REDUCTION OF MUTUAL COUPLING IN MICROSTRIP ANTENNAS ARRAY FOR MIMO APPLICATIONS

A dissertation report

Submitted in partial fulfillment of the requirements for the

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In

Electronics and Communication Engineering

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2015

DECLARATION

I hereby declare that the dissertation proposal entitled ‘Reduction of Mutual Coupling in Microstrip Antennas Array for MIMO Applications’ submitted for the M.Tech Degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: PUSHVEEN MATTU

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CERTIFICATE

This is to certify that PUSHVEEN MATTU has completed M.Tech dissertation proposal titled 'Reduction of Mutual Coupling in Microstrip Antenna Array for MIMO Applications' under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the dissertation proposal has ever been submitted for any other degree or diploma.

The dissertation proposal is fit for the submission and the partial fulfillment of the conditions for the award of M.Tech in Electronics & Communication Engineering.

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Last but not the least, I would thanks parents again and the God Almighty.

PUSHVEEN MATTU

ABSTRACT

In this report, a method is proposed to reduce mutual coupling between Microstrip antenna arrays used for MIMO applications. For this, a U section and Microstrip antennas with concave shape is used. The mutual coupling is observed to be equal to -6 dB when the antennas are placed at a distance $\lambda/10$ and is decreased to -37 dB by using the method proposed. It is also observed that there is an improvement in the return loss by -16dB as mutual coupling is reduced. Further, a corporate feed network is designed and observed that the power is divided equally well among all the ports. A 2x2 array is designed for MIMO applications using corporate feed network and as the distance between the two 2x1 array is far greater than $\lambda/2$, there will be no mutual coupling between them. It is shown in that the overall gain and directivity is improved. All the simulations were carried out in Advanced Design System (ADS) Tool.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO ANTENNAS

An antenna is a device that transmits and receives electromagnetic waves. Typically antennas are resonating devices that operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the frequency band to resonate on desired frequency, or else reception and/or transmission will be impaired. The receiving radiating element (antenna) as a part in the system is responsible of turning the electromagnetic waves into its original form (electrical signal in wire).

The applications of antennas are robust. Antenna technology has been vital and fundamental associate of communication revolution. Large amount of research has been done on antennas to enhance its performance in term of its parameters that is gain, directivity, bandwidth and radiation pattern to increase its efficiency.

A radiating element in wireless systems is usually required to increase the radiation energy in some directions and suppress it in others. So an antenna must also serve as a directional machine in addition to a probing machine.

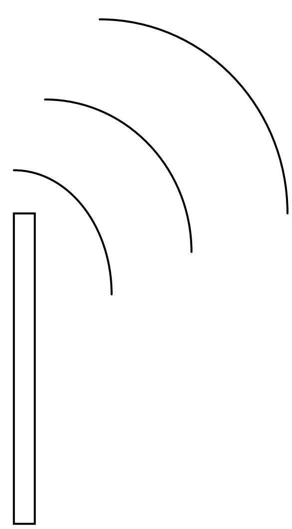


Figure 1.1 Radiating element

It can take different shape according to user demand, may be a portion of conducting wire, a patch, an aperture an assembly of elements (array), a lens, a reflector and so forth[1].Antennas are everywhere : at our homes, working places, cars ,aircrafts, satellites and spacecrafts and even as pedestrians we carry and use them. Antennas operate on the principle of electromagnetic [2].

1.2 HOW ANTENNA RADIATES?

How antenna radiates that how electromagnetic waves are generated and how signals are sent and received is primary question? The basic source of radiation is electric charge that is flow of electrons that lead to flow of current. Some of the basic condition for radiation is mention below.

1. If charge is not moving so no generation of current and no radiation.

2. If charge is moving with consistent velocity:

i. If wire is straight and infinite then there is no radiation.

ii. If wire is curved, bent, discontinuous or truncated then there is radiation.

3. Antenna radiates if wire is straight reason being if charge is oscillating in time-harmonic motion

Consider a two wire transmission line associated to antenna and connect it a voltage source. Electric field is generated that is associated to electric line of force that is tangent to electric field. These electric lines of force operate on as free electrons of conductor and displace the electrons and motion of these charges lead to the generation of magnetic field associated to magnetic line of force [1].

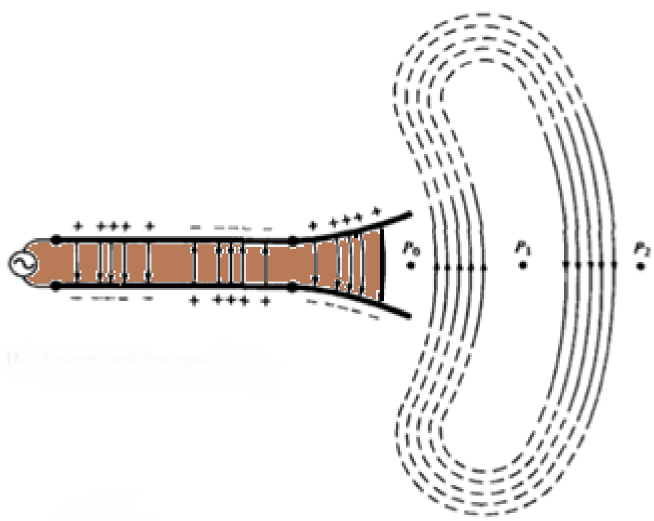


Figure 1.2   Antenna and free space

We already know that electric field line begin on positive charge and end at negative charge and if filed start at positive charge and it will at infinity. These electric lines form close loop [1].
Now the question is how wave is disconnected from antenna in free space as shown in fig 3. Electromagnetic wave produced by electric disturbance, due to short duration of disturbances EM wave travel and radiated through antenna. If continuous disturbances are there then EM wave also exist continuously and travel and radiated in free space. Same as wave produced in water when stones are thrown into it continuously [1].

1.3 INRODUCTION TO MIMO SYSTEM

To improve the performance of antenna MIMO technology is necessary. Multiple antennas are used on both transmitter and receiver side that help in increasing the spectral efficiency, increase data rate and better quality signals are obtained at receiver side, which help to reduce ISI, scattering and multipath propagation[6]. MIMO improve wireless systems capacity, consistency and range, increase in gain of array.

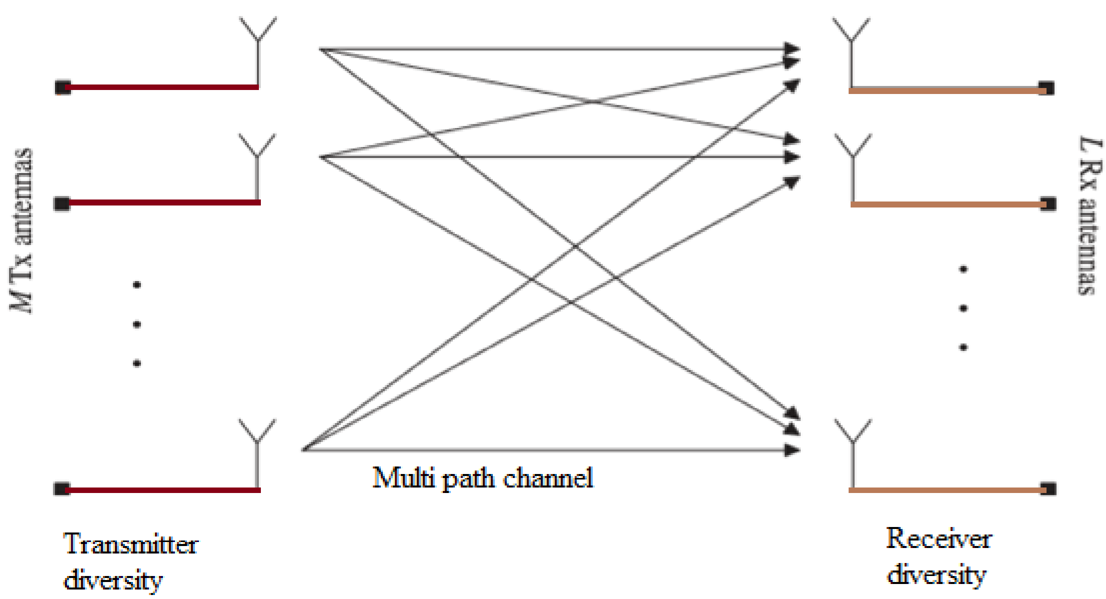


Figure 1.3 MIMO system

SISO, MISO, SIMO are special type of MIMO system. SISO mean single input single output, only single antennas are used at both receiver and transmitter side. SIMO mean single input multiple output, transmitter has only one antenna. MISO mean multiple input single input, receiver has only one antenna.

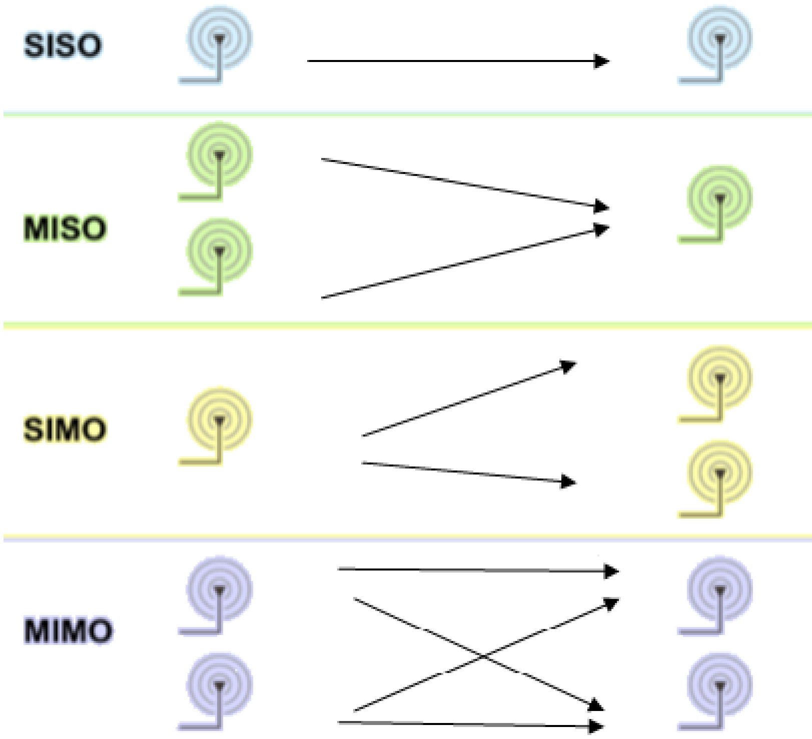


Figure 1.4 Special type of MIMO system

1.3.1 MIMO DIVERSITY

To un-correlate the fading diversity techniques provide more than one input at the receiver. Many diversity techniques are available time diversity, frequency diversity, space diversity, polarization diversity or combination of these techniques [6].MIMO diversity help in reducing all problems arises due to the multipath propagation that is fading because of scattering, diffraction, reflection etc.

1.3.1.1 SPACE DIVERSITY: It commonly used diversity technique. Different copies of same signals are generated using multiple antennas for transmitting the signal.

Phase delay is generated between transmitted signals by providing sufficient distance between antennas. Space diversity is famous nowadays because higher frequency signals can be transmitted [8].

Space diversity is classified into four categories.

- **Selection diversity:** It is simplest technique in which best signal is detected from large no received signal. Variable gain block used at receiver to adjusted to provide same signal to noise ratio [9].

