path of the OCSRR
- Displacement current path through the resonator

The basic approach is to insert resonating LC circuit within Microstrip rectangular patch. Out of resonance, the effective length of the patch is modified. The first frequency occurs when the length of the loaded antenna is λ/4. So at the resonance frequency, the impedance of the LC circuit is very high hence it appears as an open circuit from the feeding point [9]. If the resonator is placed at appropriate distance i.e. λ/4, then an additional frequency band is achieved thus giving rise to dual band antenna. Below is the HFSS design of the dual band antenna.

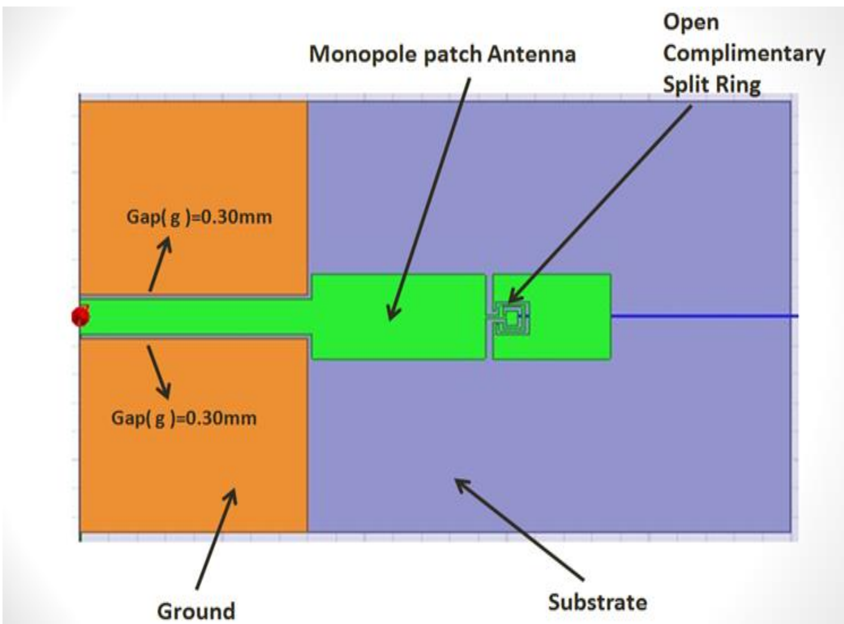

Figure 14: Dual Band HFSS design

By following this approach firstly we have designed the dual band prototype covering the bands of 2.40–2.48 GHz (Bluetooth and Wi-Fi) and 5.15–5.80 GHz (Wi-Fi). The substrate is the FR4 (dielectric coefficient = 4.5, h = 1.5mm). The resultant dimensions of the patch are L=21 mm, W=5.85 mm. We have used feeding line of 50Ω CPW. Henceforth S (length of feeding line) = 2.44mm and W (width of feeding line) = 0.30mm. Measurements of every ground plane are L = 16mm and W = 13.48mm. The slit amongst the ground planes and the monopole is g = 0.30mm. The OCSRR is positioned at a distance of d = 12.50mm, and its parameters are l = 2.30mm, c = d = 0.25mm.The slit g is set to 0.50mm.

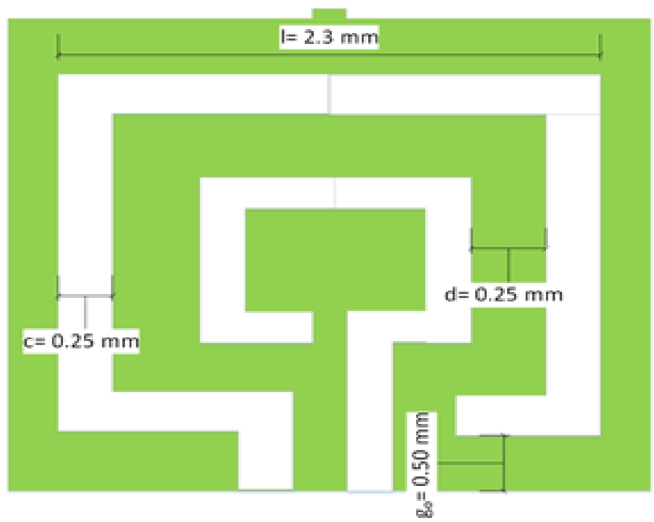

Figure 15: OCSRR

However to introduce third band another OCRR is placed at λ/4 distance of that resonant frequency from the feeding point. In this way we can achieve a triple band antenna.

