4 × 4 Micro strip Patch Antenna based MIMO Antenna for Dual band 5G Applications

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In the name of ALLAH, the Most benevolent, the Most Courteous

CERTIFICATE OF CORRECTNESS AND APPROVAL

This is to officially state that the thesis work contained in this report

"A 4 × 4 Microstrip Patch Antenna based MIMO Antenna for Dual band"

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under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Electrical (Telecom.) Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.

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Date: May 30, 2022

DECLARATION OF ORIGINALITY

We hereby declare that no portion of work presented in this thesis has been submitted in support of another award or qualification in either this institute or anywhere else.

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Allah Subhan'Wa'Tala is the sole guidance in all domains.

Our parents, colleagues and most of all, our supervisor **Assoc Prof Dr. Zeeshan Zahid** without your guidance. The group members, who through all adversities worked steadfastly.

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ABSTRACT

Antennas are very important components of communication systems. Thus, a lot of research has been going on in both government and commercial communication systems to develop low profile, inexpensive and minimal weight antennas which can be easily fabricated. This paper presents the design of a multiple-input and multiple-output (MIMO) antenna for fifth generation (5G) applications that will work in dual-band. The antenna proposed in this work operates at 2 frequency ranges, i.e. (3500) MHz and (5500) MHz. The antenna design consists of four antennas that are placed perpendicular to the edge of the system, and this makes it different from the traditional 5G antennas. The area of each antenna on the side frames is (65×65 mm), and hence can be used in internet of things (IoT) for 5G applications. The coupling parameters obtained in the simulations is less than -20 decibels for the required band, which suggests that the required impedance matching is obtained. The antenna proposed is designed by using central time zone (CST) microwave studio.

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CHAPTER 1

INTRODUCTION

Nowadays, antennas are used in various areas like mobiles communication, satellites, internet provision, automobiles automation, and radars. To fulfill this demand, microstrip patch antennas are used in them, because they are lightweight, low profile and low power handling capacity. Microstrip antennas have wide applications in dual band and for dual polarization.[1]

1.1 Overview

Wireless communication has transformed in the last Two decades. Mobile communication emerged with the first generation, having problem of less speed. In the second generation, user required something more than mere call. Apart from 1g, digital signals were used to provide data and call services. This caused new services and applications to appear which changed the scenario. Third generation was able to provide more better internet services with higher speed. Fourth generation is using new technology like OFDM to have more bandwidth.

1.2 Problem statement

Microstrip patch antennas designed for 5G mainly have

- Small Scale Fading
- Are Single Band
- Less Reliable
- /Less Bandwidth

IT manufacturers are concentrating to manufacture miniaturized antennas to provide high data rates, low latency and bit error rate to overcome above mentioned problems to be used in wireless and IoT based applications.

1.3 Proposed Solution

To design a microstrip 4 × 4 MIMO-based patch antenna [2] being

- Smaller in size
- Dual band
- Have Good Gain and directivity.

This thesis attempts analyzes dual band antennas and their prospects. CST Microwave Studio is used work mentioned in this thesis.

1.4 Working Principle

- Inset Feed
- Slot in Patch

1.5 Objectives

- For providing higher data services like 5G, microstrip MIMO based antennas characteristics are suitable.
- The main goal is to design the microstrip antenna reducing complex structures to obtain 4×4 antenna with a good directivity.

1.6 Scope

To design a microstrip 4×4 MIMO-based patch antenna smaller in size having dual band without compromising directivity and bandwidth.

1.7 Deliverables

Simulation based work

- Optimized based simulated results
- Hardware based work (fabricated antenna)
- Measured results
- Research paperwork

1.8 Relevant SDGs

Quality Education: Ensure inclusive and equitable quality available to everyone.

Economic Growth: Promote economic growth, employment being taken care of and decent work for all.

Quality of Life: Provide quality-based life to all.

5G for All: Provide modern technologies to everyone.

1.9 Structure of Thesis

Chapter 2 contains the background based on literature

Chapter 3 contains antenna parameters description

Chapter 4 contains detailed simulation results and analysis of antenna parameters

Chapter 5 contains the conclusion of the project

CHAPTER 2

Literature Review

Background

Microstrip antennas can be adjustable to planar and non-planar surfaces, easily manufacture, different forms in terms of resonant frequencies, and have low cost.[3] Many circuit elements with different frequency, variable bands and pattern can be designed by using diodes and pins between the ground plane and patch. Handheld mobile devices use monopole antenna which is fractal shape to operate on dual band is Multi-Input Multi-Output based.[4]

2.1 Characteristics of Microstrip Patch Antenna

As shown Figure below, the microstrip patch antenna is designed by drawing a radiating patch using copper or gold. Whereas dielectric substrate on top is used to design line feed A ground plane present at bottom is used as a reflector.

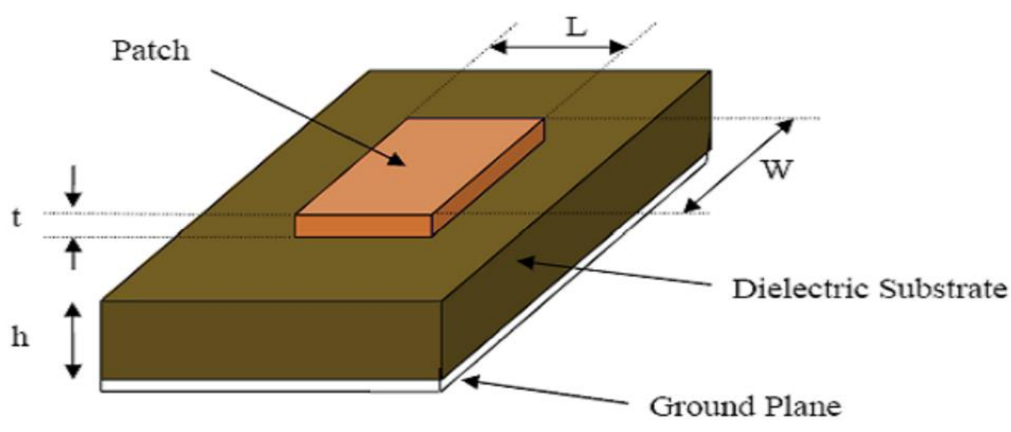


Fig 2.1: Structure

Rectangular and circular shape are preferred for antenna design because of their simplicity. Substrates having dielectric constant in range of $2.2 \leq \epsilon r \leq 12$ are used for designing of microstrip antennas. For designing rectangular patch,a Length within the range of $0.3333\lambda 0$ to 0.5 $\lambda 0$($\lambda 0$ =free space wavelength) is used. Whereas thickness is considered less than $\lambda 0$. To lessen the size of a rectangular patch antenna, A defected microstrip structure (DMS) is employed without causing harm to antennas performance.[5]

2.2 Feeding Methods

Variety of configurations like aperture coupling, coaxial probe feeding, coupling microstrip line etc are used to feed microstrip antenna. Line feed is discussed below

2.2.1 Microstrip Line Feed

A conducting strip is directly connected to microstrip patch as shown below. Width of patch is more than strip. Thus make it easier to obtain structure which is planar.

