MULTIPLE BAND MICROSTRIP PATCH ANTENNA FOR SATELLITE COMMUNICATION

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A thesis submitted to the Faculty of Electrical Engineering Department, Military College of Signals(MCS), National University of Sciences & Technology, Pakistan

In partial fulfillment of the requirements of a B.E Degree in

Electrical Engineering

May 2019

ABSTRACT

The project basically revolves around the concept of introducing staircase shape at each edge of the patch of Microstrip Patch Antenna (MPA) which will operate in S-band (2-4 GHz), C-band (4-8 GHz) and X-band (8-12 GHz).Depending on the technological developments, the variety and quality of the antennas, small size and better gain are becoming most popular specifications of antennas. The Rogers RT/Duroid 5880 with relative permittivity 2.2 and height 1.55 mm will be used as substrate material for design of the proposed antenna. Coaxial probe feed will be used to feed the proposed antenna because this type of feed provides better impedance matching to source by varying the feed position.

Microstrip Patch Antenna can be used in various wireless communication applications such as satellite, Radar, missile and aircraft. MPAs are called low profile antenna because these can be flush mounted on curved surface and they only require space for the feed line . Microstrip antennas are popular at frequencies above 100 MHz . Improper impedance matching and narrow bandwidth are two main disadvantages of MPA's. There are two techniques to enhance the bandwidth, one is by using thick dielectric substrate and the second is by using slotted patch. The first technique is limited because the thick substrate require increased length of the probe feed which introduces large inductance and increase only a few percentage of bandwidth. The second technique (slotted patch) increases the bandwidth more than the first method, reduces the size of the patch and also shifts the fundamental resonant frequencies to lower side. MPA consist of a thin metallic patch which is kept on dielectric substrate and below the dielectric substrate there is a conducting ground plane. A microstrip patch is generally of cooper placed on the top of the dielectric substrate. Ground plane is at the bottom side of the dielectric substrate.

The results of the proposed antenna are obtained in terms of Return Loss, Voltage Standing Wave Ratio, Gain and Radiation Pattern which have acceptable values of return loss less than 10 dB, VSWR less than 2 at each resonant frequencies and Gain more than 3 dB.

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of BS thesis written by **Mr Asad Saleem, Usama Aziz, Fateh Hanan and Sajawal Rashid of BETE-52 Course**, Registration No 00000124331, 00000168787, 00000133716 and 00000132989 respectively of Military College of Signals has been vetted by undersigned, found complete in all respect as per NUST Statutes/Regulations, is free of plagiarism, errors and mistakes and is accepted as partial, fulfillment for award of BS degree. It is further certified that necessary amendments as pointed out by GEC members of the student have been also incorporated in the said thesis and the thesis is original with plagiarism 8%

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Supervisor: Dr. Farooq Ahmed Bhatti, PhD

MCS, Rawalpindi

DECLARATION OF ORIGINALITY

We hereby declare that the work contained in this report and the intellectual content of this report are the product of our work. This thesis report has not been formerly published in any structure nor does it include any verbatim of the published resources which could be treated as violation of the international copyright decree.

DEDICATION

Dedicated to our parents, especially to our mothers, and our dear ones for their continuing support and encouragement throughout our BETE course work and research

ACKNOWLEDGEMENT

First of all, we would like to say thank you to our supervisor Associate Professor Dr. Farooq Ahmad Bhatti who helped us and assisted us during our research work. His kindness and encouragements had always been a morale booster whenever we had problems during our research phase. We are impressed by his humble and kind nature.

We can never forget the efforts of our parents which brought us up to this stage of our lives and without their prayers and support we could never be so much successful in our lives.

And above all, Thanks to Allah Almighty for everything.

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Chapter 1

INTRODUCTION

1.1 Overview of MS Antennas Technology:

- Invented by Bob Munson in 1972.
- Became popular starting in the 1970s
- One of the most useful antennas at microwave[1] frequencies (f > 1 GHz).
- It usually consists of a metal "patch" on top of a grounded dielectric substrate.
- The patch may be in a variety of shapes, but rectangular and circular are the most common.

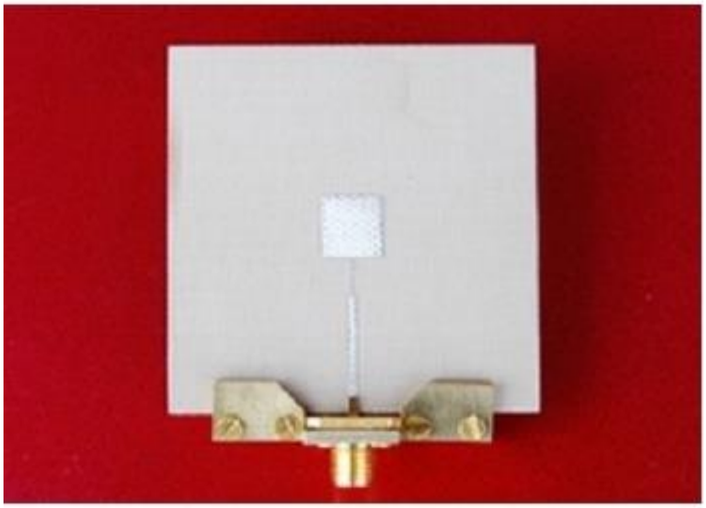


Figure 1.1 Micro strip line Feed

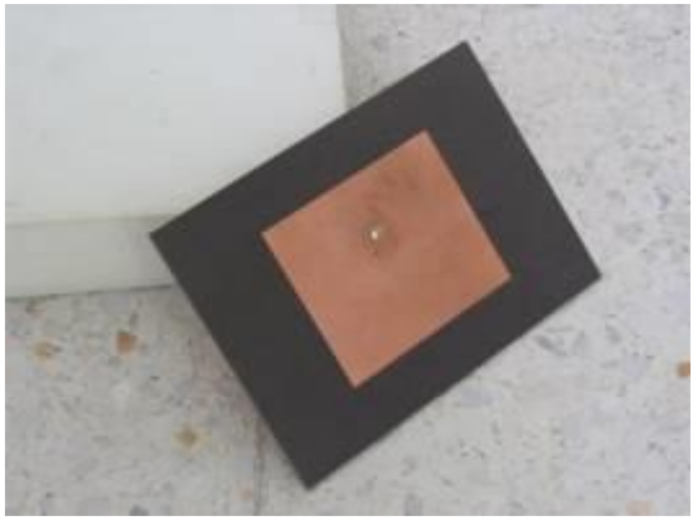
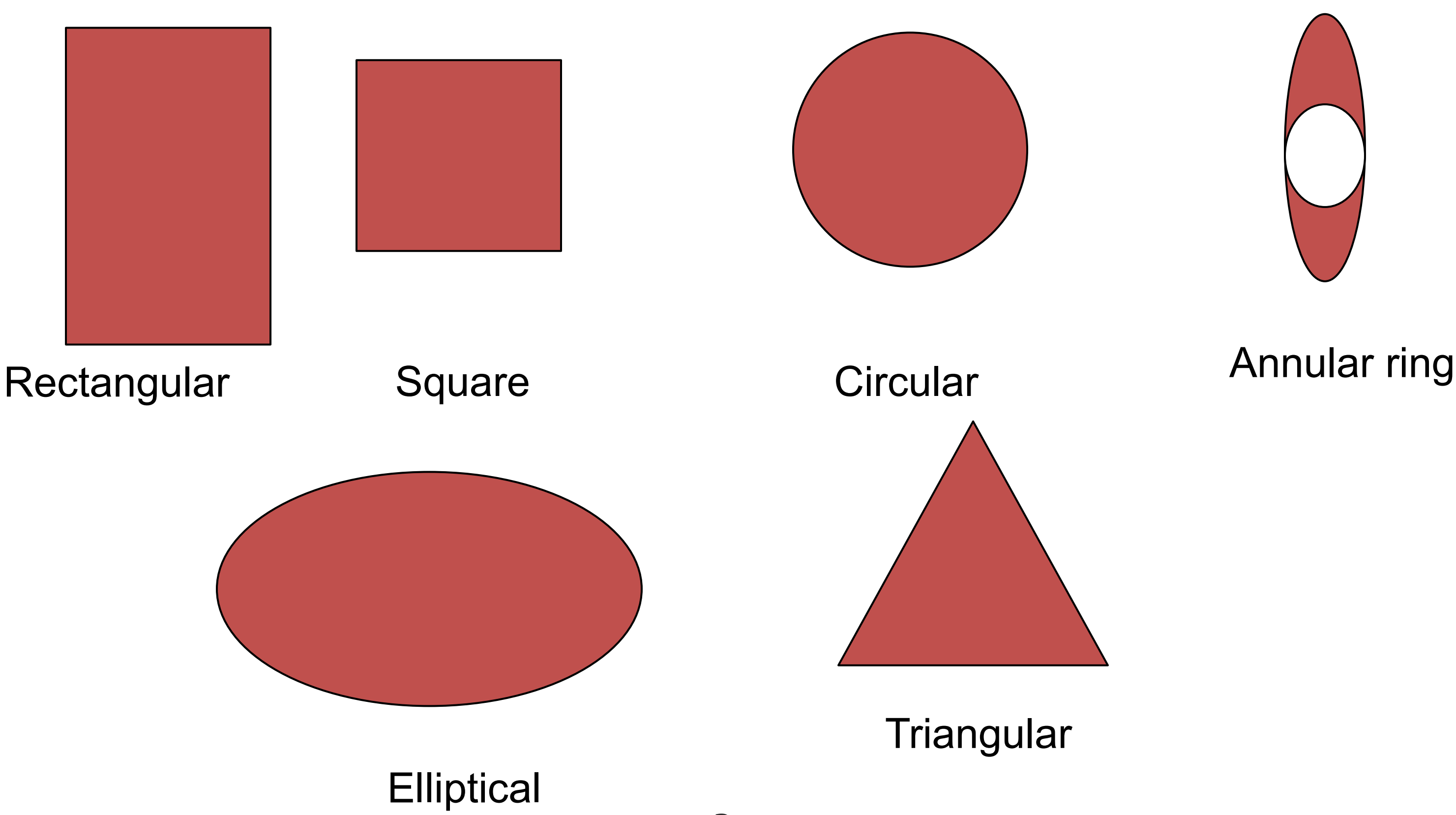


Figure 1.2 micro strip coaxial Feed

1.1.1 COMMON SHAPES



1.1.2 Advantages of microstrip antennas:

- Low profile
- Easy to fabricate.
- Easy to feed (coaxial cable, microstrip line, etc.).
- Easy to incorporate with other microstrip circuit elements and integrate into systems.
- Patterns are somewhat hemispherical, with a moderate directivity (about 6-8 dB is typical).
- Easy to use in an array to increase the directivity.

1.1.3 Disadvantages of Micro strip patch antennas:

- Low bandwidth (but can be improved by a variety of techniques). Bandwidths of a few percent are typical. Bandwidth is roughly proportional to the substrate thickness and inversely proportional to the substrate permittivity[3].
- Efficiency may be lower than with other antennas. Efficiency is limited by conductor and dielectric losses*, and by surface-wave loss**.
- Only used at microwave frequencies and above (the substrate becomes too large at lower frequencies).
- Cannot handle extremely large amounts of power (dielectric breakdown).
- Conductor and dielectric losses become more severe for thinner substrates.
- Surface-wave losses become more severe for thicker substrates (unless air or foam is used).

Applications:

- Satellite communications
- Microwave communications
- Cell phone antennas
- GPS antennas

A typical patch antenna is shown in Figure 1.2. Most often, microstrip antennas are made by etching the patch from a printed circuit board with conductor on both sides. The top metallic flat region, which is called the patch antenna, sits on a dielectric substrate.