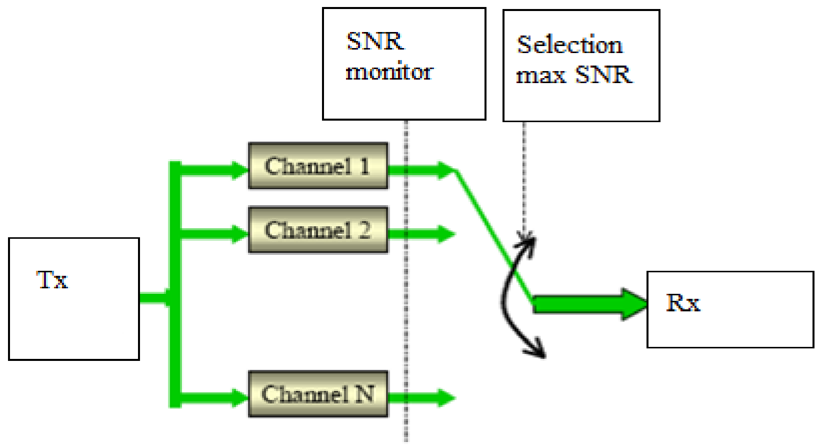


Figure 1.5 Selection diversity

- **Feedback diversity:** It is same as selection diversity but instead of choosing best signal from the entire received signal, all signals are scanned until the best one is observed higher than a predefined threshold value [9].

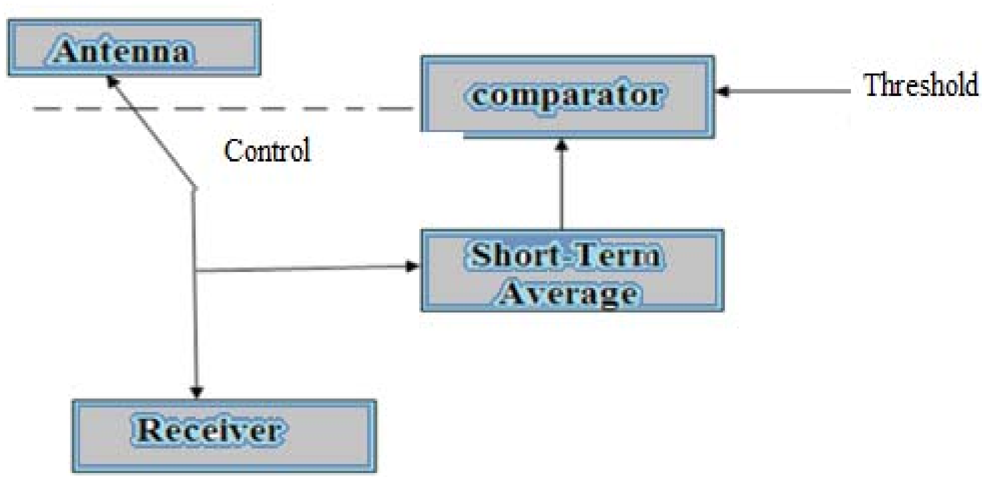


Figure 1.6 Feedback diversity

- **Maximal ratio combining:** The signal from the entire transmitter are weighted according to signal to noise power and then added to get the signal at the receiver side, all signal should be in phase before adding at receiver side [9].
- **Equal gain combining**: Gain is set to unity and all signals received are co-phased for superior selection [9].

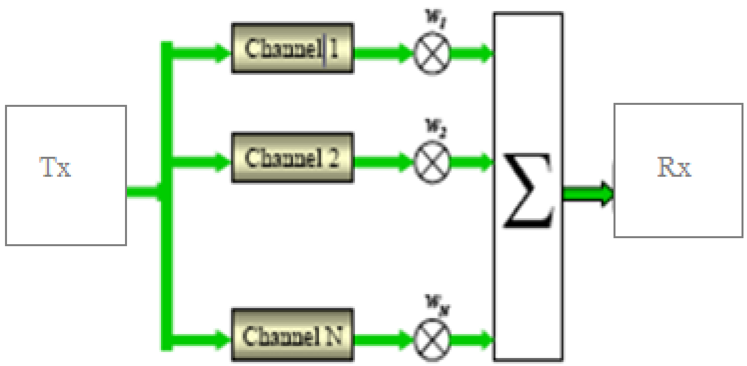


Figure 1.7 Maximal ratio combining

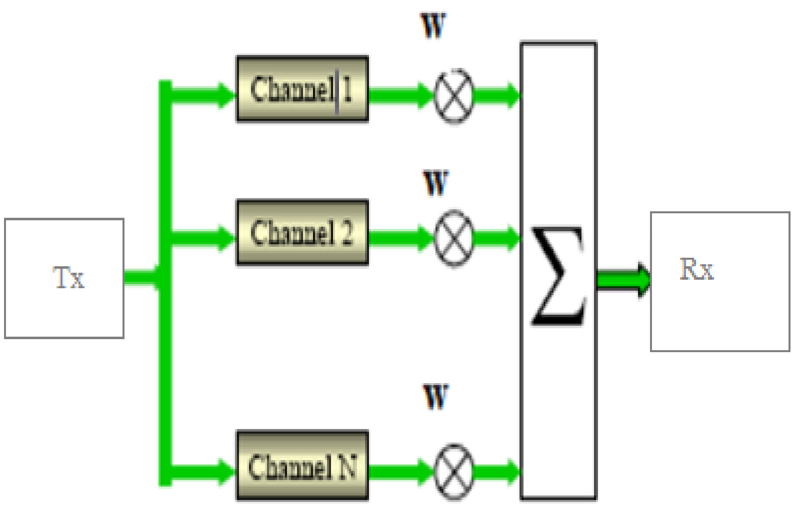


Figure 1.8 Equal gain combining

1.3.1.2 TIME DIVERSITY

In time diversity different slots are used to send the same signal to get a good gain when duration between two slots is greater than coherence time of the channel(time over which channel is constant)[6].This diversity technique is mostly used in digital signal transmission by sending the same bit again and again on different time slots. Redundancy is added using forward error correction code and bit-interleaving is used for spreading the signal. So, burst errors are neglected which reduce the difficulty of error correction techniques [8].

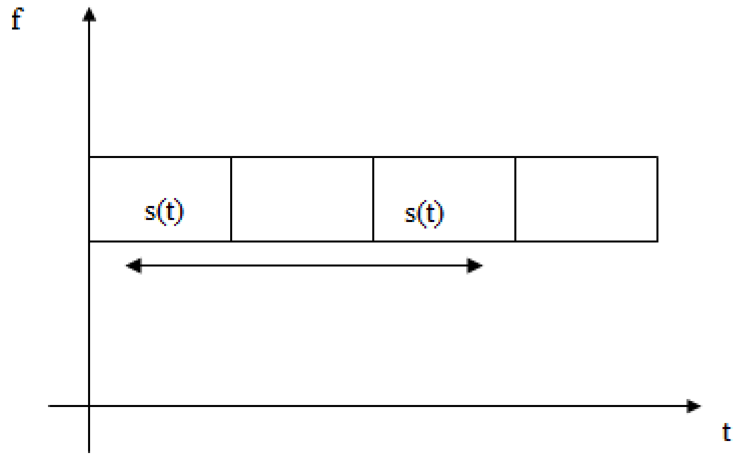


Figure 1.9 Time diversity

1.3.1.3 FREUENCY DIVERSITY

In this technique same signals are send over different subcarriers and good diversity gain is obtained when separation between two subcarriers is more than the coherence bandwidth (bandwidth over which channel is constant) [6].This technique is costly as it is difficult to generate many signals and add them [8].

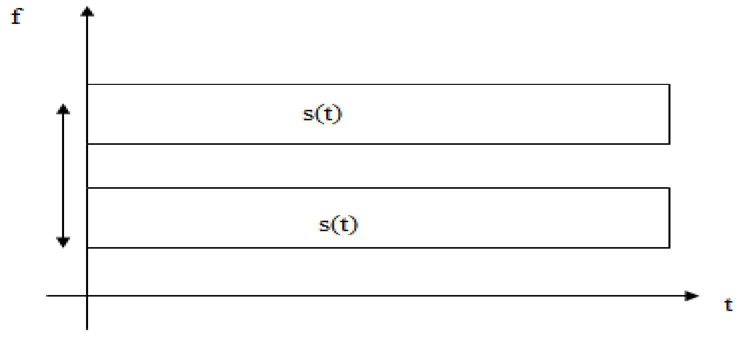


Figure 1.10 Frequency diversity

1.3.1.4 POLARIZATION DIVERSITY

Different copies of same signal is generated, transmitted and received through this polarization technique which is very simple and practical, by using different polarization. Combining techniques is used at receiver side to obtain the signal that is polarization diversity is combined with space diversity techniques [8].

CHAPTER 2

DETAILS OF ANTENNAS

2.1 BASIC CHARACTERISTICS OF ANTENNAS

2.1.1 GAIN

It is the ratio of radiation intensity in a given direction to the intensity that would be obtained if power accepted by antenna radiate isotropically. It is the measure of what amount of power is transmitted in peak direction to that of isotropic antenna.

$$\text{Gain} = 4\pi \frac{U(\theta,\phi)}{p_{in}(lossless \quad isotropic \quad source)} \qquad \text{(dimensionless)} \qquad (2\text{-}1)$$

U = radiation intensity

p_{in} = total input power (W)

θ = elevation angle

ϕ = azimuth angle

2.1.2 DIRECTIVITY

It describe how directional is antenna's radiation pattern It is ratio of maximum radiation intensity to the average radiation intensity.

$$\text{Directivity} = \frac{4\pi U}{P_{rad}} \qquad (2\text{-}2)$$

p_{rad} = total radiated power (W)

2.1.3 EFFICIENCY

Efficiency related power delivered to antenna and radiated power. High value of efficiency mean large amount of power is radiated away and low value of efficiency mean less amount power is radiated because most of the power absorbed within in antenna as losses as a result of impedance mismatching.

$$\text{Efficiency} = \frac{p_{rad}}{p_{in}} \qquad (2\text{-}3)$$

2.1.4 EFFECTIVE AREA

Effective area is a parameter that defines how much power is arrest by an antenna from wave or from other antenna and delivered to its terminal.

$$P_t = pA_e \tag{2-4}$$

P_t= power at antenna terminals

p = power density (W/m^2)

A_e = effective area

Effective area in terms of gain:

$$A_e = \frac{\lambda^2}{4\pi} G \tag{2-5}$$

G = gain

2.1.5 INPUT IMPEDANCE

The input impedance of an antenna is defined as the ratio of the voltage to the current at the terminals .Hence the impedance of the radiating elements can be written as given below.

$$Z_{in} = R_{in} + jX_{in} \tag{2-6}$$

Z_{in} = antenna impedance

R_{in} = antenna resistance

X_{in} = antenna reactance represents power stored in antenna

R_{in} is the resistance have two part radiation resistance and loss resistance. Power radiated by antenna is associated with radiation resistance and power loss by antenna is related to loss resistance.

For an antenna to be efficient the impedance of antenna and transmission line should be equal and standard value is 50Ω.

2.1.6 RETURN LOSS

It is the parameter of antenna which is defines the radiation characteristic of antenna. It is the ratio of power radiated to the power incident. It describes how much power is dissipated because of load. This parameter shows matching characteristic of antenna. Graph between S11 and frequency is return loss and graph should show dip at operating frequency that its value should be highly negative which show antenna radiate good amount of power deliver to it by source and very less power is lost.