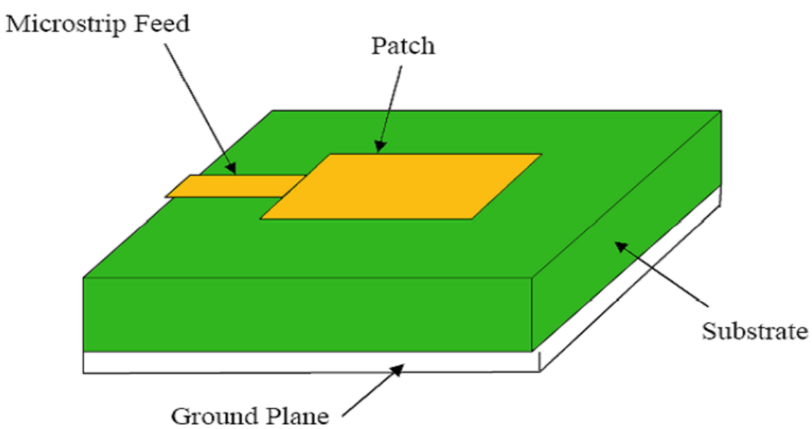


Fig 2.2: Microstrip line feeding

A drawback is if we increase thickness of substrate, feed radiations, effects if cross polarization and surface waves increases, degrading the antenna bandwidth.

2.3 Methods of Analysis

Models like Transmission line, full wave and cavity are used for analyzing microstrip antennas. Transmission line model is simple, less accurate and difficult to analyze antennas coupling effect.

2.3.1 Transmission Line Model

A non-homogeneous line of dielectrics like substrate and air is used to constitute microstrip. As depicted in below Figure, in this models, susceptance B and conductance G are used to separate two slots.

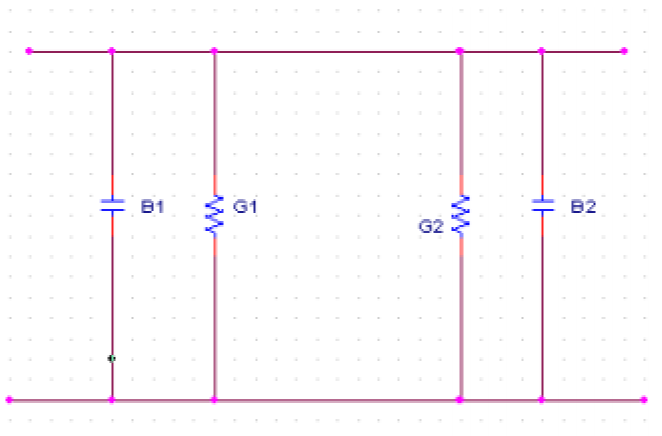


Fig 2.3: Transmission line representation

The value of $\varepsilon reff$ for many applications is near to εr as it is more than 1. But microstrip line having substrate with air above it, dielectric constant has a range of 1 to εr. Frequency directly effects value of $\varepsilon reff$. If microstrip antenna has to operate on higher requencies effective dielectric gets value near to substrate's dielectric constant.[6]

CHAPTER 3

ANTENNA PARAMETERS

Various parameters describing performance of an antenna are gain, directivity, radiation pattern etc [7]. Few of these are discussed below :-

3.1 Gain and Directivity

Antenna Gain is defined as the "ratio of radiation intensity in a given direction to the radiation intensity of an isotropic antenna".[8]. The antenna taken as reference is an isotropic antenna which has property of radiating in all directions equally. Its unit is decibels. (dB)Whereas Directivity can be taken as the "ratio of radiation intensity in a particular direction from the antenna to the average of radiation intensity taken in all directions".

3.2 Antenna Polarization

Polarization has different types like linear, circular or elliptical. It is the "orientation of electric field vector at a point in space". Linear polarization has property to stay same with respect to time, whereas if it changes orientation then it can be linear or circular.

3.3 Input Impedance

Terminal, characteristic and wave impedance are three types of impedance relevant to antennas. Terminal impedance can be taken as voltage to current ratio at connections of antenna. The transmission line connected to antenna has characteristic impedance. Coupling is better is terminal and characteristic impedance are near to each other. An antenna is perfectly matched, if both of these impedances are equal.

3.4 Voltage Standing Wave Ratio

VSWR is maximum divided by minimum voltage along transmission line. It shows efficiency of antenna coupled to transmission line. VSWR is equal to one in case of no reflection. Some of the antenna RF signal is reflected in case of no matching of transmission line and antenna. Standing wave on line are generated, which have minima and maxima. However VSWR near to 1.5 is considered excellent, whereas till 1.5 to 2.0 is good.

3.5 Bandwidth

The frequency range in which antenna operates is called its bandwidth. In our case it is 3.5 GHz and 5.5 GHz. All antenna characteristics should have an acceptable value with this bandwidth. Radiation pattern and Gain change rapidly with terminal impedance than as compared to the frequency in most of the antennas.

CHAPTER 4

DUAL BAND MICROSTRIP 4 × 4 PATCH ANTENNA MIMO BASED

Advancements in telecomm sector are demanding to have antennas which have good communication capacity and gain. Microstrip patch antennas are light weight and smaller in size, so they can be miniaturized. They do have issues like narrow bandwidth etc. Their performance can be enhanced in variety of ways to resolve this issue.

