A Multiband Four Element MIMO Antenna For 5G Communication

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Course

BETE-54

Supervisor

Lec Maryam Rasool

Submitted to the faculty of Department of Electrical Engineering,

Military College of Signals, National University of Sciences and Technology,

in partial fulfillment for the requirements of B.E Degree in Electrical Engineering

JULY 2021

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CERTIFICATE OF CORRECTIONS & APPROVAL

Certified that work contained in this thesis titled "**A Multiband Four Element MIMO Antenna For 5G Communication**", carried out by **PC Ali Younas, PC Mudassar Sajjad and ASC Danial Akram** under the supervision of **Lec Maryam Rasool** for partial fulfillment of Degree of Bachelors of Electrical Engineering, in Military College of Signals, National University of Sciences and Technology, Islamabad during the academic year 2020-2021 is correct and approved. The material that has been used from other sources it has been properly acknowledged / referred.

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Thesis Fractal MIMO Antenna PC Ali Younas

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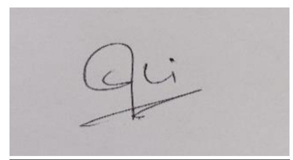

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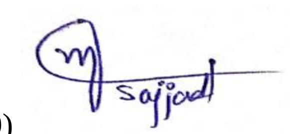

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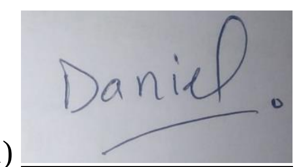

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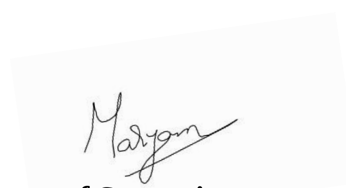

Signature of Supervisor

Lec Maryam Rasool

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Finally, we would like to express my gratitude to all the individuals who have rendered valuable assistance to our study.

Dedicated to our exceptional parents and adored siblings whose tremendous support and cooperation led us to this wonderful accomplishment.

Abstract

Spectrum and energy efficiency of latest systems needs upgrades without increasing the transmit power, so antennas need to be designed for such systems targeting the particular frequencies involved in modern 5G communications. Multiple-input multiple-output (MIMO) systems, outfitted with enormous number of antennas, can be utilized to improve the spectrum and energy efficiency of modern wireless communication systems. MIMO antennas appear as the most encouraging innovation in the fifth generation (5G) wireless communication system. The project targets the popular 5G communication devices operating in the licensed bands of 5G in the region. In this study, we have designed a fractal shape 4 element multiband MIMO Antenna operating in the sub 6 GHz band of 5G communication. We have selected FR4 Epoxy (relative permittivity of 4.4) for the material of the substrate. We have given height of 1.6 mm to the substrate and have used modified Minkowski geometry for the fractal shape. Our project has two operating frequency bands.

Key Words: *Frequency bands, 5G Communication, Multiple-input multiple-output (MIMO), Fractal Antenna, Modified Minkowski Geometry, 4-element, Dual band*

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Key to Abbreviations

1.	MIMO	Multiple Input Multiple Output
2.	HFSS	High Frequency Structure Simulator
3.	FR4	Flame Retardant 4
4.	NIE	National Institute of Electronics
5.	PCB	Printed Circuit Board
6.	MCS	Military College of Signals
7.	NUST	National University of Sciences & Technology
8.	RF	Radio Frequency
9.	MATLAB	MATrix LABoratory
10.	RIMMS	Research Institute for Microwave and Millimeter Wave Studies

CHAPTER 1: INTRODUCTION

1.1 General

Antenna:

"A metallic device utilized for radiating (transmitting) and receiving radio waves are called Antenna" this is according to webster's dictionary definition [1].

Antenna is a device which is used to transmit electromagnetic waves at transmitting end and receives electromagnetic waves at receiving end. Generally, antennas are resonating devices which works on narrow frequency band. A receiving antenna ought to be coordinated or tuned to same recurrence band through which it is associated with radio system, in any case transmission and gathering will disabled.

It is a transitional design between free space and directing gadget. Directing gadget may be a hollow tube, a coaxial cable or two wire line for the transmission of electromagnetic waves from communicating circuit to antenna (Transmitting) and from antenna to communicating circuit (Receiver). Antenna is base for wireless communication. Without it wireless communication is impossible. It has been seen that by nature every metallic body is an antenna, which works on a specific frequency known as frequency band of antenna. Thevenin and Norton had presented a circuit which is called as equivalent circuit of an antenna [2].

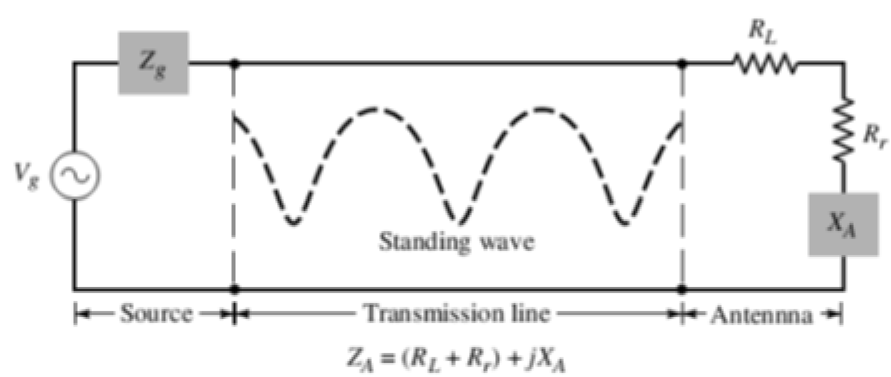


Figure 1.1: Antenna Equivalent circuit [3]

In the equation $\mathbf{Z_A}$ represents the impedance of antenna whereas $\mathbf{R_L}$ represents the antenna losses (Conduction Losses + Dielectric Losses), **Rr** represents the radiation resistance. $\mathbf{X_A}$ is reactance and shows the imaginary part of antenna impedance.

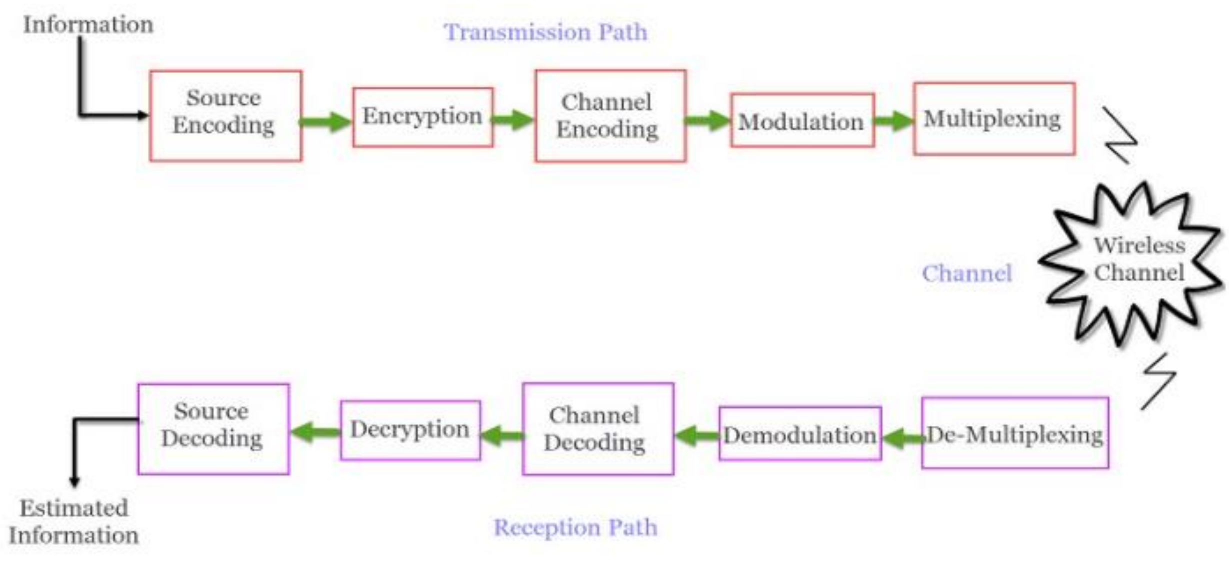
For the fruitful transmission of any signal antenna ought to be coordinated On the off chance that there is any crisscross among antenna and transmission line impedance, reflection of electromagnetic will happen because of which standing waves will be delivered and sign won't travel effectively.

1.2 Basics of Wireless Communication

In the field of Telecommunication, wireless communication is the quickest developing innovation. Wireless is technique for communicating information/data starting with one point then onto the next point with no physical media like copper link, FE link or Optical fiber link. Generally, in communication system info is communicated among transmitter and collector that are put over a restricted distance. We live in a universe of wireless communication which especially a vital piece of our lives. Some usually utilized wireless communication systems in our everyday life are smart phone, Wi-Fi, Bluetooth sound and controllers.

An antenna is the basic element without a wireless communication is not possible. Ordinary wireless communication tends to be partitioned into three sections.

1) Transmitter
2) Frequency Channel
3) Receiver



<u>Figure 1.2:</u> Basic path of Wireless Communication [4]

Transmission Path:

Transmission path generally consist of source encoding, encryption, channel encoding, modulation, and multiplexing. The data from source is encoded after that encryption of data applied after encryption channel encoding occurs. After channel encoding modulation is used different modulation schemes are used like PSK (Phase shift keying), FSK (Frequency shit keying) and QPSK (Quadrature phase shift keying) etc. after modulation all different data are multiplexed through several multiplexing techniques like TDM (Time Division Multiplexing), FDM (Frequency Division Multiplexing), etc [5].