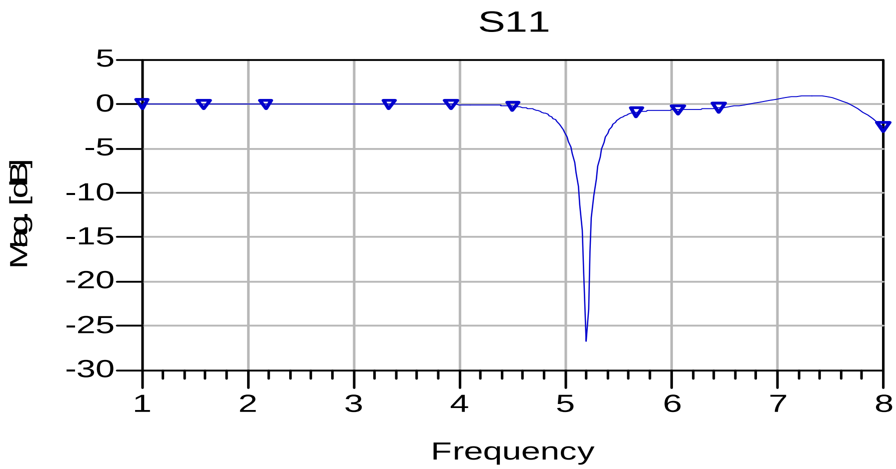


Figure 2.1 Return loss

$$\text{RL (dB)} = 10\log_{10}\frac{P_r}{P_i} \quad (2\text{-}7)$$

P_r = reflected power

P_i = incident power

2.1.7 RADIATION PATTERN

It is the variation of power radiated by antenna in far field region as function of spatial co-ordinates that is elevation angle(θ) and azimuth angle(φ).It is the power radiated by antenna per unit solid angle that is radiation intensity. Radiation pattern shows the gain and directivity at points in space. Different radiation pattern contains main lobe, minor lobes, side and back lobes. Three main type radiation patterns are isotropic, direction and omnidirectional. Isotropic pattern is ideal antenna pattern radiate in all direction.

2.1.8 BEAMWIDTH

Beamwidth is of two type Half Power Beamwidth(HPBW) and Null to Null Beamwidth as shown in figure 4. HPBW is the angular separation where radiation pattern reduces to half of its value that id 50% or 3dB. Points of HPBW are 77.7 and 102.3 degrees.

Null to Null Beamwidth is the value where radiation pattern reduces to zero. Point of Null to Null Beamwidth is 60 and 102 degree.

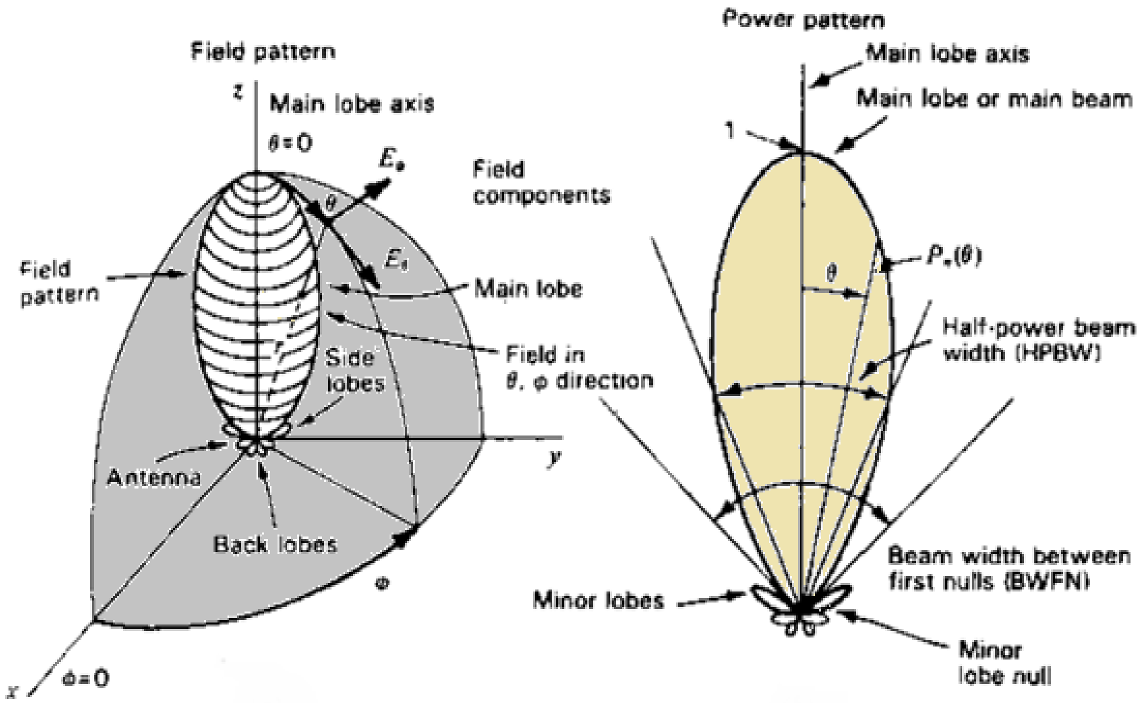


Figure 2.2 Radiation pattern

2.1.9 POLARIZATION

Polarization defines the orientation of electric field that is time varying direction and magnitude. It is of three type linear polarization, circular polarization and elliptical polarization.

2.1.10 S PARAMETERS

For microwave frequencies, the waves are associated to power other than voltage and current and microwave junctions are identify by S-parameters or scattering parameters. If input is apply to all the ports, 16 combinations in the form matrix are obtained. It provides relation between power of different ports in a microwave junction, through matrix known as scattering co-efficient or S-parameters [17].

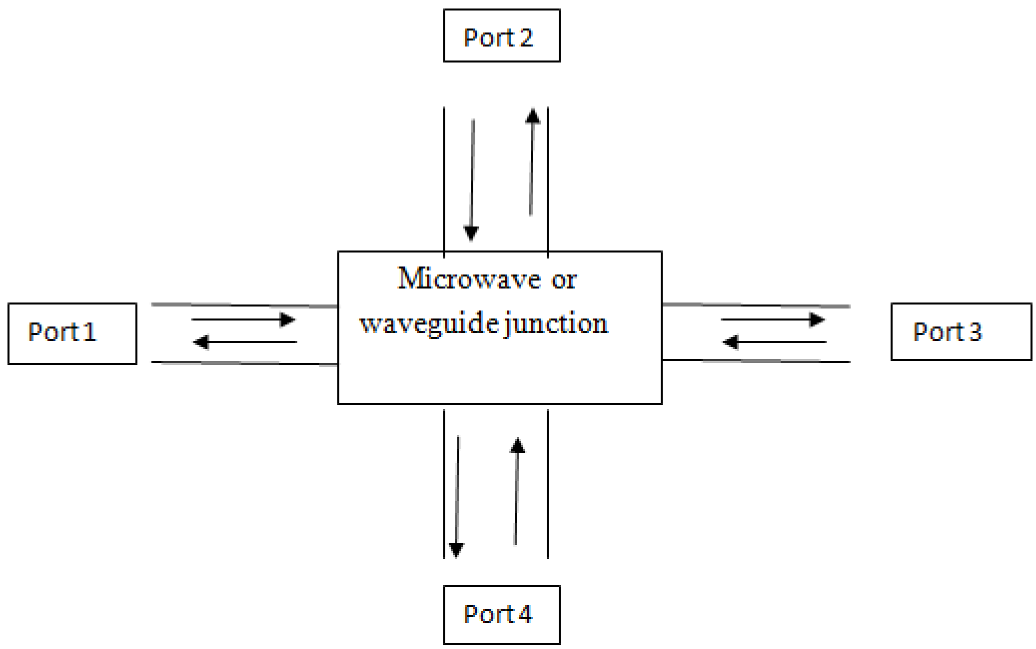


Figure 2.3 Microwave junction

2.2 TYPES OF ANTENNAS

Different types of antennas are available discussed below.

2.2.1 WIRE ANTENNAS

Wire antennas are very common and easily visible on ships, vehicles, aircrafts, spacecrafts etc. There are many types of wire antennas such as loop antennas, dipole and helix and can have any shape.

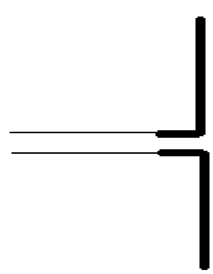


Figure 2.4 Dipole antenna

2.2.2 APERTURE ANTENNA

Aperture antenna are very famous nowadays as they operate on high frequencies, these antennas are easily mounted on aircraft and spacecrafts and protected with dielectric from dangerous conditions. Pyramidal horn, conical horn and rectangular waveguide are type of aperture antennas.

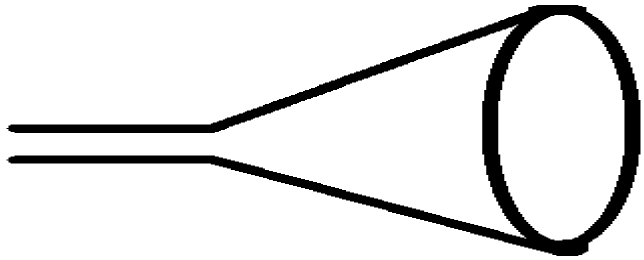


Figure 2.5 Horn antenna

2.2.3 MICROSTRIP ANTENAS

Microstrip patch antennas are broadly used because of their small size, light weight, low cost, low profile , easy to feed, mechanically robust , easy to fabricate and operate on frequencies greater than 1MHz. Patch antennas has a metallic patch on dielectric substrate that is grounded. It can be rectangular, circular, and square or of any shape but rectangular shaped patch antennas are widely used [3].

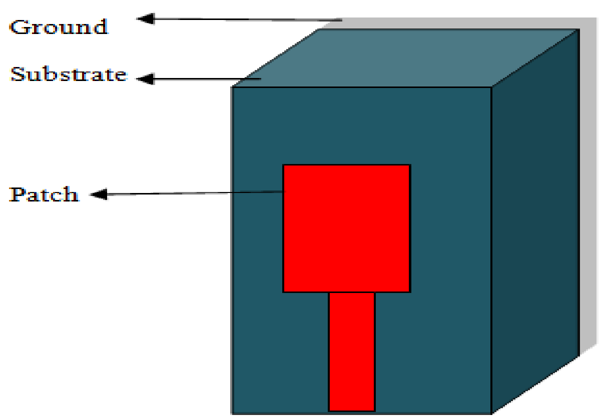


Figure 2.6 Microstrip patch antenna

2.2.4 ARRAY ANTENNAS

Two or more antennas are used to get desired radiation characteristics to get high gain, directivity and efficiency. Radiation from all antennas is added to get a good radiation pattern in needed direction.

Figure 2.7 Yagi- Uda antenna array

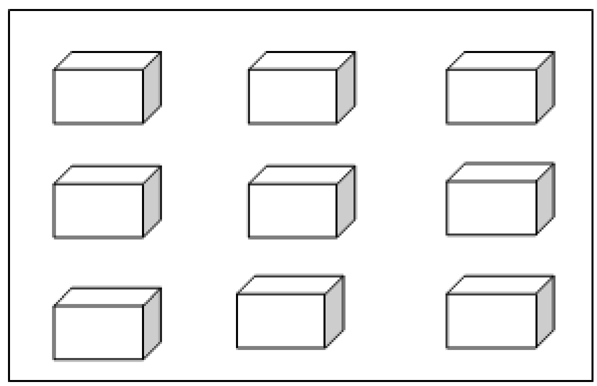


Figure 2.8 Aperture array

2.2.5 REFLECTOR ANTENNAS

To cover the different terrain profile of earth we have use to reflector antennas to send and receive signals to large distances. Parabolic antennas are commonly used for this kind of applications; diameter for this type of antenna should be large.

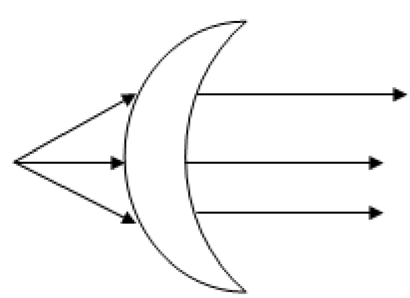


Figure 2.9 Lens antenna

2.2.6 LENS ANTENNAS

Lens antennas are used to collimate the incident energy to stop it from spreading into unwanted directions. Same as reflector antenna they are also use for high frequency applications. Classification in lens antenna is according to the material used to make it or depends on size.