4.1 Dual Band Concept

By using a substrate having low dielectric constant, patch antenna with slots (multi-band), increasing thickness of substrate, changing feeding methods and impedance matching techniques, bandwidth of microstrip antenna can be enhanced [9]. Multi-band planar antenna should have similar features in term of radiation pattern and matching impedance if they operate at more than one frequency [10]. A simple rectangular Microstrip patch antenna behaves same like as a cavity having radiating edges on magnetic walls. [11] Slot loaded patches may have two narrow slots parallel to radiating edge. [12]

4.2 Our Proposed Dual Band Antenna

A microstrip patch antenna 4 × 4 MIMO based for WIFI and IoT applications is proposed as a dual-band antenna.[13] The substrate is 65x65mm in physical size. Our FR-4 substrate has dielectric constant of 4.3 having a thickness of 1.6 mm, 0.02 is its loss-tangent. In this design, four patch antennas having slots are arranged as seen below in pictures. Dual band is achieved because of these slots.[14]

Our dual band antenna will operate at frequencies of 3.5 GHz and 5.5Ghz [15]. The radiating slot will show the second op freq of 5.5 GHz. [16]

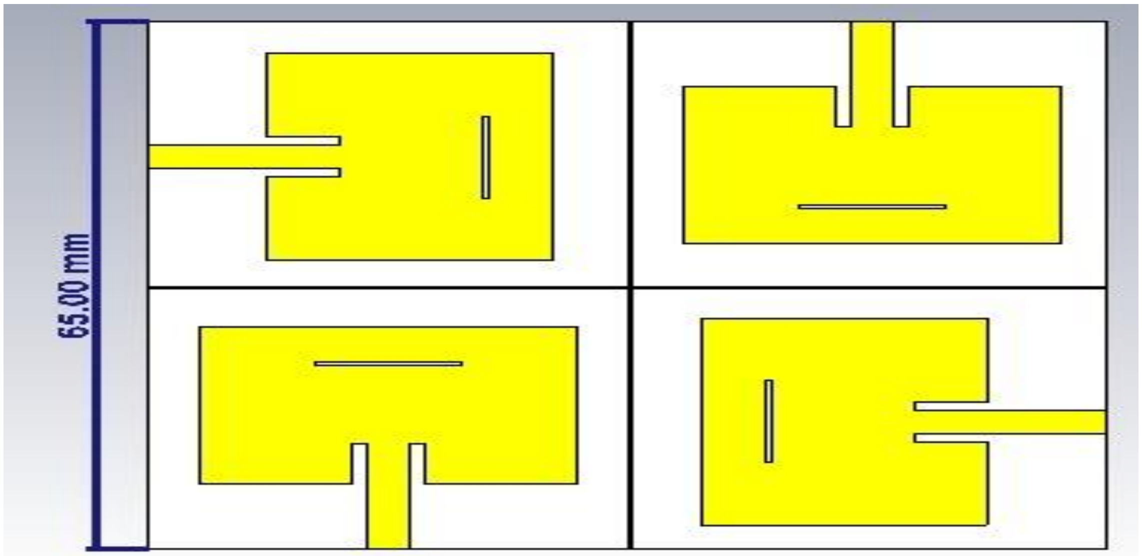


Figure 4.1: Proposed Antenna.

4.3 Simulations and Results

CST software is used to perform simulation of the proposed antenna. Return loss, directivity, and surface current are all used to complete the analysis.

4.3.1 S-Parameter Characteristics

Return loss is simulated at 3.5 GHz and 5.5 GHz frequencies as shown in Figs. From the figure, bandwidth ranges can also be interpreted. Few of the antennas S parameter are listed below. Antenna 1 having return loss of approximately -20 decibels at 3.5 GHz and a return loss of -34 decibels which shows excellent matching.

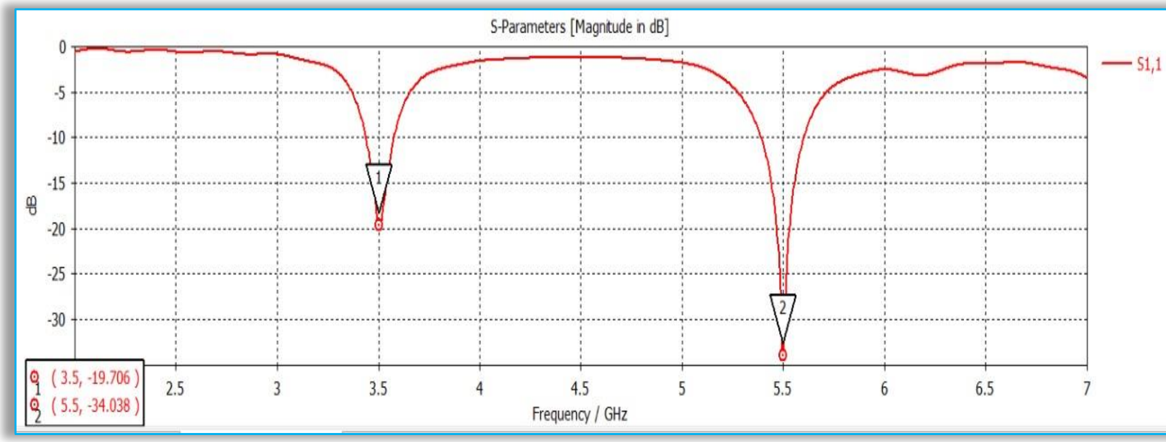


Figure 4.2: Simulation of S (1,1) Parameter

4.3.2 S PARAMETERS OF ANTENNAS IN DIAGONAL

Antennas 1 and 4 are placed in diagonal with each other. As depicted in Figure 4.2 at 3.5 GHz, -31 decibels and at 5.5 GHz -25 decibels return loss is obtained which shows excellent matching.