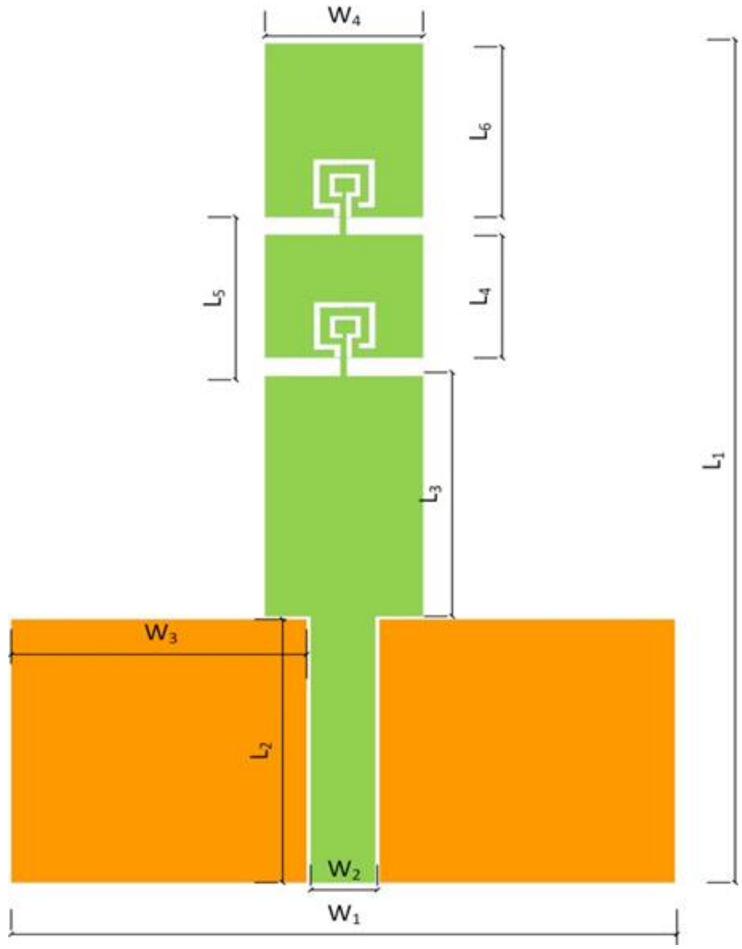

Figure 16: Triple band Antenna

Now the antenna operates on PAN (2.4-2.48GHz), Wi-Max (3.3-3.8GHz) and Wi-Fi (5.15-5.8GHz) bands. We achieved our design by using dimensions stated in the table below:

Label	Dimensions
L1	37mm
L2	16mm
L3	10.6mm
L4	4.9mm
L5	6.9mm
L6	4.35mm
W1	29.96mm
W2	2.4mm
W3	13.48mm
W4	5.85mm

Table 2: Dimensions of triple band antenna

We placed second OCSRR at a distance of 18mm from the feeding line. The OCSRR is made with the help of following dimensions.

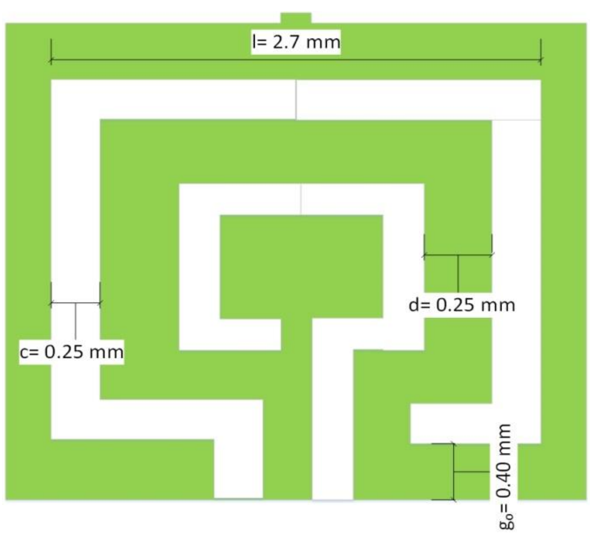

Figure 17: Second OCSRR

Chapter 4

ANTENNA FABRICATION AND RESULTS

4 ANTENNA FABRICATION AND RESULTS

4.1 HFSS Results

After optimizing the dimensions we have achieved certain results as per our requirement of the project. Gain of antenna was a great challenge because of the limitations offered by FR4 substrate. Simulated results are shown as follows.

