CIRCULARLY POLARIZED MIMO ANTENNA FOR WIRELESS APPLICATIONS

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)
(Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade)

Sangivalasa, Bheemili Mandal, Visakhapatnam dist. A.P

(2021-2022)

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PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the project report entitled **"CIRCULARLY POLARIZED MIMO ANTENNA FOR WIRELESS APPLICATIONS"** Submitted by **D.Vaishnavi(318126512112),M.N.Y.S.N Murthy(318126512089), B.Pravallika(318126512068), D.S.SaiKumar(318126512076), S .Sai Nikhil (318126512101)**, in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology in Electronics and Communication Engineering** of Anil Neerukonda Institute of Technology and Sciences,Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.

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ABSTRACT

A Multiple Input Multiple Output (MIMO) technology has caught significant attention because of its high data rate, good reliability and spectral efficiency, for assigned bandwidth, power level and to overcome multipath fading in rich scattering environment. A four element (2x2 array) MIMO based microstrip patch antenna of dimensions 128 mm x 128 mm x 1.6 mm with circular polarization is proposed. HFSS software is used for designing and simulation of the proposed MIMO antenna. Initially a basic microstrip patch antenna is designed and then a rectangular microstrip patch antenna is designed with a tree shape patch and full ground, which is providing gain of 2.6 dB at 5.9 GHz and also 6.4dB at 6.8GHz. It resonates at 4.4 GHz 5 .9 GHz and 6.8 GHz with an impedance bandwidth of 270MHz,100MHz and 150MHz respectively. To further improve the gain, circular polarization is implemented. The designed antenna provides return loss of about -25.39dB,-16.20dB, -12.28 dB at frequencies 4.7 GHz, 5.4 GHz, 6.8 GHz with impedance bandwidth of 160 MHz,210MHz and 250MHz and gain of 2.7dB and 4.7dB at 4.7GHz and 5.4GHz which is better than the basic microstrip patch antenna of an axial ratio about 2 .04 dB and 2.15dB at 4.7GHz and 6.8GHz and ECC value of 0.0000,0.0004,0.0000 at 4.7GHz,5.4GHz and 6.8GHz GHz. This antenna is used in various wireless communication systems such as WLAN, Wi-Fi, WiMAX, GPS which satisfies all the expected characteristics of a MIMO antenna.

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Figure 8.2(D): Isolation

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LIST OFABBREVATIONS

HFSS : High Frequency Structure Simulator

WLAN :Wireless Local Area Network

WIMAX : World Wide Interperobility for Microwave Access

VSWR : Voltage Standing Wave Ratio

ECC : Envelope Correlation Coefficient

TARC : Total Active Reflective Coefficient

CHAPTER-1

INTRODUCTION

INTRODUCTION

In the new era of technological advancement wireless communication applications are rapidly growing which became necessary for the development of new antenna models to meet the changing needs of applications. The contemporary wireless communication systems have high bandwidth and data rates as their primary criteria. As a part of this requirement MIMO antennas have been proposed. MIMO is an antenna technology which improves its functioning by using multiple paths when signals are transmitting from the transmitter to receiver. MIMO is implemented when there is a need for high bandwidth communications where its mandatory to avoid interference in RF and microwave systems. The latest technology MIMO uses is multipath.MIMO antenna is suitable for high data rate especially in wireless communications. At high data rate, signal blocking and attenuation have become a major problem it can be resolved by MIMO antennas. A novel Multi Input and Multi Output (MIMO) antenna technology has been created to meet the needs of modern systems and have been put to use. The MIMO system is unusual in thatit can simultaneously transmit the data and receive the data at same time, broadcast and receive data from many channels at a time without requiring more radio bandwidth and radiation strength. For high-frequency data transfer the Microstrip Patch Antenna is employed because of itseasy fabrication, less weight and low cost. When compared to linearly polarized antenna, circularly polarized antennas are very effective at combating multipath interference and polarization mismatch. The use of orthogonally polarized circularly polarized radiators has proven to be effective. In more detail, an examination of the MIMO performance achieved by using orthogonally-polarized circularly polarized radiators revealed that these radiators can achieve higher eigen values as a function of MIMO antenna orientation than orthogonally polarized linearly polarized radiators . MIMO antenna provides enhanced reliability as there were multiple antennas presented and the radio signal could propagate via many independent paths . As there is an increase in demand of mobile data a rectangular microstrip patch antenna has come into picture.In addition to that, it is also observed that multi-array MIMO antenna shows lesser attenuation at higher bandwidth. The proposed MIMO antenna's high gain can also help to overcome the atmospheric attenuation that occurs at higher frequencies. This new MIMO antenna technology takes the good advantage of multipath signal propagation and uses multiple antennas at both transmitter and receiver sides. With comparison to single antenna systems MIMO antenna arrangement provides high channel capacity, high spectral efficiency and reliable information between the transmitting and receiving ends. Circular polarization in antennas is used due to theirimmunity to multipath propagation.

1.1 Project Objective

The objective of this project is to improve the gain and working efficiency provided by the basic antenna. Hence, MIMO antennas are proposed for this purpose. For data communication at high frequencies Microstrip Patch Antenna (MPA) is used due to its light weight, low costing, and it is also very easy to fabricate.

1.2 Project Outline

MIMO is an antenna technology which improves its functioning by using multiple paths when signals are transmitting from the transmitter to receiver. MIMO is implemented when there is a need for high bandwidth communications where its mandatory to avoid interference in RF and microwave systems. The latest technology MIMO uses is multipath. MIMO antenna is suitable for high data rate especially in wireless communications. At high data rate, signal blocking and attenuation have become a major problem it can be resolved by MIMO antennas. When compared to linearly polarized antenna, circularly polarized antennas are very effective at combating multipath interference and polarization mismatch. The use of orthogonally polarized circularly polarized radiators has proven to be effective.

The proposed design is on HFSS, initially a basic microstrip patch antenna is considered next designed 2x2 array with tree shape design is developed and simulated. To further improve the results obtained from basic antenna, circular polarization is implemented with the basic Microstrip patch antenna. This antenna is used in various wireless communication systems like WLAN, Wi-Fi, GPS. The left hand circular polarization and right hand circular polarization are two different types of methods implemented. Initially by using single cuts the results are obtained and simulated. Then by introducing double cuts for further improvement of results, the design is modified and simulated. Then the findings of circular polarization numerical and experimental studies are presented and analyzed.

CHAPTER-2

LITERATURE REVIEW

LITERATURE REVIEW

1. In 2021, Jitendra Dubey et al. [1] presented new MIMO antenna technology which takes the good advantage of multipath signal propagation and uses multiple antennas at both transmitter and receiver sides. Based on their comparison of single antenna systems with the MIMO antenna arrangement provides high channel capacity, high spectral efficiency and reliable information between the transmitting and receiving ends. MIMO antenna is suitable for high data rate especially in wireless communications.

2. In 2021, David Borges et al. [2] proposed that at high data rate, signal blocking and attenuation have become a major problem it can be resolved by MIMO antennas so Multi Input and Multi Output (MIMO) antenna technology has been created to meet the needs of modern systems and have been put to use.

3. In 2021, B. Shruthi et al.[3] presented the MIMO system which can simultaneously transmit the data and receive the data at same time and also can broadcast and receive data from multiple channels at a time without requirement of more radio bandwidth and radiation strength. Proposed that for high-frequency data transfer the Microstrip Patch Antenna is employed because of its easy fabrication, less weight and low cost.

4. In 2020, Enze Jhang et al.[4] According to their perception when compared to linearly polarized antenna circularly polarized antennas are very effective at combating multipath interference and polarization mismatch. Based on their examination of the MIMO performance achieved by using orthogonally-polarized circularly polarized radiators revealed that these radiators can achieve higher eigenvalues as a function of MIMO antenna orientation than orthogonally polarized linearly polarized radiators.

5. In 2015, Prakash. G et al. [5] proposed that there are three major challenges in designing MIMO wireless antenna they are miniaturization, efficient bandwidth and high gain apart from VSWR, directivity etc. All these parameters have trade-off between each other.
   For efficient MIMO design should have better bandwidth, high gain, VSWR<2, directivity and the reduction in size of the MIMO system antenna.

6. In 2020, Rafal przesmycki et al.[6] presented that the technological solutions used in the 5G system can eliminate the disadvantages of LTE. These solutions to make use of very high frequencies.
   The 5G network makes use of new technological solutions to meet the growing requirements of users.

7. In 2022, Muhammad Bilal et al.[7] proposed that multi-array MIMO antenna shows lesser attenuation at higher bandwidth.

8. In 2020, Daniyal Ali Serai et al.[8] proposed that MIMO antenna's high gain can also help to overcome the atmospheric attenuation that occurs at higher frequencies. The mean effective gain and envelope correlation coefficient are also provided for the proposed MIMO configuration. In addition, the measured total efficiency of the proposed MIMO antenna is observed to be above 70% f or the desired millimeter wave frequencies.

9. In 2020, Sachine Kumar et al.[9] proposed the orthogonal placement of the antenna elements in a MIMO configuration was frequently used as one of the efficient decoupling methods but, at the same time, it increases the design complexity.

10. In 2020,Long Zhang et al.[10] proposed that Circular polarization in antennas can be used due to their capability of having multipath propagation.

CHAPTER-3

HFSS

HFSS

3.1 Introduction

HFSS (High Frequency Structure Simulator) uses a numerical technique called the Finite Element Method (FEM). This is a procedure where a structure is subdivided into many smaller subsections called finite elements. The finite elements used by HFSS are tetrahedra, and the entire collection of tetrahedron is called mesh A solution is found for the fields within the finite elements are interrelated so that Maxwell's equations are satisfied across inter- clement boundaries Yielding a field solution for the entire, original, structure. Once the field solution has been found, the generalized S-matrix solution is determined.

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high frequency electronic products such as antennas, antenna arrays, RF or microwave components, high speed interconnects, filters, connectors, IC packages and printed circuit boards Engineers worldwide use Ansys HFSS to design high-frequency, high-speed electronics found in communications systems, radar systems, advanced driver assistance systems (ADAS), satellites, internet-of-things (IoT) products and other high-speed RF and digital devices.

HFSS (High Frequency Structure Simulator) employs versatile solvers and an intitive GUI to give you unparalleled performance plus deep insight into all your 3D EM problems. Through integration with Ansys thermal, structural and fluid dynamics tools, HFSS provides a powerful and complete multi physics analysis of electronic products, ensuring their thermal and structural reliability. HFSS is synonymous with gold standard accuracy and reliability for tackling 3D EM challenges by virtue of its automatic adaptive meshing technique and sophisticated solvers, which can be accelerated through high performance computing (HPC) technology.

The Ansys HFSS simulation suite consists of a comprehensive set of solvers to address diverse electromagnetic problems ranging in detail and scale from passive IC components to extremely large scale EM analyses such as automotive radar scenes for ADAS systems. Its reliable automatic adaptive mesh refinement lets you focus on the design instead of spending time determining and creating the best mesh. This automation and guaranteed accuracy differentiate HFSS from I other EM simulators, which require manual user control and multiple solutions to ensure that the generated mesh is suitable and accurate. With Ansys HFSS, the physics defines the mesh rather than the mesh defining the physics Ansys HFSS is the premier EM tool for R&D and virtual design prototyping. It reduces design cycle time and boosts your product's reliability and performance. Beat the competition and capture your market with Ansys HFSS.

3.2 Requirements

- HFSS consume huge memory if fine result is needed.
- 300M+ Memory and 400M+processor is recommended.

- Personal Laptop with 8GB RAM and 1.7G processor.

3.3 Features

- Computes s-parameters and full-wave fields for arbitrarily shaped 3D passive structures .
- Powerful drawing capabilities to simplify design entry.
- Field solving engine with accuracy-driven adaptive solutions.
- Powerful post-processor for unprecedented insight into electrical performance.
- Advanced materials.
- Model Library-including spiral inductors.
- Model half, quarter, or octet symmetry.
- Calculate far-field patterns.
- Wideband fast frequency sweep.
- Create parameterized cross section models- 2D models.

3.4 Simulation Workflow

The Fig 3.1 shows the design process in HFSS. There are 6 main steps to creating and solving a proper HFSS simulation. They are:

- Creating model
- Assign Boundaries
- Assign Excitations
- Set up the Solution
- Post-process the results

3.4.1 Creating model

The initial task in creating an HFSS model consists of the creation of the physical model that a user wishes to analyze. This model creation can be done within HFSS using the 3D modeler. The 3D modeler is fully parametric and will allow a user to create a structure that is variable with regard to geometric dimensions and material properties.A parametric structure, therefore, is very useful when final dimensions are not known or design is to be "tuned." Alternatively, a user can import 3D structures from mechanical drawing package s, such as Solid Works, Pro E or AutoCAD.

When using HFSS, a user must initially specify what type of solution HFSS needs to calculate.

There are three types of solutions available:

1. Driven Modal
2. Driven Terminal
3. Eigen mode

From the figure shown in 3.1 we can see the difference between driven modal and driven terminal is that, simulations that use the driven modal solution type yield S-matrix solutions where as the driven terminal expressed in terms of the incident and reflected powers of waveguide modes. The eigen mode solver will provide results in terms of eigen modes or resonances of a given structure. This solver will provide the frequency of the resonances as well as the fields at a particular resonance.