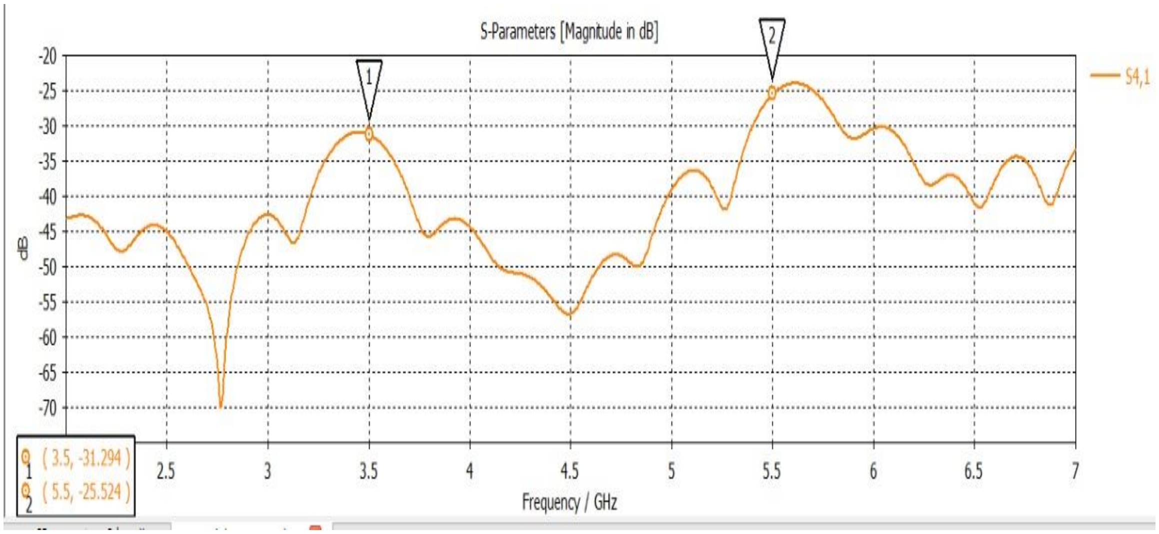


Figure 4.3: Simulation Result

Antennas 2 and 3 are placed in diagonal with each other. As depicted in Figure 4.2 at 3.5 GHz, -30 decibels and at 5.5 GHz -24.5 decibels return loss is obtained which shows excellent matching.

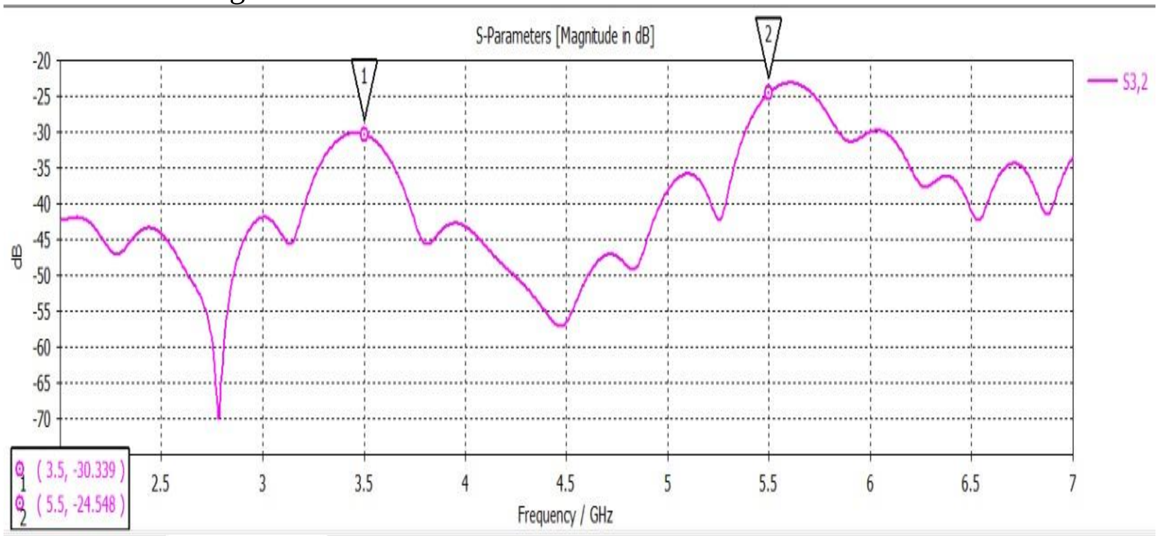


Figure 4.4: Simulation Result

4.4 Directivity

4.4.1 At 3.5 GHz

Directivity of antenna 1 and antenna 2 has been shown in figure and figure . The directivity of both antennas is above 6 decibels.