4.1.1 Dual Band

4.1.1.1 Return Loss

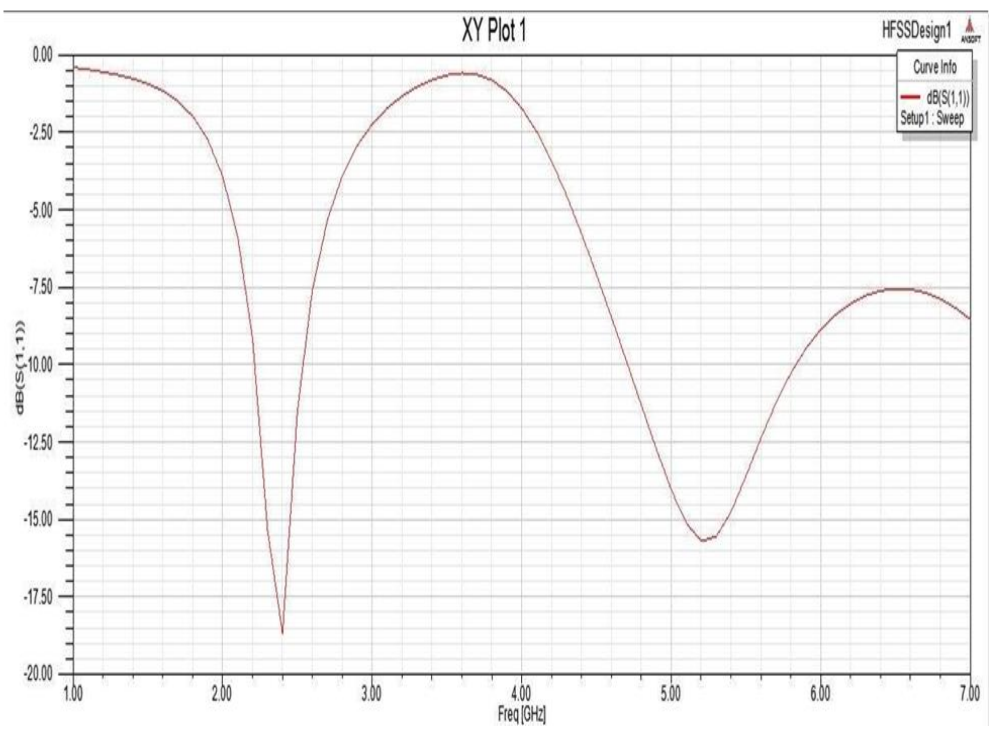

Figure 18: S11 Plot

Obtained results show return loss of less than -10dB

4.1.1.2 Gain

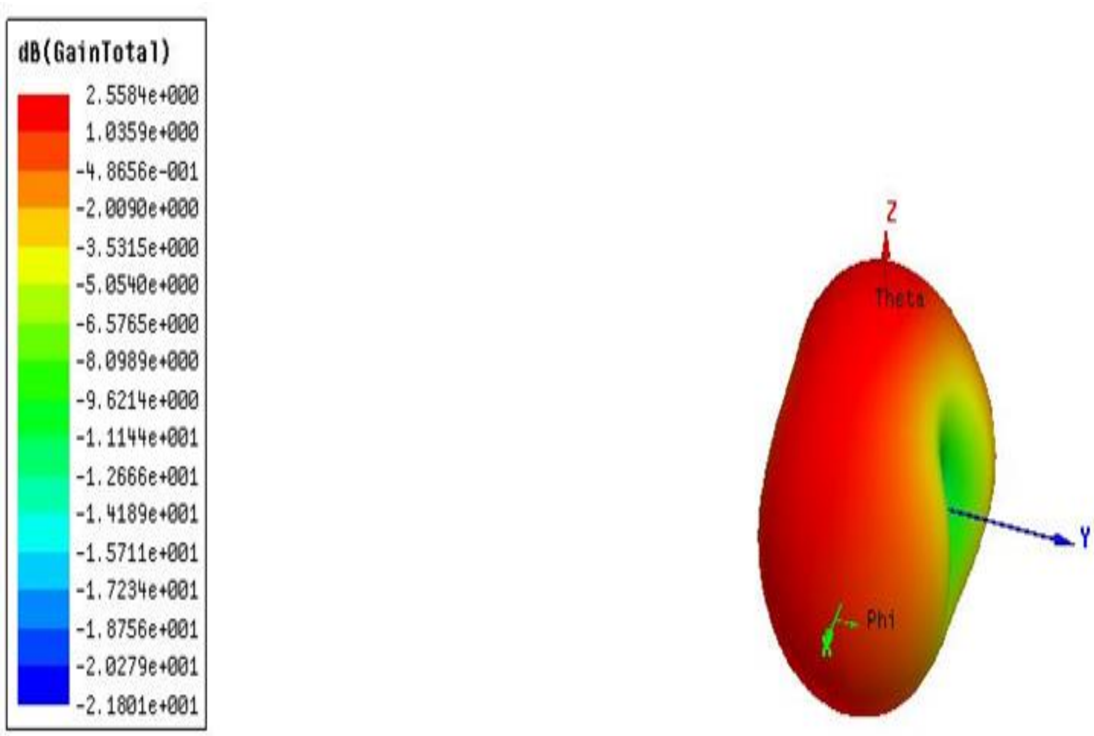

Figure 19: Gain at (2.4-2.48GHz)