A feed system supplies the RF power, and a ground plane is at the bottom of the patch antenna, sustaining the substrate.

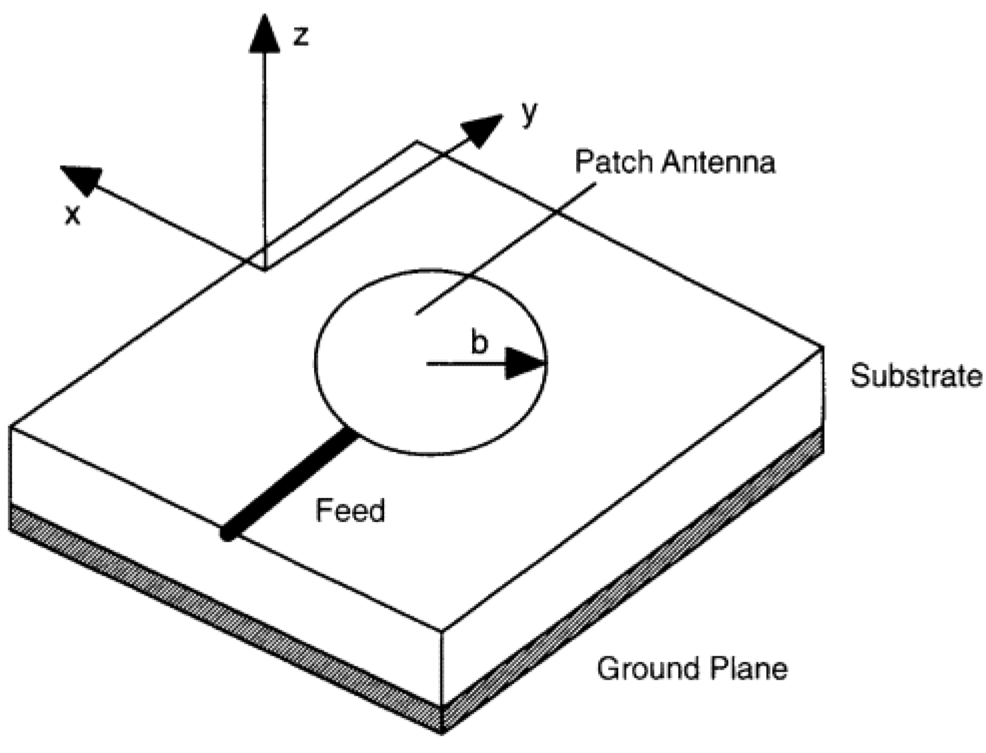


Figure 1.2. A Circular Micro strip Antenna.

1.2 Contribution of Thesis:

1.1.1 Multiple Band Micro strip Patch Antenna for Satellite Communication

Micro strip patch antennas are very important in satellite communication systems. In this one element antenna with isolation greater than -15 dB is represented. Staircase cuttings are introduced at the edges of patch to reduce the size. Better impedence matching is achieved by using coaxial probe feed by varying the feed position. Antenna geometry is optimized to achieve the best possible results.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Few areas required to be examined to get a better understanding of some fundamental knowledge needed for developing antenna. Topics studied are: Bandwidth enhancement techniques, Antenna design parameters, Modern development & techniques in antenna designing, research work carried out by different people around the world published in IEEE papers. Much software was used for simulation purposes like CST, ADS, PSpice.

2.2 Methods for Size Reduction

As wireless communication technology strives to develop compact devices, the demand for efficient antennas that occupy minimal real estate on cell phones, laptops, and other devices remains to be unwavering.

A straightforward approach to reducing the size of a microstrip patch antenna is to use a relatively high dielectric constant. Additionally, such dielectrics enhance the sensitivity of the design to minor changes in the geometrical parameters of the antenna.

Recently, the authors have introduced a novel concept of size-reduction of planar antennas, viz., loading the edges of the antenna with artificial dielectrics. The principal design methods are based on the transmission line model of the patch antenna operating in the fundamental TM mode relative to the longest dimension.

2.3 Methods for Improving Bandwidth

Bandwidth of antenna can be increased by various methods such as by increasing the thickness of substrate with low dielectric constant, by probe feeding, by cutting slot, by cutting notches and by different shapes of antenna. By probe feeding and moving the location of probe feeding and using notches we get suitable bandwidth. The enhanced bandwidth is compared with bandwidth of normal patch antenna and bandwidth of microstrip patch antenna with multiple notches.

2.4 Methods for Better Impedance Matching

Impedance matching is the practice of designing input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load. One of the various methods to improve the impedance matching of microstrip patch antenna is as follows:

Use of Coaxial probe feed because it provides better impedance matching by varying the position of the feed.

2.5 Antenna Basics

Antennas are very important components of communication systems. By definition, an antenna is a device used to transform an RF signal, traveling on a conductor into an electromagnetic wave in free space. Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics, regardless if it is transmitting or receiving. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band of the radio system to which it is connected, otherwise the reception and transmission will be impaired. When a signal is fed into an antenna, the antenna will emit radiation distributed in a space in a certain way. A graphical representation of the relative distribution of the radiated power in space is called a radiation pattern.

2.6 Micro strip Patch Antenna

Nowadays satellite communication system is becoming increasingly popular. However, the technologies for satellite communication still needs to be improved further to satisfy higher resolution and data rate requirements.

In the satellite communication system, the most important factors are cost, size, efficiency, radiation and it is the micro strip patch antenna which satisfies the above-mentioned objectives and still provides the space for improvement.

2.7 Feed Mechanism

One of the most important technique used to feed microstrip patch antenna is the coaxial feed or probe feed. It's quite evident from the figure given below is that the inner conductor extends through the dielectric and is connected to the radiating patch, while the outer conductor is connected to the ground plane.

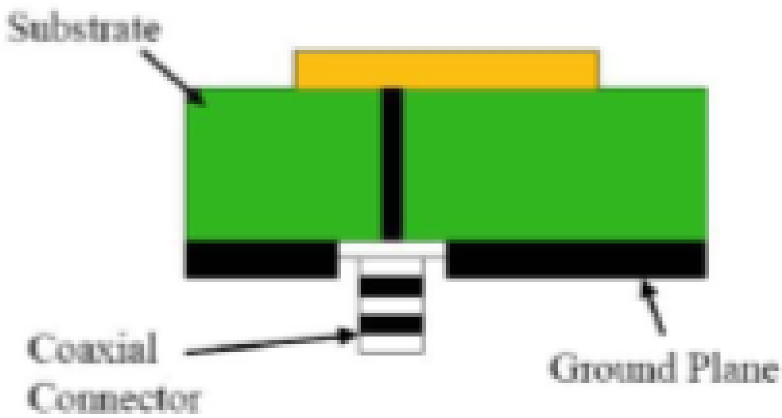


Figure 2.1 Micro strip Coaxial Feed

The main advantage of coaxial probe feed is that it provides perfect impedance matching by placing the feed at any desired location inside the patch. The coaxial probe feed is quite easy to fabricate and it reduces the fringing effect which reduces the required gain. Conversely there exist some disadvantages of this feed too, it provides narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate.

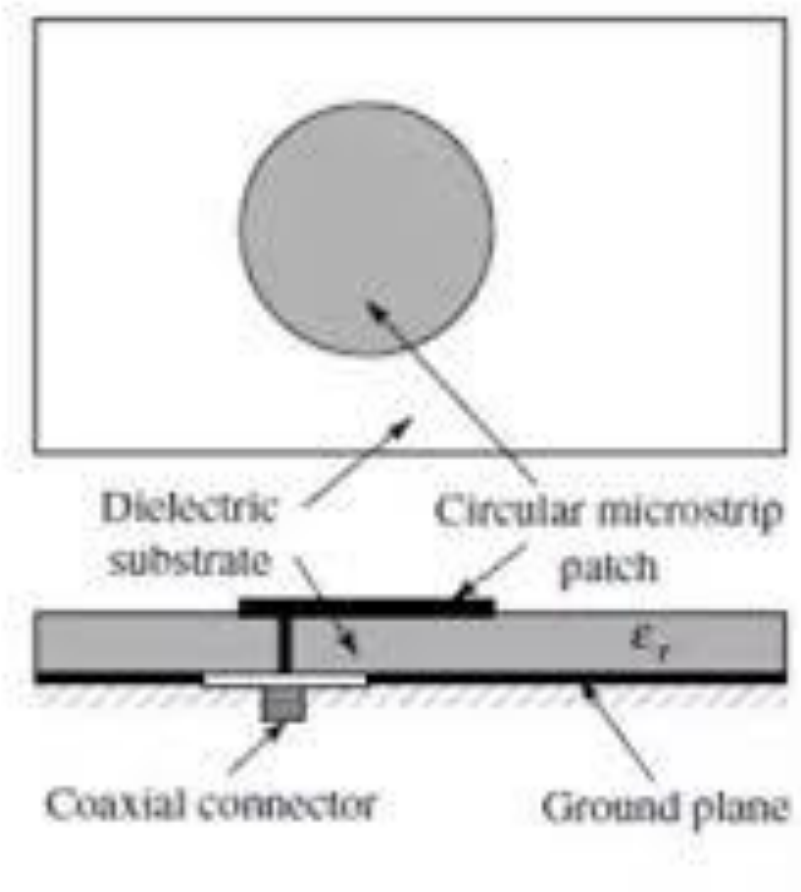


Figure 2.2 Feeding Technique.

2.8 Applications of Micro strip Patch Antenna

The micro strip patch antenna consists of radiating patch and ground plane on either side of dielectric substrate. They're also known as "Patch Antennas", "Planer Antennas", "Printed Antennas".

The utmost important applications of these antennas are:

- Used for satellite communication.
- Used in the field of biomedical.
- Used in WLAN, WIMAX, UMTS.
- They're also typically used for space and military applications.
- Used for microwave communication.

2.9 Electric & Magnetic Field in Near & Far Field Region

For the current constraints the total electric and magnetic field intensities H(total), E(total) at an arbitrary field point P(X,Y,Z) external to the element excitation source points are simply the vector some of the fields resulting from the element current and the current induced on the ground plane by the field incident by the element.

2.10 Concept of Ground Plane

The patch antenna consists of radiating patch and ground plane on either side of dielectric substrate. In a patch antenna ground plane is a of antenna in a shape of flat or nearly flat horizontal conducting surface. Its shape plays an extremely vital role in determining antenna's radiation characteristics including gain. In antenna theory ground plane is connected to the transmitter's ground wire and serves as a reflecting surface for radio waves[15].

Chapter 3

DESIGN OF MICRO STRIP PATCH ANTENNA FOR SATELLITE COMMUNICATION

In this chapter, design and analysis of a micro strip patch antenna for satellite communication is presented. The design process of this antenna is divided in two major stages. First, the design of Simple micro strip patch antenna. Second stage incudes the introduction of staircase on the sides of patch. The aim of design process is to come up with a multiple band micro strip patch antenna with greater impedance matching and high gain. In the next chapter measured result are discussed for the proof of concept.

3.1 Simple Micro strip patch antenna

3.1.1 Basic Structure (Stage 1)

The design process started by the creating ground, patch and selection of dielectric substrate. In this case, a FR4 (with dielectric constant 4.4, thickness 1.55mm and loss tangent 0.009) is chosen as dielectric substrate. FR4 is very low-cost substrate and easily available in market. The goal of this design is to achieve multiple bands while keeping the size of antenna 50mm x 59mm.