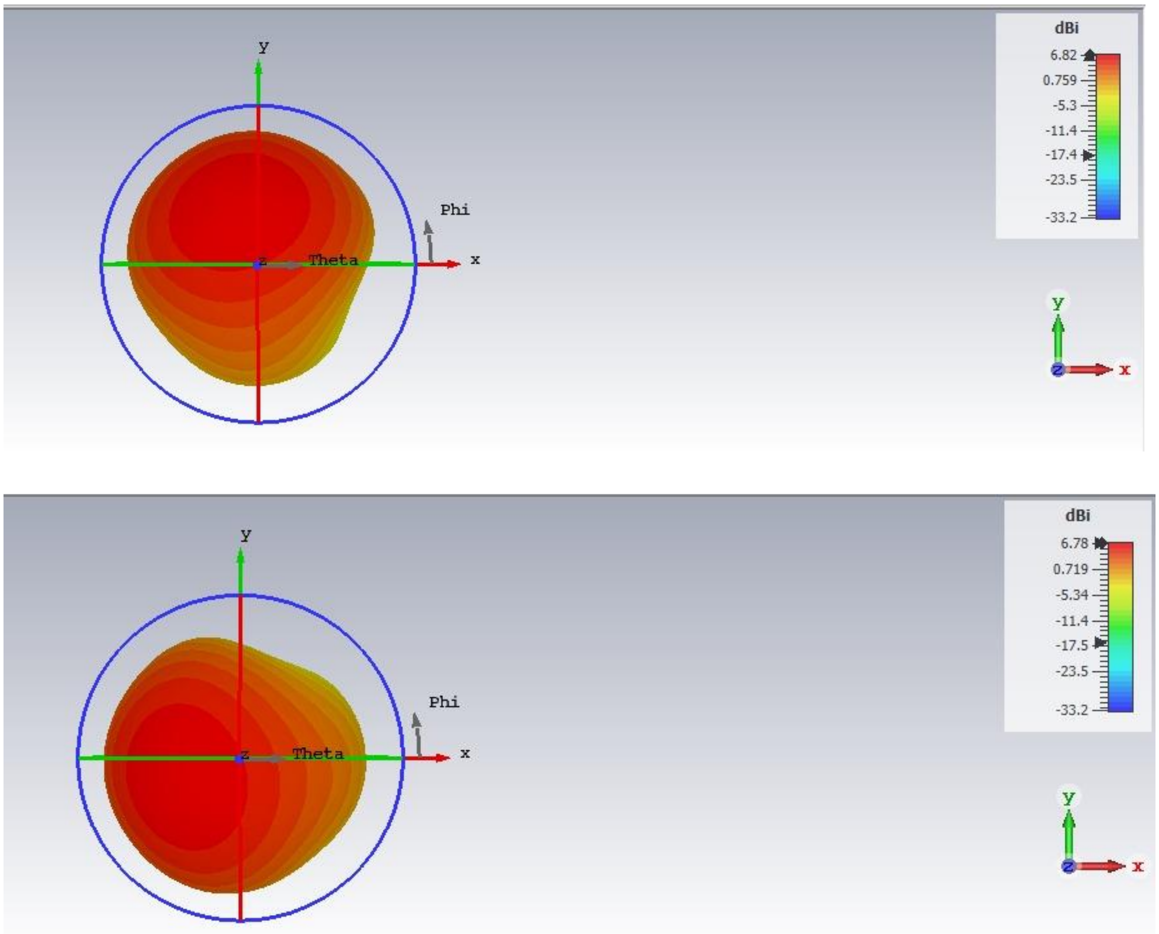
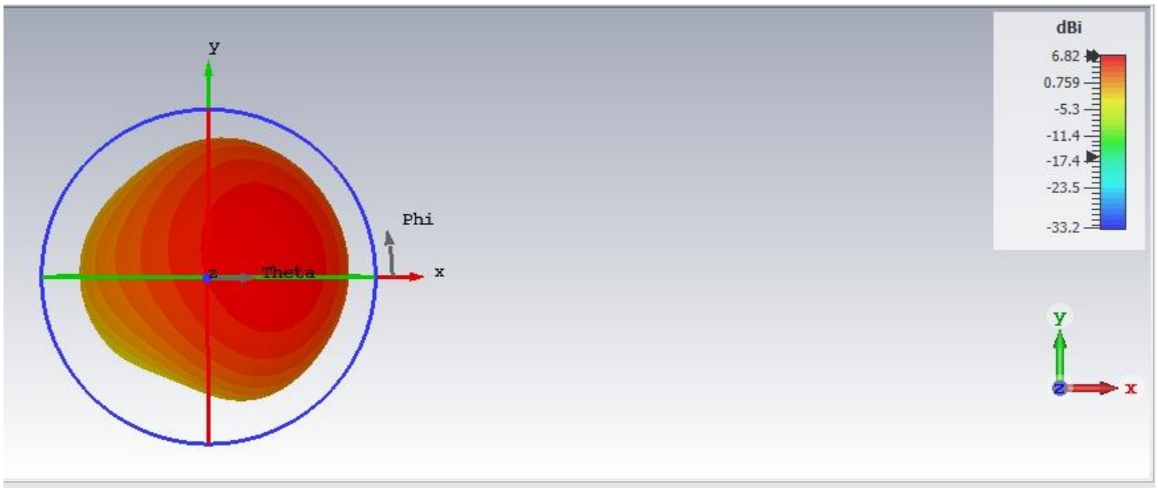


Figure 4.5

Directivity of antenna 3 and antenna 4 has been shown in figure and figure . The directivity of both antennas near to 7 decibels.



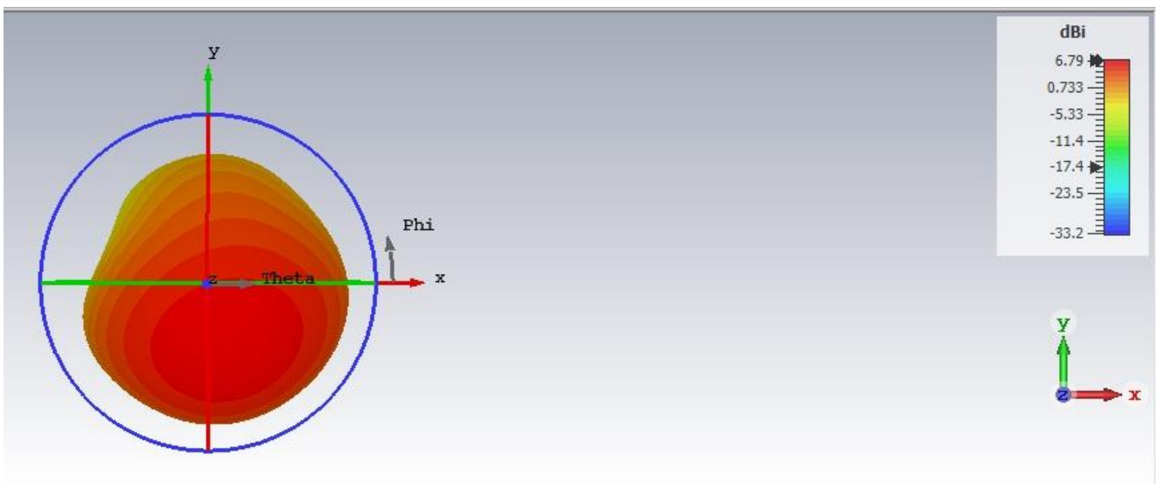


Figure 4.6

4.4.2 Directivity at 5.5 GHz

Directivity of antenna 1 and antenna 2 has been shown in figure below . The directivity of both antennas is above 6 decibels.