2.3 INTRODUCTION TO MICROSTRIP ANTENNA

In 1953, Deschamps introduced microstrip antenna [1]. Microstrip antenna commonly known as patch antenna are in demand nowadays because of their planner structure and easy fabrication techniques. Patch antenna are mainly used in mobile phone market because of their planer structure and small size.

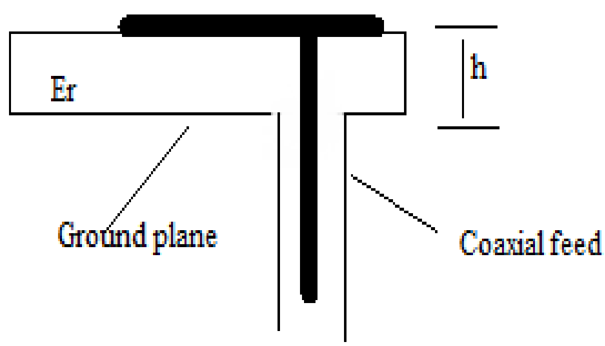


Figure 2.10 Side view of microstrip antenna

Microstrip antennas are planar resonant cavities that through its edges because of fringing fields. Microstrip patch antennas are broadly used because of their small size, light weight, low cost, low profile, easy to feed, mechanically robust, easy to fabricate and operates on frequencies greater than 1MHz. Patch antennas has a metallic patch on dielectric substrate that is grounded. It can be rectangular, circular, and square or of any shape but rectangular shaped patch antennas are widely used [3].

When patch antennas are agitated with frequency of operation then a strong field is generated and current on the surface of microstrip antenna which is the cause radiations.

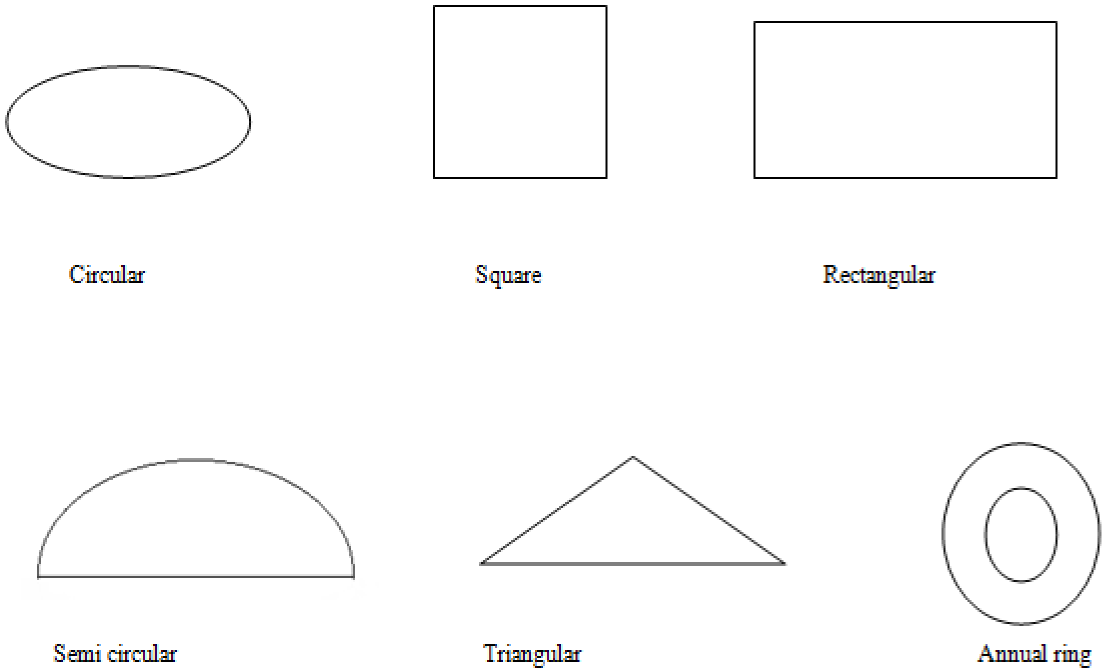


Figure 2.11 Different shapes of microstrip antenna

2.3.1 CHARACTERISTICS OF MICROSTRIP ANTENNAS

Different characteristics of patch antennas are discussed below.

2.3.1.1 ADVANTAGES OF MICROSTRIP ANTENNAS

Some advantages of patch antennas are mention below [4]:

- Patch antennas are light weight, Compact, robust, small size, and low profile.
- Easy fabrication so produced in large numbers.
- Conformal to host plane.
- Both linear and circular polarizations are possible.
- Easily integrated with microwave integrated circuits (MICs).
- Allow multiband frequency operations.

2.3.1.2 DISADVANTAGES OF MICROSTRIP ANTENNAS

There are some disadvantages of patch antenna mention below [4]:

- Bandwidth is narrow.

- Gain is less.
- Power handling capacity is low.
- Unnecessary radiations from feeding points.
- Generation of surface waves.

2.3.1.3 APPLICATIONS OF MICROSTRIP ANTENNAS

Advantages mention above of patch antenna leads to many applications mainly in field of communications. Some of the systems with applications are discussed below [4].

2.3.1.3.1 AIRCRAFT AND SHIP ANTENNAS

- Communication and navigation
- Altimeters
- Blind landing systems

2.3.1.3.2 MISSILES

- Radar
- Proximity fuses
- Telemetry

2.3.1.3.3 SATELLITE COMMUNICATION

- Domestic TV broadcast
- Automobile based antennas

2.3.1.3.4 MOBILE RADIO

- Pagers
- Hand telephones
- Mobile vehicles

2.3.1.3.5 REMOTE SENSING AND BIOMEDICALS

- Applications in microwave hyperthermia.
- Intruder alarms
- Personal communication

2.3.2 FEEDING TECHNIQUES FOR MICROSTRIP ANTENNAS

Many techniques are to feed the patch antenna out of which four are very popular and widely used are microstrip line feed, coaxial probe feed, aperture coupled feed and proximity coupled feed. Feeding techniques can be divided into two types that is contacting and non-contacting. In contacting method power is directly provided to antenna using some contacting element and in non contacting electromagnetic coupling is required to feed the antenna.

2.3.2.1 MICROSTRIP FEED LINE

This technique is easiest from all techniques because of easy fabrication, easy to control inset position. On same substrate feed can be etched. Bandwidth is limited in this case because substrate thickness has been increased that lead to generation of unwanted radiation from edges of patch and surface waves, cross polarization. No additional matching techniques is required to match the impedance because correct position of inset feed help in matching the impedance [1].

2.3.2.2 COAXIAL LINE FEED

In this technique patch is connected to inner conductor of coaxial cable so coaxial conductor extend through dielectric and ground plane is attached to outer conductor using soldering. It is also fabricated very easily because feed can be placed anywhere and less spurious radiation, but narrow bandwidth and difficulty in modeling that is drilling of hole in substrate are the disadvantages. Structure is not planar because of coaxial cable. When thick substrate is use the probe length lead to impedance mismatching [1].

2.3.2.3 APERTURECOUPLED FEED

Microstrip feed line and patch antenna is separated by ground, patch and feed line are coupled through a slot or aperture in ground plane. Due to coupling at center of patch low cross polarization. Measurement of coupling from feed line is done with help of shape and size of aperture. Bottom substrate is made of high dielectric material and low dielectric is used for top substrate for good radiation from patch antenna, but difficulty in fabrication because of large number of layers (increase thickness of structure) limit the use of aperture coupling. This technique also leads to narrow bandwidth [1].

2.3.2.4 PROXIMITY COUPLED FEED

Proximity coupled technique also called electromagnetic coupling. Feed line is between two dielectric substrates mainly used to suppress the spurious radiations and a good bandwidth. Matching is done by controlling the feed line length and width-to-line ratio of microstrip antenna. Fabrication is the limit because of two dielectric layers that need proper placement and also increase the thickness of overall structure. Patch can have different dielectric and feed can have its own for good performance [4].

2.4 METHOD OF ANALYSIS

2.4.1 THE TRANSMISSION LINE MODEL

Transmission line method is the easiest method but less accurate provide good physical insight more difficult to model the coupling. Microstrip is considered as transmission line resonator [1]. Transmission line model portray the patch antennas by two slots of width W and height h and transmission line length L. Some portion of electric field lines resides in air and some in substrate, so transmission line does not maintain transverse electric-magnetic (TEM) mode so phase velocity in air and substrate is different. So, dominant mode is quasi-TEM mode [5].This method is mainly for rectangular patch antenna .Effective dielectric constant is constant for low frequencies but at intermediate frequencies its value decrease. To in fundamental mode, length patch should be less than $\frac{\lambda}{2}$ where λ is the wavelength. The TM10 show that field changes a cycle of $\lambda/2$ with the length, and constant width. Width has maximum voltage and low current because of its open ends. With respect to the ground plane the fields at the edges can be set on into tangential and normal components [5].

Electric field has normal components along the two edges in opposite directions. As the microstrip patch antenna is $\frac{\lambda}{2}$ long and so they cancel each other in the broadside direction. The tangential components of electric field are in phase, resulting fields add to give maximum radiated field normal to the surface of the structure, so the edges along the width are considered to be two radiating slots, which are at $\frac{\lambda}{2}$ distance and excited in phase and radiates in the half space over the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna appear greater than its original dimensions. So, length of patch is extended to ΔL [5].

2.4.2 THE CAVITY MODEL

Region between patch and ground plane is considered as cavity, enclosed by magnetic field wall and by electric field on top and bottom side. Cavity is uniform along the thickness of substrate because of use of thin substrate. The field under the patch for normal shapes as rectangular, circular, triangular is expressed in the form of assumptions of different resonant modes of 2D resonator. The fringing fields on boundary are handled carefully by extending the patch boundary outward so that effective dimension of patch is greater than original dimension of patch [4].

The consequence of the radiation from the microstrip patch antenna and losses from conductor are accounted for by combining these losses to the loss tangent of the dielectric substrate. The far field and radiated power are obtained from the magnetic current in the region of the periphery, another way of incorporating the radiation effect in the cavity model by introducing an impedance boundary condition at the walls of the cavity. Due to localization cavity, the far field is difficult to obtain [4].

2.4.3 THE MNM

This model is the extension of cavity model to study the patch antennas. The EM field below the patch and exterior of patch are modeled independently. Patch has multiple ports and is 2D planar network that provide multiport impedance matrix. Radiated field and fringing fields are integrated with addition edge admittance network. Overall impedance matrix is obtained by using segmentation method. Voltage distribution provide radiation field [4].

CHAPTER 3
LITERATURE REVIEW

In [10] Saeed Farsi et al describe the work on reduction of mutual coupling by using a U section between microstrip radiating elements .Mutual coupling is an unavoidable phenomenon in MIMO systems, usually degrading the system efficiency. Huge amount of works has been to focus on the reduction of this effect. The objective is to maintain the mutual coupling structure as uncomplicated as possible with high amount of mutual coupling reduction. This paper represents a novel structure reducing the mutual coupling between closely-spaced patch radiating elements. Structure consists of only a simple U-shaped microstrip between two closely-spaced microstrip radiating elements, which degrade the mutual coupling significantly. The construction of antennas has been done properly and tested and results prove the high efficiency.
When two patches are placed closely to each other, they couple to each other through all media present that is the substrate, air layer and the air half-space. The coupling through the air-superstrate layers is because via surface waves. The coupling through the air half-space is due to direct patch-to-patch near-field coupling. Both couplings may become dominant depending on the precise shape and dimensions of patches. The direct MC between two elements can be nullifying by adding an extra indirect coupling path. A genuine design aims at generating an indirect signal coming via the extra coupling path that opposes the signal going directly from one radiating element to another element. If the two amplitudes are comparable, the two signals add up destructively, and the mutual interaction is reduced. Structure inserted between radiating elements s should not reduce the radiation properties.