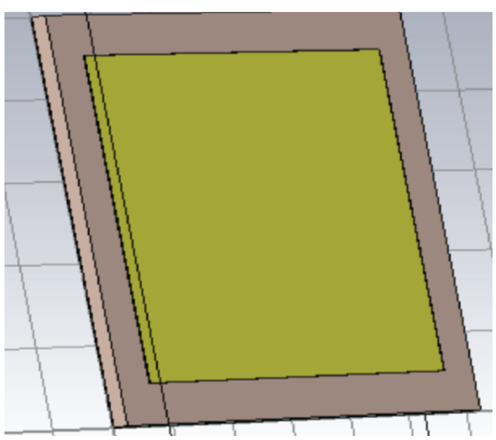


Figure 3.1 Basic structure of micro strip patch Antenna

The design of micro strip patch antenna starts with the selection of the shape of radiating patch and the transmission line feed structure. Rectangular patch is selected as radiating element of micro strip patch antenna and its size is 59 mm x 50 mm. The radiating patch of antenna limits the overall size of antenna. The antenna is fed by coaxial feed. The height of feed is 1.55 mm. The basic structure of antenna at this stage is shown in Fig 3.1.

3.1.2 Simulation

Fig 3.2 shows the simulated S Parameter (return loss) of micro strip patch antenna (Fig 3.1). The simulated results show that multiple bands are achieved but there are small ripples that can cause loss in gain.

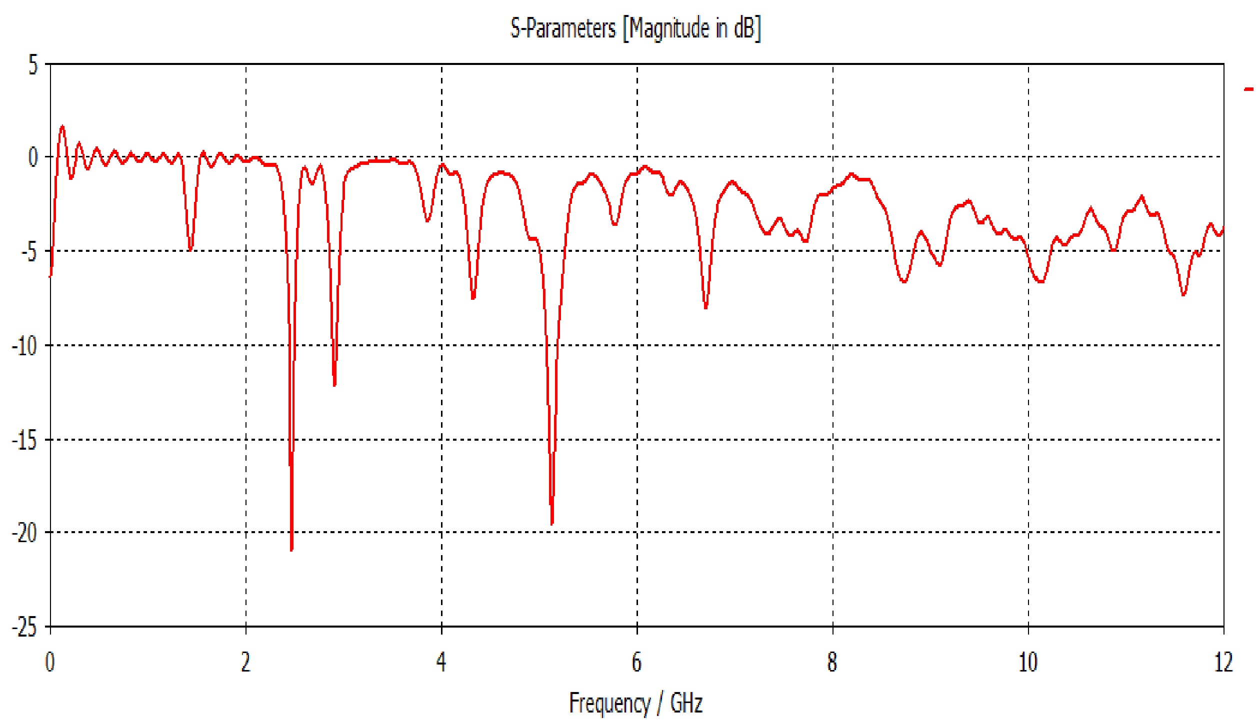


Figure 3.2 Return loss of patch antenna

3.1.3 Problem

This antenna has three different bands but at those bands gain remains in negative as shown in fig 3.3 below

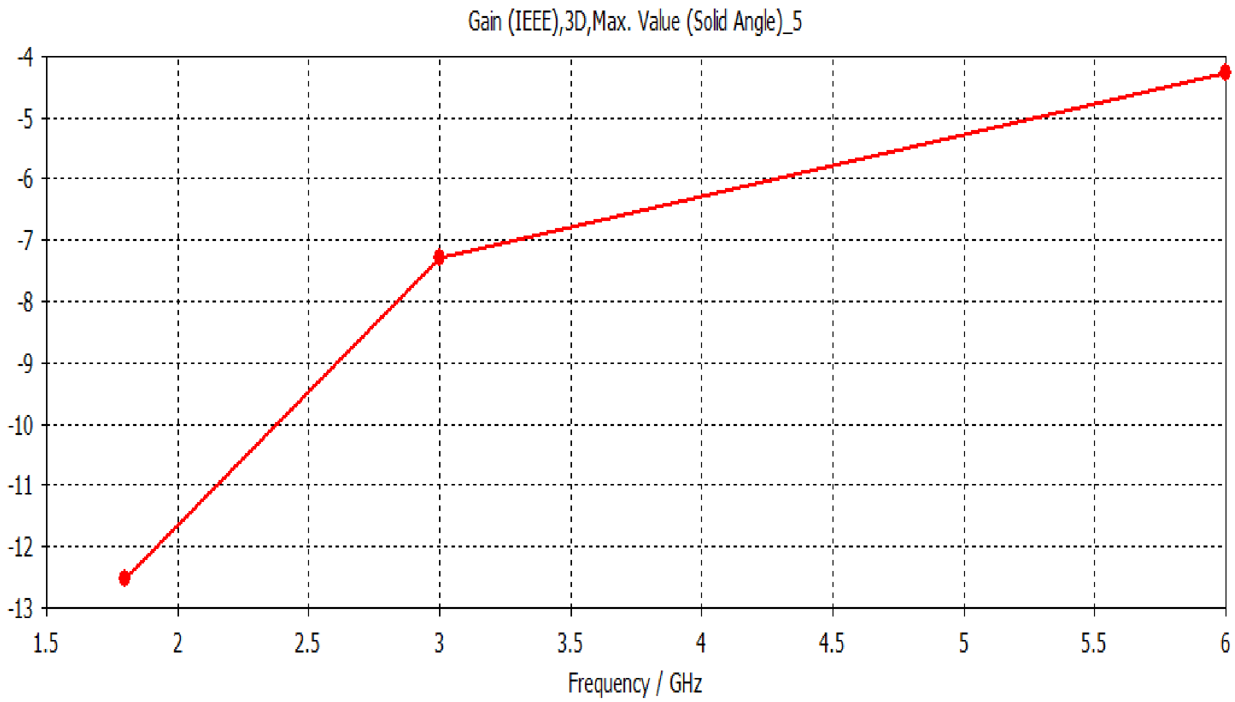


Figure 3.3 Gain of antenna

3.2 Multiple Band Micro strip Patch Antenna

3.2.1 creating ladder steps in Patch(stage 2)

Now we create [1]ladder steps on all four sides of patch of antenna as shown in fig 3.4 below.

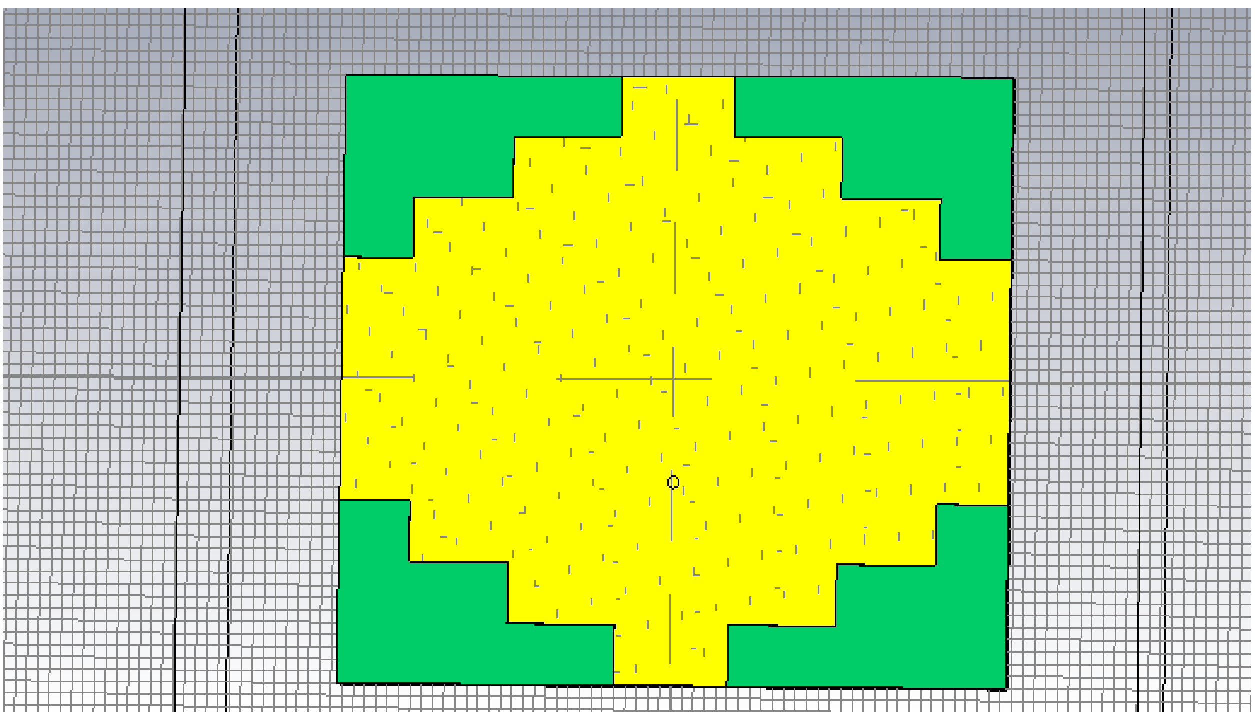


Figure 3.4 Main Shape of antenna

3.2.2 Problem

Again return loss and gain are not achieved as shown in fig 3.6 and fig 3.7 respectively.