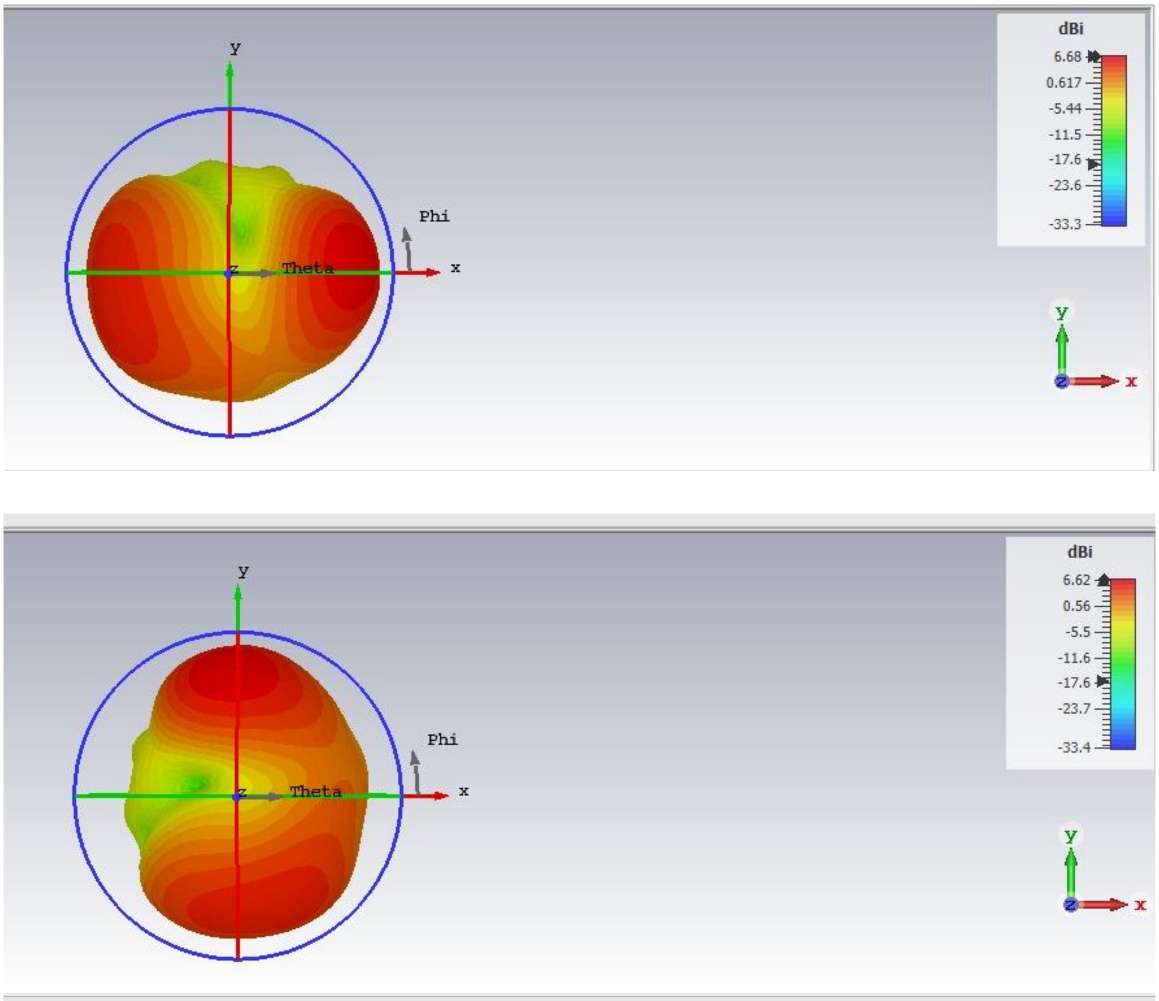
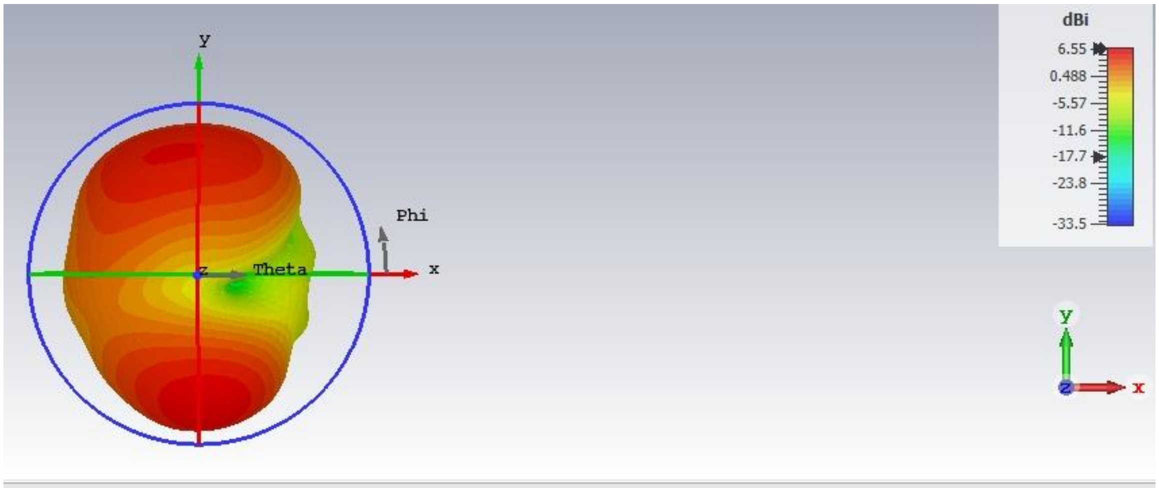


Figure 4.7

Directivity of antenna 3 and antenna 4 has been shown in figure. The directivity of both antennas is above 6.55 decibels and 6.67 decibels respectively.