Frequency Channel:

Frequency channel indicates the medium of transmission. After whole data multiplexed sent over frequency channel via an antenna. Interference, noise, distortion scattering may be occurred in channel due which receiver end receives errors in information [6].

Reception Path:

Receiver gets signal from the channel and replicate it as source signal. After receiving signal de-multiplexing occurs then demodulation of signal occurs after demodulation channel decoding, decryption and source decoding occurs [4].

1.2.1 Evolution in 5G communication

In firstly deployed technology 1^{st} Generation (1G) simply allowed us to call each other when 2^{nd} Generation (2G) deployed it allowed us to send and receive short service messages. The broadband connectivity and Internet accompanied third Generation (3G) and fourth Generation (4G) which made association speed significantly faster. First thing that we have to understand that 5^{th} Generation (5G) is not a fixed standard and second thing that it will not replace 4G simply. It is much like an organic entity that will change and evolve over the time.

5G is distinct advantage it does not permit cell phone to interface with web yet in addition permit to associate with one another. 4G is quick yet 5G has ongoing access which is right around multiple times quicker than 4G. Speed isn't the lone thing significant in the varying media industry, in the

AV business, network, thickness, limit of traffic and deferral are likewise huge differences. The concede will drop to 1ms [millisecond] in 5G, stood out from the current 50ms 4G deferment [7].

The ability to send sound, explicitly, in this sort of sign promptly, will bring various extra freedoms. There is moreover a change in way the signals are sent [8].

1.2.2 Frequency & Application

The frequency bands which we are targeting basically lie in sub 6 GHz frequency of 5G Communication. We are targeting at least two frequency bands which are 3.0-3.2 GHz and 4.8-5 GHz.

The applications of these bands are that they are common bands which can be used for 5G Communication. The targeted frequency band of 4.8-5 GHz is of China and it tends to be useful for us later on. Pakistan has not yet acquired 5G license, so we have chosen the frequency bands which are commonly used.

1.3 Types of Antennas

There numerous kinds of antennas but following types are antennas are mostly we can find every in every antenna related literature work.

- Wire Antennas
    - Short Dipole Antenna
    - Dipole Antenna
    - Loop Antenna
    - Monopole Antenna
- Travelling-wave Antennas
    - Long Wire Antenna
    - Yagi–Uda Antenna
    - Helical Wire Antenna
    - Spiral Antenna
- Array Antennas
    - Two-Element Array Antenna
    - Linear Array Antenna
    - Phased Array Antennas
- Aperture Antennas
    - Slot Antenna

    - Horn Antenna
- Lens Antennas
- Log Periodic Antennas
    - Bow Tie Antennas
    - Log-Periodic Antennas
    - Log-Periodic Dipole Array
- Microstrip Antennas
    - Rectangular Microstrip Patch Antenna
    - Quarter-Wave Patch Antenna
- Reflector Antennas
    - Flat-plate Reflector Antenna
    - Corner Reflector Antenna
    - Parabolic Reflector Antenna [9]

Now we will discuss following three types of antennas

1) Multi-input multi-output (MIMO)
2) Fractal Antennas
3) Patch Antennas

1.3.1 Multi-input multi-output (MIMO)

In wireless communication we increment the limit of a radio connection by utilizing different transmission and accepting receiving antenna to misuse multipath engendering this strategy/procedure is known as Multiple-input multiple-output (MIMO). MIMO is an fundamental part of wireless communication standards like IEEE 802.11ac (Wi-Fi), IEEE 802.1n (Wi-Fi), LTE, WIMAX and HSPA+ (3G). In MIMO we not just utilize various reception apparatuses at transmission and accepting end we send and get more than one data signal meanwhile over a comparative repeat channel by abusing multipath spread. MIMO antenna generally is unique in relation to brilliant reception apparatus methods which are created to improve the presentation of single information signal, beamforming and variety and so forth [10].

In conventional radio system one antenna is used at transmitting (Tx) end and other antenna is used at Receiving (Rx) end for the transmission of information/data over a frequency channel, that’s why such a system called Single-input single-output (SISO). The block diagram of SISO is given in 1.3(a).

But in MIMO we increase the capacity of a channel by using multiple antennas at Transmitting (Tx) end and multiple antennas at Receiving (Rx) end [11].

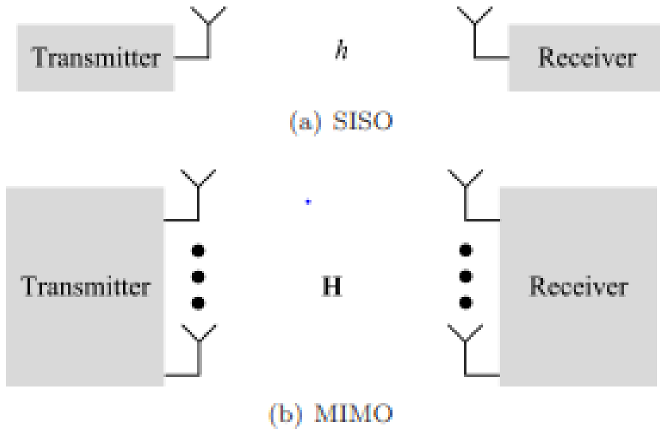


Figure 1.3: **Block diagram of SISO & MIMO System diagram [11]**

In MIMO multipath propagation occurs, in free space when an electromagnetic wave transmitted from Tx antenna it reaches Rx receiving antenna along the Line-of-sight proliferation way. But in mobile communication the major mechanism used for propagation is N-LOS (Non-Line-of-sight propagation). This is brought about by collaboration of radio waves with various dispersing objects in the radio channel. For instance, the Tx wave can be shadowed by enormous protested, reflected by smooth surface, dissipated from unpleasant surface, and diffracted at the edges of scatterers. The got signal is consequently a summation of various duplicates of the communicated signal that movement through these distinctive spread ways, known as multi-way parts (MPCs). These MPCs add productively and ruinously, causing the multi-way blurring marvel. In a SISO framework, one requirement to configuration devoted handset calculations (e.g., leveling) to battle execution debasement due to multi-way blurring. In any case, multi-way blurring ends up being the key for using multi-antenna procedures. For example, there is a fundamentally more modest likelihood that every one of the signs across spatially isolated antennas experience profound blur at the same time, when contrasted with it happening in the sign from one antenna. The methodologies that misuse this part of multi-antenna frameworks are known as space variety [11].

1.3.2 Fractal antenna

In modern era of communication an antenna should have wider bandwidth, low profile and multiband frequency range. Antennas are in immense interest for both military and business applications. Generally, an antenna works on single recurrence or double recurrence though various antennas are required for various applications. Fractal antennas have some extraordinary attributes that are connected to the different math and properties of fractals. In 1975 fractal was first presented by Benoit Mandelbrot. Fractal can be utilized in various fields like picture pressure, examination of high elevation lightning wonders [12].

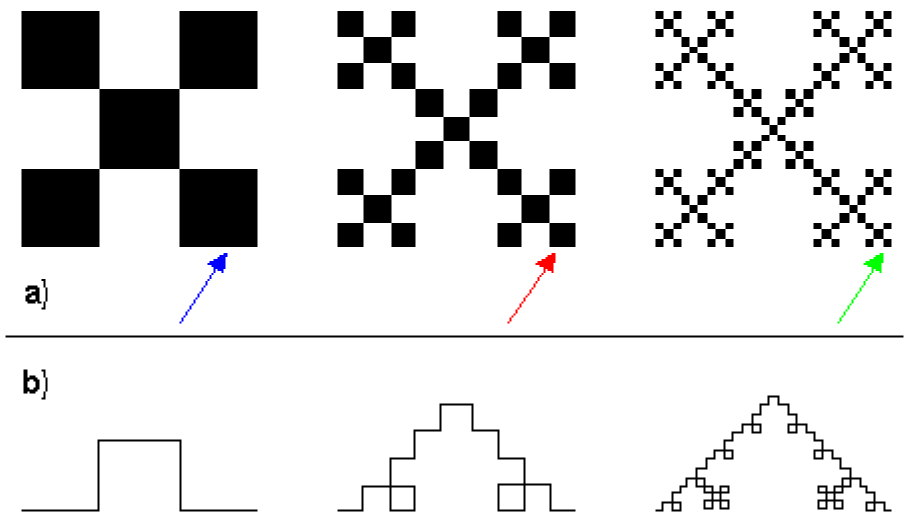
There are different advantages when we apply these fractals to create different antenna elements:

a) we can optimize the gain of antenna
b) we can create a smaller size antenna
c) we can achieve multiband frequencies or wideband frequency band
d) we can achieve resonating frequencies that are multiband.

Fractals have limitless intricacy and detail that can be utilized to lessen antenna estimate and grow low profile antennas. Why we need fractal antennas?