In [11] Shahram Mohana et al describe about reducing the mutual coupling by using and return loss by using concave shaped patch antennas. Concavity is made on both vertical and horizontal side patch antenna and then there type antennas are simulated. Optimizing technique is used to enhance the performance of antennas by using the genetic algorithm. Fabrications of these type of antennas is also performed to verify the results which prove that there is less mutual coupling and return loss. Concave patch antennas are simulated on resonant frequency 8.4 GHz with impedance of 50Ω.

Concavity help in reducing the mutual coupling by fringing efects ,that it help to prevent the waves to propagate to nearby antennas that will grasp the power of wave and less power is radiated to the desired direction and less gain, directivity are the results. BY optimizing the width and length frequency is shifted to desired range .Changing in the width and length of result in shifting resonant frequency so dimension patch must be decreased and electrical distance between patch must be increased according to genetic algorithm. Width of the patch and other parameters should be alter to maintain patch impedance. Simulation is performed on FEKO. Some differences are there between simulated and fabricated results because some assumption of ground plane. But this paper has provided a capable solution toward the problem that is reduction of mutual coupling.

In [12] G.N Giakward et al explain about different technique for reduction of mutual coupling using EBG(Electromagnetic Band Gap) structures also known as Photonic Band Gap Structure so related to optics, these structures are periodic or non periodic dielectrics and metallic conductors help in stopping the EM wave to propagate in specific band of frequency . This paper explain about phase antenna array .Mutual coupling lead to very serious problems like degradation of radiation pattern, surface phase leads to gain reduction, and side lobes also increased, but EBG structure improve the performance of overall system by improving the efficiency, gain, VSWR , directivity. EBG structure help in increasing isolation between antenna arrays.IE3D software is used for antenna simulation. The lumped LC model is used for analysis the EBG structure. Surface waves are reduced using EBG by drilling holes in dielectric substrate or in ground plane as surface waves are very dangerous and is the main cause of degrading the performance of antennas arrays. Network Analyzer is used to test the antennas and after testing the antennas fabrication is performed.

Coaxial feed is used to feed the antenna .Dimension of slots is 8mmx8mm and 14mm is separation of slots .To microstrip antennas are separated by EBG structure of 48mm.15x5 matrix. A highly negative return loss is obtained, 5.32dB value of gain, VSWR is equal to one and S21 is -55dB using EBG. Frequency of operation is 2.4 GHz. Some geometry is added to form the cross structure. EBG is double layer structure that is both sides of substrate EBG exist. The main advantages of EBG are that it suppresses the surface wave and stop the propagation of EM wave in specific bands of frequency.EBG reduce coupling at microwave frequencies.

In [13] Chandan K. Gosh et al explain about the reduction of mutual coupling using DGS (Defeated Ground Structure) and U shaped structure between microstrip antennas that are slotted and operate on multiband frequency. Mutual coupling can be reduced by adding a indirect path through which a indirect signal pass that resist the signal going directly from one antenna to other. If two signals are having equal magnitude then they are combined destructively that help in decreasing mutual coupling, otherwise coupling lead to severe issue of degrading the overall performance of antenna. Main cause of coupling is surface wave that are reduced. Dimension of slots are changed and optimized for simulating. Substrate of 1.58mm thickness is used with 4.4 dielectric constant.

In this paper slotted microstrip antennas are used. Resonant frequencies are 2.45 GHz and 4.5GHz as antennas multiband and necessary calculations are made using basic formulas. Mutual coupling is reduced by DGS and U section collectively for frequencies are 2.45 GHz and 4.5GHz respectively. Mutual is reduced by 15.7dB and 8dB by DGs and U section. A good return loss is obtained. Then these microstrip antennas are fabricated to verify the results, little difference is there but that is acceptable with an efficient technique.

In [14] Hamideh Kondoril et al explain the technique of reducing mutual coupling using spiral resonator with metamaterials, periodic structure in between microstrip antenna sis used. Metamaterials have either negative value of permeability or permittivity and it can suppress the EW wave to travel in specific band of frequency so surface waves are suppressed. HFSS (High Frequency Structure Simulator) is used to simulate the structures. Main emphasis is on the length, width and spacing of spiral resonator and dielectric value so as to get results on desired frequency of operation.

FR4 substrate is used having value 4.4 with dimensions 70mm x 30m x.6mm.13.95mm.13.95mm and 1.5mm are the dimension of feed line for patches in that order. Patch dimensions are 14mm length and 18mm width with resonant frequency 4.5GHz.3 rows of spiral resonator are used with MNG metamaterial , rows effect the mutual coupling and return loss. Width and separation between rings is also effecting the mutual coupling and return loss so results are obtained on different values of width, lower amount of width reduce the mutual coupling and enhance the performance of antennas .Results in different directions are obtained with different distances.S21 is near about 36dBand S11 is 26dB.

In [6] Ankit Dalela et al explain about different diversity techniques for MIMO applications. To improve the performance of antenna MIMO technology is necessary. Multiple antennas are used on both transmitter and receiver side that help in increasing the spectral efficiency, increase data rate and better quality signals are obtained at receiver side ,which help to reduce ISI, scattering and multipath propagation. To un-correlate the fading diversity techniques provide more than one input at the receiver. Many diversity techniques are available time diversity, frequency diversity, space diversity, polarization diversity or combination of these techniques. MIMO diversity help in reducing all problems arises due to the multipath propagation that is fading because of scattering, diffraction, reflection etc.

In paper different diversity techniques: time diversity, space diversity, polarization diversity and frequency diversity is discussed. In space diversity, different copies of same signals are generated using multiple antennas for transmitting the signal. Phase delay is generated between transmitted signals by providing sufficient distance between antennas. In frequency diversity same signals are sent over different frequency (subcarriers) and in time diversity same signals are sent over different time slots on same frequency. In polarization diversity same signals are sent over different polarizations.

In [15] Md. Tanvir Ishtaiques-ul et al Md. Tanvir discussed about the performance of microstrip patch antenna fed with corporate feed network. The patch antenna discussed here is circular in shape and operate on X band. A 4x2 antenna array id designed and analyzed. SONNET, a n antenna simulator is used to simulate the antennas and provide radiation pattern,S11 and current distribution in antennas.TLY-5 is used as dielectric substrate with ε_r value 2.2 and height of substrate id 1.588mm.The corporate feed network is used to feed the microstrip antennas which is best feeding technique for antenna arrays. This feeding network results in good radiation pattern, gain, directivity and degrades the beam fluctuation and help in controlling the phase.

CHAPTER 4
OBJECTIVE AND SCOPE OF STUDY

4.1 OBJECTIVE OF STUDY

The objective of study is to remove mutual coupling in microstrip antenna arrays for MIMO applications. In this dissertation, first two patches are design and several techniques are implemented on these patch antennas are performed, first we cut the patches length wise and then add a U section between concave patches reduce mutual coupling. After reducing mutual coupling, the main task was to design an array so corporate feed network was designed to feed the array and a 2x2 array is designed for MIMO applications.

Mutual coupling and return loss are very significant factors which must be considered in the design of array radiating elements. As one array element radiates, a portion of its emitted power is eaten by other elements and induces current on them and leads to problems such as degradation of array radiation pattern , change in the array manifold (the received element voltages) ,change in the matching characteristic of the radiating elements (change the input impedances) so input power is wasted . So the effect of mutual coupling must be reduced in array radiating elements design. The induced current derived a voltage at the terminals of other elements.

Mutual coupling is energy absorbed by one radiating elements when another nearby radiating elements is operating. Mutual coupling is typically undesirable because energy that should be radiated away is absorbed by nearby radiating elements. Similarly, energy that could have been captured by one radiating elements is instead absorbed by nearby radiating elements. Hence, mutual coupling reduces the radiating elements efficiency and performance of radiating elements in both the transmit and receive mode.

In this thesis work, we have only study about mutual coupling and how it affects the S-parameters of microstrip antenna using ADS TOOL.

4.2 SCOPE OF STUDY

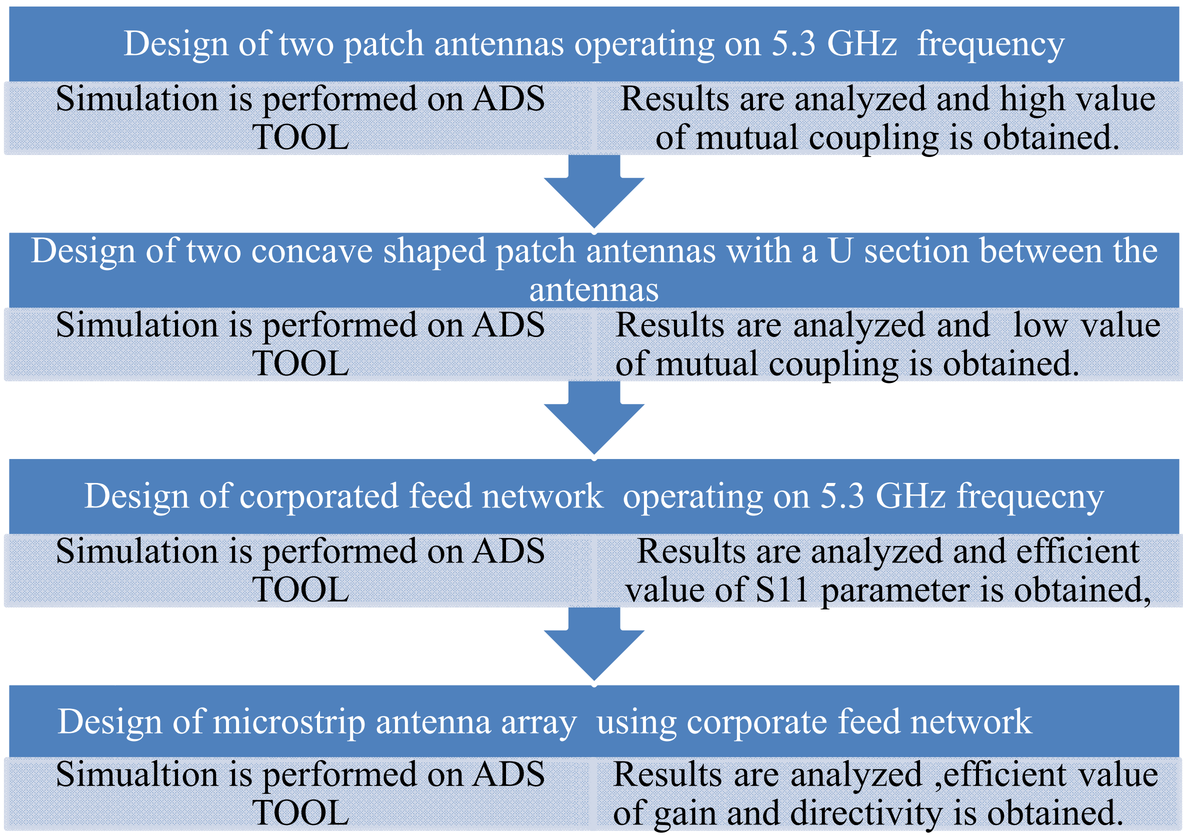
The main aim of thesis was to reduce mutual coupling between microstrip antenna arrays for MIMO applications. Hence, scope of study is to use these antennas in MIMO applications. Main area for work for antennas nowadays is MIMO(multiple input multiple output) that is the use of multiple antenna on transmitter and receiver side for better signal characteristic that lead to highly efficient communication system. In MIMO multiple antennas are used on transmitter and receiver side by using diversity techniques. MIMO technique improve gain, directivity, spectral efficiency and IS and ICI.MIMO is a wide area and having fast applications for example 3G,4G,Wifi,Wimax,LTE networks, HSPA+ and many more.

Further work can be improve by using different dimension of patch and concavity and mutual coupling can reduced to very large level .Thus, these antennas can be used for many more applications.