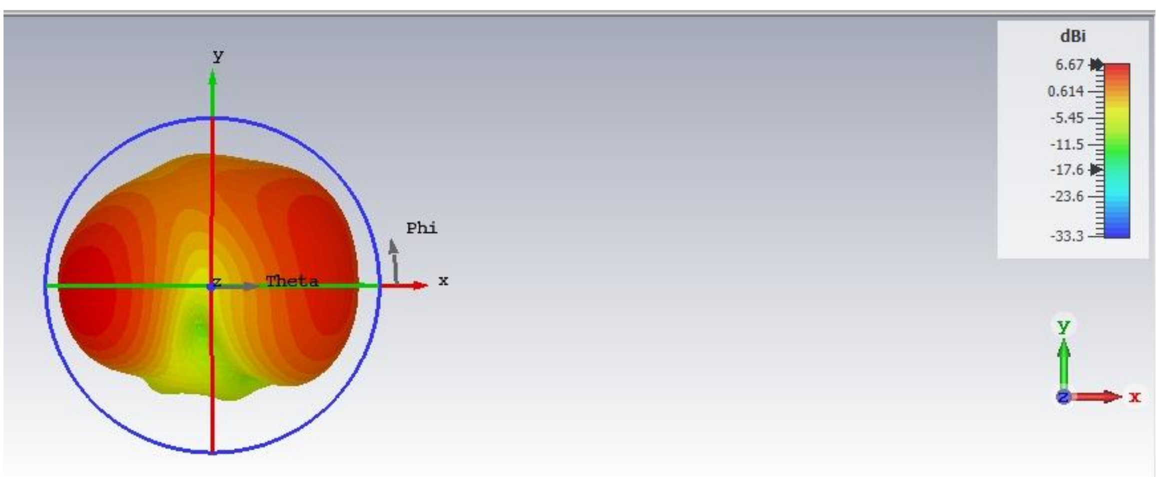
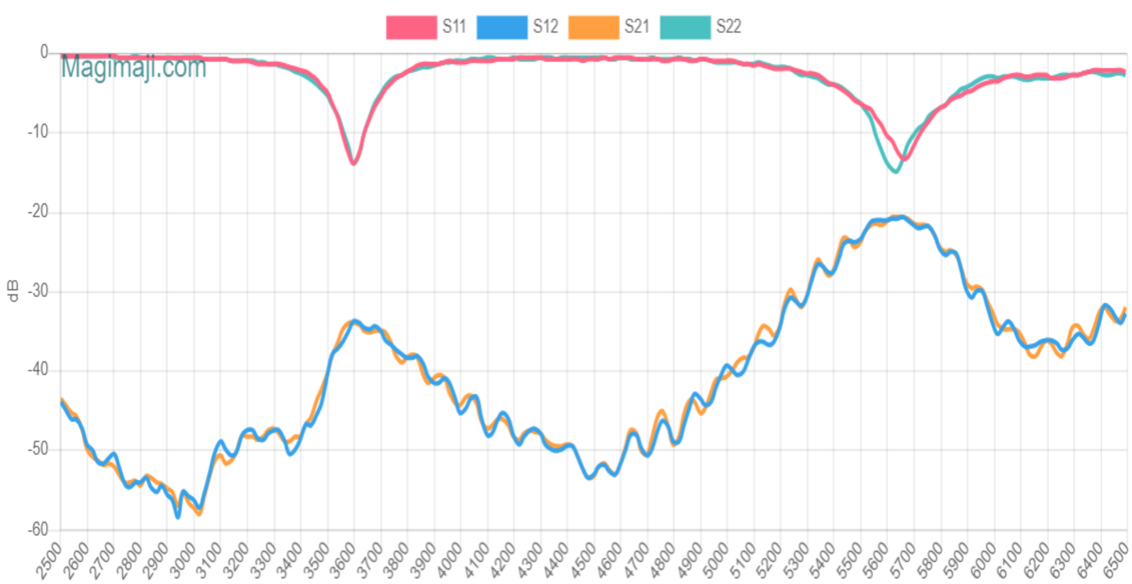


Figure 4.8

4.5 MEASURED RESULTS OF RETURN LOSS

4.5.1 Antennas 1 & 2

S Parameters of antenna 1 and 2 were tested in RIMS, NUST. And the results were very promising. At 3.6 GHz, S(1,1) shows return loss of -13 decibels compared to -12.5 decibels at 5.6 GHz. At 3.6 GHz, S(1,2) shows return loss of -34 decibels compared to -21 decibels at 5.6 GHz. At 3.6 GHz, S(2,1) shows return loss of -34 decibels compared to -21 decibels at 5.6 GHz. At 3.6 GHz, S(2,2) shows return loss of -13 decibels compared to -15 decibels at 5.6 GHz.



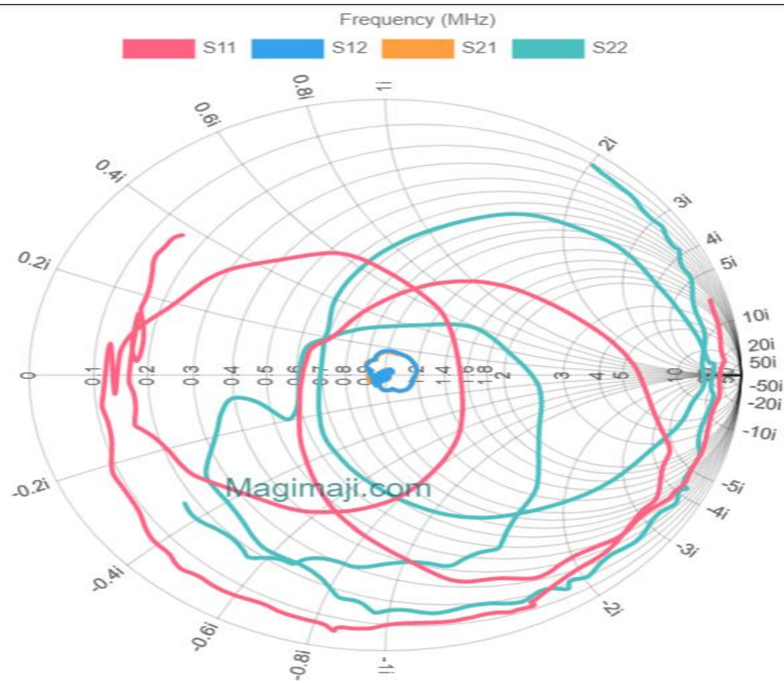
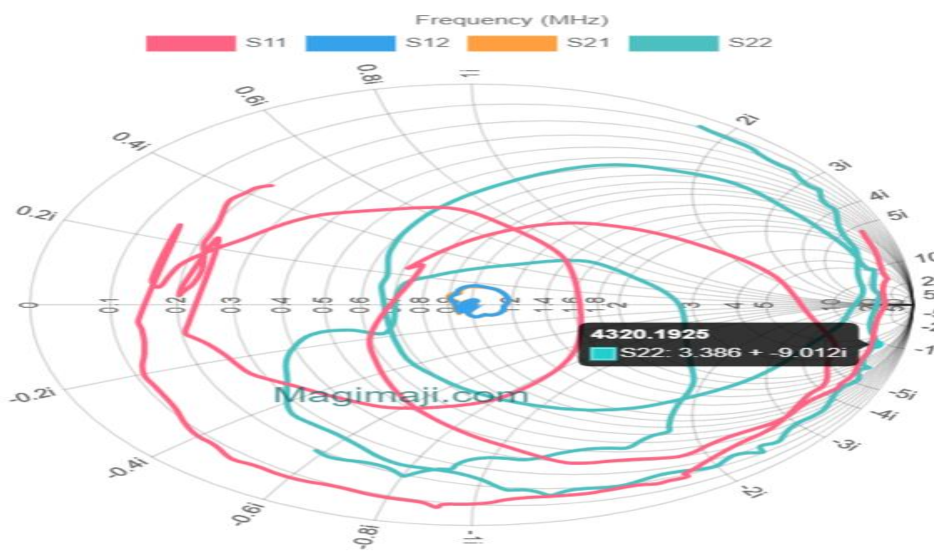
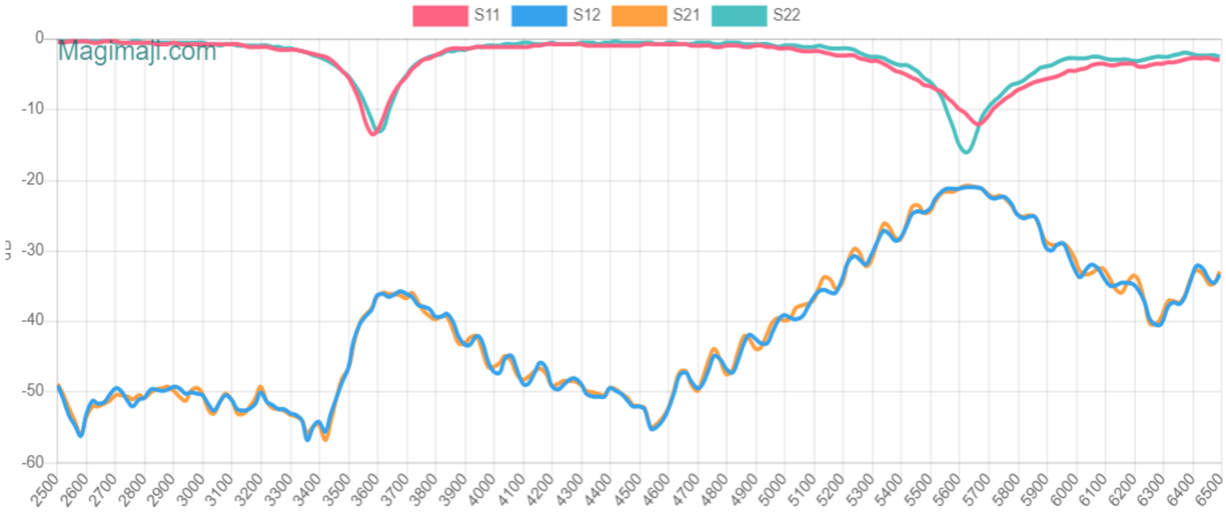