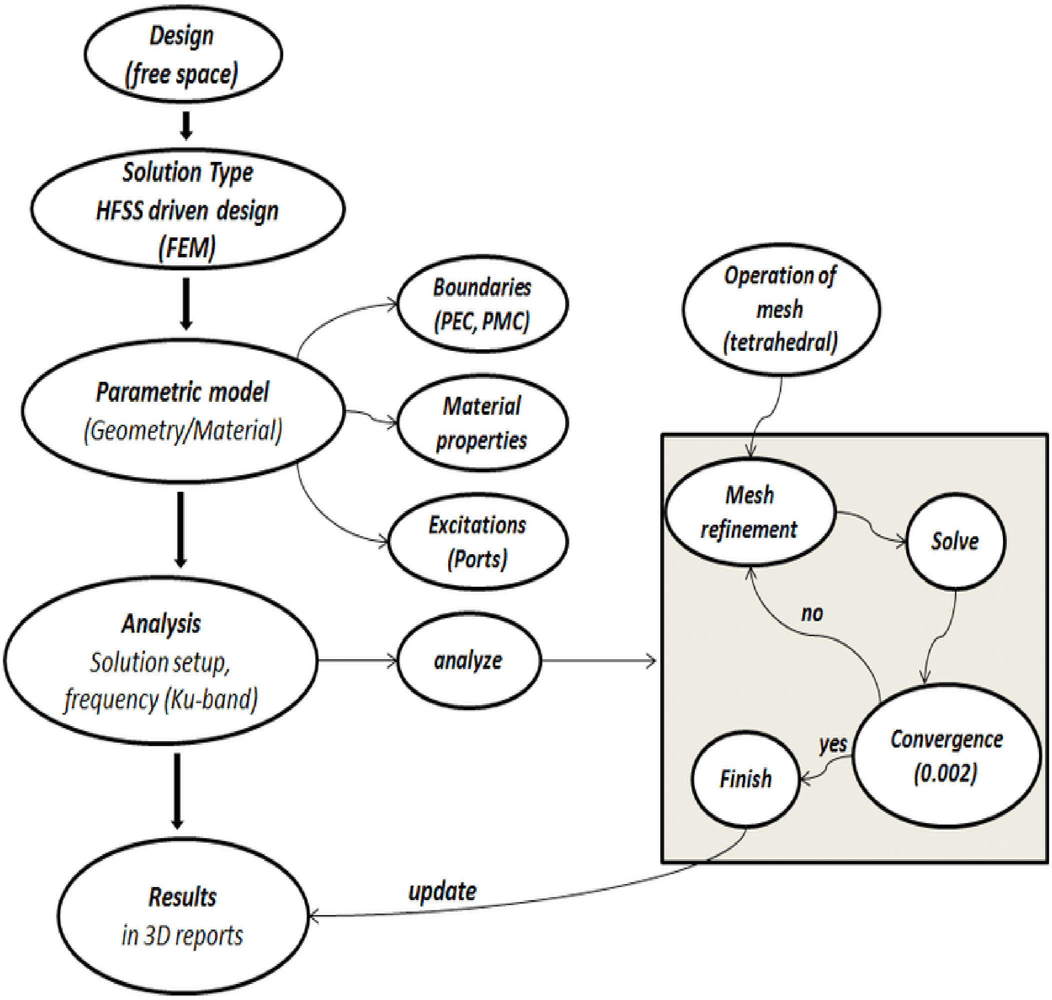

Figure 3.1 Simulation Workflow of HFSS

3.4.1 Assign Boundaries

The assignment of "boundaries" generally is done next. Boundaries are applied to specifically created 2D (sheet) objects or specific surfaces of 3D objects. Boundaries have a direct impact on the solutions that HFSS therefore, users are encouraged to closely review the section on Boundaries in this document.

There are twelve boundaries available within HFSS. Boundaries are applied to specifically created 2D sheet surfaces of 3D objects. The twelve boundaries are:

1. Perfect Electric Conductor (PEC): default HFSS boundary fully encloses the solution space and creates closed model.
2. Radiation: used to create an open model
3. Perfectly Matched layer(PML): used to create an open model and preferred for antenna simulations.
4. Finite Conductivity: allows creation of single layer conductors.
5. Layered Impedance: allows creation of multilayer conductors thin dielectrics.
6. Impedance: allows creation of ohm per square material layers.
7. Lumped RLC: allows creation of ideal lumped components.
8. Symmetry used to enforce a symmetry boundary
9. Master: Used in conjunction with Slave Boundary to model infinitely large repeating array structure.
10. Slave: Used in conjunction with Master Boundary to model large infinitely repeating array structures.
11. Screening Impedance: allows creation of large screens or grids.
12. Perfect H: allows creation of a symmetry plane.

3.4.2 Assign Excitations:

After the boundaries have been the excitations (or ports) should be applied. As with boundaries, the excitations have a direct impact on the quality of the that HFSS will yield for a given model. Because of are again encouraged to closely review the section on excitations in this document. While the proper creation and use of excitations is important to obtaining the most accurate .HFSS results, there are several convenient rules of thumb that a user can follow.

3.4.3 Set up the Solution:

Once boundness and excitations have been created, the neat step is to create a solution setup. During this step a user will select a solution frequency, the desired convergence criteria, the maximum number of adaptive steps to perform a frequency band over which solutions are desired, and the particular solution and frequency sweep methodology to use.

3.4.4 Solve:

When the initial four steps have been completed by an HFSS user,, the model is now ready to be analyzed. The time required for an analysis highly dependent upon the model geometry, the solution frequency, and available compute resources. A Solution can take from a few seconds to the time needed to get a coffee, to an overnight run. It is often beneficial to use the remote solve capability of HFSS to send a particular simulation run to another computer that is local to the user's site. This will free up the user's PC so it can be used to perform other work.

3.4.5 Post-process the results:

Once the solution has finished, a user can post-process the results Post processing of results can be as simple as examining the S-parameters of the device modelled or plotting the fields in and around the structure Users can also can the far fields created by an antenna. In essence, any field quantity or S.YZ parameter can be plotted in the post-processor. Additionally, if a parameterized model has been analyzed, families of curves can be created.

In this chapter, we have discussed the methodology and High Frequency Structure Simulator. HFSS is used to simulate the proposed antennas. The antenna designing steps with HFSS has been elaborated step by step.

3.5 Methodology

Symmetry techniques are always helpful to improve the output. Accurate symmetry exhibits better results. So, we have implemented symmetrical cutting while designing the antenna structures. Antenna may have the impedance loss because of improper impedance matching. and this can be overcome by using parameter sweep technique which is also helpful to find the position of the feed point for best impedance matching. While designing the antenna, the cutting either on the fractal shape, patch or ground plane should be done in the appropriate way that it should reduce the cost as well as enhance the bandwidth. Manufacturing cost will get less, as it depends on the material used. The antenna performance also depends on the height and dielectric constant of the substrate.

3.6 Designing steps of an Antenna

1. Create the substrate first.

2. Assign the dimensions to the substrate.

3. Assign the material to substrate.

4. Than create the Patch and assign the dimensions to the patch.

5. Assign the boundary to patch.

6. In the Next Step, create the Feed Line and assign dimensions to the feed line.

7. Than unite the feed line.

8. After this, create the Ground Plane.

9. Than Create the Excitation Port to provide the electromagnetic energy to the antenna.

10. After this, create the radiation box and assign the radiation boundary to the radiation box.

Steps for Simulating and Analyzing the results of Antenna

1. To analyze the different parameters of designed antenna, the analysis setup is created first and desired solution frequency is assigned.

2. After assigning the solution frequency, the next step is to add the frequency sweep which is used to generate the solution frequency across the frequency ranges.

3. Than far field radiation setup is used to analyze the gain and radiation pattern of designedantenna.

4. After this, antenna is validated, analyzed band report is created.

Applications for antennas:

- Microwave transiting Waveguide components
- RF filters
- Three-dimensional discontinuities
- Passive circuit elements

CHAPTER-4

ANTENNA FUNDAMENTALS

ANTENNA FUNDAMENTALS

In this chapter, the elementary concept of an antenna is provided, and its working is explained. Next, some critical performance parameters of antennas are discussed. Finally, some communal types of antennas are introduced.

4.1 INTRODUCTION:

An antenna is an array of conductors , electrically connected to the receiver or transmitter. Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional, or high-gain, or “beam” antennas).

4.1.1 EVOLUTION OFANTENNA:

Antennas have been around now for nearly 125 years. In those 125 years wireless communication has become increasingly important. Personal mobile communication applications are putting huge constraints on the antennas that need to be housed in limited spaces. Therefore the common practice of wireless engineers to consider the antenna as a black-box component is not valid anymore. The modern wireless engineer needs to have a basic understanding of antenna theory. Before we dive into the derivation of antenna characteristics, however, we will in this chapter present a brief overview of antenna history and the mechanisms of radiation. Thus, a solid foundation will be presented for understanding antenna characteristics and their derivations. When James Clerk Maxwell, in the 1860s, united electricity and magnetism into electromagnetism, he described light as and proved it to be an electromagnetic phenomenon. He predicted the existence of electromagnetic waves at radio frequencies, that is at much lower frequencies than light. In 1886, Maxwell was proven right by Heinrich Rudolf Hertz who without realizing it himself created the first ever radio system, consisting of a transmitter and a receiver.

4.1.2 HOW DOESAN ANTENNA WORK :

Suppose you're the boss of a radio station and you want to transmit your programs to the wider world. How do you go about it?

You use microphones to capture the people's voices and turn them into electrical energy. You take that electricity and, loosely speaking, make it flow along a tall metal antenna. As the electrons in the electric current wiggle back and forth along the antenna.From the figure 4.1 antenna creates invisible electromagnetic radiation in the form of radio waves. These waves travel out at the speed of light , taking your radio program with them .The radio waves you sent flow through the metal antenna and cause electrons to wiggle back and f orth. That generates an electric current a signal that the electronic components inside my radio turn back into sound I can hear.

Transmitter and receiver antennas are often very similar in design. For example, if you're using something like a satellite phone that can send and receive a video-telephone call to any other place on Earth using space satellites , the signals you transmit and receive all pass through a single satellite dish a special kind of antenna shaped like a bowl . Of ten, though, transmitters and receivers look very different. TV or radio broadcasting antennas are huge masts sometimes stretching hundreds of meters/feet into the air, because they have to send powerful signals over long distances. But you don't need anything that big on your TV or radio at home: a much smaller antenna will do the job fine.

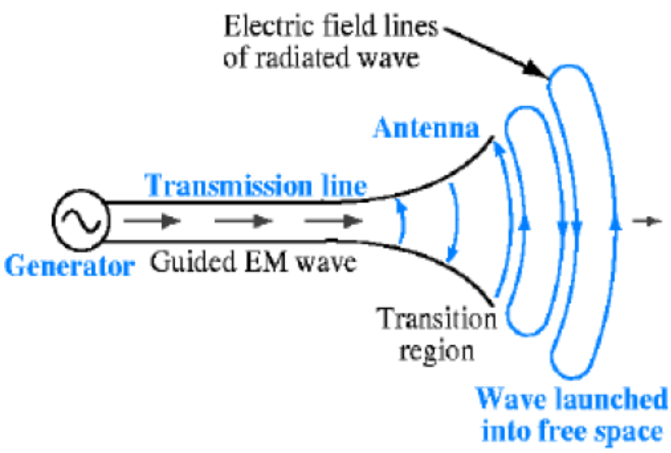

Figure 4.1:Antenna radiation

4.2 Antenna Performance Parameters:

4.2.1. Radiation Pattern

In the field of antenna design the term radiation pattern refers to the directional dependence of the strength of the radio waves from the antenna or other source.

The radiation pattern has main lobe, side lobes and back lobes as shown in the figure 4.2

Radiation pattern of antenna

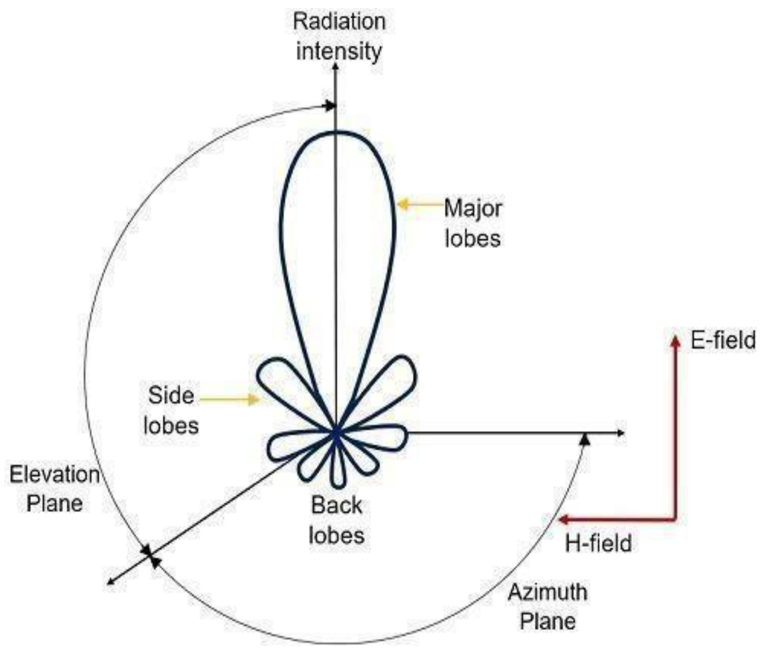

Figure 4.2 Radiation pattern of antenna

As shown in the figure 4.3 the major part of the radiated field, which covers a larger area, is the main lobe or major lobe. This is the portion where maximum radiated energy exists. The direction of this lobe indicates the directivity of the antenna.

The other parts of the pattern where the radiation is distributed side wards are known as side lobes or minor lobes. These are the areas where the power is wasted.

There is other lobe, which is exactly opposite to the direction of main lobe. It is known as back lobe, which is also a minor lobe. A considerable amount of energy is wasted even here.

Minor lobes usually represent radiation in undesired directions, and they should be minimized. Side lobes are normally the largest of the minor lobes.

In most radar systems, low side lobe ratios are very important to minimize false targetindications through the side lobes (e.g., -30 dB)

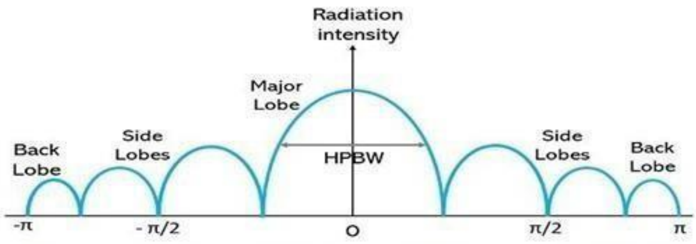

Figure 4.3 : Linear plot of power patterns and respective lobes

Components in the amplitude pattern:

There would be, in general, three electric-field components (E_r ,E_θ, E_φ) at each observation point on the surface of a sphere of constant radius.

In the far field, the radial *Er* component for all antennas is zero or vanishingly small.

1. Isotropic antenna: The antenna which radiates equally in all directions is called isotropic antenna. The radiation pattern of this antenna is called spherical.

2. Directional antenna: Radiates more in a particular direction and less in other direction

3. Omni directional antenna: The antenna which radiates power only in one direction is called omni directional antenna.

EXAMPLES:

Directional – Dipole antenna, Folded dipole antenna.

Omni directional – Horn antenna, Yagi-Uda antenna.

4.2.2 Directivity:

Directivity is the measure of the concentration of an antenna's radiation pattern in a particular direction. Directivity is expressed in db. The higher the directivity, the more concentrated or focused is the beam radiated by an antenna. A higher directivity also means that the beam will travel further.