Reason are

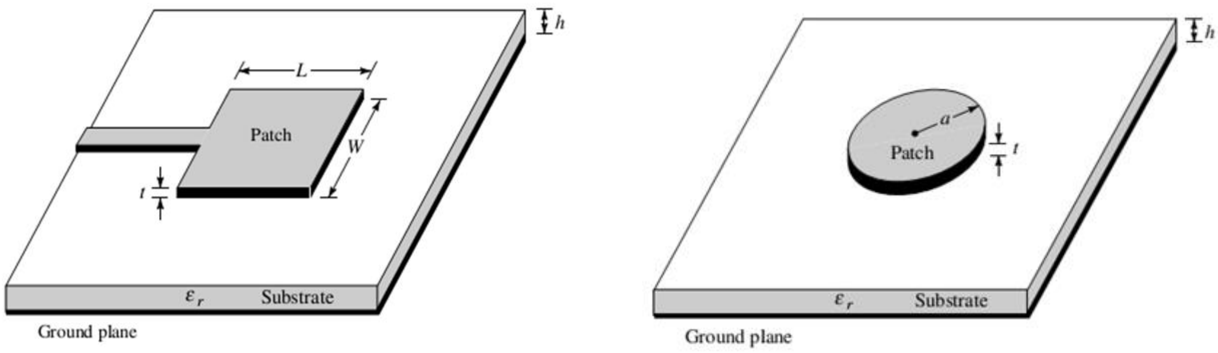
1) broadband and multiband frequency response
2) mechanical simplicity and robustness
3) compact size compared to conventional antennas
4) attributes of fractal antennas are because of its geometry not on account of expansion of discrete parts
5) Configuration to suit specific multi-frequency attributes containing determined stop groups just as explicit different pass groups as required [13]



<u>Figure 1.4:</u> Common Examples of fractal geometries [14][15]

1.3.3 Patch antenna

A patch is an antenna with low profile, which can be mounted on level surface. Patch antenna comprise of planar rectangular, three-sided, roundabout or any mathematical sheet or "patch" of metal mounted on ground plane. Ground plane is a metallic sheet which is bigger in size as contrast with patch. In patch antennas as prior talked about the state of patch could be ordinary or sporadic. Patch is planted on substrate; they are generally non-metallic in nature and supported by ground plane [16].



a) Rectangular **b) Circular**

Figure 1.5: Patch antenna structure a) Rectangular b) Circular [17]

Patch antennas have many applications in Civil, Military, GPS system and space. They are low profile, light weight, simple, easy to fabricate, planer and Non planer surfaces, low cost, these qualities made patch antenna very advantageous to be used [17].

Different patch antennas are used in cell phones which is shorted antenna or Planar modified – F antenna (PIFA). In this antenna, one corner of the patch is grounded with a ground pin, this has finer coordinating then ordinary patch [16].

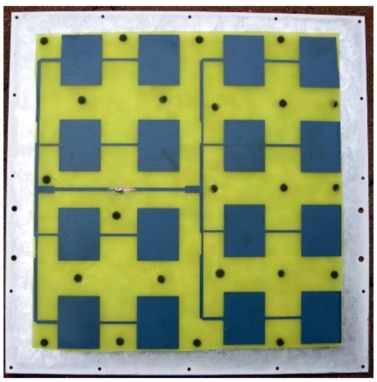
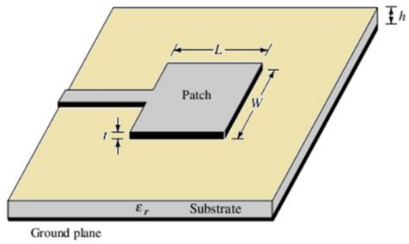


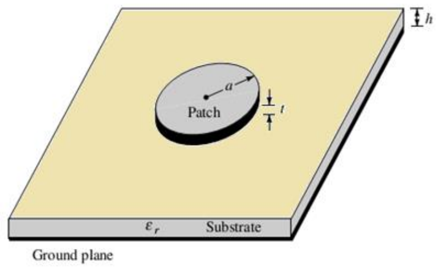
Figure 1.6: 2.4GHz Patch antenna [16]

1.4 Microstrip Patch antenna

In 1970 first time Microstrip patch antenna used. They have many Civil, Military, GPS system and Space applications. They have planar resonating cavities which are used for radiation. They consist of a regular or irregular simple patch planted on a substrate and ground plane on the opposite side of substrate. Patch and ground plane are metallic, and substrate is usually a non-metallic. In microstrip patch antennas as earlier discussed the shape of patch could be regular or irregular. They are low profile, light weight, simple, easy to fabricate, planer and Non planer surfaces, low cost, these qualities made patch antenna very advantageous to be used [17].

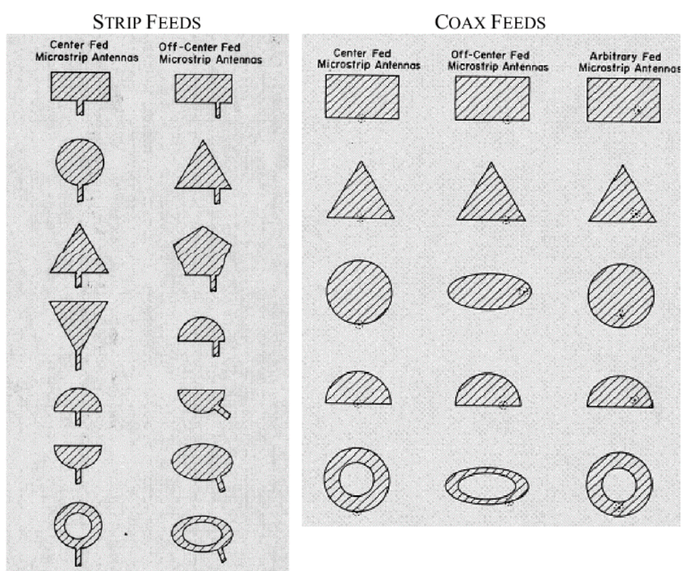


<u>Figure 1.7:</u> Rectangular Microstrip Patch antenna [17]



<u>Figure 1.8:</u> Circular Microstrip Patch antenna [17]

Excitation of microstrip patch antenna is very easy, they can be excited using strip feed line or coax feed. Mutual induction and mutual coupling can also be used to excite microstrip patch antenna.



<u>Figure 1.9:</u> Microstrip feed mechanism [17]

Different methods to excite micro strip antennas are discussed in this chapter, which are isolated into two classes i.e. Contacting and Non-contacting. At the point when the RF power is taken care of to the transmitting patch straight by utilizing miniature strip line as an interfacing component then this method is characterized to contact. On the other hand, when the power between micro strip line and radiation patch is transferred by using the electromagnetic field coupling then it is non-contacting. Following are the most important feeding techniques that are used for the feeding purposes mostly

As earlier discussed, there are some advantages of microstrip patch antenna but it's also have disadvantages. Advantages are mentioned again.

a) Light weight
b) Low cost
c) Low profile
d) Planar structure
e) Easy to fabricate
f) Linear as well as circular polarization support capability
g) Mechanically robust when mounted on rigid surface.

Unfortunately, Microstrip patch antennas have more drawbacks than other antennas some of which are mentioned below.

a) Low power handling capacity
b) Narrow bandwidth
c) Low efficiency
d) Poor end Fire radiator
e) Surface wave excitation

Micro strip antennas due to their low sizes and cost have become very attractive for wireless communication. Some of their applications are listed below

f) Satellite communication
g) Military purposes
h) GPS systems
i) Implantable purposes
j) Portable devices

1.5 MIMO: An Evolving Technology for 5G

Multiple-input/multiple-out (MIMO) innovation is a set up wireless communications method for imparting and accepting various information signals all the while over a similar radio channel. MIMO procedures assume a noticeable part in Wi-Fi correspondences, just as 3G, 4G, and 4G LTE organizations.

5G New Radio, nevertheless, takes it to the accompanying level, introducing the possibility of massive MIMO, which — as the name induces — remembers the use of MIMO development for much greater extension for more prominent organization inclusion and limit. Massive MIMO utilizes a lot more send and get receiving antennas to build transmission acquire and unearthly productivity. To accomplish massive MIMO limit, acquire, different UEs should create downlink traffic all the while. Numerous factors sway the real increase given by massive MIMO [18].

Massive MIMO — alongside shrewd antenna procedures, for example, beamforming and bar directing — are among the basic advances for enabling the higher throughput and cutoff gains ensured by 5G. Moreover, they are major for passing on the 100x data rates and as far as possible goals showed in the International Mobile Telecommunications-2020 (IMT-2020) vision [19].

Since massive MIMO utilizes a lot a greater number of antennas than the quantity of UEs in the cell, the shaft is much smaller, empowering the base station to convey RF energy to the UE all the more correctly and effectively. The antenna's stage and gain are controlled independently, with the channel data staying with the base station, working on UE without adding various beneficiary antennas. Establishment of countless base station antennas will expand the sign to-commotion proportion in the cell, which prompts higher cell site limit and throughput. Since 5G massive MIMO execution is on mm Wave frequencies, the antennas required are little and simple to introduce and keep up [20].

1.6 Problem Statement

The range and energy effectiveness of current modern systems needs improvements without increasing the transmit power. Antennas need to be designed for such systems focusing on the particular frequencies associated in modern 5G communications.

We are required to design antenna having specific frequency ranges for 5G Communication having more range and energy effectiveness without significant changes in the modern system.

1.7 Proposed Solution

Massive MIMO is our proposed answer for the issue listed above. Multiple-input multiple-output (MIMO systems are outfitted with tremendous number of antennas. It can be utilized to improve the range and energy productivity of present day modern wireless communication systems.

It is the as of now most convincing sub-6 GHz remote access innovation for 5G. Since its commencement about 10 years prior, it has advanced from a wild "scholastic" plan to one of the most blazing examination themes in the remote correspondences local area, just as a principle work thing in 5G normalization.