CHAPTER 5

RESEARCH METHODOLOGY

5.1 FLOWCHART OF WORK



5.2 DIMENSIONAL PARAMETERS

Dimension of patch, concavity in patch, U section and for corporate feed network is given below.

5.2.1 DIMENSION FOR PATCH ANTENNA

Patch antennas are design with dielectric substrate with a permittivity 4.4 and height of patch is 1.6mm with a microstrip line feed having input impedance 50Ω. Dimension of patch are calculated according to the formulas in [1-16] below.

Width of patch is given as:

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{5-1}$$

Length of patch is given as:

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_r} \sqrt{\varepsilon_o \mu_o}} - 2\Delta L \tag{5-2}$$

Effective length is given as:

$$\Delta L = h(0.412) \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{5-3}$$

Effective dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{5-4}$$

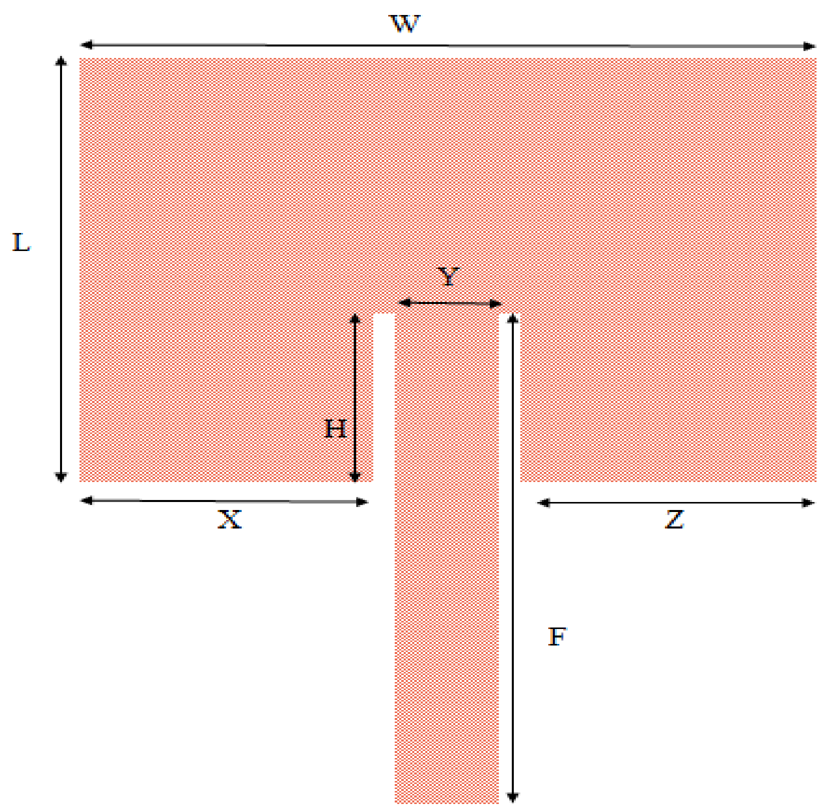


Figure 5.1 Dimension of patch antenna

Valued for the patches are calculated according to the above equations for frequency 5.3 GHz. Patch antennas dimension are calculated at the resonance frequency 5.3 GHz .According to frequency, length of patches = 12.95mm and width of patches (W) = 17.22mm.

5.2.2 CALCULATION FOR INSET FEED

Calculation for inset feed is given below.

$$G_1 = \frac{1}{90}\left(\frac{w}{\lambda_o}\right)^2 \quad (5\text{-}5)$$

$$R_{in} = \frac{1}{2G_1} \quad (5\text{-}6)$$

$$R_c = R_{in}\cos^2\left(\frac{\pi}{L}H\right) \quad (5\text{-}7)$$

For Z and X:

$$X = Z = \frac{2W}{5} \quad (5\text{-}8)$$

Inset feed length (F) = 15mm, H = 5.127mm and X = Z = 6.888mm and Y=2.44mm.

And after all this calculations two patches are design and simulated on ADS and results are observed and distance between two patches is 18.33mm.

5.2.3 DIMENSIONS FOR U SECTION AND CAVITY FOR PATCH ANTENNAS

Dimensions of U section are given as length of U section’s bigger arm is 9.14mm long and having width of arm is 0.24mm and length and width of small arm between bigger arms is 0.48mm and 0.34mm respectively. U section is a resonator that resists signal travelling from one antenna to other in an array by adding an extra coupling path.

Length of concavity for patch antennas designed earlier is h = 0.9mm. By doing this, the distances between patches increases with no change in the radiation characteristics.

Then two patch antennas with concavity (length wise) and U section designed and simulated on ADS TOOL.

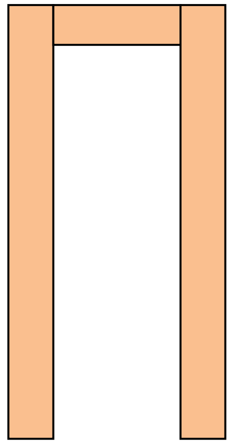


Figure 5.2 U section

5.2.4 CALCULATION FOR CORPORATE FEED NETWORK

Corporate feed network (multiple feed lines) is designed and simulated and ensured that equal power division among all the ports. It is a power divider network divide power in all ports equally with input impedance of 50Ω .Corporate feed network is made of microstrip lines so calculation for lines are according to the impedance and according to the frequency 5.3Ghz [17] as given below .This feed network then simulated on ADS.

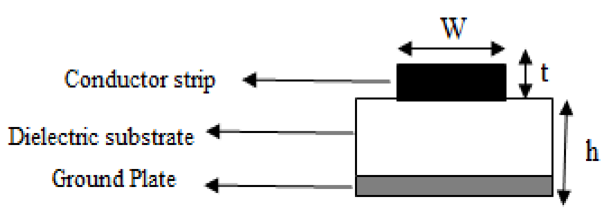


Figure 5.3 Microstrip line

Characteristic impedance of microstrip line is given as:

$$Z_o = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98h}{0.8w + t}\right] \text{ for h} < 0.8 \text{ w} \quad (5\text{-}9)$$

For wide width is given as:

$$Z_o = \frac{377}{\sqrt{\varepsilon_r}} \cdot \frac{h}{w} \quad (5\text{-}10)$$

Equivalent impedance is given as:

$$Z_{eq} = \sqrt{Z_1.Z_2} \tag{5-11}$$

After design corporate feed network, antenna array is design and results are observed on ADS Tool. Dimensions are optimized for results.

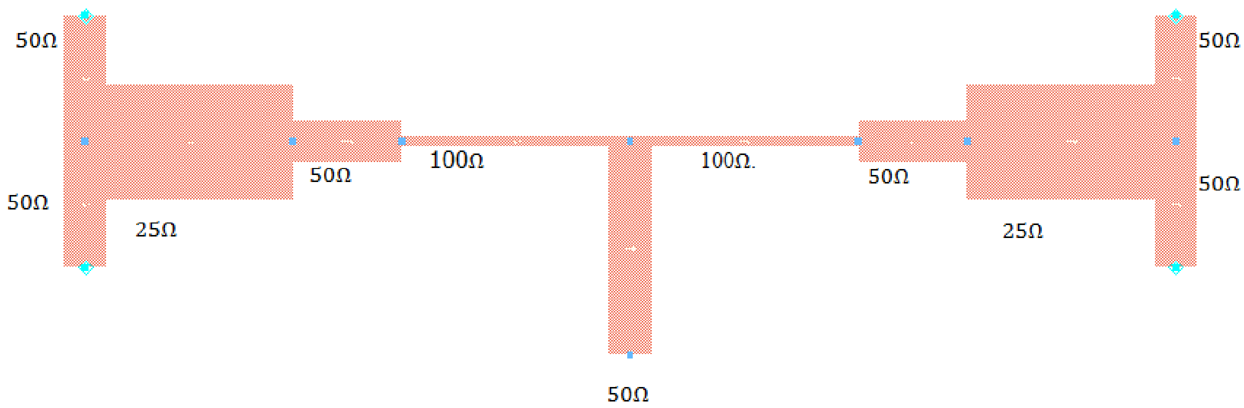


Figure 5.4 Corporate feed networks

5.3 SIMULATION TOOL

ADS (Advanced Design System) Laboratory tool is used to simulation antennas .This tool is mostly used for RF and microwave communication, wireless, networking etc. that is for their electronic circuits to simulate the results.

TOOL contain schematic window which help in generating the circuit using limped components and layout window in which we can design any antenna or circuit according our choice. This tool is very easy, novel and mainly used for 3EM simulator.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 RESULTS FOR TWO PATCH ANTENNAS

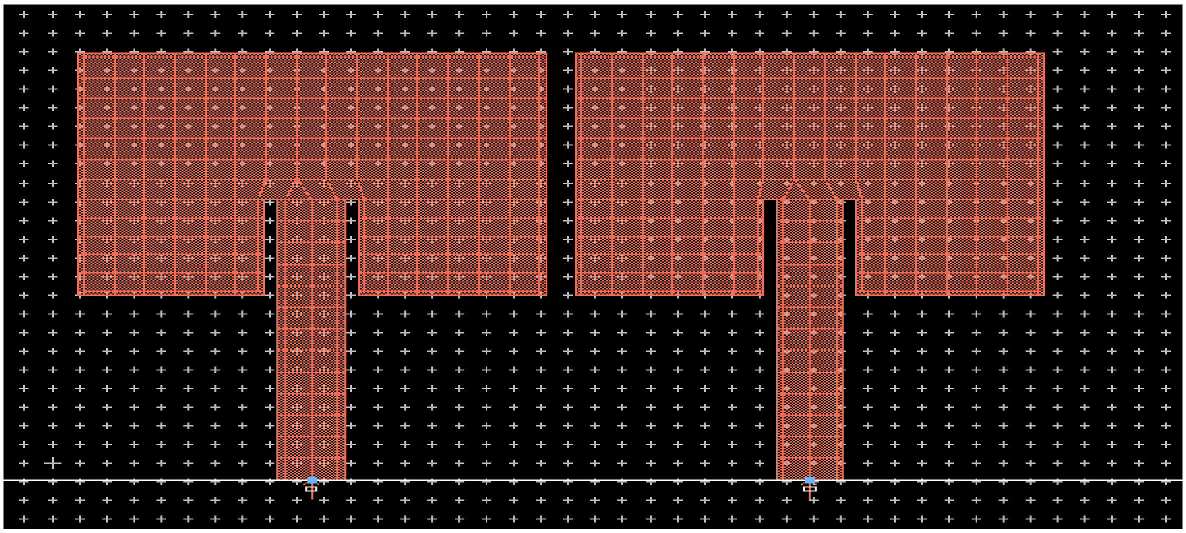


Figure 6.1 Structure of patch antenna array

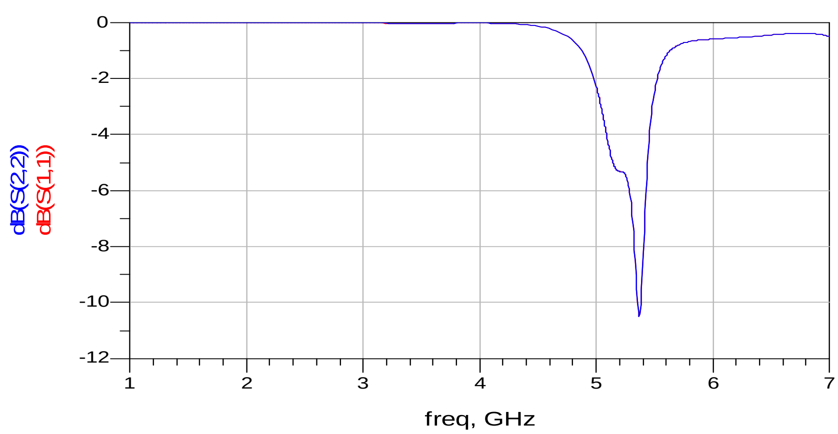


Figure 6.2 Plot of return loss for closely spaced patch antenna array

Distance far less than $\frac{\lambda}{2}$ is considered to see the effect of mutual coupling. If distance is equal to or greater than $\frac{\lambda}{2}$ then there will be no mutual coupling between antennas. Input is provided through a port of impedance 50 Ω and then S12, S21 which is mutual coupling and S11, S22 that is return loss is calculated using ADS Tool. It is observed thatS11andS22 = -10.51dB and S12andS21= -6.48dB at frequency 5.3GHz and Gain = 6.16dB and directivity =6.85dB.