An antenna that radiated equally well in all directions would be omni-directional and have a directivity of 1 (0 dB).

Antenna gain = directivity * antenna efficiency

Gain is the product of directivity and efficiency. Where efficiency accounts for the losses on the antenna such as manufacturing faults, surface coating losses, dielectric, resistance, VSWR, or any other factor.

A high directivity is not always better, for example, many applications like mobile devices require omni-directional antennas and thus require antennas with a low/no directivity. High-directivity antennas are used in permanent installations such as satellite television, wireless backhaul etc. as they need to transmit and receive information over longer distances, in a particular direction.

4.2.3 Input Impedance:

The input impedance of antenna is basically the impedance offered by the antenna at its terminals. It is defined as the ratio of voltage to the current across the two input terminals o f the antenna. Generally, the antenna impedance is given as:

$$Za=Ra +j\ Xa \qquad \text{..... 4.1}$$

We have already discussed in our previous article that antennas are used in wireless communication in order to transmit the signal in the form of waves. It is designed to change electrical energy into the electromagnetic signals at the transmitting end. While electromagnetic signal back to electrical one at the receiving end. So, it basically integrates the electric field and magnetic field in order to generate voltage and current so as to actuate electrical devices.

Hence we can say that the impedance provided by the antenna at its input terminal is known as antenna impedance. We know that when a certain voltage is provided to any transmitting antenna then it generates current by following ohm's law.

$$V = I*R \qquad \text{.....4.2}$$

Here R represents the resistance of the input terminal of the antenna. Further on considering the imaginary part, we will have

$$E=I*Z \qquad \text{...... 4.3}$$

So, if we have a transmitting antenna that is radiating some power then impedance Z will be present behind it. This is known as the impedance of the antenna.

4.2.4 Return loss(RL):

Return loss is the measure of how small the return or reflection/echo is. We want a small return, so a large loss on the return "echo" is good. Smaller return loss is bad and means less energy is going into our antenna. RF engineers often measure return loss on a "dB" logarithmic scale

4.2.5 Bandwidth(BW):

Bandwidth of an antenna is an important concept. The bandwidth of an antenna refers to the range of frequencies over which the antenna satisfies a particular parameter specification. The parameters generally specified are gain, radiation pattern, the VSWR etc.

4.2.6 Antenna Gain:

Antenna gain is a measure of the maximum effectiveness with which the antenna can radiate the power delivered to it by the transmitter towards a target. Antenna gain is typically given the symbol G .If an antenna's gain is 2 (3 dB), it means that twice the amount of effective power will be sent in the direction of a target than from an isotropic radiator, and so has the equivalent effect of doubling the power of the transmitter in that particular direction. In practice, the gain of a ship's radar antenna will be around 30 dB (1000 times). By definition, the gain of an isotropic radiator is 0 dB (unity).

4.3 TYPES OFANTENNAS:

Antennas come in different shapes and sizes to suit different types of wireless applications. The characteristics of an antenna are very much determined by its shape, size and the type of material that it is made of. Some of the commonly used antennas are briefly described below.

4.1.3 WIRE ANTENNAS:

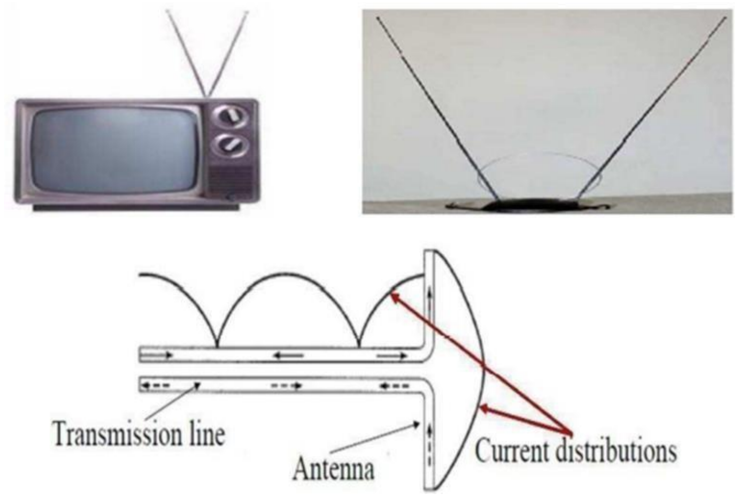

Figure.4.3.1 Wire antennas

Dipole, monopole, loop antenna, helix antennas:- These were shown in Figure.4.3.1 and are usually used in personal applications, automobiles, buildings, ships, aircrafts and spacecrafts.

4.1.4 APERTURE ANTENNAS:

Horn antennas, waveguide opening :- Usually aperture antennas are used in aircrafts and space crafts, because these antennas can be flush. These are shown in Figure.4 .3.2

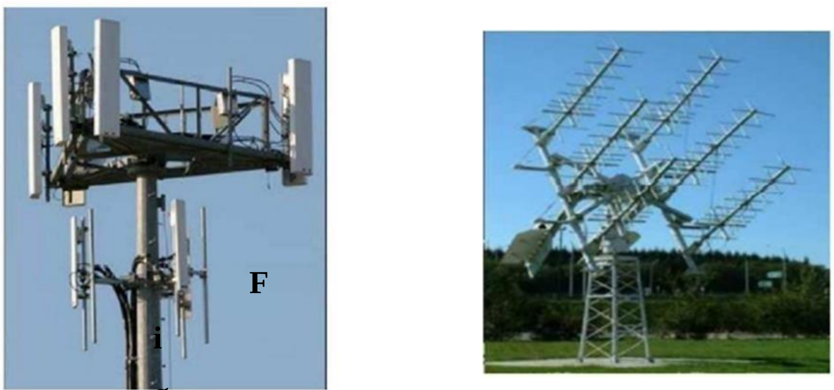

Figure.4.3.2 Aperture antennas

4.1.5 REFLECTOR ANTENNAS:

Parabolic reflectors, corner reflectors :- These are high gain antennas usually used in radio astronomy, microwave communication and satellite tracking. The reflector antennas are shown in Figure.4.3.3

Figure.4.3.3 Reflector antennas

4.1.6 LENS ANTENNAS:

Convex-plane, convex-convex , convex-concave and concave-plane lenses o These antennas are usually used for very high frequency applications

4.1.7 MICROSTRIP ANTENNAS:

Rectangular, circular etc. shaped metallic patch above a ground plane :- Micro strip antennas are low-profile antennas. A metal patch mounted at a ground level with a di-electric material in-between constitutes a **Micro strip** or **Patch Antenna**. These are very low size antenna having low radiation. Used in aircraft, spacecraft, satellites, missiles, cars, mobile phones etc and are shown in Figure.4.3.5

Figure.4.3.5 Microstrip antennas

CHAPTER-5

MICROSTRIP PATCH ANTENNA

MICRO STRIP PATCH ANTENNA

In this chapter, an introduction of Microstrip Patch Antenna is followed by its advantages and disadvantages and also feeding techniques were discussed. Finally, Microstrip Patch Antenna analysis theory is discussed. Working mechanism is also discussed.

5.1 Introduction

A Microstrip patch antenna consists of a radiating patch on one side of a dielectric which has a ground plane on the other side as shown in Figure 5.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and feed lines are usually photo etched on the dielectric substrate.

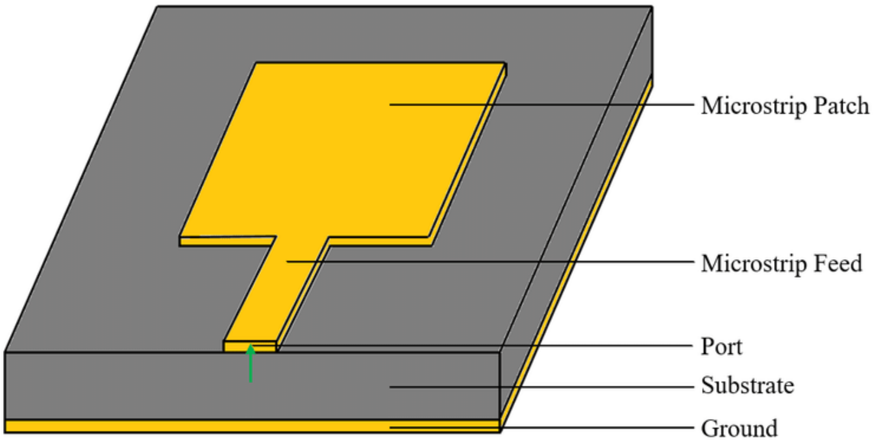

Figure 5.1 Structure of a Microstrip Patch Antenna

In order to simplify analysis or performance prediction, the patch is generally square, rectangular, dipole, circular, triangular, elliptical, disc sector, circular ring, ring sector are shown in Figure 5.2.

For rectangular patch, the length L of the patch is generally $0.3333\lambda_o<L<0.5\lambda_o$ where λ_o is free space wavelength. The patch is very thin such that $t<<\lambda_o$ where t is the thickness of the patch. The height h of the dielectric substrate is generally $0.003\lambda_o<h<0.05\lambda_o$. The dielectric constant of the substrate(ε) is in the range $2.2<\varepsilon_r<12$.

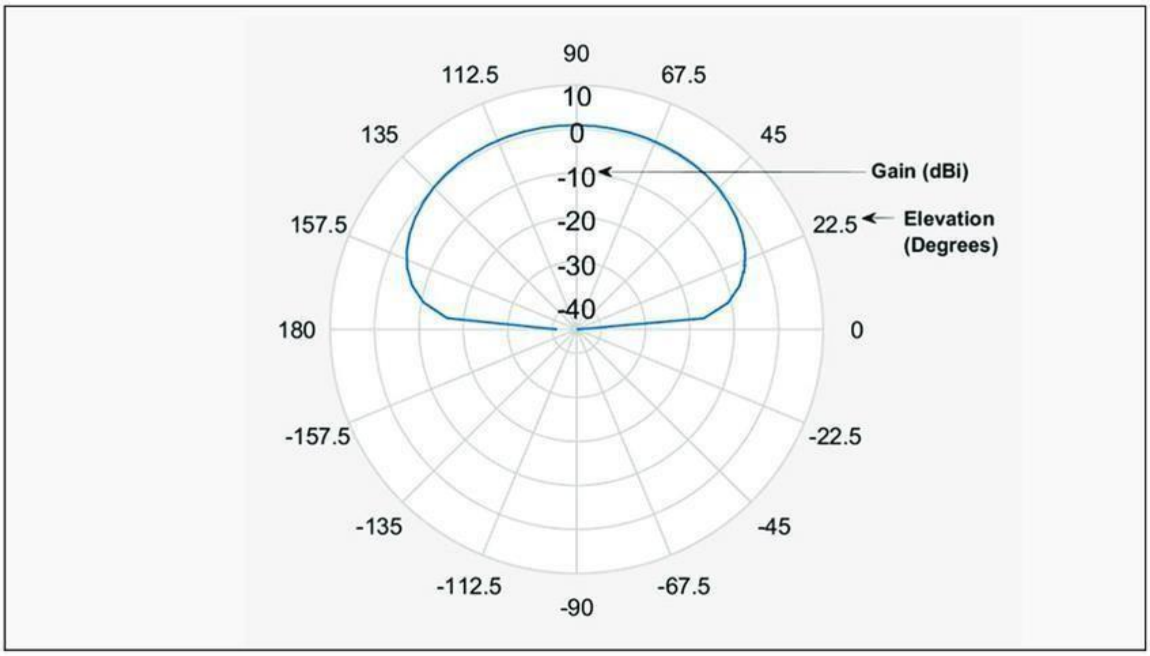

Figure 5.2:Microstrip patch antenna radiation pattern

The microstrip patch antenna can have different shapes but some of the common shapes are shown in the figure 5.3

COMMON SHAPES OF MICRO STRIP PATCH ANTENNA:

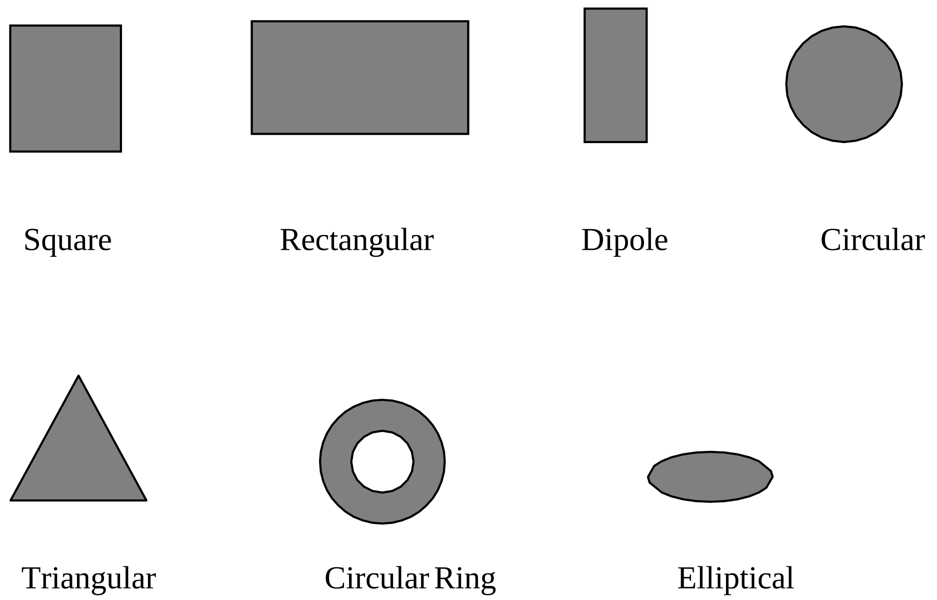

Figure 5.3: microstrip patch elements shapes

Microstrip patch antenna radiate because of fringingfields between patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is required since this provides better efficiency, larger bandwidth and better radiation. However such configuration leads to a larger antenna size. In order to compact Microstrip Patch Antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth.

5.2 FR4 Substrate

"FR" stands for flame/fire retardant. FR-4 is a designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards. It is a composite material composed of fibre glass clot an epoxy resin binder that is flame resistant. FR-4 glass epoxy is famous and flexible high-pressure thermoset plastic laminate material with high strength to weight ratios.

If the material has to be flame or fire retardant, there are certain requirements to be fulfilled for the material to be certified as FR. The FR4 substrate is manufactured by compressing an epoxy resin at high pressure and a glass fibre mat is embedded within the structure.