It is a multi-client MIMO innovation that can offer consistently great support to remote terminals in high-versatility conditions. The key idea is to outfit base stations with varieties of a large number, which are utilized to serve numerous terminals all the while, in a similar time-recurrence asset. "Massive" allude to the quantity of receiving antennas and not the actual size.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

Before starting our project, we made a project timeline so that we can follow it and do tasks in mentioned time limit. Following shows our project timeline:

Table 2.1: Project Timeline

S/No	Activity	Estimated Time
1	Literature Review	Sep-Oct 20
2	Initial Software Design (Single element with single band)	Nov 20
3	Single element with dual band	Dec 20
4	Two-element with dual band	Jan 21
5	Four-element with dual band	Jan 20- Feb 21
6	Optimization (tri band or more elements) (optional)	Mar-Apr 21
7	Antenna fabrication	May 21
8	Antenna testing	May-Jun 21
9	Thesis	May-Jun 21

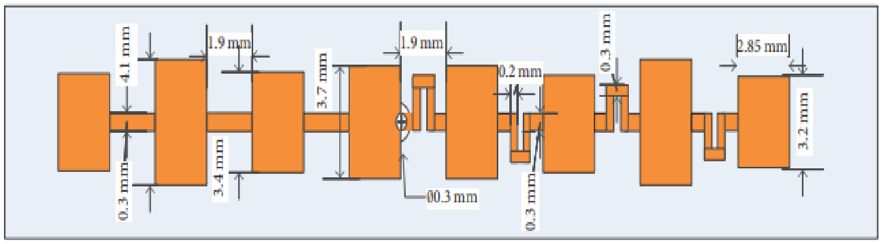
Before working on the project, we studied several research papers. Literature review is the first and most important step of any study. A detailed study of different papers is required for any good project. So, we did a detailed study of different research papers to get a clear and proper idea of many topics like 5G Communication, MIMO, 4-element and much more. This was necessary for the good final antenna design.

2.1.1 Research papers studied

We read different research papers and selected four of them which were related to our project domain and study.

2.2 Research Paper #1

Our first research paper is **"5G MIMO Conformal Microstrip Antenna Design"** by Qian Wang, Ning Mu, LingLi Wang, Safieddin Safavi-Naeini, and JingPing Liu. Its operating frequency bands are 32.45-36.2 GHz. Antenna design figure is shown below:



<u>Figure 2.1:</u> 5G MIMO Conformal Microstrip Antenna Design

2.3 Research Paper #2

Our next research paper is **"Single-Band PIFA MIMO Antenna System Design for Future 5G Wireless Communication Applications"** by Osama M. Haraz, Mohammad Ashraf, Saleh Alshebeili. This is used as a paper to guide us for the 5G Communication and MIMO antenna. Its operating frequency band is 27.5-28.5 GHz. Basic antenna diagram is given below:

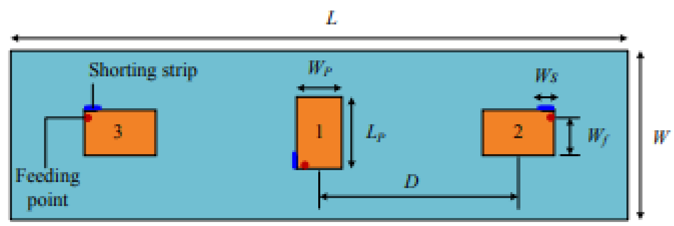


Figure 2.2: Single-Band PIFA MIMO Antenna System Design

2.4 Research Paper #3

The next research paper is **"Design and Optimization of LTE 1800 MIMO Antenna"** by Huey Shin Wong, Mohammad Tariqul Islam, Salehin Kibria. This paper is used for getting a clear idea for MIMO antenna. Its operating frequency is 1600-1900 MHz. Following shows the antenna diagram:

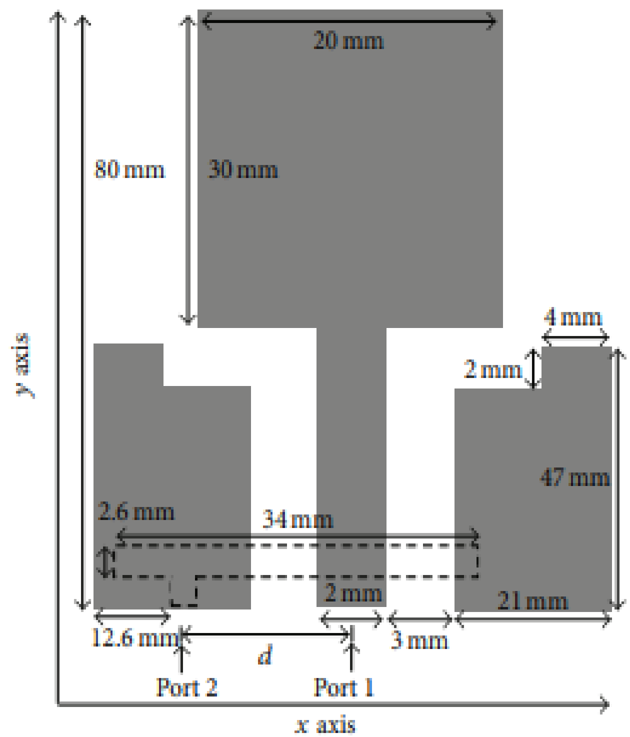
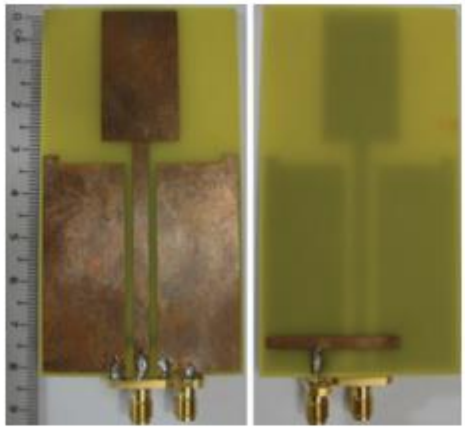


Figure 2.3: Design of LTE 1800 MIMO Antenna

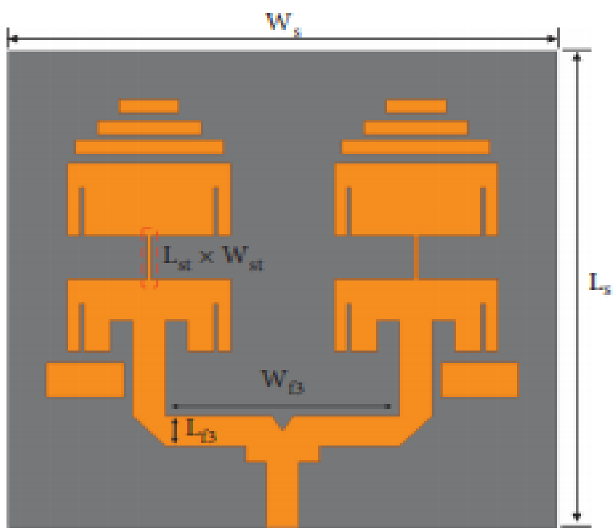
The fabrication of this design is given below:



<u>Figure 2.4:</u> Fabricated of LTE 1800 MIMO Antenna

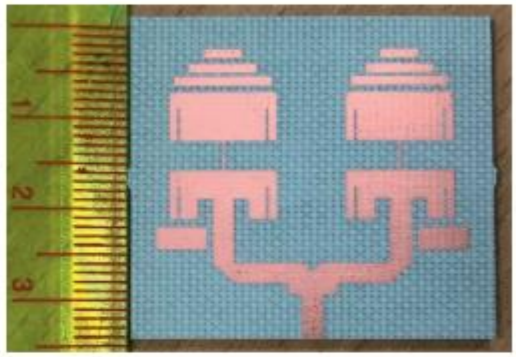
2.5 Research Paper #4

Last but not least, we have **"Four-Element Microstrip Patch Array Antenna with Corporate-Series Feed Network for 5G Communication"** by Janam Maharjan and Dong-You Choi. It was used to take the basic idea of a four-element 5G antenna. Its operating frequency band is 26-30 GHz. The antenna design of this paper is given below:



<u>Figure 2.5:</u> Four-Element Microstrip Patch Array Antenna with Corporate-Series Feed Network for 5G Communication

Its fabricated design is as under:



<u>Figure 2.6:</u> Fabricated design of Four-Element Microstrip Patch Array Antenna with Corporate-Series Feed Network for 5G Communication

2.6 Comparison of papers

The comparison of these papers is summarized in the table below:

<u>Table 2.2:</u> Comparison of papers

Research Paper	Operating Frequencies
Research Paper #1	Operating Frequency bands= 32.45-36.2 GHz
Research Paper #2	Operating Frequency band= 27.5-28.5 GHz
Research Paper #3	Operating Frequency band= 1600-1900 MHz
Research Paper #4	Operating Frequency band= 26-30 GHz

These papers have different operating frequencies and different designs. So, studying them deeply helped us get a clear idea of what to do for our antenna design and how to make our project timeline.

CHAPTER 3: ANTENNA DESIGN AND DEVELOPMENT

3.1 Single element single band

In order to design a single element single band, we studied many research papers. After studying we selected one as our main reference paper and then started working on our project. We used HFSS for doing the software part of our antenna. So, for the design of single element single band, first we draw a box having height of 1.6 mm and named it as “substrate”. Later, we assigned FR4-Epoxy as a material for it. Then, we made a modified ground on the bottom layer of substrate by using rectangular shapes. After that, we again used rectangular shapes for the top layer. Then, we made a rectangle and give it a 45 degrees’ rotation and placed it at the top of other rectangles (on top layer), unite them and we named it as a “patch”. At the end, we made use of the modified Minkowski Geometry for fractal shape.