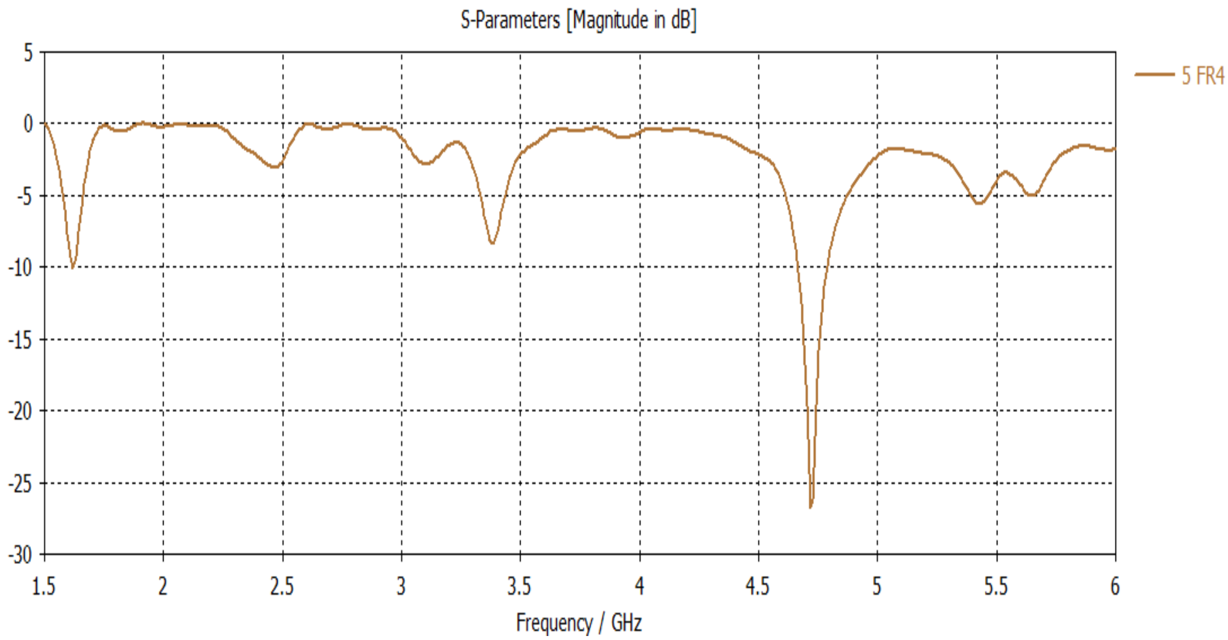


Figure 3.5 Return Loss

You can see return loss is not achieved.

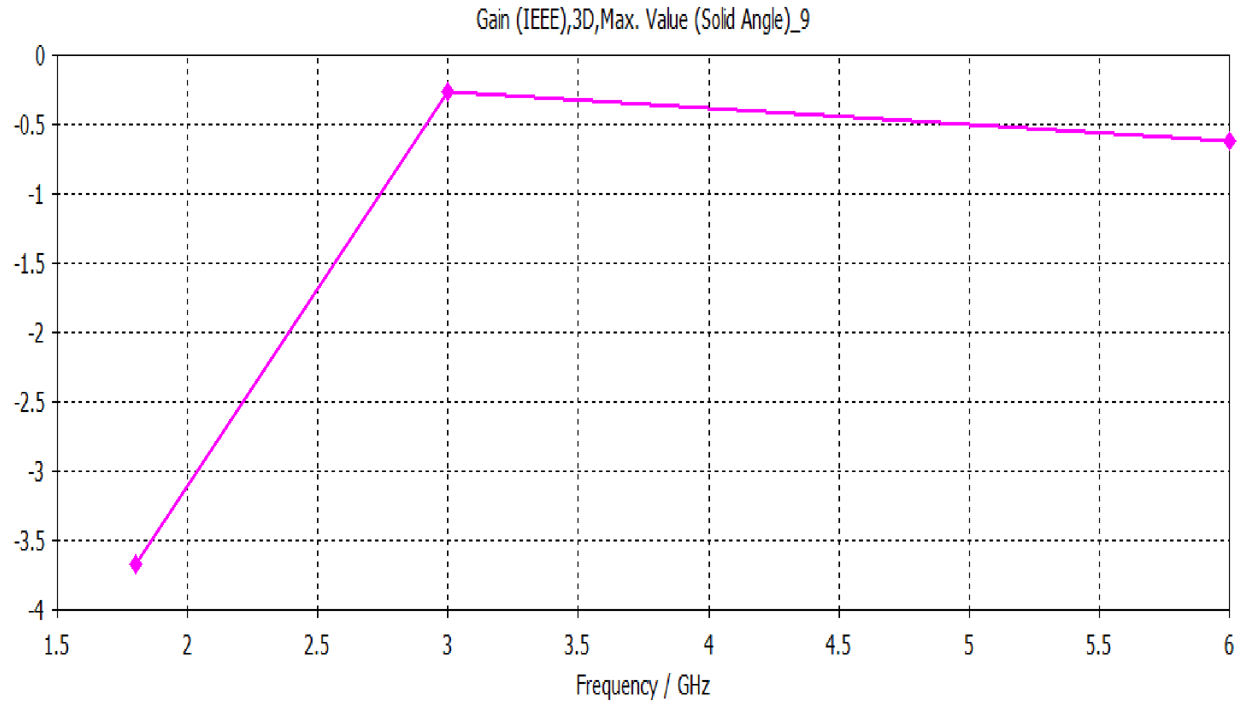


Figure 3.6 Gain of antenna

Here one cann see that gain is negative.

3.2.3 Change of Material Patch

We change the Material of Substrate from FR4 to Rogerr 5880 and our return loss and gain improved as shown in fig 3.7 and fig 3.8 respectively.