The microstrip patch antenna design depends upon substrate thickness. The thick substrates with low dielectric constants are required one to obtain the larger bandwidth and higher efficiency due to loosely bound fringing fields. While thin substrates with large dielectric constants reduce overall size of antenna, due to high loss tangents thin substrates areless efficient that results with narrow bandwidth. Therefore substrate plays an important role while designing an antenna.

5.3 FR4 substrate Advantages and Disadvantages

Microstrip patch antenna are increasing in popularity for use in wireless applications due to their low profile structure. They are compatible for embedded antennas in wireless devices such as cellular phones, etc…

5.3.1Advantages

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal face.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both linear and circular polarization.
- Can be easily integrated with microwave integrated circuits.
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

5.3.2 Disadvantages

5.3.2.1 Narrow bandwidth
5.3.2.2 Low efficiency
5.3.2.3 Low Gain
5.3.2.4 Extraneous radiation from feeds and junctions
5.3.2.5 Poor and fire radiator except tapered slot antennas
5.3.2.6 Low power handling capacity
5.3.2.7 Surface wave excitation

Microstrip patch antennas have a high antenna quality factor(Q). Q represents losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate.

5.4 Feeding Techniques

Microstrip patch antenna can be fed by variety of methods. These methods can be classified into 2 types-contacting and non-contacting. In contacting method, the RF power is fed directly to the radiating patch using a connecting element such as microstrip line. In non- contacting method, electromagnetic field coupling is done to transfer power between microstrip line and radiating patch. The four most feeding techniques used are microstrip line, coaxial probe (both are contacting methods), aperture coupling and proximity coupling(both are non-contacting methods) .

5.4.1 Microstrip line feed

In this type of feeding technique, the conducting strip is directly connected to the edge of the microstrip patch as shown in Figure 5.4. The conductingstrip is smaller in width as compared to patch and this kind of feed arrangement has advantage that the feed can be etched on same substrate to provide planar structure.

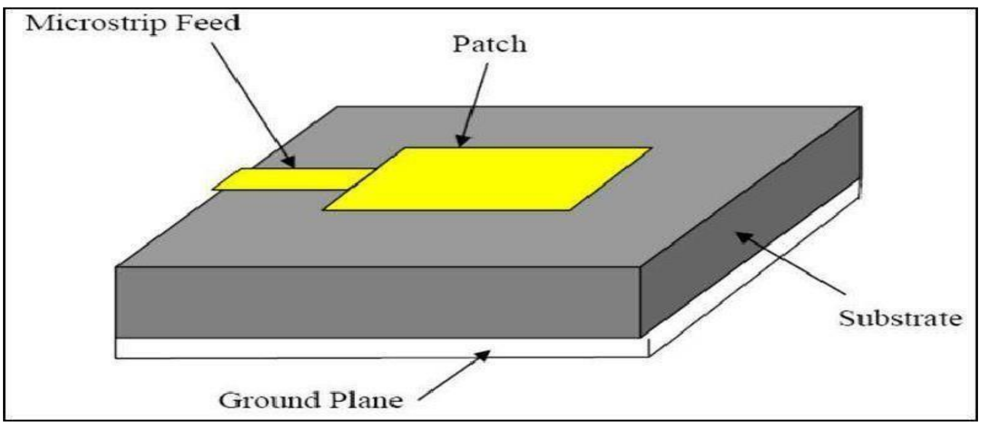

Figure5.4 : Microstrip Line Feed

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides case of fabrication and simplicity in modelling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

5.4.2 Coaxial feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 5.5, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

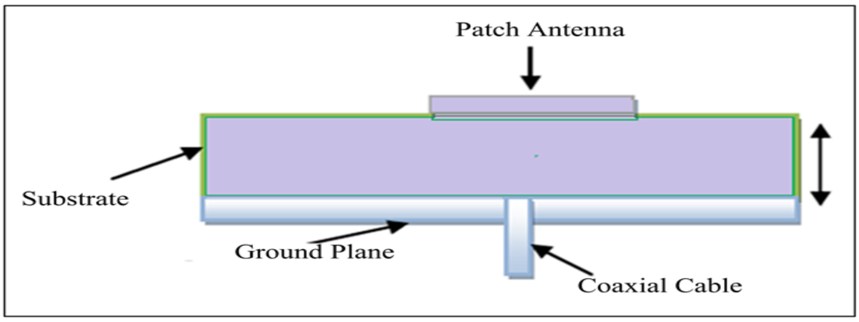

Figure 5.5 :Probe Feed rectangular Microstrip Patch Antenna

The main advantage of this type of feeding scheme is that the f eed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates . Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problem

5.4.3 Aperture Coupled Feed

In this type of feed technique, the and the microstrip feed line areseparated by the ground plane as shown in Figure 5.6. Coupling between the patch andthe feed line is made through a slot or an aperture in the ground plane.

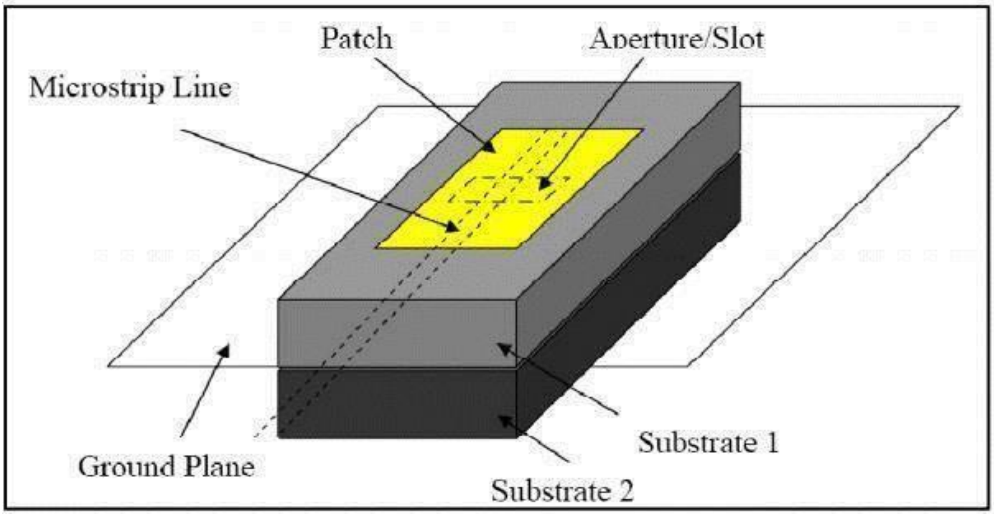

Figure 5.6: Aperture Coupled Feed

The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for the bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

5.4.4 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 5.7, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed techniques that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) , due to overall increase in the thickness of the microstrip patch antenna

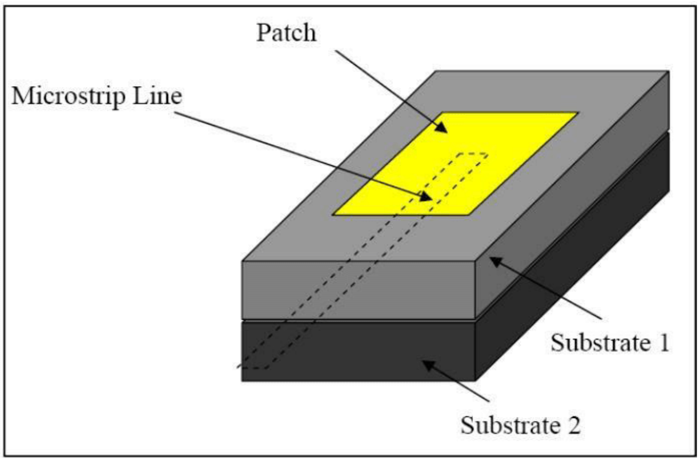

Figure 5.7 Proximity Coupled Feed

Matching can be achieved by controlling the length of the feed line and the width -to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna. Table 1 below summarizes the characteristics of the different feed techniques

Table 1: Comparing the different feed techniques

Characteristics	**Micro strip Line Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth(achieved with impedance matching)	2-5%	2-5%	2-5%	13%

5.5 Rectangular Patch Antenna

The rectangular microstrip patch is by far the most widely used configuration. It is very easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrates. We begin with the transmission-line model because it is easier to illustrate.

5.5.1 Transmission Line Model

The transmission line model treated rectangular microstrip as a part of transmission line As the rectangular microstrip antenna consists two radiating slots, transmission line modeller presents each radiating slots by an equivalent admittance which are separated by a distance equal to the length. The resistive part of them represents the radiation loss from the each slot. At the resonance the reactive part of the input impedance cancelled out and the input impedance become pure resistive Transmission line model consider the elects of various parameters described below.

5.6 Circular Microstrip Antenna

Circular patch is the second most widely used geometry for the microstrip patch antenna. As in rectangular microstrip antenna we have two degree of f reedom (length and width) to control the antenna characteristics, here we have only radius of circular patch. A circular microstrip antenna is shown in the Fig.5.8below.

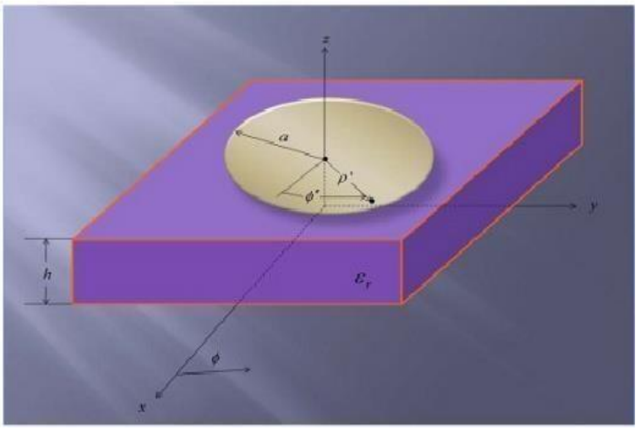

Figure 5.8: Circular Patch Antenna

5.7 Antenna Polarization:

Introduction:

We know that antennas are transducers that change one form of energy into another. It is a device that allows free-space propagation of wave by converting the electrical signal into electromagnetic waves.

As the antenna is associated with the transmission and reception of waves thus, the orientation of the wave while propagation describes the polarization of the antenna.

Antenna polarization is mainly specified along the main beam as the characteristics are usually constant along the main beam. However, there exists a difference in the polarization of the radiation from the side lobes than the main beam. Thus, if the direction of polarization is not given then the direction from where the maximum gain is achieved is taken into consideration.

Types of Antenna Polarization

On a general basis, antenna polarization is classified as:

5.7.1 Linear Polarization:

A type of polarization in which all the waves possess similar alignment in space either vertical or horizontal is known as linear polarization. We have already discussed the vertically and horizontally polarized electromagnetic waves in the previous section. Both these types of polarizations are regarded as linear polarization.

An antenna that either radiates vertically polarized or horizontally polarized waves is known as a linearly polarized antenna. This type of polarization is mainly used by the antenna that is employed in space wave propagation.

5.7.2 Circular Polarization:

Antennas that are designed to radiate horizontally, vertically along with all planes in between are called circularly polarized antenna.

So, when two linearly polarized waves specifically of equal amplitudes are produced by a single antenna in the same direction in mutually perpendicular orientation w.r. t each other, then circularly polarized waves are produced. This means the two linearly polarized waves must possess a phase difference of 90°.

Also, according to the rotational format, the circular polarization may be right or left-handed. This depends on the polarity of the phase difference.

Circular polarization suits VHF, UHF and microwave applications. For example: in radar applications for reducing clutter echoes, in artificial satellites, etc.

Maximum efficiency between transmitting and receiving antennas are obtained when both the antennas exhibit circular polarization.

5.7.3 Difference between linear and circular polarization:

Linear polarization occurs when electromagnetic waves broadcast on a single plane (either vertical or horizontal). Linear polarized antennas must have a known RFID tag orientation and the tag must be fixed upon the same plane as the antenna in order to get a consistent read. Some examples of linear polarized antennas are the MTI MT- 263003 Outdoor Antenna, and the Times-7 A5531 Indoor Antenna.

Due to the concentrated emission, linear polarized antennas typically have greater read range than circular polarized antennas of the same gain.

Circular polarized antennas, such as the **LAIRD S9028PCR INDOOR RFID ANTENNA** emit electromagnetic fields in a corkscrew-like fashion. Technically speaking, they are broadcasting electromagnetic waves on two planes making one complete revolution in a single wavelength.

Compared to linear polarized antennas of the same gain, circular polarized antennas wil have a shorter read range because they lose about 3 dB splitting their power across two separate planes.

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CHAPTER-6

MIMO ANTENNA

MIMO ANTENNA

6.1 Introduction

In radio, multiple-input and multiple-output, or MIMO , is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation. MIMO has become an essential element of wireless communication standards including IEEE 802.11n (Wi-Fi 4), IEEE 802.11ac (Wi-Fi 5), HSPA+ (3G), WiMAX, and Long Term Evolution (LTE). More recently, MIMO has been applied to power-line communication for three-wire installations as part of the ITU G.hn standard and of the Home Plug AV2 specification.

At one time, in wireless the term "MIMO" referred to the use of multiple antennas at the transmitter and the receiver. In modern usage, "MIMO" specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same radio channel by exploiting multipath propagation. Although the "multipath" phenomenon may be interesting, it is the use of orthogonal frequency-division multiplexing (OFDM) to encode the channels that is responsible for the increase in data capacity. MIMO is fundamentally different from smart antenna techniques developed to enhance the performance of a single data signal, such as beam forming and diversity.

6.2 Early research

MIMO is often traced back to 1970s research papers concerning multi-channel digital transmission systems and interference (crosstalk) between wire pairs in a cable bundle: AR Kaye and DA George (1970), Brander burgand Wyner (1974), and W. van Etten (1975, 1976). Although these are not examples of exploiting multipath propagation to send multiple information streams, some of the mathematical techniques for dealing with mutual interference proved useful to MIMO development. In the mid-1980s Jack Salz at Bell Laboratories took this research a step further, investigating multi-user systems operating over "mutually cross-coupled linear networks with additive noise sources" such as time -division multiplexing and dually-polarized radio systems.

Methods were developed to improve the performance of cellular radio networks and enable more aggressive frequency reuse in the early 1990s. Space-division multiple access (SDMA) uses directional or smart antennas to communicate on the same frequency with users in different locations within range of the same base station. An SDMA system was proposed by Richard Roy and Björn Ottersten, researchers at Array Comm, in 1991. Their US patent (No. 5515378 issued in 1996) describes a method for increasing capacity using "an array of receivingantennas at the base station" with a "plurality of remote users.