The observed gain of the band of **PAN (2.4-2.48GHz)** is **$2.5584e^{+000}$**

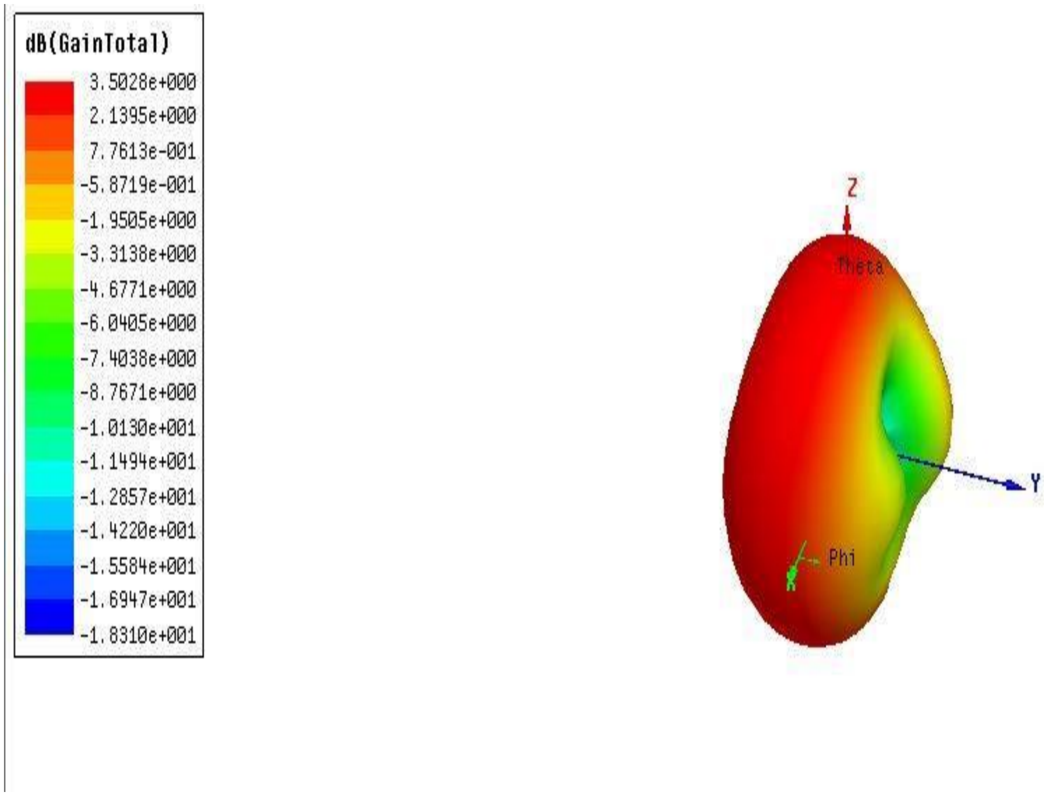

Figure 20: Gain at (5.15-5.8GHz)