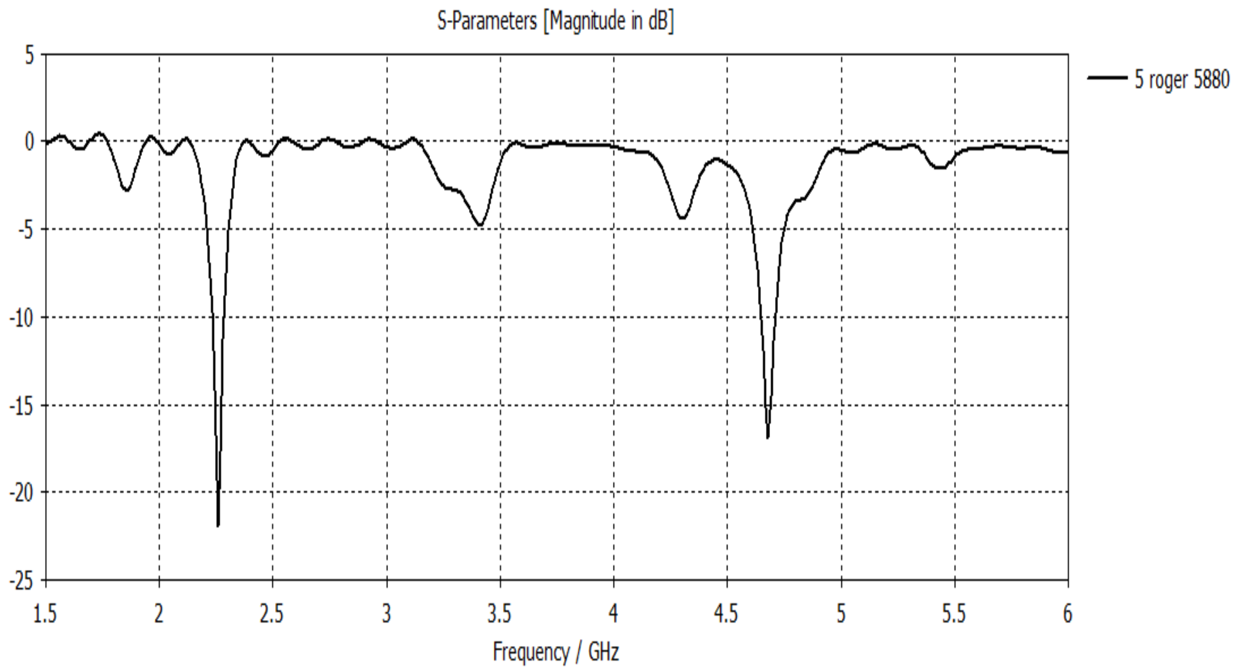


Figure 3.7 Return Loss

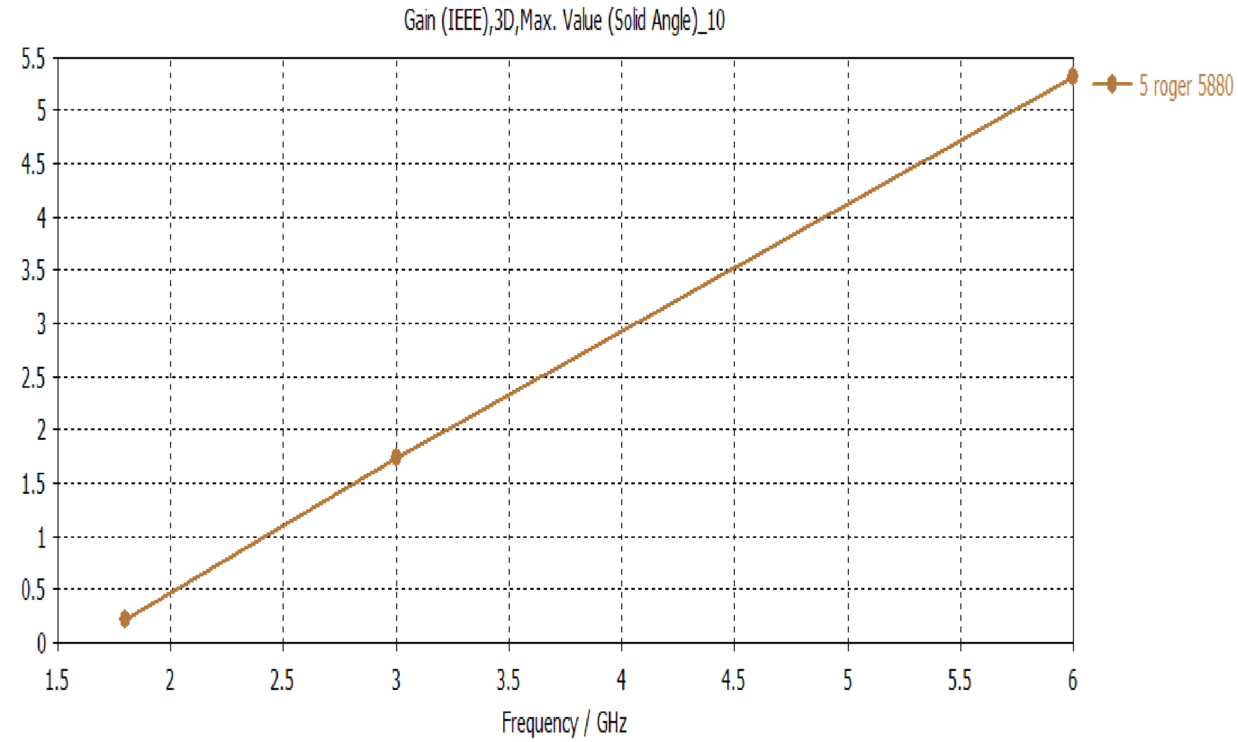


Figure 3.8 Gain Of Antenna

3.2.4 Change Ladder Steps in Patch

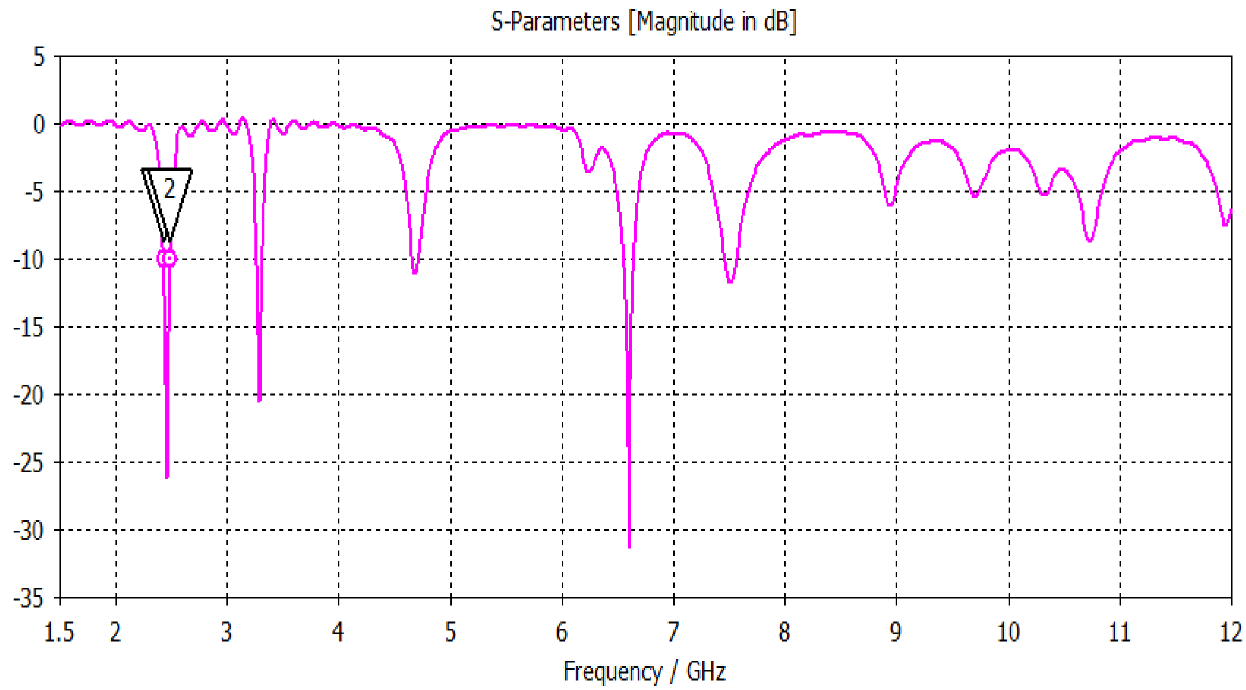


Figure 3.9 Return Loss

3.2.5 Change of Feed Position

By changing the feed position several times we have got our desired multiple bands which all are satellite communication bands. Fig 3.10 and fig 3.11 show the return loss and gain of antenna respectively. Our antenna becomes a multiband, working in ISM Band[12], C, S and X band. The Gain remain positive and in acceptable range.

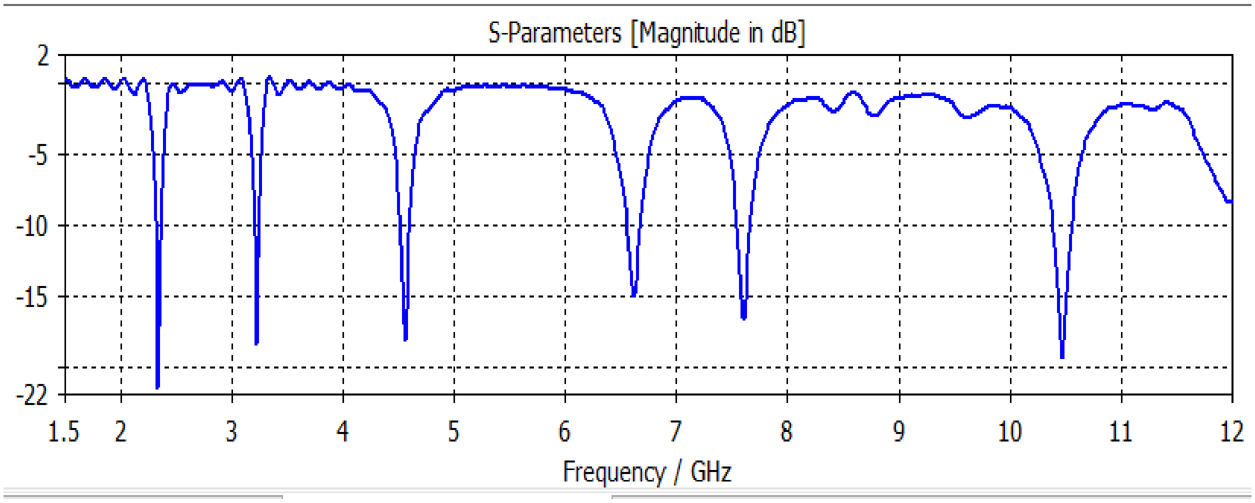


Figure 3.10 Return Loss

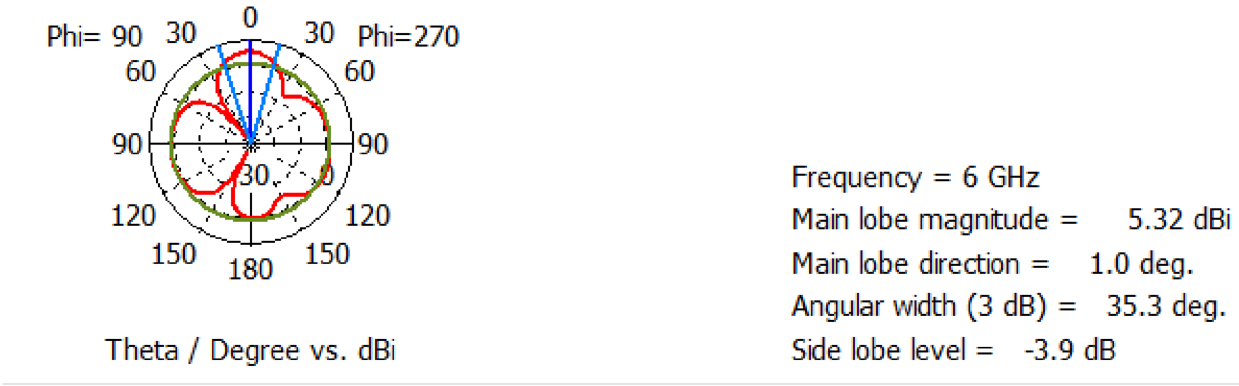


Figure 3.11 Polar Plot

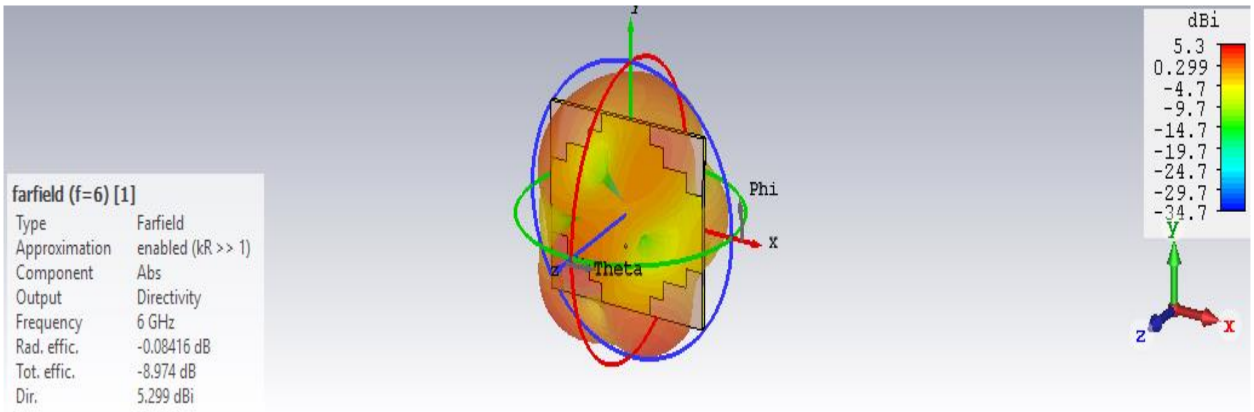


Figure 3.12 3D Radiation Plot

Chapter 4

INTRODUCTION OF MIMO

4.1 Why MIMO

Multiple antenna configurations can be used to overcome the detrimental effects of signal [9]multipath and fading when trying to achieve high data throughput in [7]limited-bandwidth channels.

4.2 Design of MIMO

In MIMO antenna, we use [8]2*2 MIMO, for this antenna.

In this antenna two ports are presents, those two ports creates, four return-losses as we know that 2*2=4. We can see Antenna geometry and its return loss in figure 4.1 as shown below.