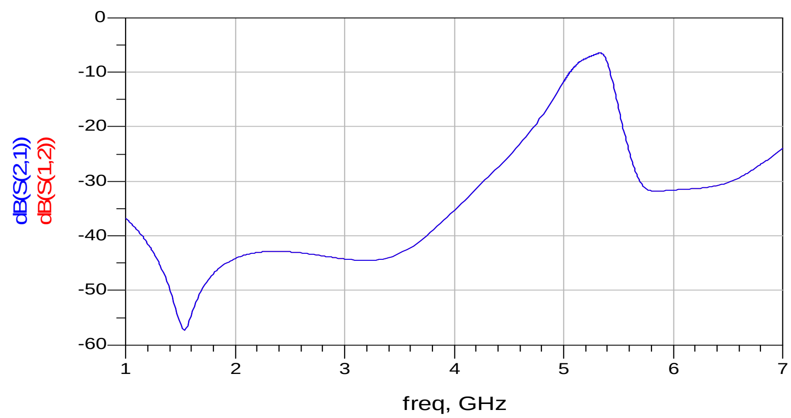


Figure 6.3 Plot of Mutual coupling for closely spaced patch antenna array

6.2 FOR CONCAVE AND U SHAPED PATCH ANTENNA

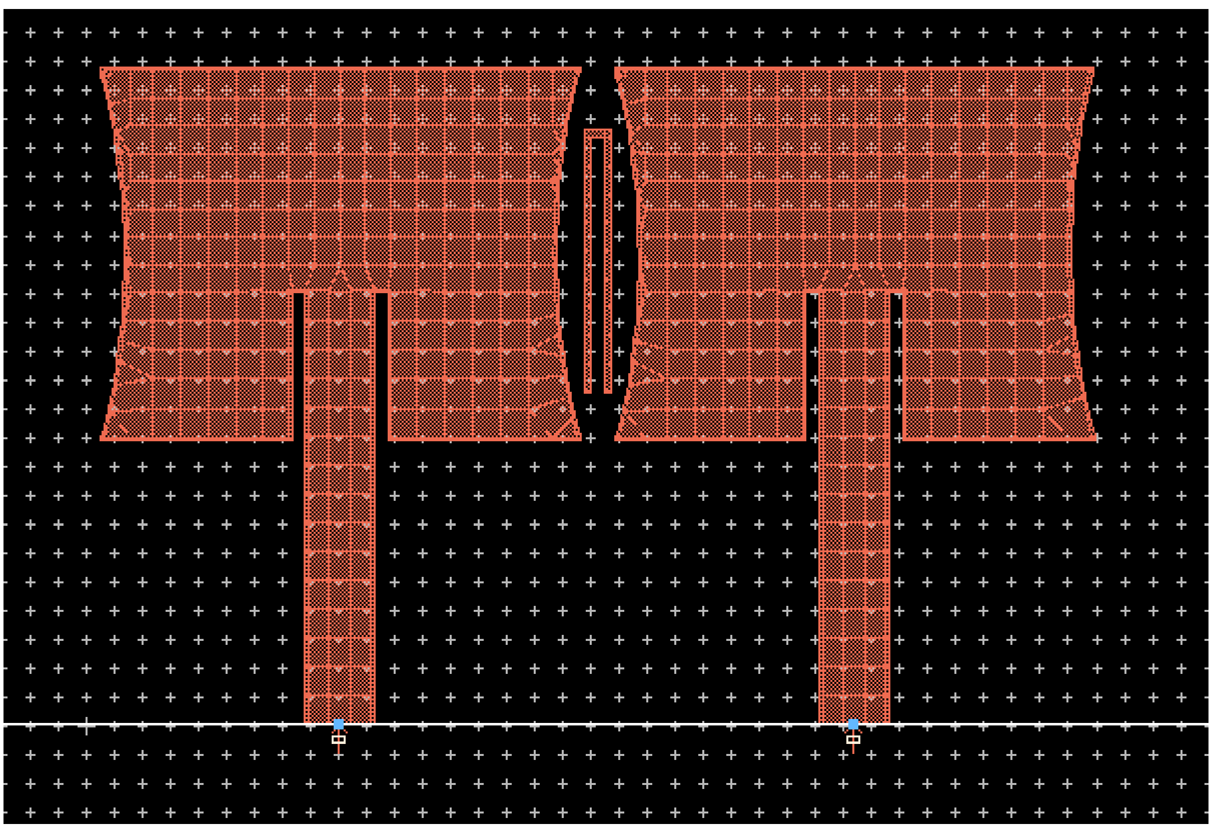


Figure 6.4 Structure of length concavity patches with U section

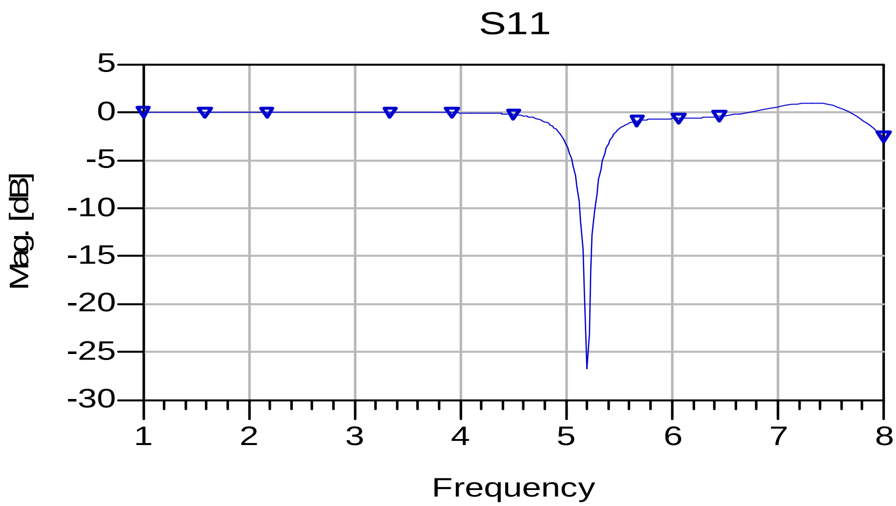


Figure 6.5 Plot of return loss (S11) for length concavity patches with U section

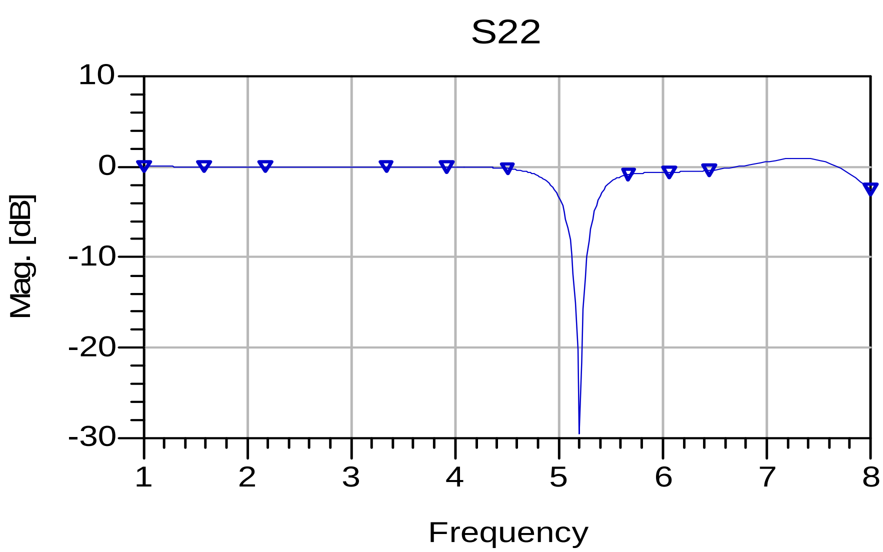


Figure 6.6 Plot of return loss (S22) for length concavity patches with U section

Now resonance frequency is 5.2 GHz with S11 = - 26.75dB and S22 = -29.5dB and S12 and S21 = -37.33 dB. So there is difference of about 30dB which shows that patch antenna have good matching characteristics and mutual coupling decreases. As Frequency is 5.2 GHz because of concavity width is slightly changed that cause frequency shift. We can use best use these patches for WLAN applications, directivity = 7.55dB and gain = 6.51dB, gain has been decreased but directivity increase and above all mutual coupling decrease.

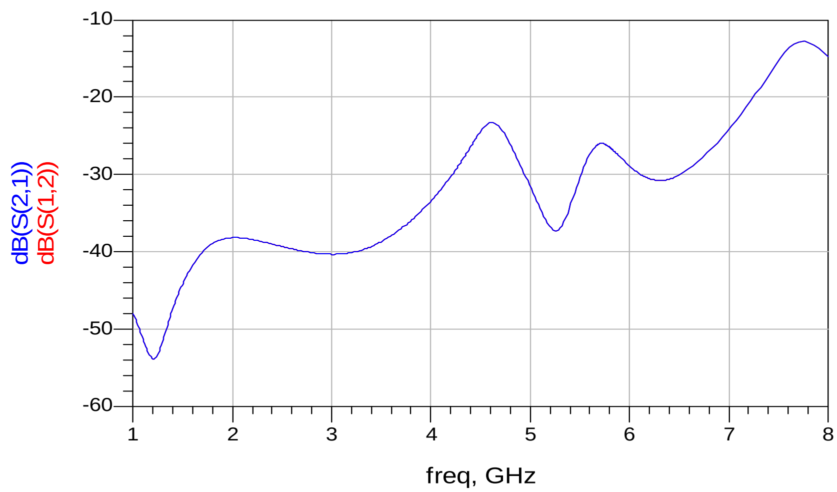


Figure 6.7 Plot of return loss for length concavity patches with U section

6.3 CORPORATE FEED NETWORK

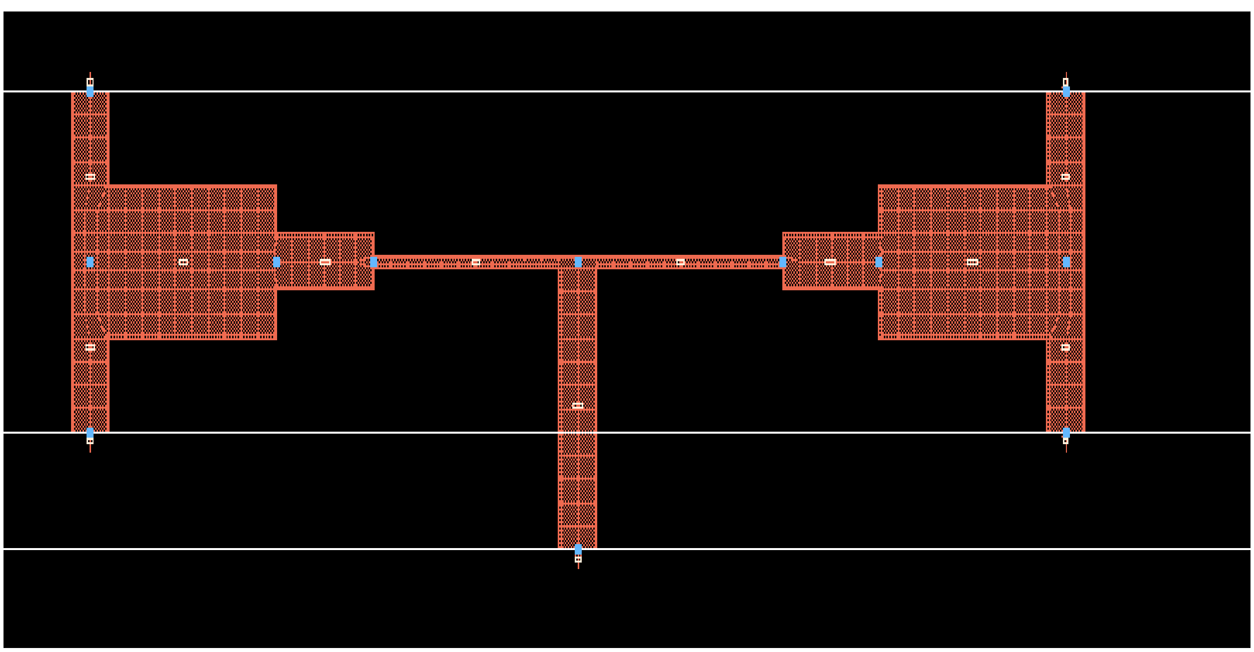


Figure 6.8 Corporate feed networks

Corporate feed network is used to provide power to microstrip patch antennas and it work as a power splitter and provide a power split of 2n (n=2, 4, 8, etc.). Quarter wavelength transformer