6.3 Multi-antenna types

Multi-antenna MIMO (or single-user MIMO) technology has been developed and implemented in some standards, e.g., 802.11nproducts.

SISO/SIMO/MISO are special cases of MIMO.

Multiple-input single-output (MISO) is a special case when the receiver has a single antenna.

Single-input multiple-output (SIMO) is a special case when the transmitter has a single antenna.

Single-input single-output (SISO) is a conventional radio system where neither transmitter nor receiver has multiple antennas.

Principal single-user MIMO techniques

Bell Laboratories Layered Space-Time (BLAST), Gerard. J. Foschini (1996)

Per Antenna Rate Control (PARC), Varanasi, Guess (1998), Chung, Huang, Lozano (2001)

Selective Per Antenna Rate Control (SPARC), Ericsson (2004)

Some limitations

The physical antenna spacing is selected to be large; multiple wavelengths at the base station. The antenna separation at the receiver is heavily space-constrained in handsets, though advanced antenna design and algorithm techniques are under discussion.

6.4 MIMO -Multiple Input Multiple Output basics

A channel may be affected by fading and this will impact the signal to noise ratio. In turn this will impact the error rate, assuming digital data is being transmitted. The principle of diversity is to provide the receiver with multiple versions of the same signal. If these can be made to be affected in different ways by the signal path, the probability that they will all be affected at the same time is considerably reduced. Accordingly, diversity helps to stabilize a link and improves performance, reducing error rate.

Several different diversity modes are available and provide a number of advantages:

- **Time diversity:** Using time diversity, a message may be transmitted at different times, e.g. using different timeslots and channel coding.

- **Frequency diversity*:*** This form of diversity uses different frequencies. It may be in the form of using different channels, or technologies such as spread spectrum / OFDM.

- **Space diversity :** Space diversity used in the broadest sense of the definition is used as the basis for MIMO. It uses antennas located in different positions to take advantage of the different radio paths that exist in a typical terrestrial environment.

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

6.4.1 The importance of MIMO for users

The 3rd Generation Partnership Project (3GPP) added MIMO with Release 8 of the Mobile Broadband Standard. MIMO technology is used for Wi-Fi networks and cellular fourth-generation (4G) Long-Term Evolution (LTE) and fifth-generation (5G) technology in a wide range of markets, including law enforcement, broadcast TV production and government. It also can be used in wireless local area networks (WLANs) and is supported by all wireless products with 802.11n.

MIMO is often used for high-bandwidth communications where it's important to not have interference from microwave or RF systems. For example, it's frequently used by f irst responders who can't always rely on cell networks during a disaster or power outage or when a cell network is overloaded.

Wi-Fi 6 -- also known as 802.11ax -- raised the bar for wireless connectivity by introducing several new technologies to help eliminate the limitations associated with adding more Wi-Fi devices to a network. Wi-Fi 7 is currently in development with an expected release in 2024.

6.4.2 LTE applications of MIMO

MIMO is one of the most common forms of wireless, and it played a key role in the deployment of LTE and the wireless broadband technology standard Worldwide Interoperability for Microwave Access (WiMAX>). LTE uses MIMO and orthogonal frequency-division multiplexing(OFDM) to increase speeds up to 100 megabits per second (mbps) and beyond. These rates are double what was offered in previous 802.11a Wi-Fi. LTE uses MIMO for transmit diversity, spatial multiplexing (to transmit spatially separated independent channels), and single-user and multiuser systems.

MIMO in LTE enables more reliable transmission of data, while also increasing data rates. It separates the data into individual streams before transmission. During transmission, the data and reference signals travel through the air to a receiver that will already be familiar with these signals, which helps the receiver with channel estimation.

6.4.3 MIMO and 5G massive systems

MIMO continues to upgrade and grow through its use in massive new applications, as the wireless industry works to accommodate more antennas, networks and devices. One of the most prominent examples of this is the rollout of 5G technology.

These massive 5G MIMO systems use numerous small antennas to boost bandwidth to users -- not just transmission rates as with third-generation (3G) and 4G cellular technology -- and support more users per antenna. Unlike 4G MIMO, which uses a frequency division duplex (FDD) system for supporting multiple devices, 5G massive MIMO uses a different setup called time division duplex (TDD). This offers numerous advantages over FDD

6.5 MIMO PARAMETERS :

The diversity capabilities with respect to any MIMO antenna are analyzed by the computation of Mean Effective Gain (Mean),Total Active Reflection Coefficient (TARC), and Envelope Correlation Coefficient (ECC).These parameters are calculated using the formulas given as mentioned below

6.5.1 Envelope Correlation Coefficient(ECC):

Envelope Correlation Coefficient tells us how independent two antennas' radiation patterns are. So if one antenna was completely horizontally polarized, and the other was completely vertically polarized, the two antennas would have a correlation of zero. Similarly, if one antenna only radiated energy towards the sky, and the other only radiated energy towards the ground, these antennas would also have an ECC of 0. Hence, Envelope Correlation Coefficient takes into account the antennas' radiation pattern shape, polarization, and even the relative phase of the fields between the two antennas.

$$ECC = \frac{|s_{pp}^{*}s_{pq} + s_{qp}^{*}s_{qq}|^2}{\left(1-|s_{pp}|^2-|s_{pq}|^2\right)\left(1-|s_{qp}|^2-|s_{qq}|^2\right)^{*}} \quad \text{....6.1}$$

6.5.2 Total Active Reflection Coefficient (TARC):

From the graph, it is evident that the ecc vs frequency plot is far less than 0.5 which satisfies the standard condition. Also the difference between the mag vs frequency plots is almost equal to 0.1 which is less than 3dB thereby satisfies the standard condition.

TARC vs frequency plot shows that the plot obtained was below -10dB over the range of our operating frequency range which also satisfied the standard conditions. All these plots shows that our antenna would work efficiently.

$$TARC = -\sqrt{\frac{(s_{pp}+s_{pq})^2+(s_{qp}+s_{qq})^2}{2}} \quad \text{....6.2}$$

Applications of MIMO antenna:

6.5.1 Third Generation (3G) (CDMA and UMTS) allows for implementing space-time transmit diversity schemes, in combination with transmit beamforming at base stations.

6.5.2 Fourth Generation (4G) LTE And LTE Advanced define very advanced air interfaces extensively relying on MIMO techniques.

6.5.3 LTE primarily focuses on single-link MIMO relying on Spatial Multiplexing and space- time coding while LTE-Advanced further extends the design to multi-user MIMO.

6.5.4 In wireless local area networks (WLAN), the IEEE 802.11n (Wi-Fi), MIMO technology is implemented in the standard using three different techniques: antenna selection, space-time coding and possibly beam forming.

6.5.5 MIMO wireless communications architectures and processing techniques can be applied to sensing problems. This is studied in a sub-discipline called MIMO radar.

6.5.6 5G and Internet of Things requires massive data rate. MIMO technology with Beamforming is one of the significant transmission terminologies for super charged 5G networks and IoT.

CHAPTER-7

ANTENNA DESIGN

ANTENNA DESIGN

The proposed design is on HFSS, the rectangular microstrip patch antenna construction with tree shape design is developed and simulated. The Circular Polarized Microstrip patch antenna is used in various wireless communication systems like WLAN, Wi-Fi, GPS. The left hand circular polarization and right hand circular polarization are two different types of methods implemented. Initially by using single cuts the results are obtained and simulated. Then by introducing double cuts for further improvement of results, the design is modified and simulated. Then the findings of circular polarization numerical and experimental studies are presented and analyzed.

7.1 BASIC MICROSTRIP PATCH ANTENNA

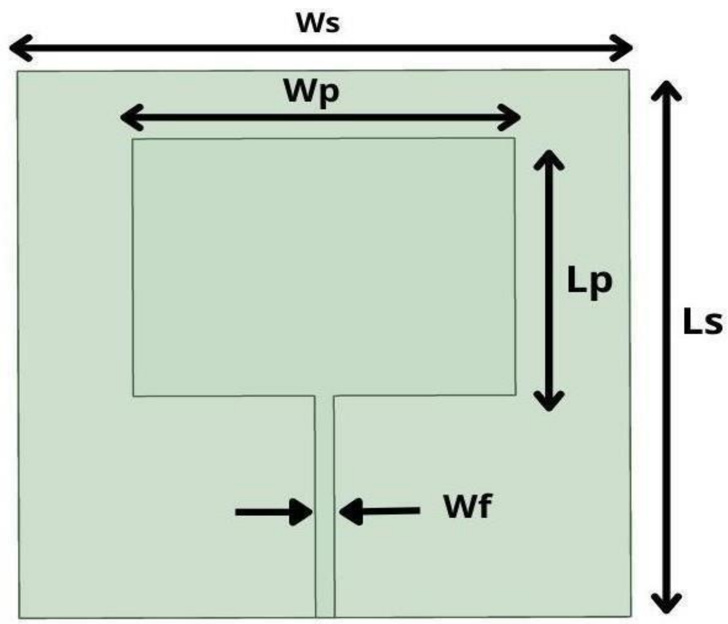
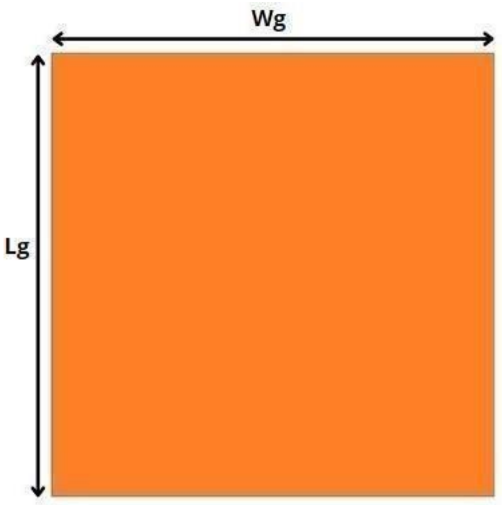


Figure 7.1 : Basic microstrip patch antenna

The above figure shows a basic rectangular microstrip patch antenna with Ws as width of the substrate, Ls as the length of the substrate. The patch has Wp as the width of the patch and Lp as the length of the patch. The feedline is given to the patch with Wf as width of the feedline and Lf is the length of the patch.

7.2 MIMO RECTANGULAR MICROSTRIP PATCH ANTENNA



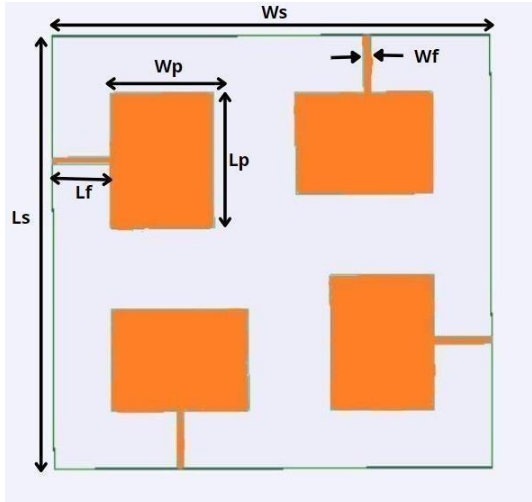


Figure 7.2(a) : The proposed antenna bottom view antenna with no cuts (orange colour – Ground)

Figure 7.2(b) : Top view of the MIMO

As shown in the figures 7.2(a) and 7.2(b),In FR4 substrate material , the 2x2 MIMO consisting of four rectangular microstrip patch antennas is arranged in tree shape on one side and the ground plane is on the other side . The ground plane has dimensions of length 128mm, width 128 mm and thickness of 1.6 mm. The proposed antenna has patch dimensions of length 30.1 mm and width 40 mm, it is given strip line feeding from the either sides of the substrate which is connected to each rectangular microstrip patch antenna. The loss tangent of the FR4 substrate is 0.02 and dielectric constant of 4.4. Figures 7.2 (a) and 7.2 (b) show the top view and bottom view of the antenna respectively. A rectangular patch is designed orthogonally to observe the S11 parameters.

7.3 MIMO Antenna with dual cuts on the patch

In order to further improve the gain and isolation, dual patch cut is done on right bottom corner and left top corner of the patch as shown in the figure 7.3. It is observed that gain has been improved from 5.35 dB to 5.677 dB and isolation between the patch elements has improved from -55.0936 dB to -66.1412 dB.

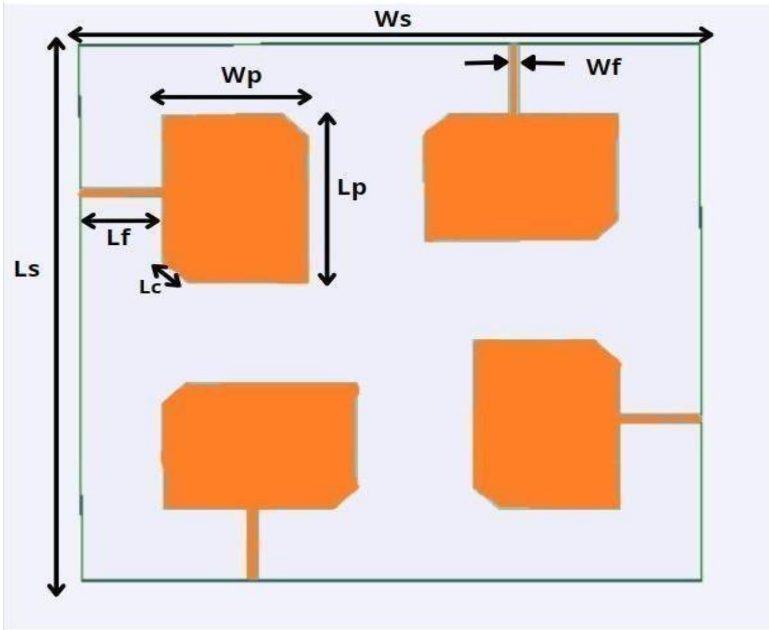


Figure 7.3 : MIMO antenna with dual sided cut

Table 2 : Dimensions of 2x2 MIMO Rectangular Microstrip Patch Antenna

Parameters	Description	Values
Ws	Substrate Width	128 mm
Ls	Substrate Length	128 mm
Wp	Patch Width	40 mm
Lp	Patch Length	30.1 mm
Wf	Feedline Width	2 mm
Lf	Feedline Length	25.95 mm
H	Substrate Height	1.6 mm
Er	Dielectric Constant	4.3
Wg	Ground Plane Width	128 mm
Lg	Ground Plane Length	128 mm
Lc	Length of the patch cut	16.2mm

CHAPTER-8

SIMULATED RESULTS

SIMULATED RESULTS

For the antenna designs shown in Fig 7.1,7.2(a),7.2(b),,7.3. Result plots for return loss from all the remaining ports for given input from one port (S12,S13,S14,S21, S23 ,S24 ,S31,S32,S34,S41,S42,S43) , radiation patterns at the resonant frequencies , 3D Gain polar plots , Axial Ratio, ECC, TARC have been plotted using the simulator software.

