HALF E SHAPED 3×3 ANTENNA ARRAY FOR SATELLITE COMMUNICATION IN X BAND

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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OF

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IN
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Submitted by:

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I, Aishwarya Verma, Roll No. 2K17/MOC/01 student of M.Tech. (MICROWAVE AND OPTICAL COMMUNICATION), hereby declare that the project Dissertation titled **"HALF E SHAPED 3×3 ANTENNA ARRAY FOR SATELLITE COMMUNICATION IN X BAND"** which is submitted by me to the Department of ELECTRONICS AND COMMUNICATION ENGINEERING, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled **"HALF E SHAPED 3×3 ANTENNA A RRAY FOR SATELLITE COMMUNICATION IN X BAND"** which is submitted by AISHWARYA VERMA, Roll No 2K17/MOC/01 Department of Electronics And Communication Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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Date: **SUPERVISOR**

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ABSTRACT

To understand about our universe scientists have been putting a lot of efforts by doing space exploration. People are keen to know more and more about the evolution in this field. They feel excited by not only knowing about the technologies used in current exploration but also they want to know what's coming next. They want to know every technology that is needed for space exploration missions. The data about mars reaches earth by using high gain antenna which has ultrahigh frequency band. It is attached to a spacecraft send on mars. The frequency used by this antenna is X band frequency. This full system is mainly used directly from the earth by up linking the commands and downlinking the small telemetry data on earth.

The currently used high gain antenna gives gain of about 25 dB in X band. Due to long distance communication a lot of losses occur in the form of large space loss of direct to earth link and low radiated power that is effective to transmit data to earth. Now for future missions a high performance communication system is needed that are direct to earth linked. But this up gradation requires large antenna system and large power amplifier. Making an antenna which gives good power handling property and higher gain and that to in X band will give higher data rates and greater flexibility.

According to the antennas used during mars exploration the high gain antenna used for enhanced direct to earth(DTE) communication a lot of requirement are understood for future exploration. To improve the expedition these improvement are necessary as it will enhance the potential of high gain antennas (HGA) currently being used. Requirements are as follows:

- Right hand circularly polarized output (RCP);
- Tramsition gain of above 30 dBic at a frequency of 8.6 GHz.;
- The operational frequency band should be of 70MHz of bandwidth which would be centered at 8.6 GHz frequency;
- Volume of antenna should be less than 38*38*5 centimeter cube.

The main reason behind making this antenna was the size of antenna as heavy and large antennas make it difficult in stowage during launch, cruise, entry, descent and landing. For interoperability of antenna with deep space network earth station circular polarization was

chosen. Polarization alignment and atmospheric effects like Faraday rotation are also reduced with circular polarization. The complete structure consists of small patches subarray which will be fed with a waveguide divider. This enables high power handling from the transmitter. The requirements of circular polarization, fabrication friendly for X band frequencies and dual band will be fulfilled with this circular polarized subarray.

The antenna formed has 9 different patches. Each patch is provided with a separate feed. That is total 9 coaxial feeds are applied with each feed equal to 1W. This structure gives high gain and also works in two different bands s band and x band. It can be converted as per the use. It has low return losses. Substrate used is roger and it makes it light weight. The complete structure is smaller than current used antennas used in mars navigation. It can further be turned into single feed by applying a waveguide power divider which provides power to each patch. This will further reduce the power consumptions. Half E shape of patch gives high gain with required bandwidth. A sorting bar enables the mode to radiate in x direction instead of z direction.

After analysis in HFSS of all three antennas we came to conclusion that in single patch half E antenna the resonant frequency is 9.2 GHz. Frequency band is from 8.97GHz to 9.34 GHz. The return loss of this antenna is -19.21dB; efficiency of this antenna is 96%; gain received is 7.9 dB and VSWR is 1.2 dB.

For 2×2array half E shaped patch antenna has resonant frequency 8.6 GHz; Frequency band is from 8.38GHz to 8.87 GHz; the return loss of this antenna is -25.6; efficiency is 98%; gain is 11.1 dB; VSWR is 1.1.

For 3×3 array half E shaped patch antenna resonant frequency is 8.6; Frequency band is from 8.7GHz to 9.7 GHz; return loss of this antenna is -20.37 dB; antenna efficiency is 96%; gain of antenna is 31.7 dB and VSWR is 1.4dB.

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CHAPTER 1
INTRODUCTION

1.1BACKGROUND

These days' people like to know more about the outer world which brought the focus of technology to space exploration. This leads to the increase of fundamental discoveries that give base to our scientific knowledge to the latest discoveries that takes form of technologies. These technologies help a lot in space exploration. The spacecraft technologies have gathered a lot of valuable information for study. It also helps to know about the interplanetary study. Mars exploration was one of them.