The observed gain of the band of **Wi-Fi (5.15-5.8GHz)** is **3.5028e+000**

4.1.2 Triple Band

4.1.2.1 Return Loss

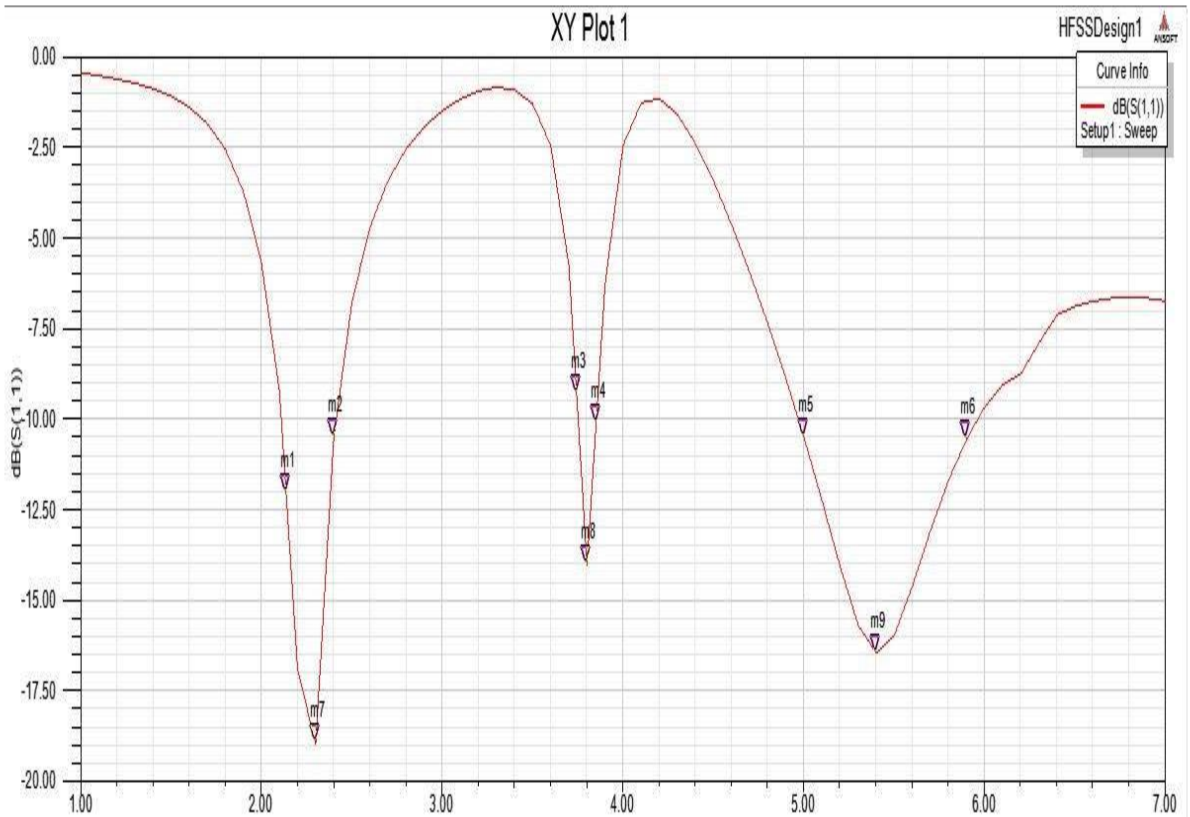

Figure 21: S11 Plot

Obtained results show return loss of less than -10dB

4.1.2.2 Gain

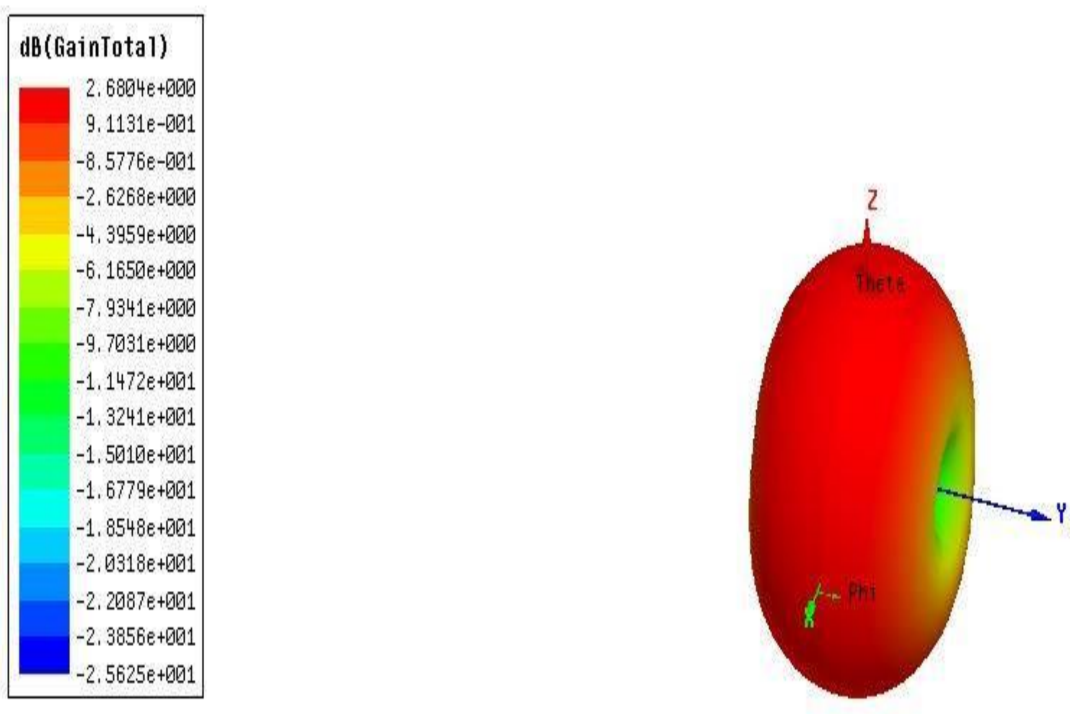

Figure 22: Gain at (2.4-2.48GHz)