Figure 4.9

4.5.2 Antennas 3 & 4

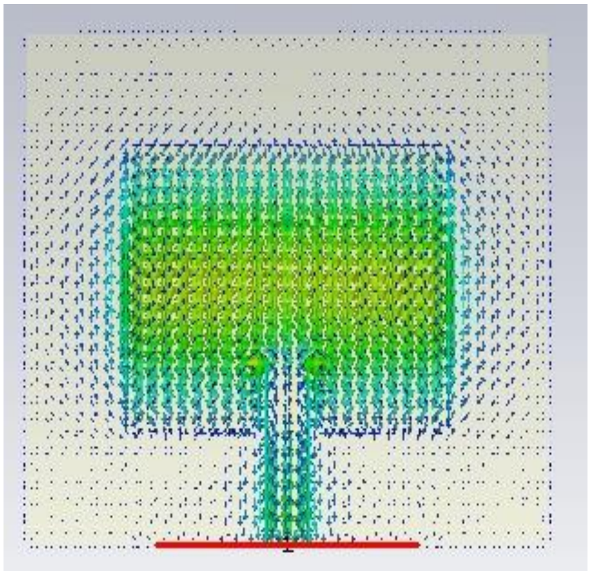
Parameters of antenna 3 and 4 were tested in RIMS, NUST. And the results were very promising. At 3.6 GHz, S(1,1) shows return loss of -13.5 decibels compared to -12 decibels at 5.6 GHz. At 3.6 GHz, S(1,2) shows return loss of -36 decibels compared to -21 decibels at 5.6 GHz. At 3.6, GHz S(2,1) shows return loss of -36 decibels compared to -21 decibels at 5.6 GHz. At 3.6 GHz, S(2,2) shows return loss of -13 decibels compared to -16 decibels at 5.6 GHz.



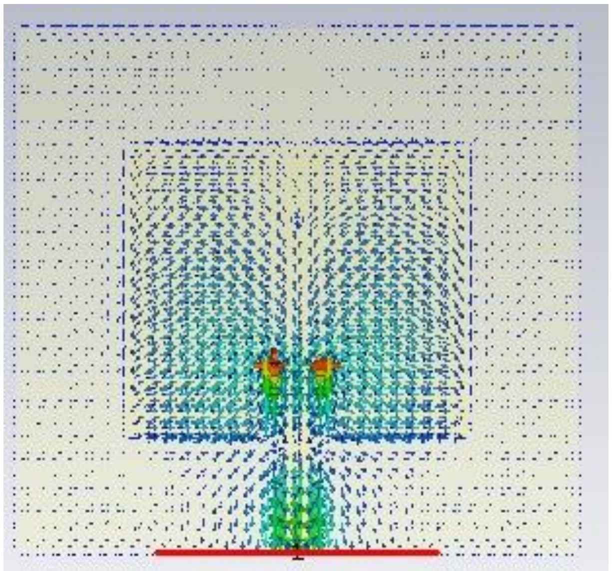


4.5 Surface Current Distribution

Figure.3 shows the distribution of surface current at various resonance frequencies. The red part denotes not just the areas with the highest current density, but also the areas where resonant frequencies occur. The antenna's properties will alter if the form of the very packed zone is changed.



3.5 GHz Figure 4.11



5.5 GHz Figure 4.12

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

A dual band microstrip antenna mimo based 4 × 4 for 5G, IoT based applications and wifi etc. is demonstrated in this Paper. All those applications are covered by the developed antenna, which operates at dual frequencies of 3.5 GHz and 5.5 GHz. CST shows our return loss is less than -20 decibels, whereas in lab, measured results came less than -10 decibels which is within prerequisite for a realistic and desirable antenna. CST has shown antenna's gain is more than 6 decibels at both frequencies. Current distribution performance is conducted is to select the best possible position for dual band slot. According to simulated and measured results, our innovative designed 4 × 4 antenna meets the demands for a next-generation advanced antenna that has high bandwidth, smaller in size, simpler, and easy to build and can be used in 5G applications.

5.2 FUTURE SCOPE

The following points are offered to further increase the outcome of present research :-

- ♣ Isolator can be inserted into the antenna design to further decrease the distance between antennas and increase their matching.
- ♣ Instead of Transmission line model, to achieve better understanding of field configurations which exist within dielectric, Cavity modelling technique can be used.
- ♣ Work can be done to change the frequency bands to get more better results and also to analyze more antenna parameters.

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