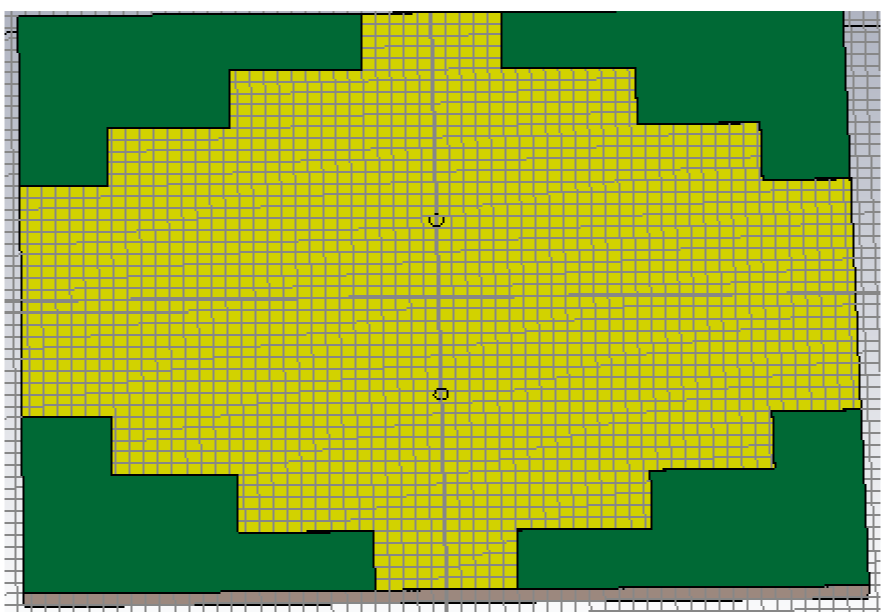


Figure 4.1 Geometry of MIMO Antenna

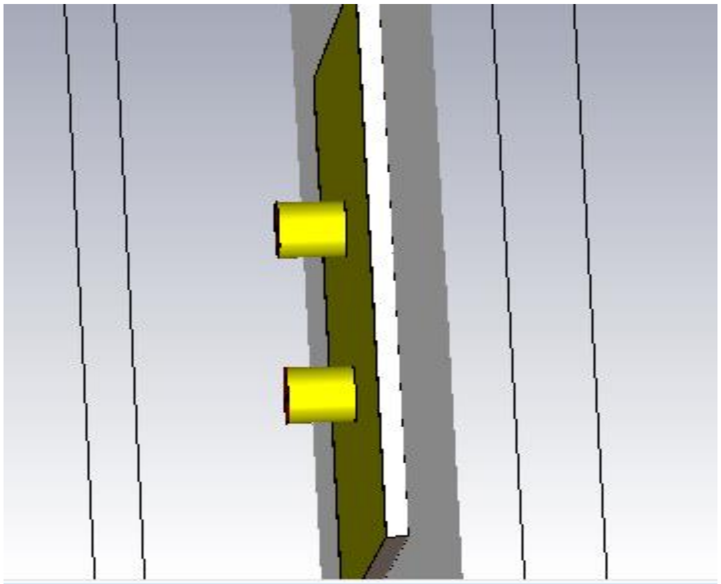


Figure 4.2 Side View of MIMO Antenna

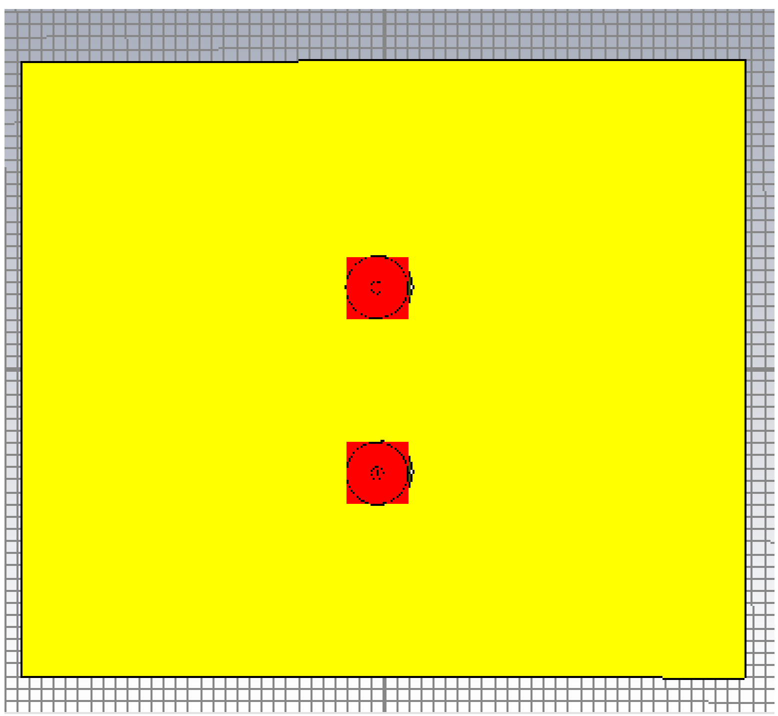


Figure 4.3 Back View of MIMO Antenna

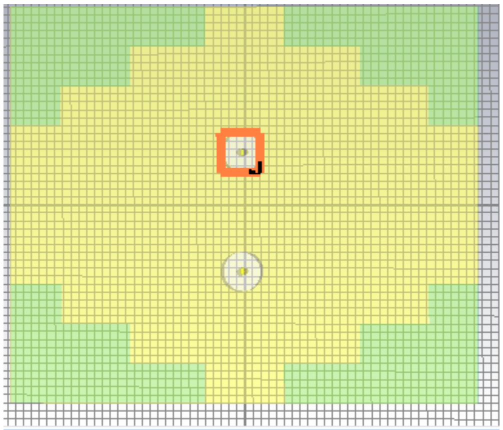


Figure 4.4 New Port View

4.3 Simulation

After Simulating the antnna, we obtained following four results for return loss and also we got good Gain of MIMO antenna as shown in below figures.

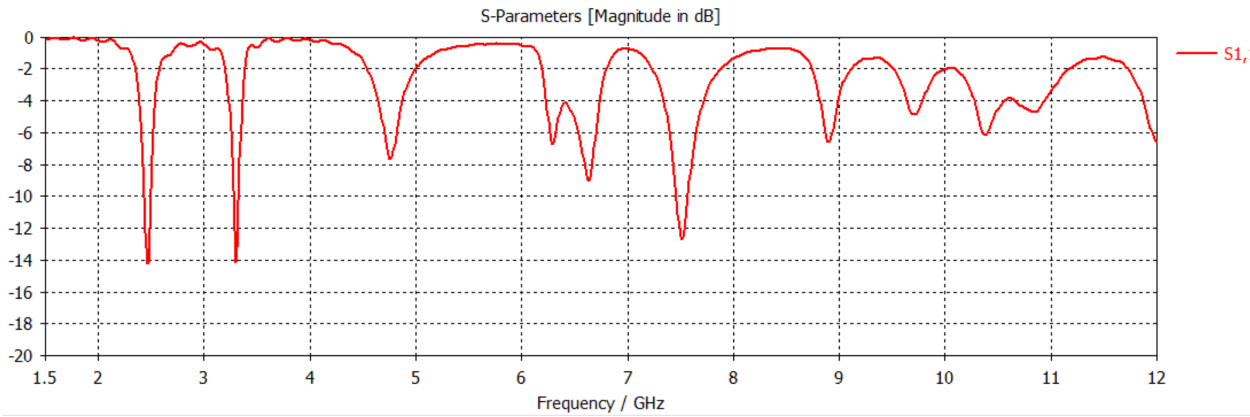


FIG 4.5: Return loss S1,1

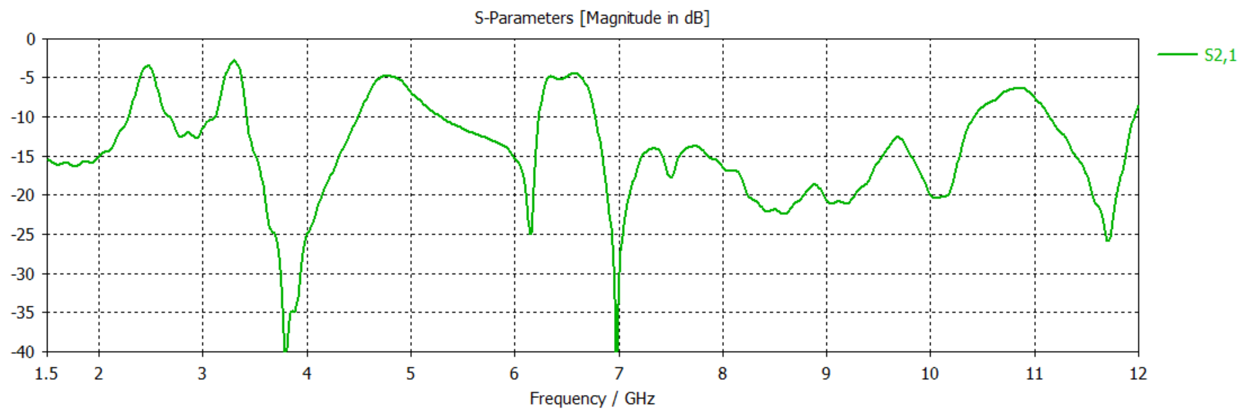


FIG 4.6: Return loss S2,1

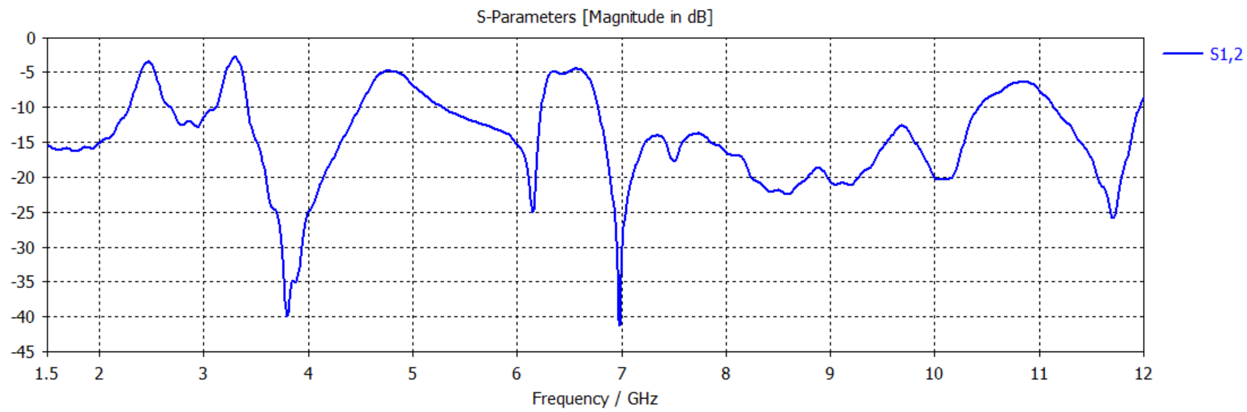


FIG 4.7: Return loss S1,2

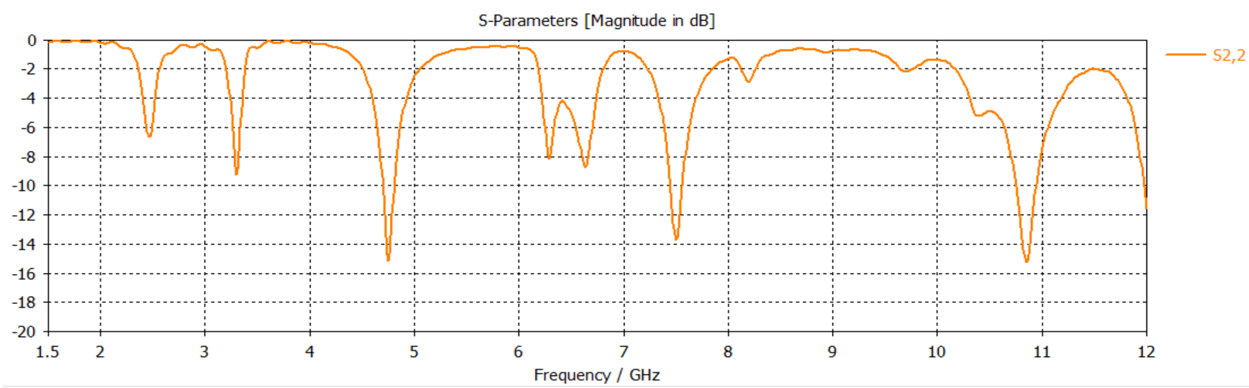


FIG 4.8: Return loss S2,2

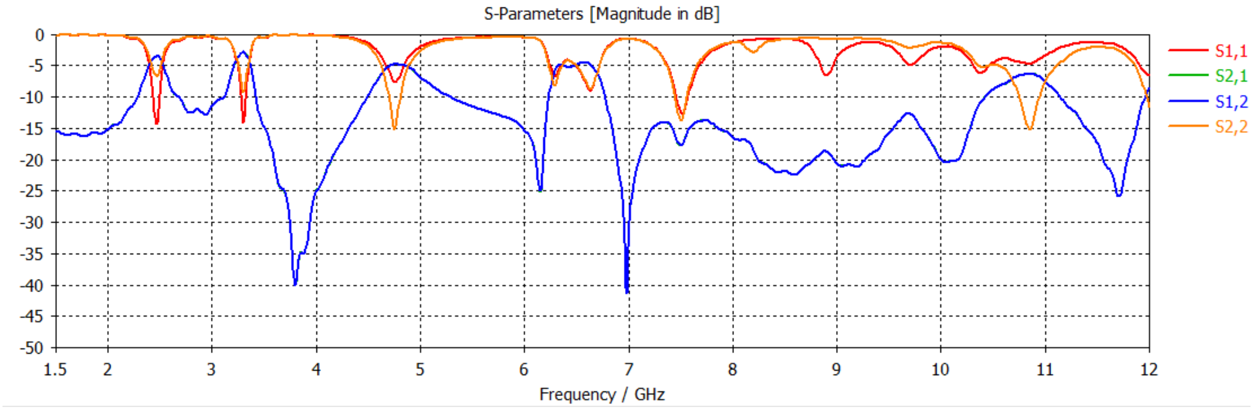


FIG 4.9: All return losses in one graph

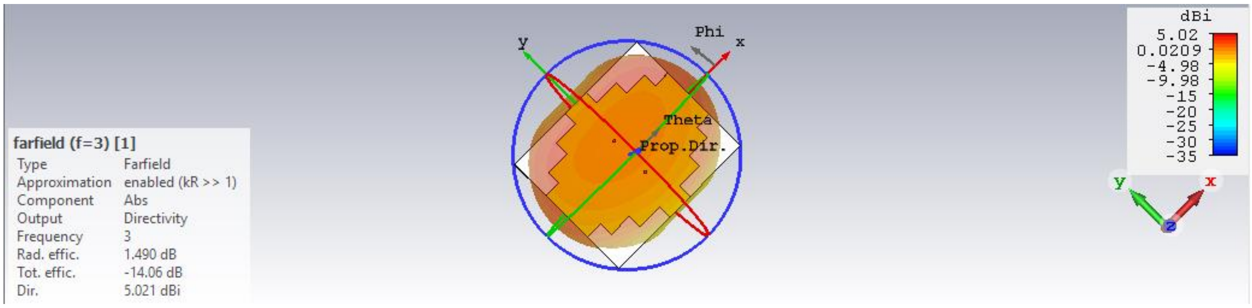


FIG 4.10: 3D Radiation Plot

4.4 Result Based Analysis

- Future work can be done on [10]MIMO for more better results.
- Return loss and gain are in acceptable limits.
- Mimo array[11] can be introduced

Chapter 5

FABRICATION

5.1 Selection of Material for Fabrication

Material plays vital role in the performance of antenna. The material is selected on the basis of weight, strength and radiating performance. Many types of material are used in the fabrication of antenna like aluminum, brass, copper and many more. Every material differs from one another in its quality and performance. The working efficiency also depends on the antenna resistance against weather.