3.2 Single element dual band

Earlier we designed single element single band so now our target was to make it a dual band. For design of single element dual band, we simply changed the dimensions of early designed single element single band antenna to get the dual band.

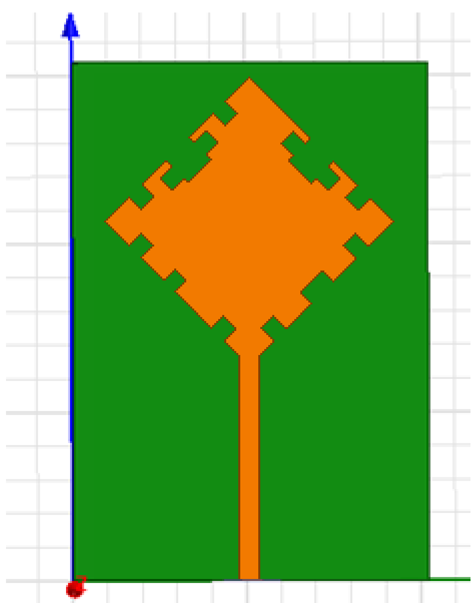
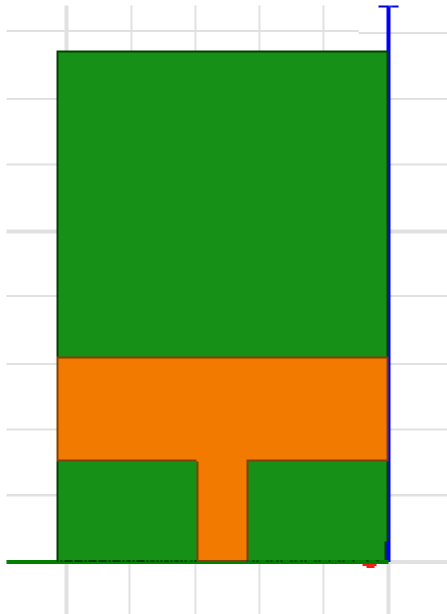


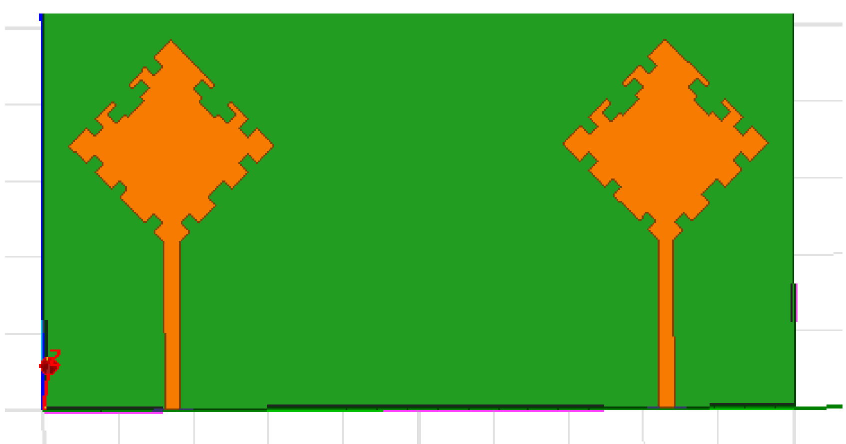
Figure 3.1: Top View of Single element dual band



<u>Figure 3.2:</u> Bottom View of Single element dual band

3.3 2-element dual band MIMO

In order to design a two-element dual band MIMO, we simply duplicated the single element as we designed earlier to the right side of it and get the two-element dual band MIMO.

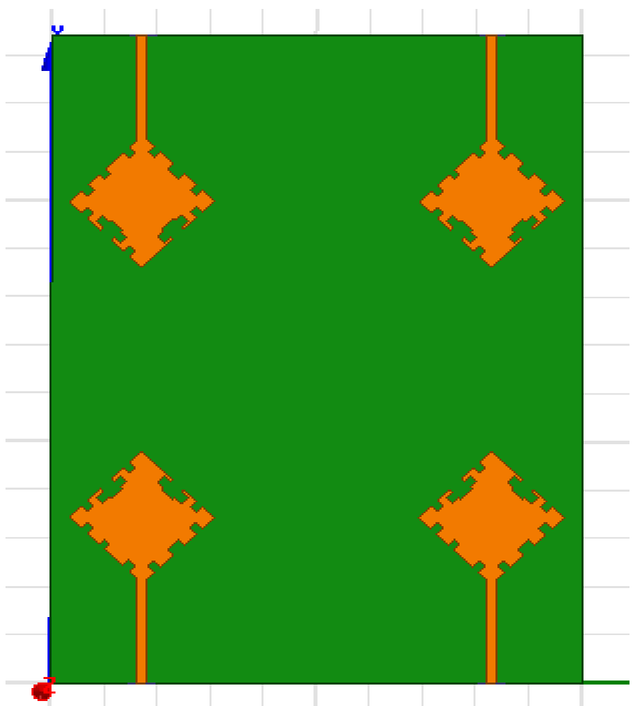


<u>Figure 3.3:</u> Top View of 2-element dual band MIMO

<u>Figure 3.4:</u> Bottom View of 2-element dual band MIMO

3.4 4-element dual band MIMO

As we already drew a 2-element dual band MIMO so for the designing of a 4-element dual band MIMO, we duplicated our 2-element dual band MIMO as a mirror on the other side of both the layers (top and ground).



<u>Figure 3.5:</u> Top View of 4-element dual band MIMO

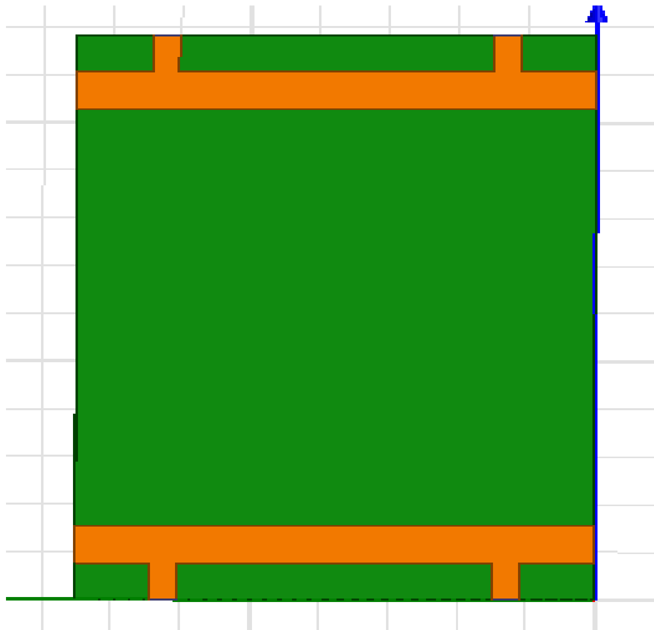


Figure 3.6: **Bottom View of 4-element dual band MIMO**

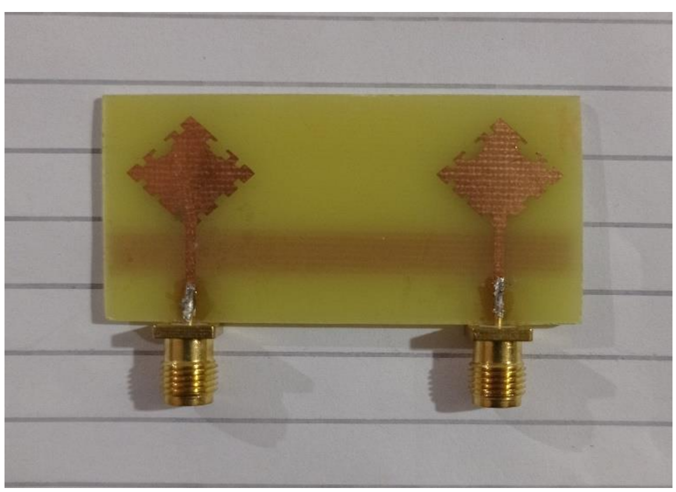
3.5 Fabricated antenna

After the software part on HFSS, we fabricated our designs. We went to NIE Islamabad for the fabrication of our designs. We did antenna fabrication on a FR4 having dielectric permittivity of 4.4. The height (thickness) of the substrate was 1.6 mm. FR4 substrates are the foremost selection of PCB applications. Since it is cheap and is easily available, it became the best choice for us to use it for our design implementation. We have also attached the connectors with our designs after fabrication. We went to our college, MCS - NUST Rawalpindi, for this purpose. We made use of RF Lab and did the soldering on our own.