8.1 RECTANGULAR MICROSTRIP PATCH ANTENNA

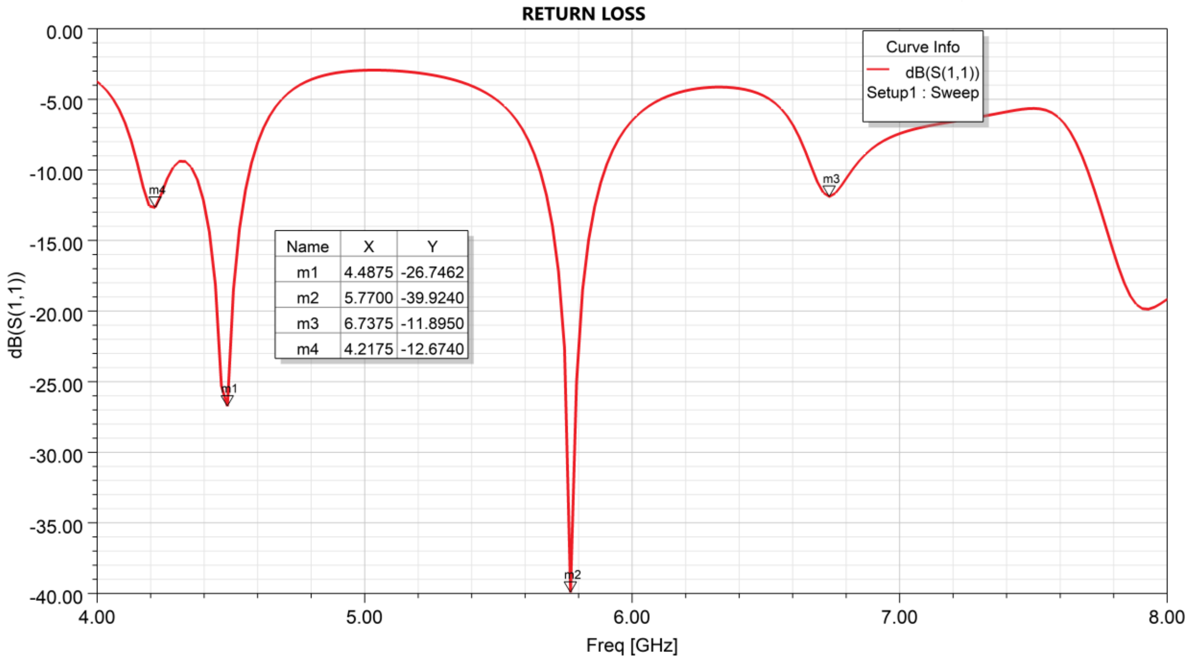


Figure 8.1(A) : RETURN LOSS OF MICROSTRIP PATCH ANTENNA

The microstrip patch antenna was simulated using the HFSS Software. The return loss plots (S11,S22,S33,S44) for the antenna design shown in Fig 7.2(a) is shown in Fig8.1(a). At 4.48 GHz the return loss is -26.74 dB with an impedance bandwidthof 267MHz and at 5.77 GHz the return loss value is obtained at -39.92 dB with an impedance bandwidth of 330MHz. Similarly, at 6.73 GHz the return loss is -11.89 dB with an impedance bandwidth of 140MHz.

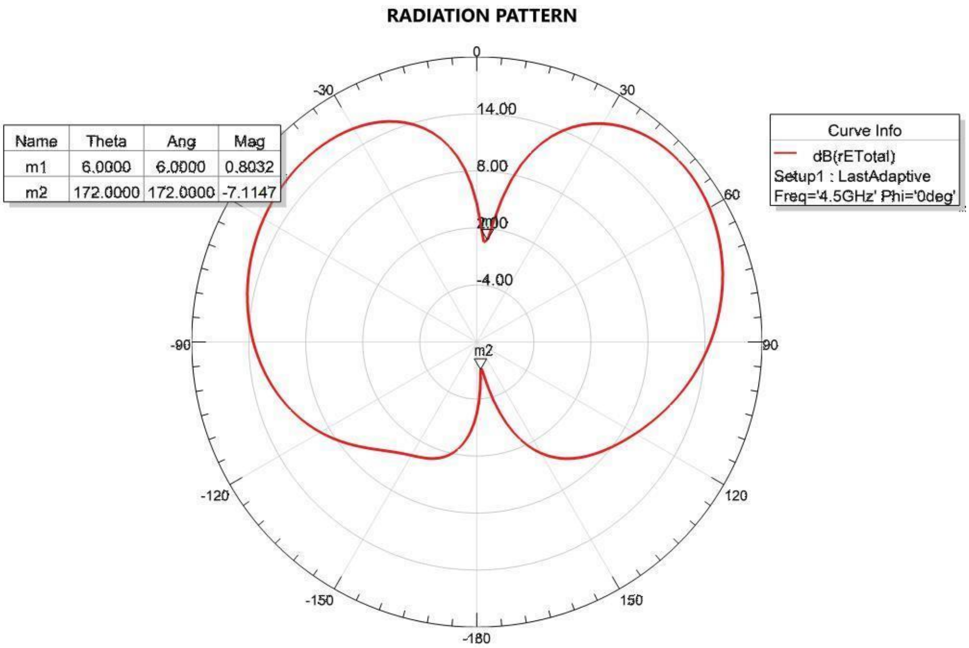


Figure 8.1(B): RADIATION PATTERN OF MICROSTRIP PATCH ANTENNA

The Fig 8.1(B) shows the radiation pattern of the MIMO with rectangular microstrip patch antenna i.e for the antenna design shown in the Fig 7.2(a) . The radiation pattern has line width of about 5mm. The front to back ratio obtained is 14.718 dB.

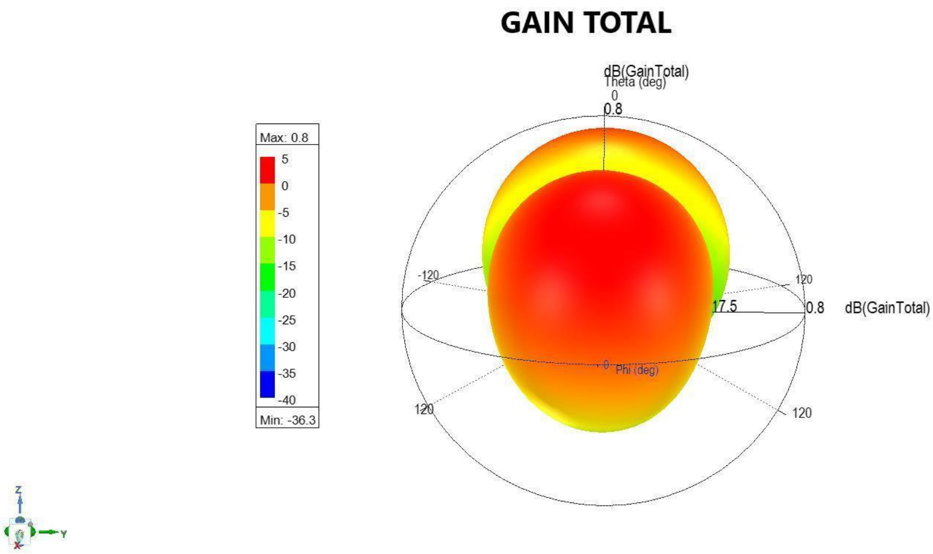


Figure 8.1(C) : GAIN TOTAL OF MICROSTRIP PATCH ANTENNA

In the Fig 8.1(C) , the antenna is radiating nearly with a gain of 1 dB. Generally an antenna will have a gain of lesser than 3 dB.

8.2 MIMO RECTANGULAR PATCH ANTENNA

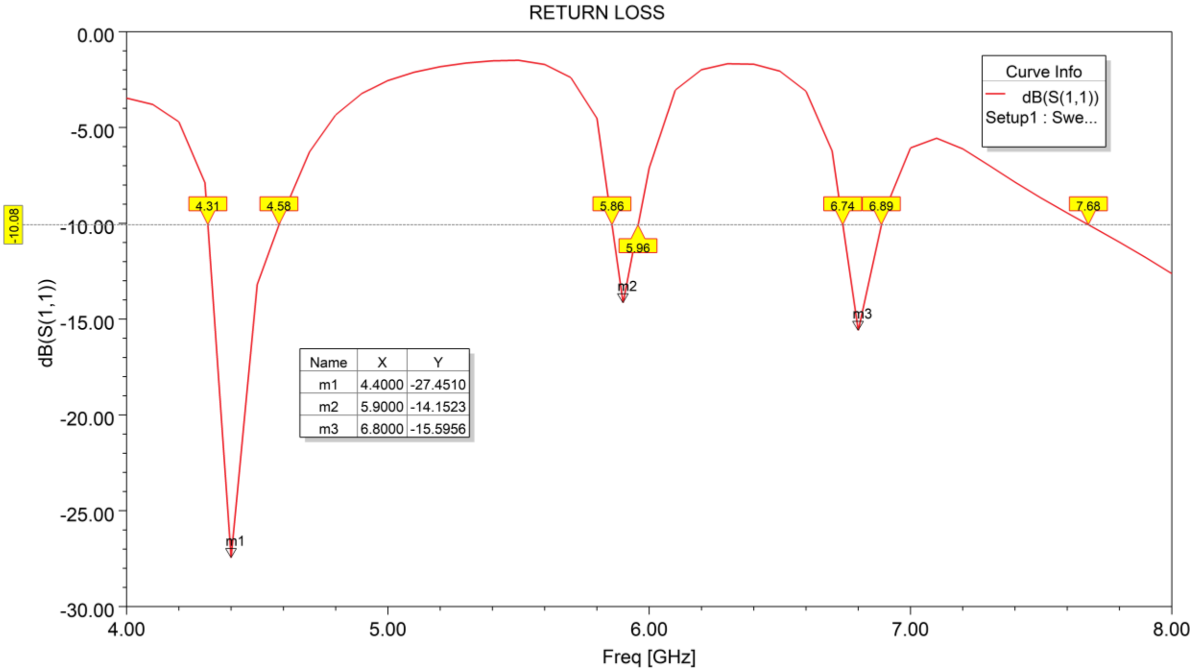


Figure 8.2(A): RETURN LOSS OF MIMO RECTANGULAR PATCH ANTENNA

The 2x2 MIMO with tree shaped patch and an etched ground plane was simulated using the HFSS Software. The return loss plots (S11,S22,S33,S44) for the antenna design shown in Fig 7.2(b) is shown in Fig 8.2(a). At 4.4 GHz the return loss is -27.4510 dB with an impedance bandwidth of 270MHz and at 5.9 GHz the return loss value is obtained at -14.1523 d B with an impedance bandwidth of 100 MHz. Similarly, at 6.8 GHz the return loss is -15.5956 dB**.**with an impedance bandwidth 150

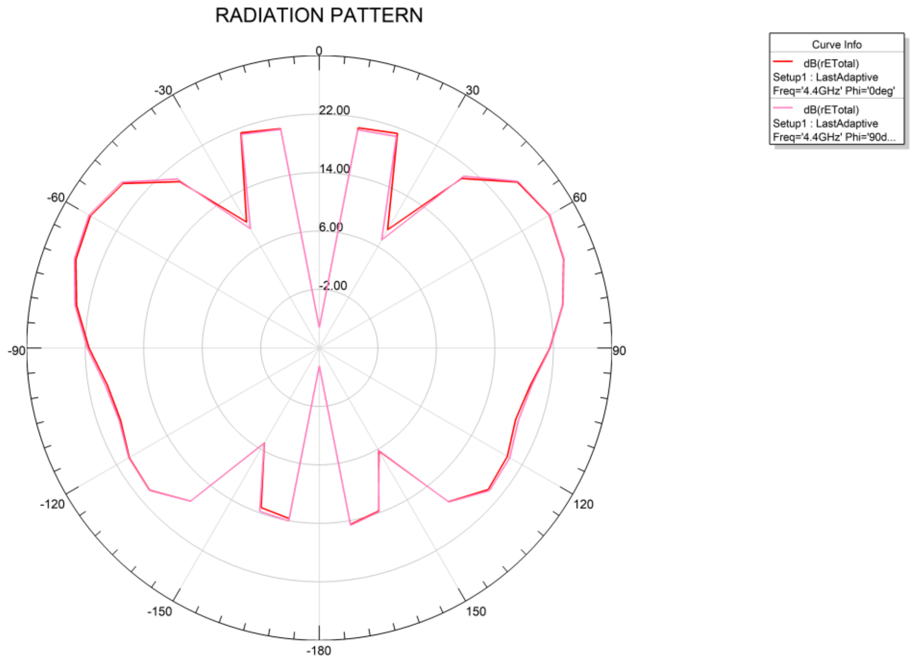


Figure 8.2(B):RADIATION PATTERN OF MIMO RECTANGULAR PATCH ANTENNA

The Fig 8.2(B) shows the radiation pattern of the MIMO with rectangular microstrip patch antenna having no cuts i.e for the antenna design shown in the Fig 7.2(b) . The radiation pattern has line width of about 5mm. The front to back ratio obtained is 35 .248 d B. A good antenna generally produces the front to back ratio of minimum of 15 dB

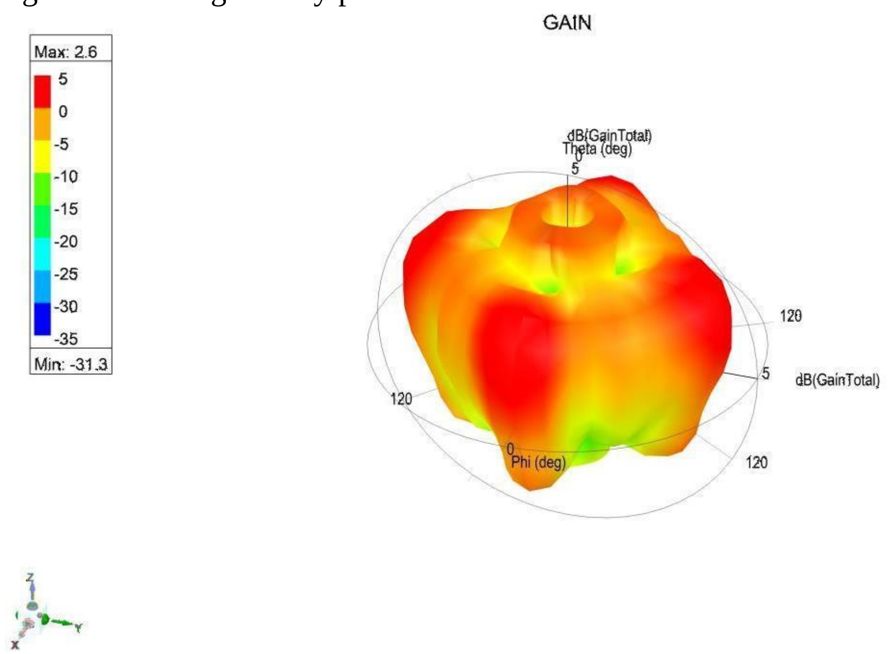


Figure 8.2(C) : GAIN PLOT OF MIMO RECTANGULAR PATCH ANTENNA

In the Fig 8.2(C) , the antenna is radiating nearly with a gain of 2.6 dB at 5 .9 GHz and 6.44 dB at 6.8 GHz. Generally an antenna will have a gain of lesser than 3 dB but as we are using a MIMO array antenna the gain almost gets doubled i.e twice that of the normal antenna. This shows that this is an efficient antenna to some extent.