The observed gain of the band of **PAN (2.4-2.48GHz)** is **$2.6804e^{+000}$**

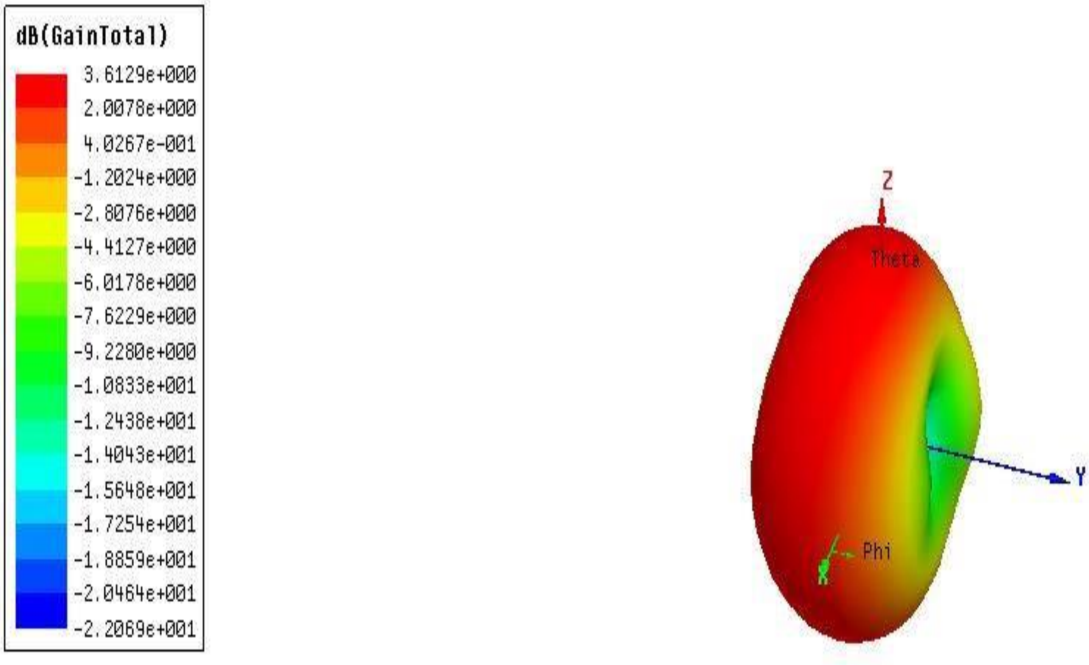

Figure 23: Gain at (5.15-5.8GHz)

The observed gain of the band of **Wi-Fi (5.15-5.8GHz)** is **3.6129e+000**

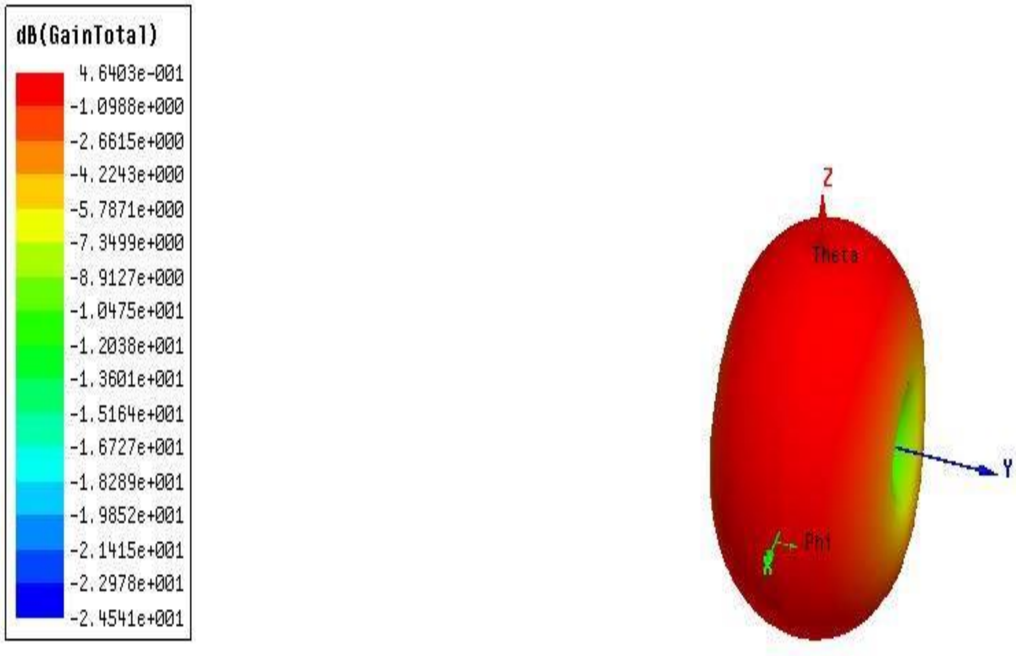

Figure 24: Gain at (3.3-3.8GHz)

The observed gain of the band of **Wi-Max (3.3-3.8GHz)** is **4.6403 e+000**

4.2 Substrate Selection

FR4 epoxy glass substrate is mostly selected for PCB applications. The material is very low cost and possesses tremendous mechanical characteristics, making it suitable for a large range of electrical components applications. Since it is cheap and easily available in the market, it became the best choice for us to use it for our design implementation. After studying different designs from various research papers of IEEE we decided to implement our design using FR4 with 1.5 mm thickness.