5.1.1 Roger Duroid 5880

RT/Duroid is easy to cut, machined to shape and sheared. It is also resistant to all types of reagents and solvents which are normally used in etching printed circuits or plating holes and edges.

These high frequency laminates have the lowest dielectric constant of all products and due to this property they're well suited for broad band/ high frequency applications where losses and dispersion need to be minimized. RT/Duroid is also used in applications in high moisture environments due to its extremely low water absorption characteristics.

5.1.2 Light Weight

RT/Duroid 5880 filled PTFE composites are designed for exacting strip line and microstrip circuit applications. The unique filler results in a low density, light weight material for high performance weight sensitive applications.

5.1.3 Low Moisture Absorption

Due to its low moisture absorption property, it is used in high moisture applications applications. These high frequency laminates have the lowest dielectric constant of all products and due to this property, they're well suited for broad band/ high frequency applications where losses and dispersion need to be minimized.

5.1.4 Isotropic

Isotropic material is a material which radiates in all directions equally but in our case Roger/Duroid 5880 is nearly an isotropic material.

5.1.5 [2]Electrical properties over Frequency

At 10 GHz Roger/Duroid possess dielectric constant of 1.96 which is very low. In microwave frequencies Roger/Duroid 5880 supports broadband applications in millimeter range, where circuit loss and dispersion must be minimized.

5.1.6 Easily Cut

RT/Duroid is easy to cut, machined to shape and sheared. It is also resistant to all types of reagents and solvents which are normally used in etching printed circuits or plating holes and edges.

5.1.7 Uniformity

The dielectric constant of RT/Duroid 5880 is 1.96 and its laminates is uniform from panel to panel. Over a wide frequency range, it is constant. Moreover, RT/Duroid is quite useful due to its low dissipation factor which laminates to Ku-band and above.

5.1.8 Copper

The oldest metals known to man are copper and gold. They were easily visible by their bright color. If we drop them, they do not shatter. If we cool them below 0 degree Celsius, they do not brittle. Non-magnetic copper has the qualities of being non magnetic and non sparking. It is used in special tools and military applications because of the above described qualities.

5.1.9 Alloys Easily

To make alloys we can combine copper with other metals. Brass and bronze are the most well-known alloys. Its needs to be hardened and strengthened for several industrial works although copper has excellent thermal and electrical qualities. When we solidify the solution made up of liquid metals.

5.1.10 Attractive Colors

The alloys of copper and copper itself are used for ornaments and jewelry. The natural golden attractive color differentiates with the content of copper. They last long because they've good resistance to tarnishing. It is very much suitable for decorative purposes. Statues, parts of buildings and jewelry can be made up of copper, brass or bronze and remain attractive for years and years.

5.1.11 Easily Joined

By soldering or brazing copper can be joined easily. It is beneficial in pipe work and in making sealed copper vessels. Copper and copper alloys are extremely tough. If we drop them, they do not shatter and if we cool them below 0 degree Celsius they become not brittle. It has the qualities of being non-magnetic and non-sparking. It is used in making special tools and military applications.

5.1.12 Corrosion Resistant

In the reactivity series copper is low. It displays that it doesn't tend to corrode. It is important because it is used in pipes, radiators, electrical cables and saucepans. It is suitable for decorative purposes, statues, parts of buildings and jewelry can be made up of copper, brass or bronze and remain attractive for years and years.

5.1.13 Anti-Bacterial

Copper slow down the growth of germs because it is naturally [3]hygienic metal such as legionella, MRSA and E-coil. Its needs to be hardened and strengthened for several industrial works although copper has excellent thermal and electrical qualities. When we solidify the solution made up of liquid metals.

Chapter 6

Miscellaneous Tasks

6.1 Project Compilation Timeline

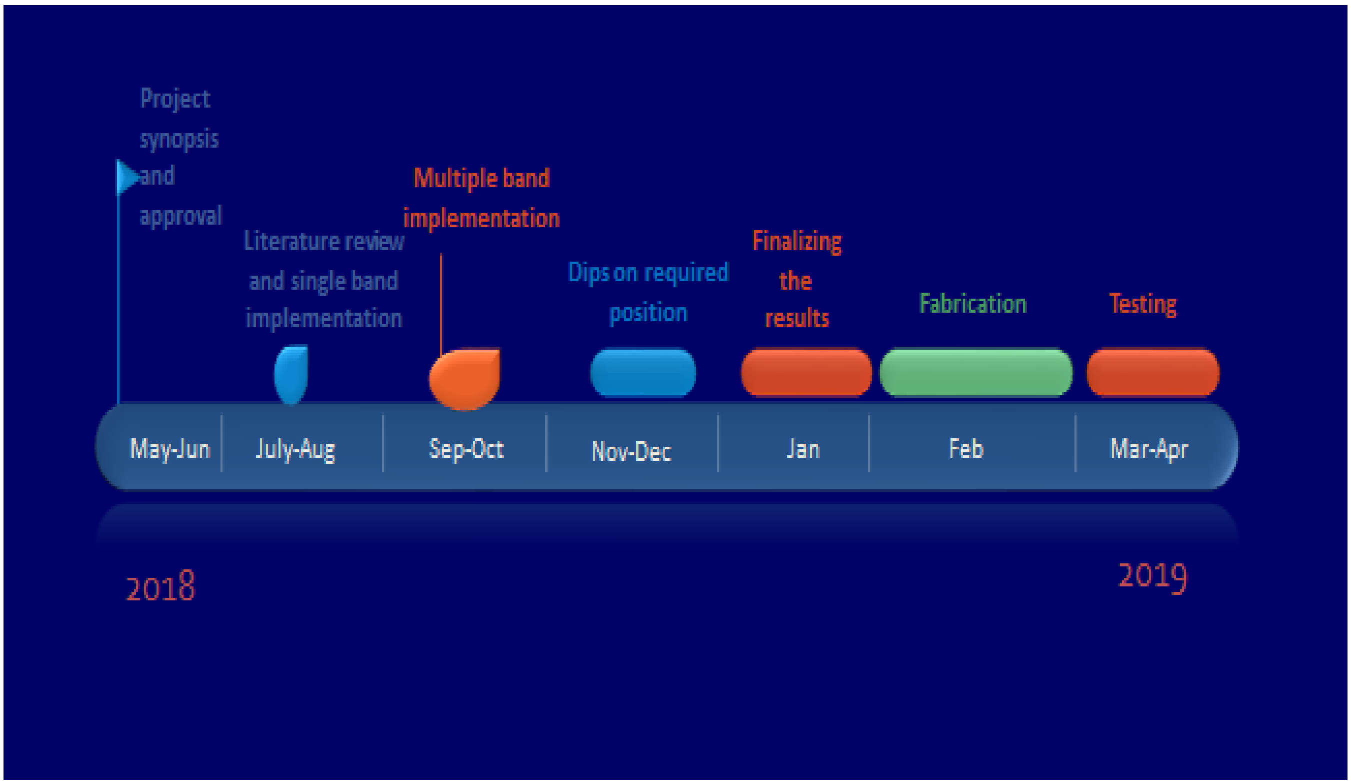


Figure 6.1 Timeline

6.2 Fabrication

Our antenna was fabricated on a Roger 5880 with dielectric permittivity of 2.2 and height of 1.55mm. RT/Duroid is easy to cut, sheared and machined to shape. It is also resistant to all types of reagents and solvents which are normally used in etching printed circuits or plating holes and edges.

These high frequency laminates have the lowest dielectric constant of all products and due to this property they’re well suited for broad band/ high frequency applications where losses and dispersion need to be minimized. RT/Duroid is also used in applications in high moisture environments due to its extremely low water absorption characteristics.

Also we have achieved good gain and better return loss as compared to FR4 Epoxy substrate material.

For better and accurate results we have got our antenna fabricated from NIE, Islamabad so that these results are close to the simulated results on CST.