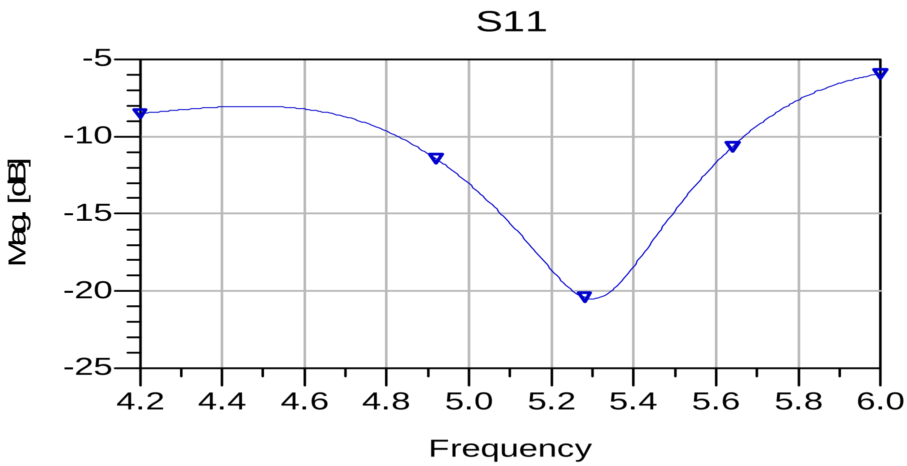


Figure 6.9 Plot S11 for corporate feed network

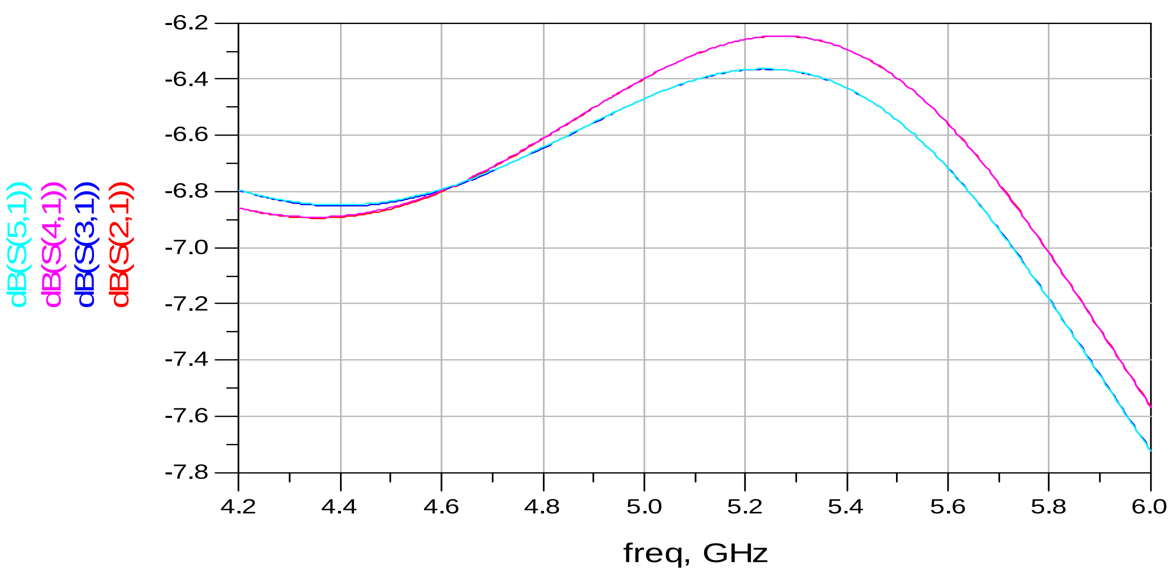


Figure 6.10 Plots of S21, S31, S41 and S51

S11 parameter is -20.52dB which shows that corporate feed network is radiating properly and the power provide to it distributed equally to all the four ports that is near about 6dB shown in Table II. Thus, we can use this feed network to antenna array for MIMO applications.

6.4 CORPORATE FEED NETWORK WITH CONCAVE SHAPED PATCH ANTENNA ARRAY WITH U SECTION

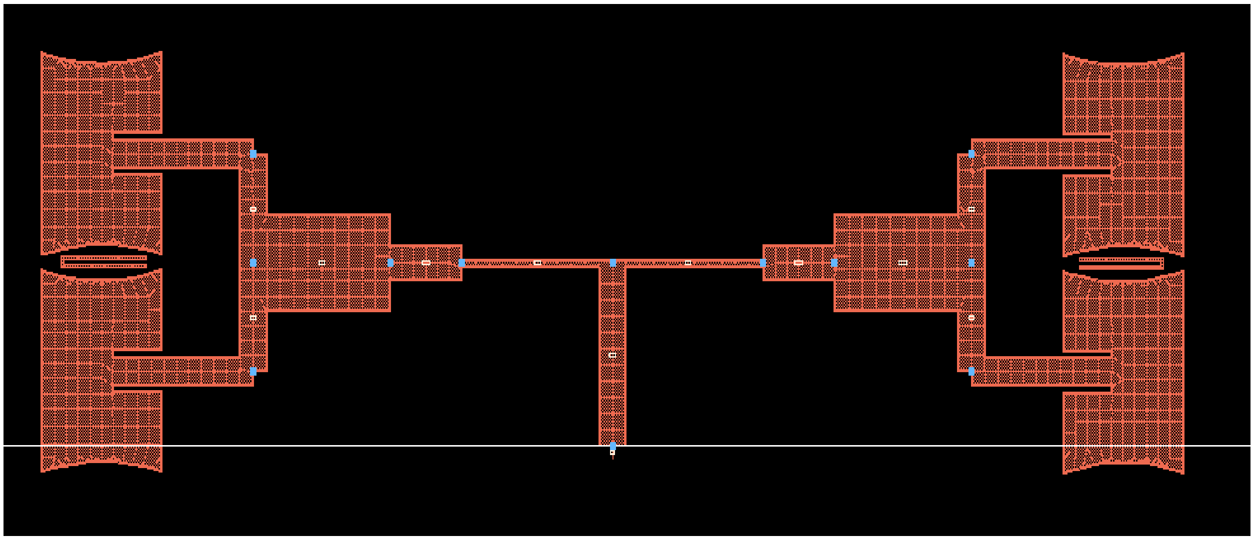


Figure 6.11 Structure of corporate feed antenna array with concave patches and a U section

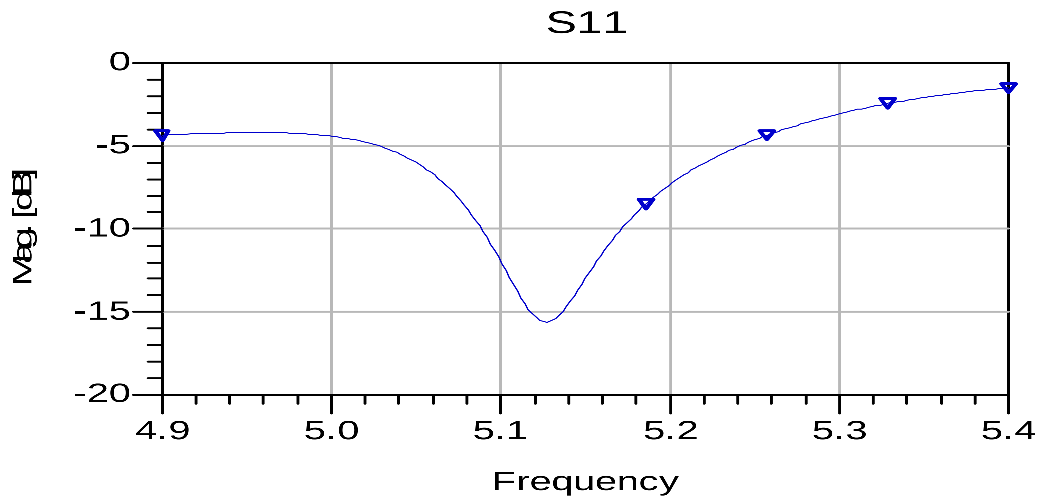


Figure 6.12 Plot for S11 parameter for corporate feed antenna array with concave patches and a U section

S11= -15.61dB at frequency 5.1GHz ,there is shift in frequency due to fringing field of patch antennas, this result shows that power divided properly in antenna arrays and a good amount of power is radiated with good gain and directivity so this structures can be used for MIMO applications.

6.5 COMPARISON OF RESULT

TABLE I
S PARAMETERS OF PATCH ANTENNA ARRAY

Antenna structure	S11	S22	S21	S12
Antenna array without U section and concavity	-10.51dB	-10.51dB	-6.48 dB	-6.48 dB
Antenna array with U section and concavity	-26.75 dB	-29.5 dB	-37.33 dB	-37.33dB

TABLE II
S PARAMETERS FOR CORPORATE FEED NETWORK

S Parameter	Value
S11	-20.52dB
S21	-6.24 dB
S31	-6.36 dB
S41	-6.24 dB
S51	-6.36 dB

TABLE III
COMPARISON OF S11 PARAMETER

Corporate feed network	-20.52dB
Corporate feed network with patch antenna array	-15.6dB

TABLE IV
GAIN AND DIRECTIVITY FOR ANTENNA ARRAY

Antenna structure	Gain	Directivity
Antenna array with U section and concavity	6.51 dB	7.55 dB
Antenna array with U section and Concavity and with corporate feed network	8.65dB	9.45dB

CHAPTER 7

CONCLUSION

In this report we have discussed about reduction of mutual coupling between radiating elements for MIMO application as all communication system is based on antennas and designing of optimum antennas with good efficiency is main work now a days. We have designed patch antennas with less spacing between them to see the effect of mutual coupling with help of ADS TOOL. Basic idea defined in base paper to reduce mutual coupling is using U section between the closely spaced elements and we have further use concave shape of patch antennas with U section to reduce mutual coupling, so that maximum power can be transmitted using microsrip antenna arrays and to improve gain and directivity corporate feed network is used.

This study presents a simple technique which is very easy to implement to reduce mutual coupling with the use of concavity shaped patch and U section between them. It is also shown that, this technique not only cancels mutual coupling but also increases the return loss with very less spacing between the antennas. The gain and directivity is also increased with 2x2 arrays which are designed using corporate feed network. This array can be used to implement spatial diversity for WiMAX applications.

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