4.2.1 Permittivity

The permittivity of selected substrate FR4 epoxy glass substrate is 4.4

4.3 Fabricated Antenna

After achieving the simulated results triple band antenna was fabricated in NIE (National Institute of Electronics) and tested in the same lab. Below is the figure of fabricated triple band antenna.

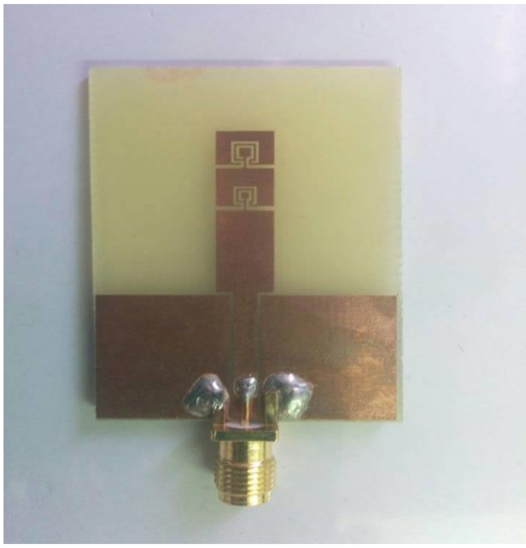

Figure 25: Top view

The results were measured and compared with the simulated results obtained in HFSS. Matlab plots of comparison can be seen in the figure below.

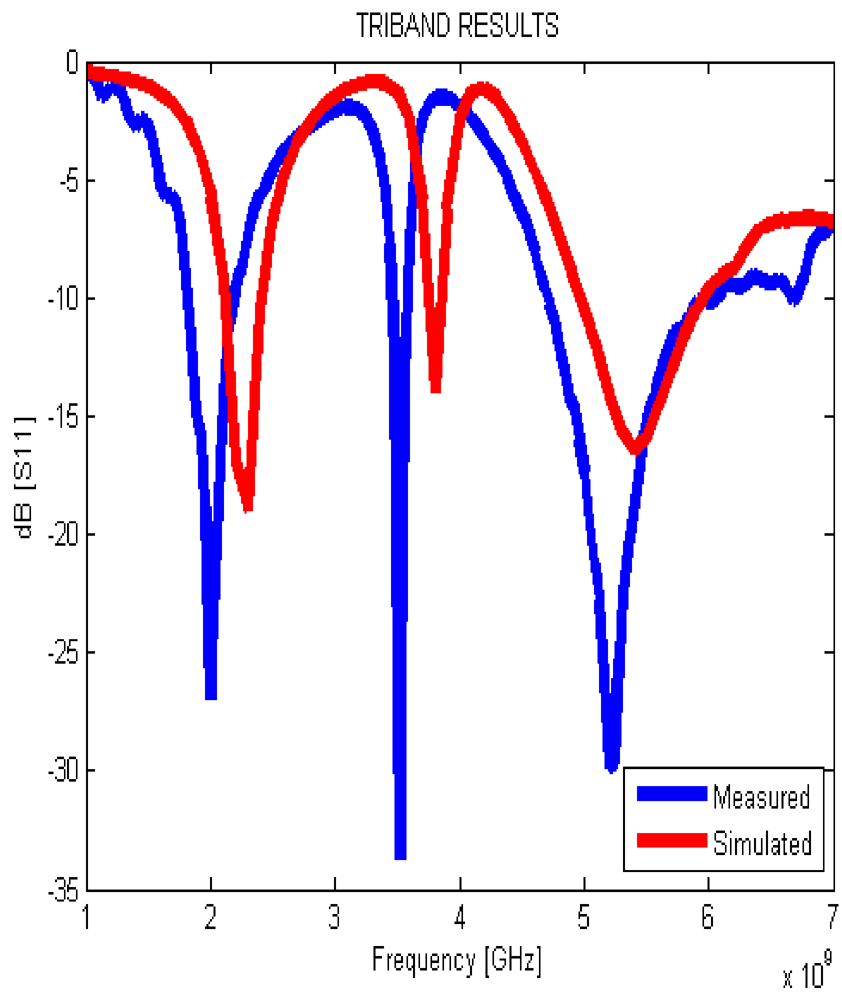

Figure 26: S11 Plot

As can be seen from the figure our results are quite close and acceptable in real scenario. Blue graph shows the S11 plot of fabricated antenna whereas Red graph shows the S11 plot of HFSS simulated antenna. All operating frequencies have return loss of less than -10dB which is acceptable and considered good according to IEEE standards.