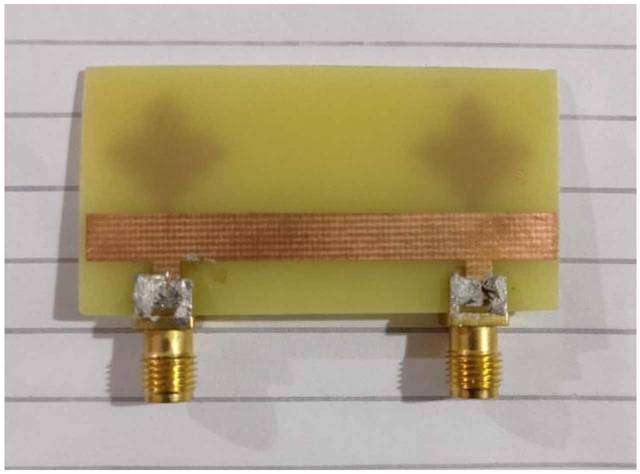
Here are the figures for our fabricated designs:

Figure 3.7: **Top View of Single element dual band after fabrication and soldering of connectors**

<u>Figure 3.8:</u> Bottom View of Single element dual band after fabrication and soldering of connectors

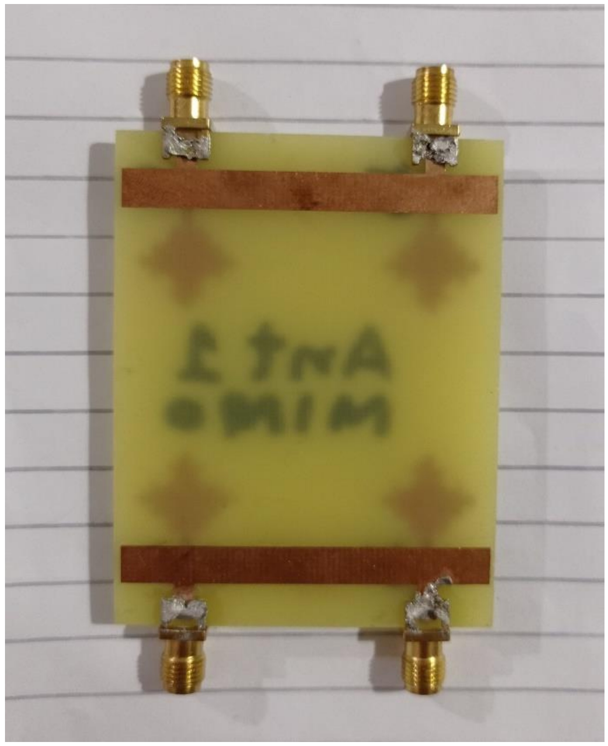


<u>Figure 3.9:</u> Top View of 2-element dual band MIMO after fabrication and soldering of connectors



<u>Figure 3.10:</u> Bottom View of 2-element dual band MIMO after fabrication and soldering of connectors

<u>Figure 3.11:</u> Top View of 4-element dual band MIMO after fabrication and soldering of connectors



<u>Figure 3.12:</u> Bottom View of 4-element dual band MIMO after fabrication and soldering of connectors

CHAPTER 4: ANTENNA MEASUREMENTS AND RESULTS

4.1 Simulated Results of Single element dual band

As we first made single element dual band antenna, so we calculated its results earlier. Correct result in this design was necessary for us to move on.

4.1.1 S_{11}

We checked the results of our single element dual band antenna and the most important result was return loss (S11). So, we calculated S11 result on HFSS and exported it as .csv file for displaying it on MATLAB. After that, we deleted the first row of the exported file and created .m MATLAB code for displaying result of S11. We get the following S11 result of our single element design:

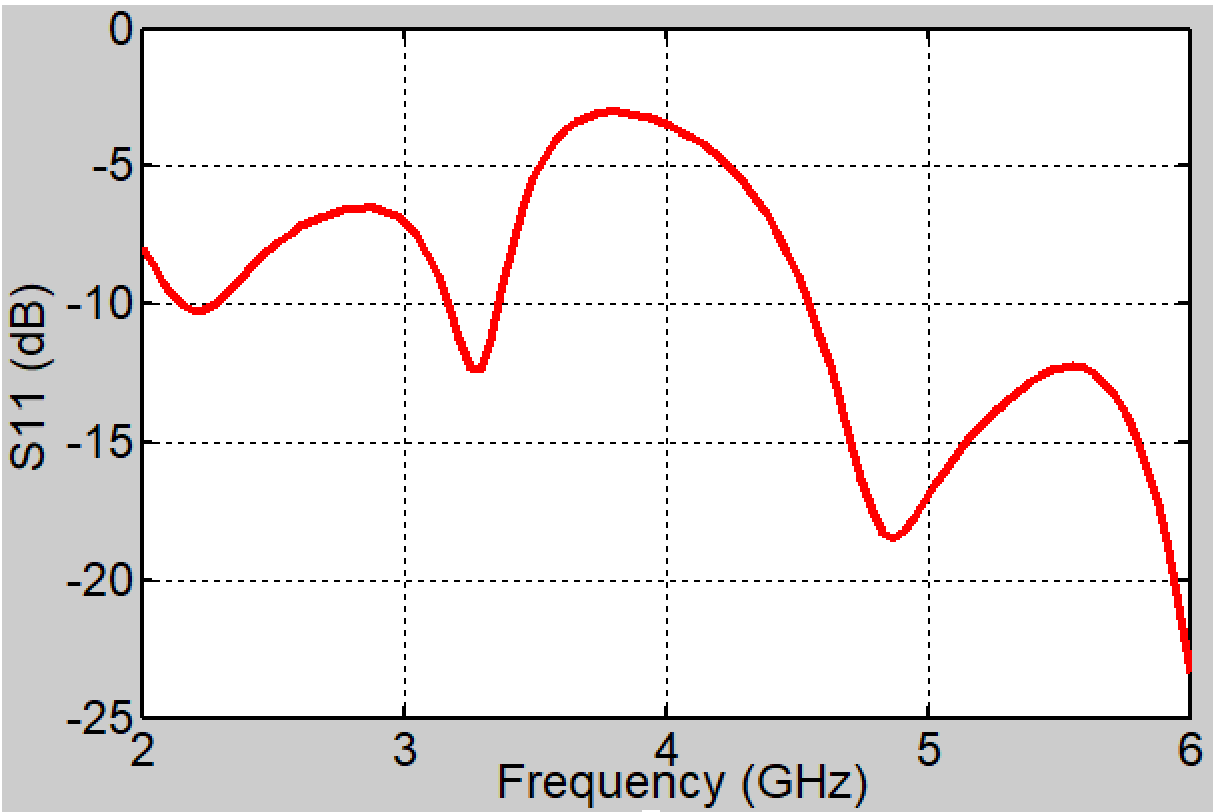
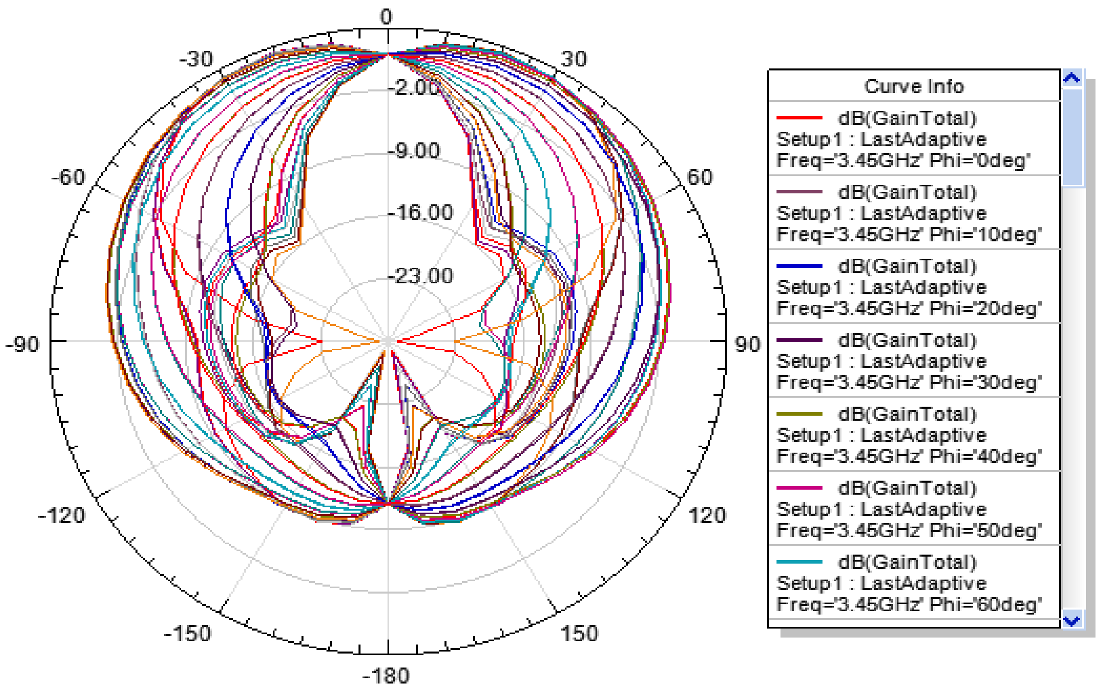


Figure 4.1: S11 result for Single element dual band on MATLAB

4.1.2 Radiation Pattern

Next, we observed its radiation pattern on HFSS which is shown below:



<u>Figure 4.2:</u> Radiation pattern for Single element dual band on HFSS

We observed that our single element design is having dual band. So, we moved on to our next target to have more elements.