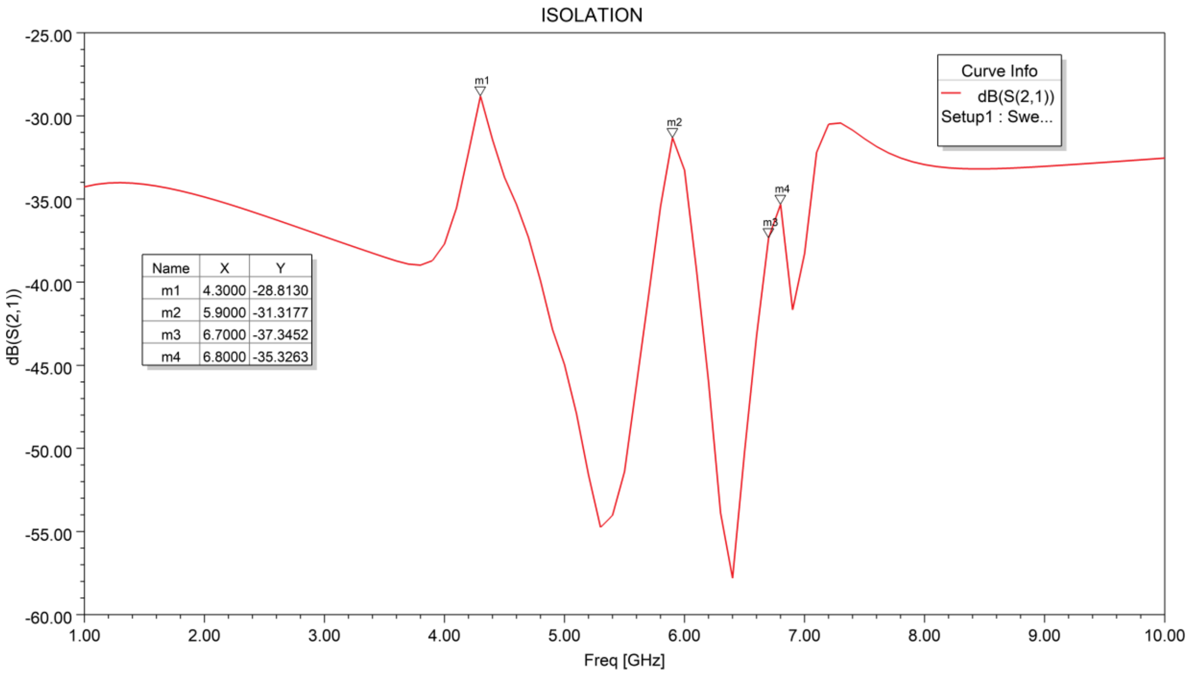


Figure 8.2(D) : ISOLATION OF MIMO RECTANGULAR PATCH ANTENNA

From the plot in Fig 8.2(D), at 4.4 GHz isolation is -28.8130 dB, 5.9 GHz the isolation obtained is -31.3177 dB and 6.8 GHz it is -15.5956 dB. In general if the isolation is less than-20 dB, it is said that there good isolation between the patch elements. The isolation in the above plot is represented by S21 curve i.e indicating the power transmitted from port 1 to port 2

8.3 MIMO ANTENNA WITH CUTS ON DUALSIDE:

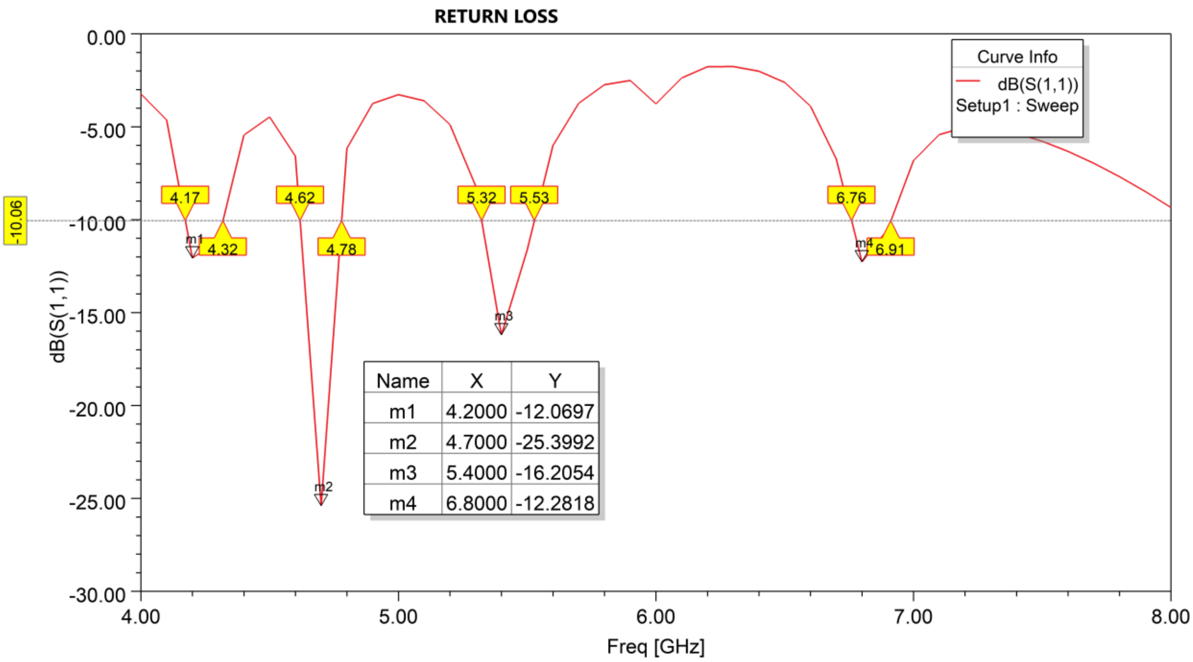


Figure 8.3(A) : RETURN LOSS OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

The plot 8.3(A) shows that the return loss value for the above antenna design shown in the figure 7.3 with dual cuts on the patch of the antenna element. At 4.4 GHz return loss is -27.4510 dB with an impedance bandwidth of 160MHz, at 5.9 GHz the return lo ss is at -14.1523 dB with an impedance bandwidth of 210MHz and similarly at 6.8 GHz the return loss is at -15.5956 dB with an impedance bandwidth of 250MHz indicating lesser back radiation

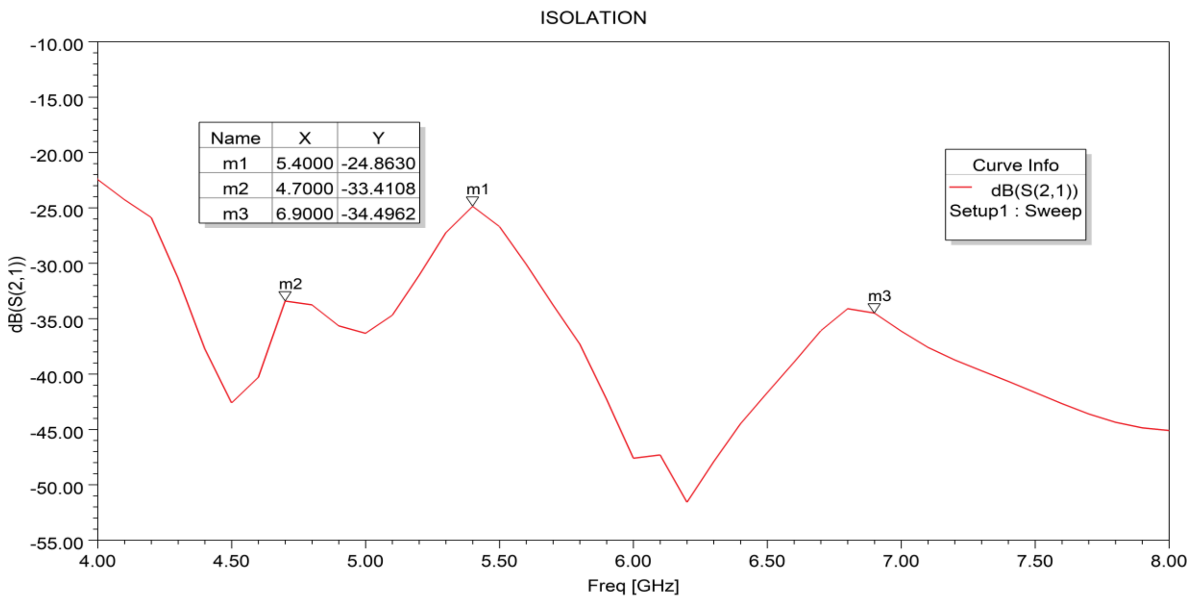


Figure 8.3(B) : ISOLATION

From the plot in Fig 8.3(B), at 4.7 GHz isolation is -33.41 dB, 5.4 GHz the isolation obtained is -24.86 dB and 6.9 GHz it is -34.49 dB. In general if the isolation is less than -20 d B, it is said that there good isolation between the patch elements. The isolation in the above plot is represented by S21 curve i.e indicating the power transmitted from port 1 to port 2

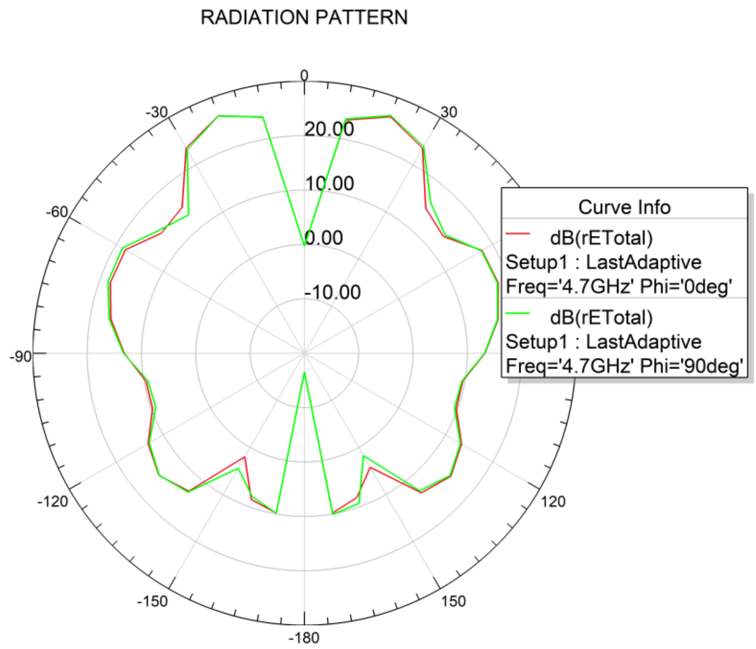


Figure 8.3(C) : RADIATION PATTERN AT 4.7 GHz OFMIMO ANTENNA WITH CUTS ON DUAL SIDE

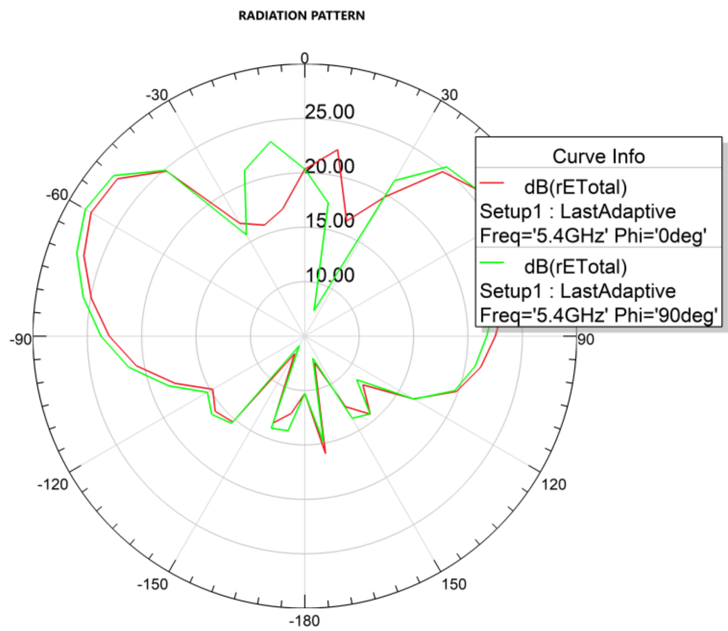


Figure 8.3(D) : RADIATION PATTERN AT 5.4GHz MIMO ANTENNA WITH CUTS ON DUAL SIDE

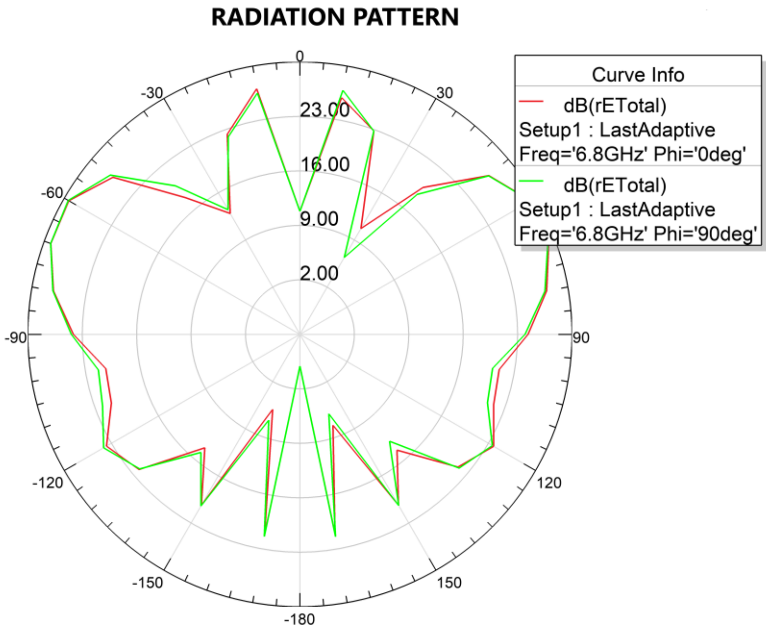


Figure 8.3(E): RADIATION PATTERN AT 6.8GHz OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

The fig 8.3(C),8.3(D),8.3(E) shows the radiation patterns of the above antenna design in Fig 7. 3 at resonant frequencies. The front to back ratio is 18.69 dB at 5.9 GHz.