4.4 Hardware Implementation:

For the purpose of showing working of our antenna, we attached the fabricated antenna with a Wi-Fi module to fulfill the requirement of hardware implementation of resultant antenna.

Figure 27: Hardware Implementation

Chapter 5

RECOMMENDATION FOR FUTURE WORK AND CONCLUSION

5 RECOMMENDATION FOR FUTURE WORK AND CONCLUSION

5.1 Future Work:

The proposed antenna can be made reconfigurable by dynamically adjusting the antenna parameters namely frequency, radiation pattern and polarization [13]. Such antennas have reconfiguration mechanism built inside rather than in an external network, which optimizes the antenna performance to satisfy varying operating requirements.

5.1.1 Radiation Pattern Reconfiguration

Radiation pattern reconfiguration is achieved by adjustment of spherical distribution of radiation pattern to maximize the antenna gain. Research work shows that PIN diodes can be used to control the radiation direction by switching the strips between being director or reflector and selecting the appropriate radiator [14]. Moreover feeding direction of the antenna can also be switched to achieve radiation pattern reconfiguration [15].

5.1.2 Polarization Reconfiguration

Polarization reconfigurable antennas have the ability to switch between different polarization modes (circular, horizontal and vertical) to decrease mismatching losses produced because of polarization in transportable devices. This can be achieved via altering the current path by activating and deactivating the PIN diodes placed at desired positions with appropriate gap for switching [16][17].

5.1.3 Frequency Reconfiguration

Frequency reconfigurable antennas can dynamically vary their operating frequency according to the application in which they are being used. Thus they give us an advantage in the conditions where different systems converge, resultantly the required multiple antennas will be substituted by a single reconfigurable antenna. This can be achieved by modifying the antenna dimensions using RF switches [18]. By placing a RF switch mostly PIN diode in between different resonating elements of a multiband antenna can give us a frequency reconfigurable antenna that can switch different bands according to the location of PIN diodes [19][20] and can be a solid advantage for applications that require switching of operating frequencies in multi band antennas.

Hence by using PIN diodes we can upgrade our triple band patch antenna into a reconfigurable antenna of any above mentioned type.

5.2 Applications

Since our aim is to reduce the size and improving the bandwidth so that our antenna can be used in modern day devices. It has applications for:

- Wi-Max
- PAN
- W-LAN

5.3 Conclusion

The designed and fabricated antenna is capable of operating on triple bands. By increasing the number of OCSRR placed we can increase the number of bands available and by using Pin diodes we can make it reconfigurable.

5.4 Bibliography

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1 APPENDIX A

APPROVED SYNOPSIS

Compact Slotted Microstrip Multiband Patch Antenna

Extended Title: A Compact Slotted Microstrip Muliband Patch Antenna for Wireless Communications
Brief Description of The Project / Thesis with Salient Specifications: Microstrip patch antennas posses a number of unique and interesting properties which make them very attractive for many wireless 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. With the availability of multiple frequency bands for various wireless communication systems, it is required for an antenna to operate at different bands of frequencies without any complicated mechanisms. There is a growing demand for multiband terminal antennas that are smaller in size and are capable of receiving multiple services introduced by different wireless technology networks. So the need of the hour is to create antennas able to transmit and receive these multiple bands. We intend to design a microstrip patch antenna operating on multiple bands to cover wireless communication applications like WiMax, WiFi, and WLAN etc.
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. Also the compactness of antenna will allow it to fit in majority of the existing devices.
Academic Objectives : Patch antenna designing techniques, specifically those involving introduction of slots for achieving multi band operation, will be explored and practiced in details. Moreover

relationship between certain antenna parameters (like enhanced bandwidth, improved gain and return loss) with slot dimensions of patch will also be dealt with.
Application / End Goal Objectives : The antenna designed will be novel, compact in size, easy to fabricate, low cost and will be able to transmit and receive multiple frequency bands for wireless communications like WiMax, WLAN, WiFi etc
Previous Work Done on The Subject : Many researchers have investigated multiband antennas, most of the initial research is focused on dual bands, modern day research involves development of tri band and quad band antennas which are smaller in size and are low cost. Researchers around the world continue to explore different slot shapes and sizes for achieving multiple bands operating on several different frequencies.
Material Resources Required: High Frequency Structure Simulator Version 13 Patch Antenna Fabrication Tools Patch Antennas Results Measurement Equipment
No of Students Required : 4 **Group Members:** Rabiya Farooq (Group Leader) Abdullah Zafar Hashir Rashid Hira Afzal
Special Skills Required: HFSS 13 - Patch antenna designing and simulation