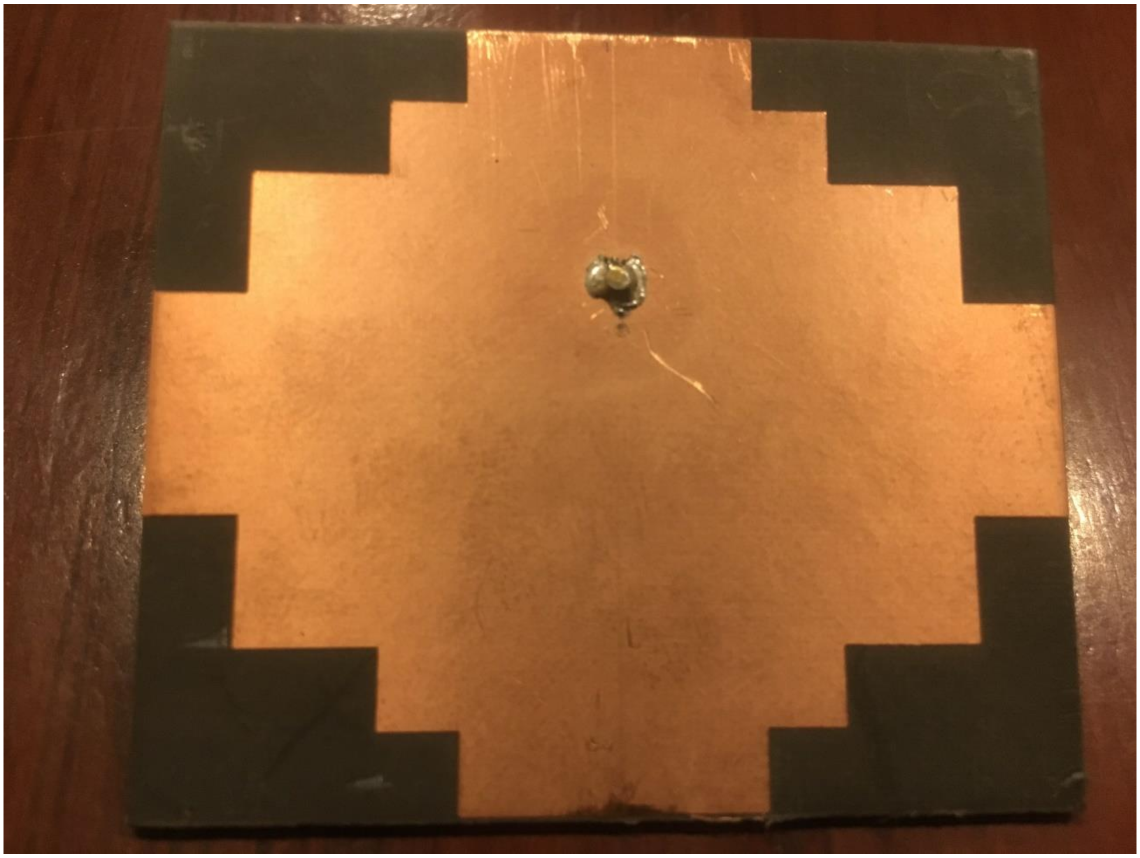


Figure 6.2 Front View of Fabricated Antenna

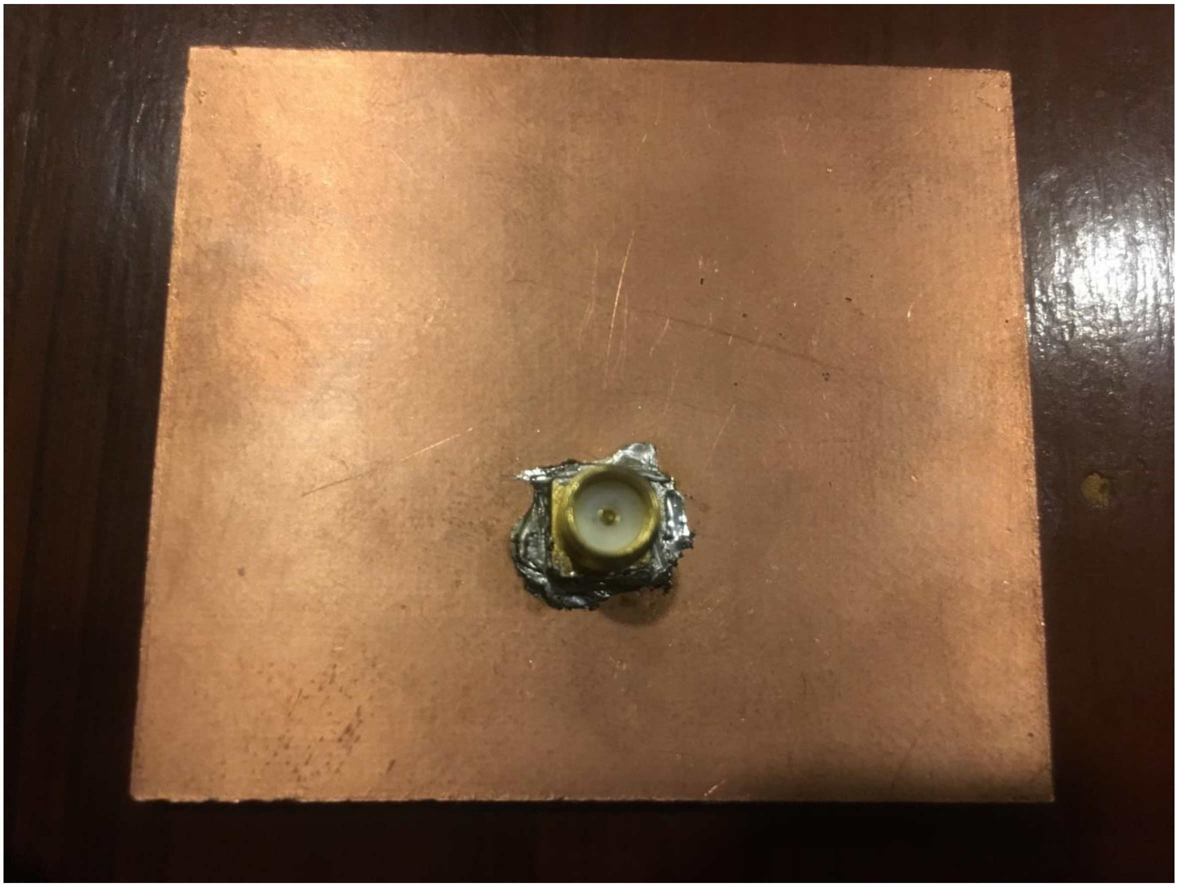


Figure 6.3 Back View of Fabricated Antenna

6.3 Testing of Results in Lab

We have got the testing of results of fabricated antenna done from NUST H-12 campus. We have got results similar to what we were able to achieve in CST simulation.

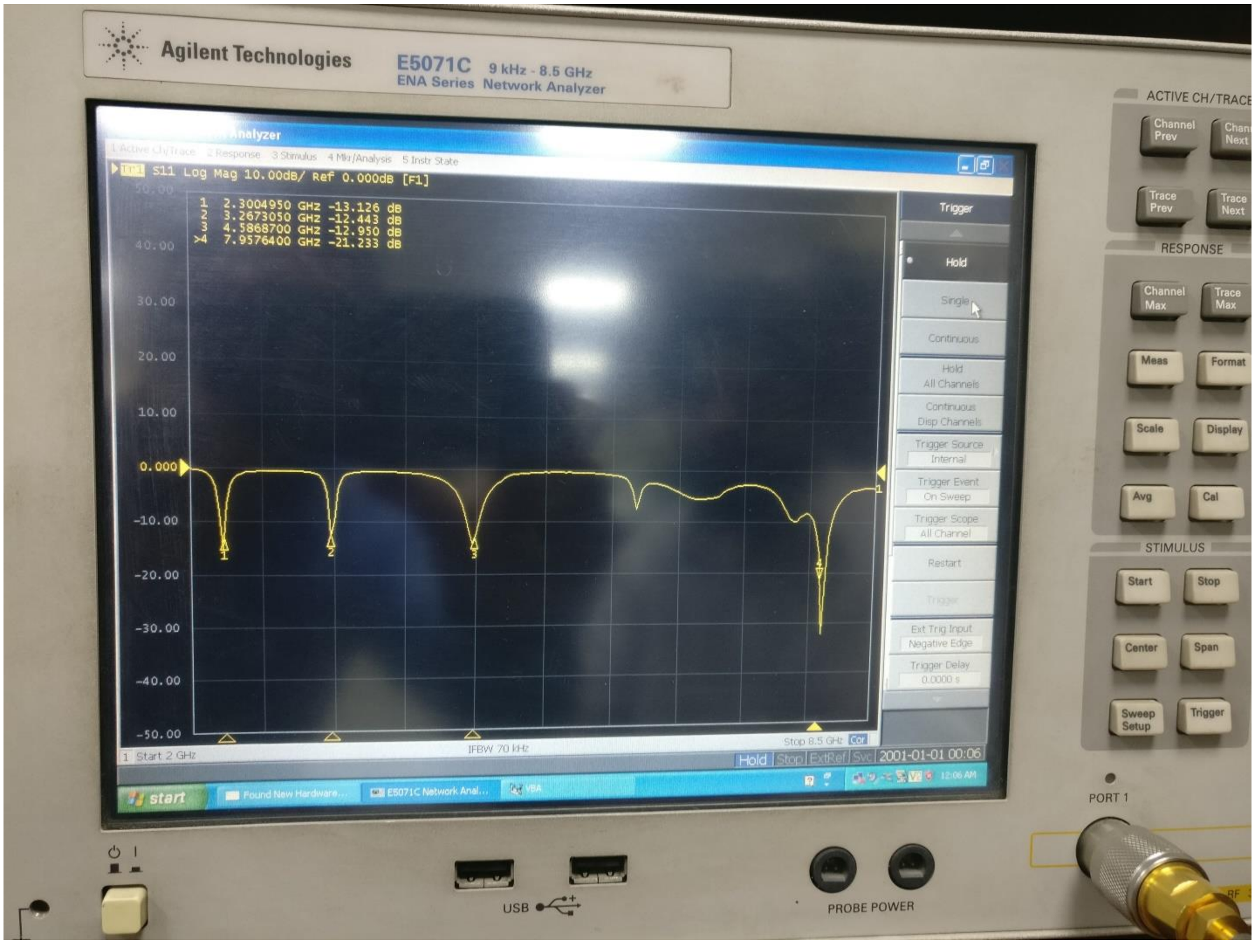


Figure 6.4 Testing results

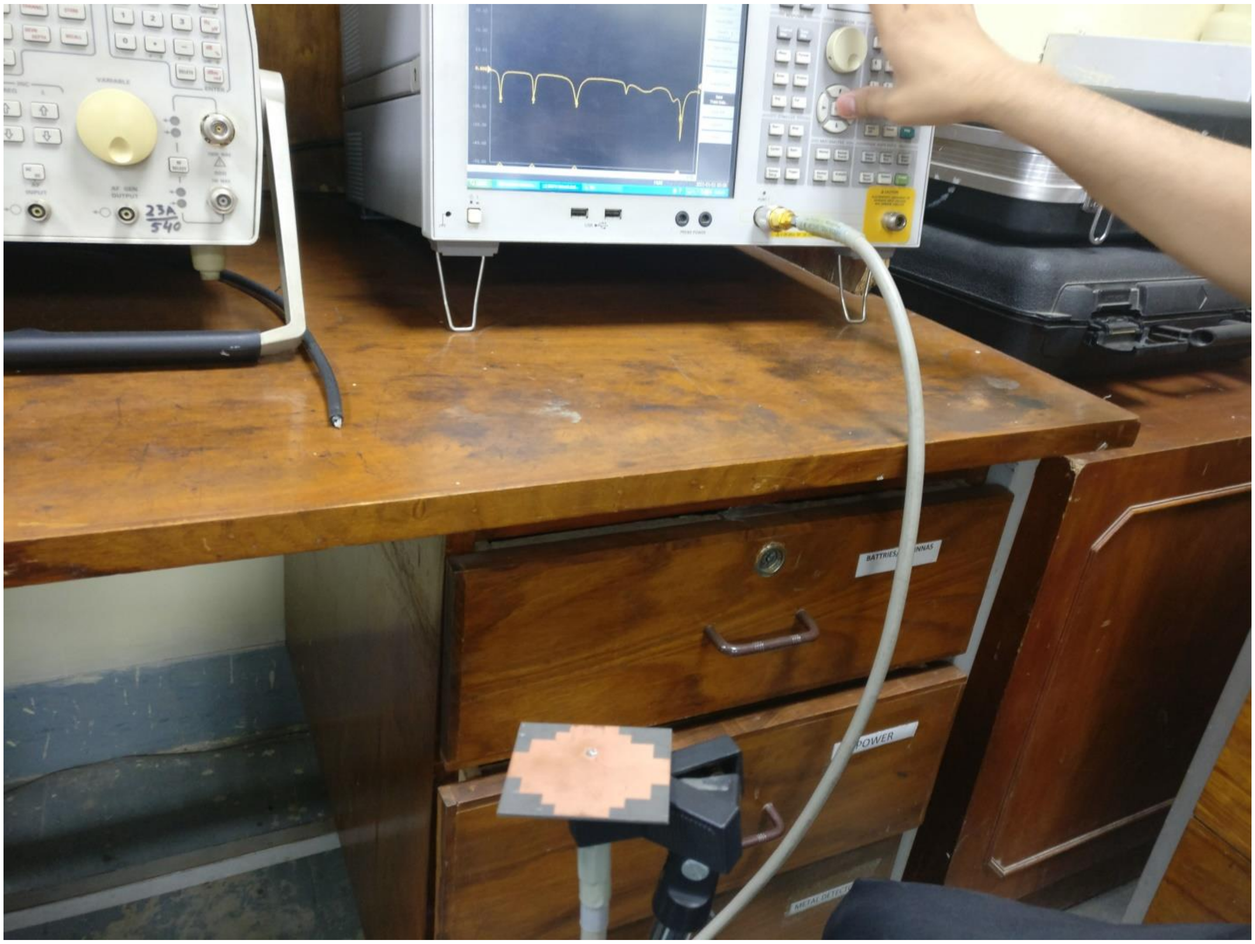


Figure 6.5 Testing Results

6.4 Applications of Antenna

The utmost important applications of these antennas are:

- Used for [5]satellite communication
- Used in the field of [3]biomedical
- Used in WLAN, [6]WIMAX, UMTS
- They're also typically used for space and military applications
- Used for [4]microwave communication

6.5 Facilities Used

- CST (Computer Simulation Technology)
- NIE (National Institute of Technology)
- SMRIMMS (Samar- Mubarakmand Research Institute of Microwave and Millimeter wave Studies)

6.6 References

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