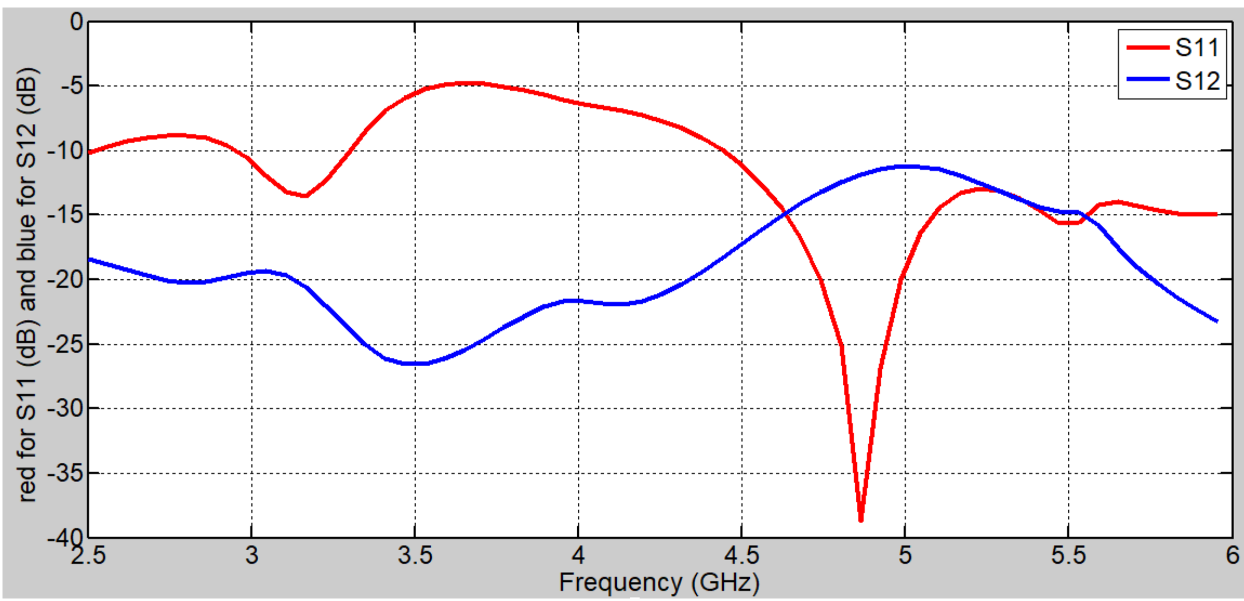
4.2 Simulated results of 4-element dual band MIMO

Here we will discuss about our simulated results of 4-element dual band MIMO.

4.2.1 S_{11} and S_{12}

First, we validated then analyzed our design and created results in HFSS. After that, we used MATLAB software as well for getting better results and for other purposes like displaying two results (different graphs) on single graph.

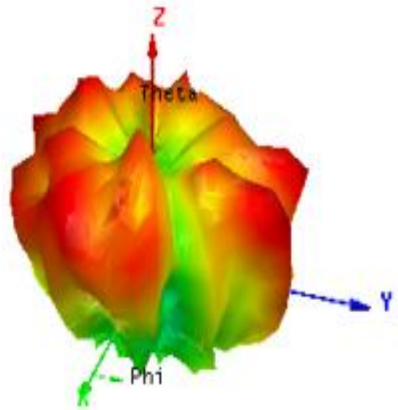
Then we exported the S11 and S12 results as a .csv files and stored both of them in one folder. After that, we deleted the first row of both the exported files and created .m MATLAB code for displaying results of S11 and S12 on same graph (using "hold on" command). We get the following S11 and S12 results of our design:



<u>Figure 4.3:</u> MATLAB result for S11 and S12

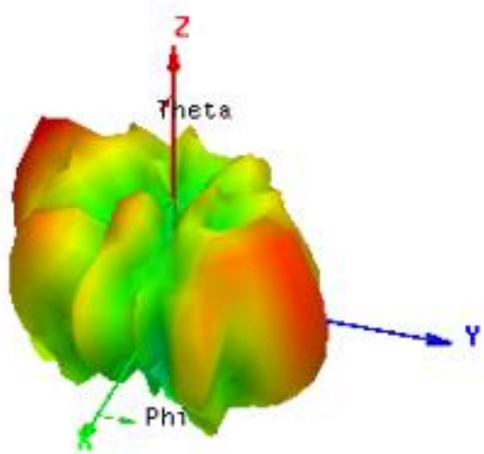
4.2.2 Gain

For calculating gain at two frequency peaks, we used HFSS and get the following results:



<u>Figure 4.4:</u> HFSS Gain for frequency peak 4.8636 GHz for 4-element dual band MIMO

The simulated result was 14.698 dB gain at the frequency peak of 4.8636 GHz while testing the antenna, the result we measured was 14.45 dB.



<u>Figure 4.5:</u> HFSS Gain for frequency peak 3.1667 GHz for 4-element dual band MIMO

The simulated result was 2.1 dB gain at the frequency peak of 3.1667 GHz while testing the antenna, the result we measured was 1.96 dB.

4.2.3 Radiation Pattern

Next, we observed its radiation pattern on HFSS which is shown below:

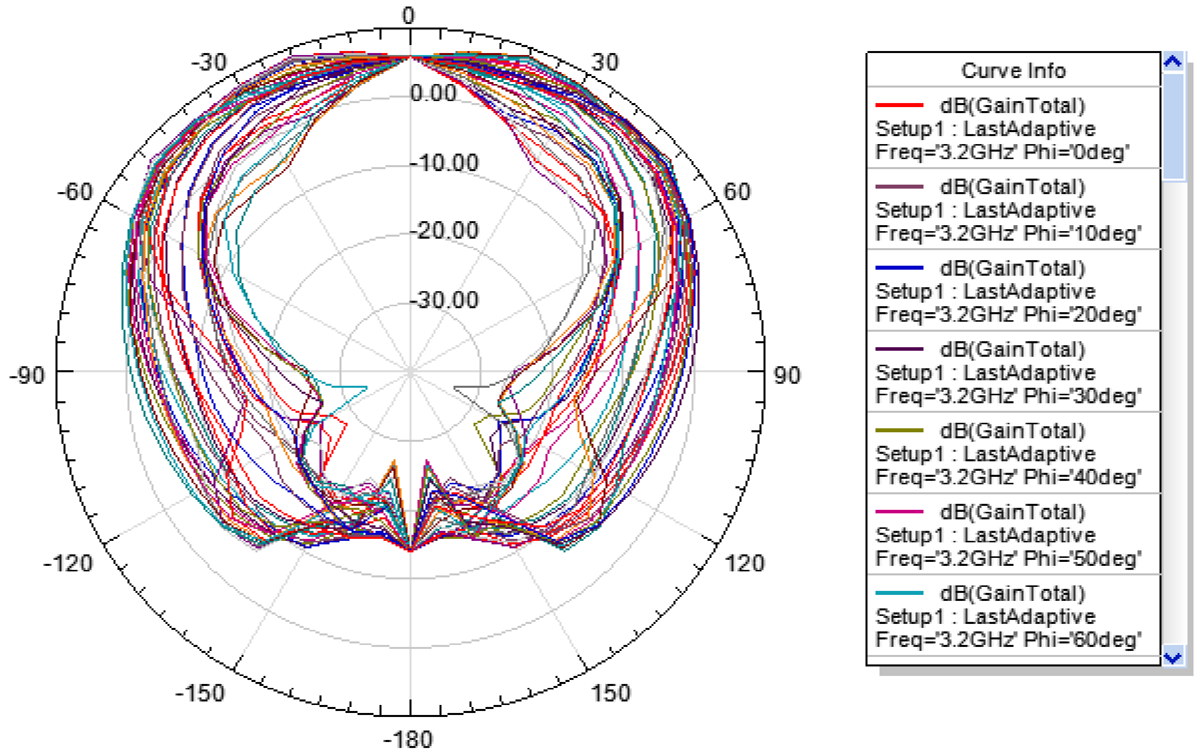


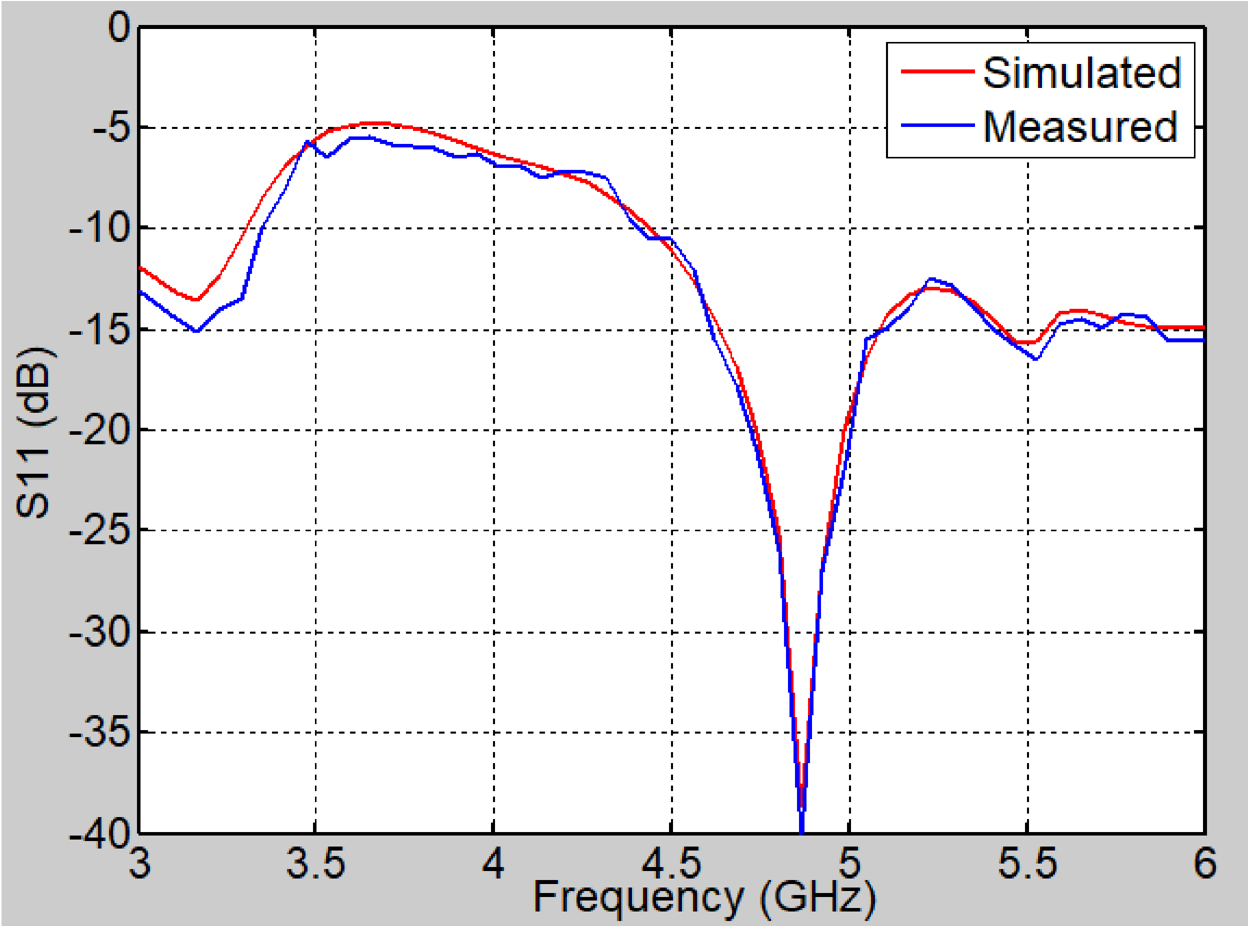
Figure 4.6: Radiation pattern for 4-element dual band MIMO on HFSS