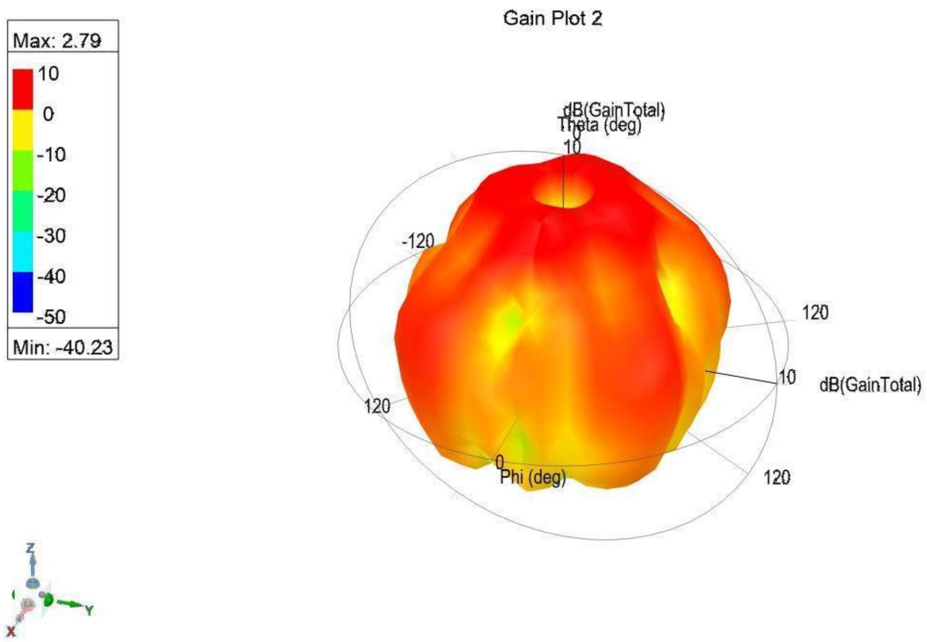


Figure 8.3(F) : GAIN PLOT AT 4.7 GHz OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

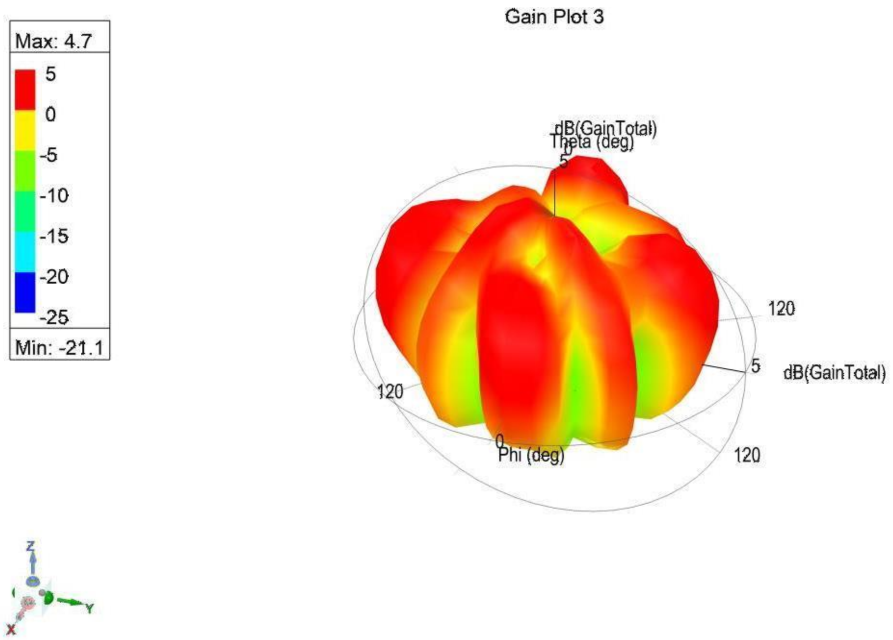


Figure 8.3(G) : GAIN PLOT AT 5.4 GHz OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

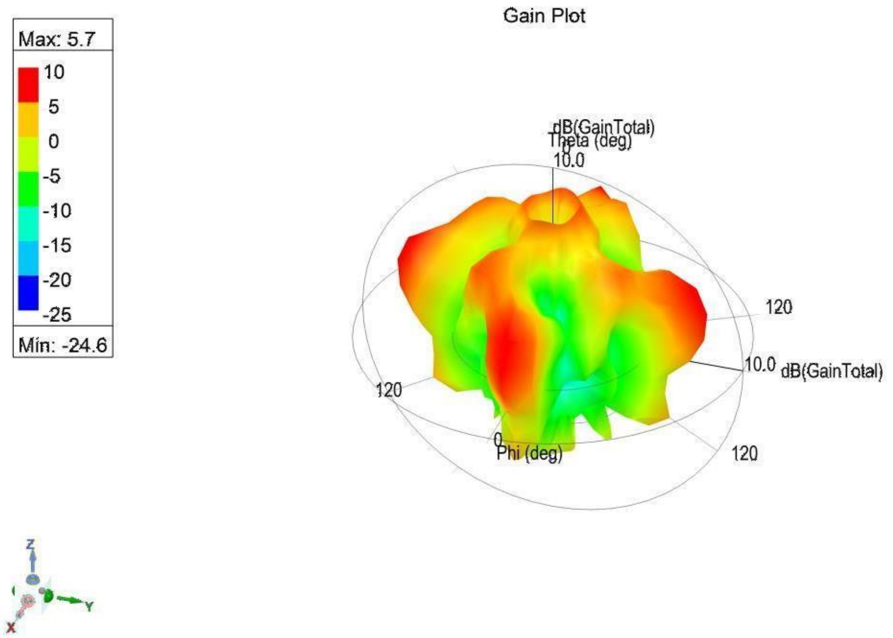


Figure 8.3(H) : GAIN PLOT AT 6.9 GHz OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

The figures 8.3(F), 8.3(G),8.3(H), the antenna is radiating nearly with a gain of 2.79 dB at 4.4 GHz, 4.7 dB at 5.9 GHz and 5.7 dB at 6.4 GHz. Generally an antenna will have a gain of lesser than 3 dB but as we are using a MIMO array antenna the gain almost gets doubled i.e twice that of the normal antenna. This shows that this is an efficient antenna to some extent.

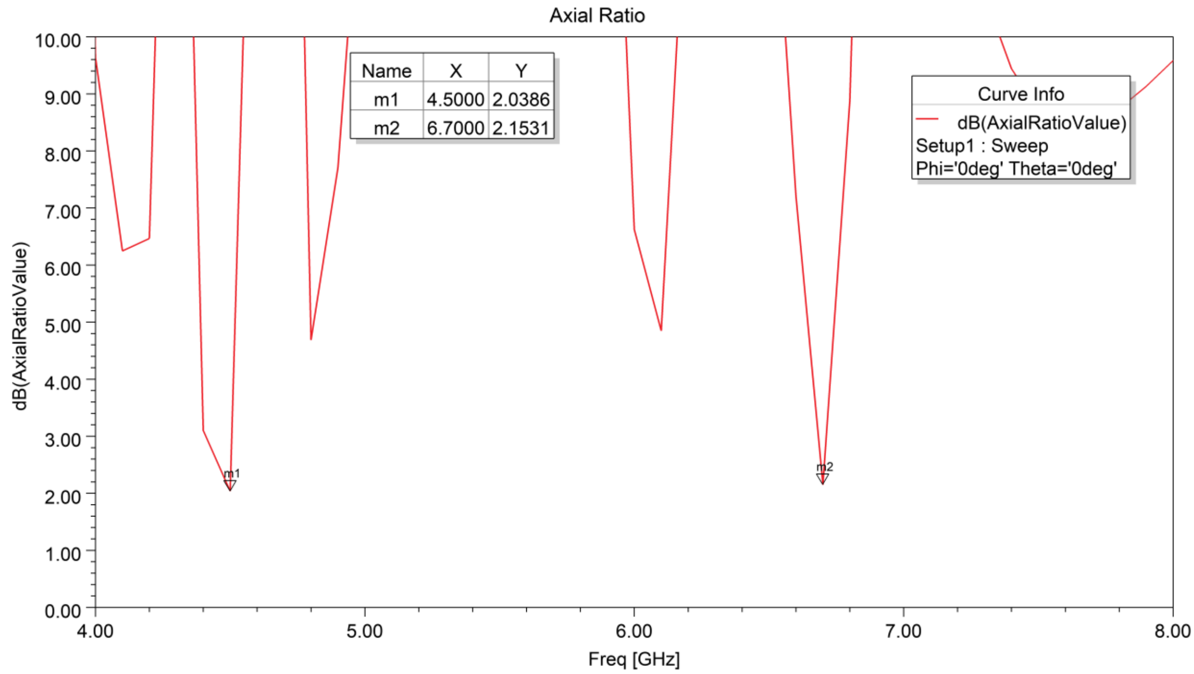


Figure 8.3(I) : AXIAL RATIO OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

The axial ratio determines whether a given antenna is circularly polarized or not. Additionally if the axial ratio is less than or equal to 3 dB then it is considered to be circular polarization, hence the above fig 8.3(I) shows that The axial ratio is 2.03 dB at 4.5 GHz and 2.15dB at 6.7GHz , showing the designed antenna is circularly polarizing

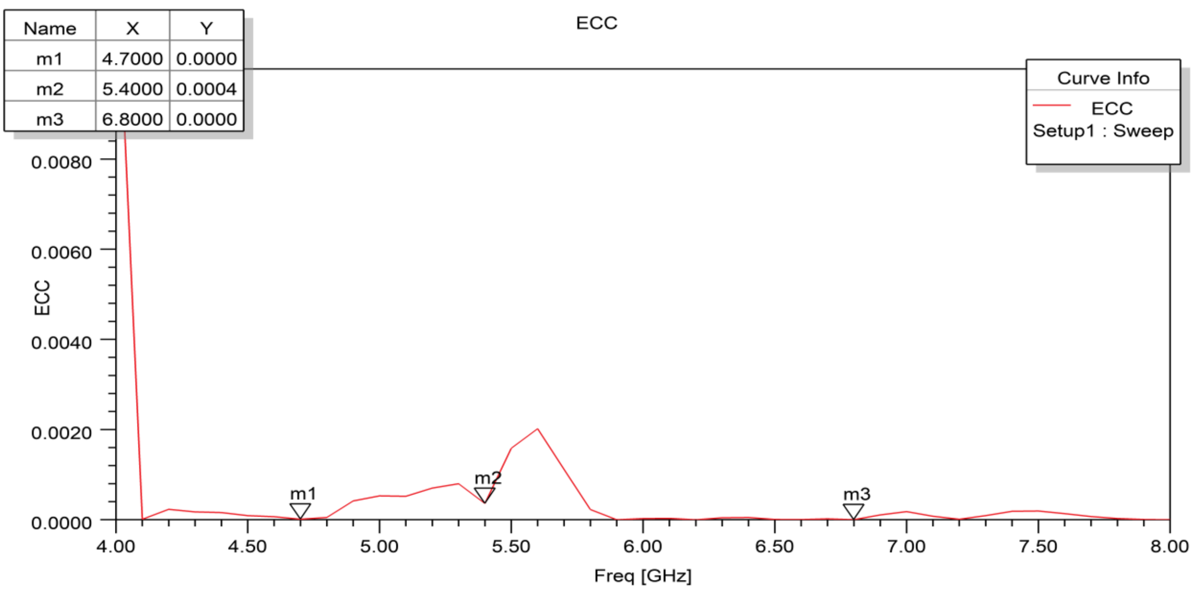


Figure 8.3(J) : ECC OF MIMO ANTENNA WITH CUTS ON DUAL SIDE

The plot 8.3(J) shows ECC value of 0.0000 at 4 .7 GHz,5.4 GHz and 6 .8 GHz which is less than 0.3 that is enough for a good MIMO antenna. Generally the ECC value should be less than 0.3 to 0.5 range. The above obtained value is nearly 0, this indicates that there is no correlation between the patch elements and they are completely independent

CONCLUSION

Conclusion

The design presents a 2x2 MIMO rectangular microstrip patch antenna with 4 to 8 GHz (C-band) frequency range. Its multiple input multiple output features are determined by the special MIMO parameters like axial ratio and ECC. The designed antenna shows that there is much improvement in the gain which is being used in many applications like WiMAX. The above antenna resonates at 4.7GHz, 5.7GHz and 6.8GHz frequencies which are applicable for WLAN applications. The gain finally observed is 2.7dB at 4.7GHz , 4.7dB at 5.4GHz and 5.7 dB at 6.8 GHz represents a higher gain than the basic rectangular microstrip patch antenna. The return loss is obtained at -25.40 dB,16.20dB and -12.28 at 4.7GHz,5.4 GHz and 6.8GHz resonant frequencies that is below -10 dB which implies that there is lesser radiations reflected and more power is utilized indicating an efficient antenna. The axial ratio is 2.03 dB at 4.5 GHz and 2.15dB at 6.7GHz , showing the designed antenna is circularly polarizing. The ECC is 0.0000 representing the elements are completely independent of each other at same resonant frequencies.

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