The scientific data is returned to earth through space craft in the orbit of mars using ultrahigh frequency band relay link. The spacecraft orbiting around mars transmits the data to earth from a small deep space transponder using X band radio and a high gain antenna. This whole system commands the rovers directly from earth through uplink and small amount of data is received by earth through downlink.

The current X band high gain antenna has a 25 dB gain. In direct to earth link large amount of data is lost due to space loss. DTE communication which results in high performance is necessary for future missions. The performance up gradation depends on large antenna system and large power amplifier. Antenna that provides higher gain and good power handling capacity in X band enables greater flexibility and higher data rates.

1.1.1 Ultra-High Frequency Antenna:

Ultra-high frequency antenna having frequency about 400MHz for communication at earth because the rover and orbiter antennas are in close range to each other. They act like walky talky. For long range communication with earth low gain and high gain antennas are used.

Generally radio signals take 5 to 20 minutes to travel distance between mars and earth. Mass and power constrained rover achieves high data rates of nearly 2Mbps but for short distance so for long distance we need larger antennas and transmitters to transmit data on long distance and receive the data back. It is the third antenna used along the above two. All three combinational work together. It supports earth bound scientific missions

1.1.2 The X-Band High-Gain Antenna:

They are used as it can point its radio beam in a particular direction. Its benefit is that the entire rover does not have to change its position to focus on earth. Its just like turning your neck to talk to someone instead of turning your whole body. Its high directive beam focuses in one direction providing high data rates back to earth. It is mounted at the midaft's port side of curiosity's deck. It is hexagonal in shape and its size is 1ft i.e. 0.3 meters in diameter. It is the main antenna of all. It is also supporting mars orbiter mission. A fiber optic or a satellite provides the necessary connection between the IDSN site and Network control system or spacecraft control system. This antenna provides uplink for two bands respectively i.e. S band (20 to 2kW) and X band (2.5 kW). It works in either of the two polarizations, left circular polarization or right circular polarization. It can receive one carrier in X band and two Carriers in S band together.

1.1.3 The X-Band Low-Gain Antenna:

Low gain antenna is used basically for receiving signals. This antenna is used to send and receive data in all direction like an omnidirectional antenna. It has low data rate as it does not have directivity property. It is the second antenna being used along with 32 meter deep space antenna. It supports interplanetary missions. It is a fully steerable antenna

1.2TECHNOLOGIES

1.2.1. Telecommunications:

It serves as walkie talkies that tells spacecraft operator on earth to send commands and receive data faster and in large amount. Other than transmission and reception antennas are used for many different purposes as focusing radiation in a desired direction and reducing in rest direction. Hence it also works as a directional device. Antenna is one of the most useful electric components in telecommunication network. It works in the same way as human eye. Now a day's traditional antenna are improved for enhancement like microstrip antenna has been improved for bandwidth enhancement and reducing antenna size. Fractal antennas have indicated a new idea into modern world. Multiple input multiple outputs (MIMO) are used for improving telecommunication.

1.2.2. Inherited Technologies:

Antennas were used for direct communication with earth. One is high gain antenna and other is low gain antenna. Their appearance is similar to satellite television dish antenna

but the frequency transmitted by them is much higher i.e. X band frequencies. The higher frequency can transmit a lot of data at the same time as compared to shorter wavelength but transmission should be more directives or focused to the receiver at the other side.

The other antenna used is the low gain antenna which transmits broader and less focused signals. The signal transmitted by this antenna is spread in all direction. So in which direction antenna may be pointing signal will reach the earth. Basically it is used to locate the satellite. Once the rover is located i.e. its exact location is tracked then the high gain antennas are switched on for further communication. The second antenna sends more focused and directed beam on earth.

1.2.3. Communication:

The communication is looked after by two coherent transponders and two 230 W travelling wave tube antenna. The current antenna array consists of 3 antennas i.e. low gain antenna, high gain antenna and a medium gain antenna. The high gain antenna consists of a single 2.2 meter reflector with feed at S band. It is generally used for transmitting and receiving telemetry and tracking data.