4.3 Measured results

After getting correct simulated results and doing fabrication from NIE, we went to RIMMS – NUST for testing our fabricated antenna.

We make use of the .snp files from RIMMS to get the results in MATLAB.

We observed S11 simulated and measured results in MATLAB:



<u>Figure 4.7:</u> S11 result on MATLAB

We get the correct results from testing our antenna. It has frequency peaks at almost 3.15 GHz and 4.85 GHz which is very close to our simulated result of S11.

Then we used MATLAB on other .snp file to get the S12 result. We observed the S12 simulated and measured results in MATLAB:

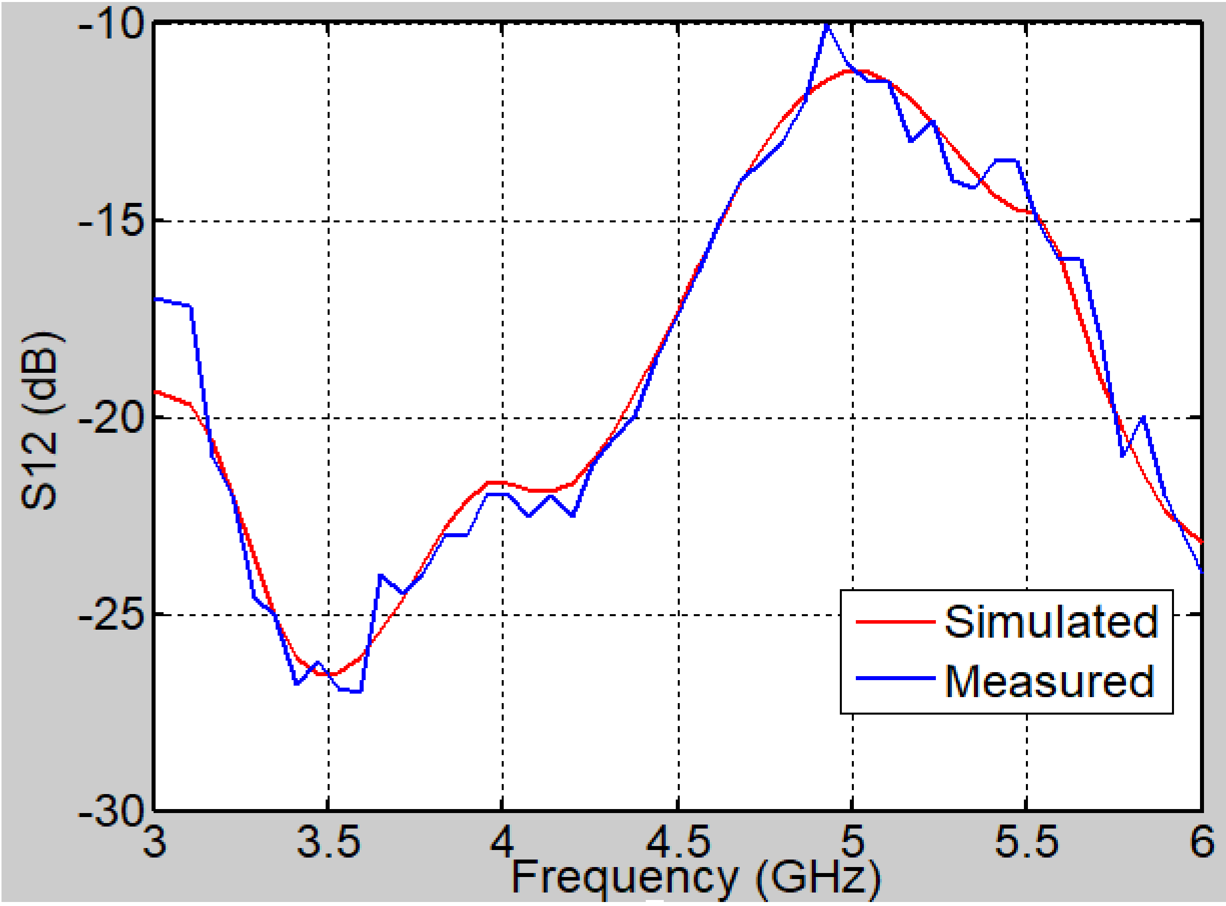


Figure 4.8: S12 result on MATLAB

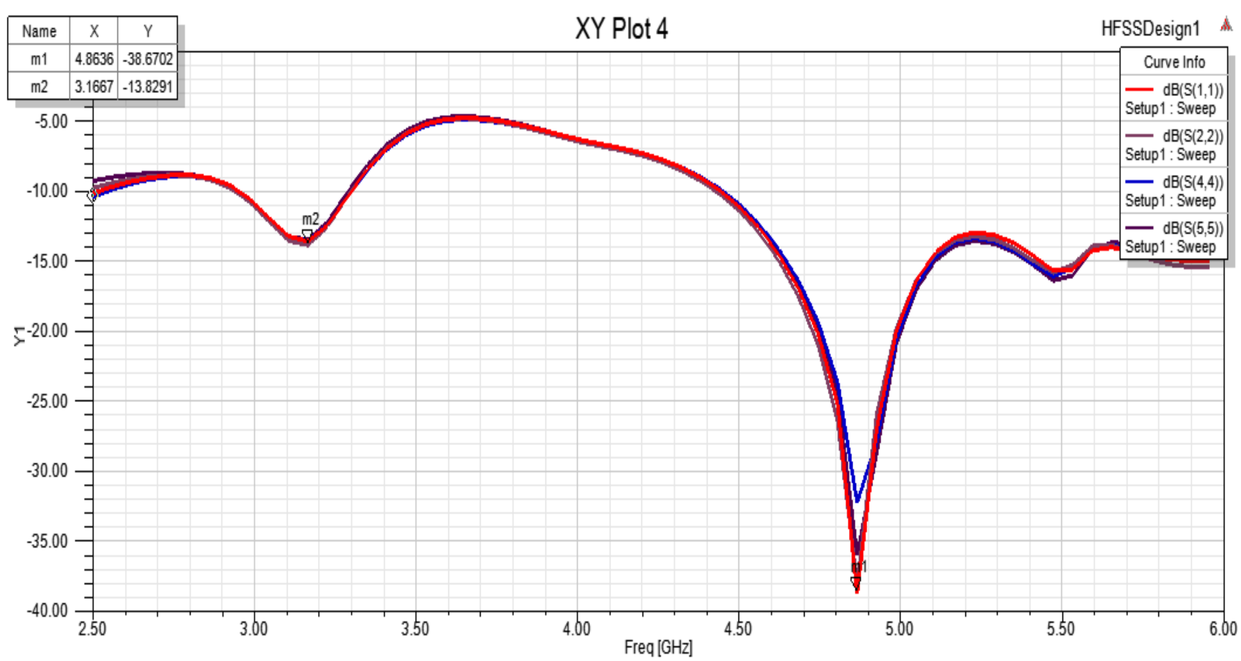


Figure 4.9: S-parameters result on HFSS

<u>CHAPTER 5:</u> CONCLUSION AND FUTURE WORK

5.1 Conclusion

We have designed our antenna to meet requirements of the future. We targeted 4 element MIMO antenna having dual band which operates in sub 6 GHz frequency for 5G Communication. 5G Communication is the futuristic communication which will ultimately enhance the speed and quality of the internet and voice both. Our antenna if used by Pakistani cellular companies will bring boost their business and will bring Pakistan in power with the countries having fastest communication networks. It will also be helpful for Pakistan to improve the economy and create job opportunities for the youth in the coming future. By adopting this antenna Pakistan will be benefitted to communicate the world in fastest and accurate means.

5.2 Future work

After the creation of our 5G communication antenna, there will be still a room of improvement as far as its size, elements and operating bands are concerned. Following are the things on which one can improve our antenna design:

- One can improve the antenna by enhancing it from 4-element to 5-element or even more. The dual band can also be improved to triple or more bands.
- One can reduce the size of the antenna as well.
- We have used FR4 Epoxy as the material of our substrate. One can also use different material in order to check whether it make results better or not.

Due to time constraint, we were able to complete our antenna, but next courses can target to the improve it qualitatively and quantitatively.

CHAPTER 6: REFERENCES

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ANNEX A

Thesis Fractal MIMO Antenna PC Ali Younas

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