TECHNICAL DETAILS:

Minimum frequency	8.4 GHz
Maximum frequency	8.5 GHz
Gain	8 dBi
3dB beamwidth	65 degree
Return loss	10dB
Polarization	Linear
Antenna port	SMA

Table 1: antenna description

1.3 STATEMENT OF THE PROBLEM:

The whole system is used for controlling rovers send on mars. They are command directly from earth through unlinking. In back communication from rover to earth small amount of data is transmitted through downlinking. The currently used high gain antenna working in X band gives a 25 dB gain. A lot of data loss occurs in space through direct to earth link. Radiated power efficiency is also low. Hence performance of high gain antenna used is not

good. Size of these antennas is too huge to carry. These antennas also need a lot of power for its proper functioning. A good power handling system is also required. We receive less data as a lot of data is lost due to ace losses and low efficiency.

1.4 OBJECTIVE:

The latest success of mars exploration by NASA as well as ISRO has taken whole world into its grip of new interest of mars exploration. The antenna used in such exploration needs to be improved and latest development is in circularly polarized patch sub arrays. This antenna can provide a gain up to 30dB. It will result in an enhanced communication of dual band direct to earth link that to in X band. Currently used dual band or wide band circularly polarized patch array are not good for X band frequencies. It also has other problems like it does not work properly in harsh environments in space.

1.5 LITERATURE REVIEW:

A rover contains a high gain antenna and a low gain antenna on its back area. These antennas act as its ear and voice. The low gain antenna acts as an omni directional antenna it sends and receives data from all direction. A deep space network antenna is placed on earth receives the low rate radio waves transmitted by the antenna. The high gain antenna sends a beam of information in a particular direction. It can change its direction also hence antenna can point directly to earth. The main advantage of having a rotatable antenna is that the entire rover doesn’t have to rotate to get linked to earth. It’s just like turning your neck to talk to someone instead of turning your whole body. Other than transferring information to earth rover can uplink the information to other spacecraft that are orbiting around the mars. Orbiters are close to rover as compared to deep space network antennas that are situated on earth. Hence data is uplinked to them. The orbiters are directly linked to earth station for a long period of time.

Researchers tried to find out different ways to add dual band performance in a patch antenna with circular polarized results. The drawback with most of the designs was that they needed multiple layers. Other problem was slot should be thin but it could not be effectively scaled to X band frequencies.

Designs with slotted ground don’t have this issue but their result reduced antenna’s directivity. It was because the slot radiated behind the antenna. Rest of the antennas obtained good dual band features but the frequency ratio between the two operational bands is quite large.

The circularly polarized U slot patch antenna, L shaped probe has shown a increase in bandwidth. This was obtained by low permittivity and thick substrate. The wide band designs are too large.

E shaped patch antenna resulted in wide bandwidth and fabrication is also simple. Half E shaped circularly polarized patch antenna resulted in increase in gain. It also reduced its 50% size. The shorting bar directs the radiation in x direction.

1.6 THESIS OUTLINE

This chapter started with a preliminary discussion about the satellite antenna technology. Later it centers on the issues which prompt the inspiration and need behind the research in this thesis. A literature survey is written to draw attention towards the developments in this field till now and how this project came into existence.

The 2nd chapter will shed some light on the basics on antenna, definitions, and antenna parameters. It provides the foundation of the terms used later in the thesis.

The 3rd chapter starts with the microstrip antenna and feeding techniques. A brief about techniques used to study and analyze the antenna. It contains the brief discussion about polarization and multiple input systems. At the end a brief discussion about the antenna is done.

The chapter 4th consists of software used and its applications. Then a brief introduction is given about the fabrication techniques used for the antennas.

The 5th chapter is about the methodology followed for the development of the half E shaped circularly polarized antenna, from antenna design, simulation to the fabrication. The design of the antenna is explained in detail with material selection. Then the fabrication process is explained.

The 6th chapter focuses on the results obtained after simulation on software HFSS. The results of single patch, 2×2 array and 3×3 array is discussed and compared also. The fabrication results are also analyzed. Finally compare the stimulated and measured results. The chapter ends with the conclusions and future scope.

CHAPTER 2

ANTENNA THEORY

2.1 FUNDAMENTALS OF ANTENNA

2.1.1 Layout

Definition of Antenna refers to "a usually metallic device (as a rod or wire) for radiating or receiving radio waves". Or another way it can be say that a device which is radiating or receiving the radio waves. It does configuration between wired and wireless.

Therefore, it is passive element which can create a wireless connection between devices. They are reciprocal devices as all their properties are same whether it acts as a receiver or transmitter. This guiding structure is a transmission line which can be of form of coaxial cable or hollow pipe. A waveguide takes EM energy from source to the transmitting end, and vice versa at the receiver end i.e. waveguide takes electromagnetic energy from receiver end to the destination. In first case we use a transmitting antenna and in second case we use a receiving antenna.

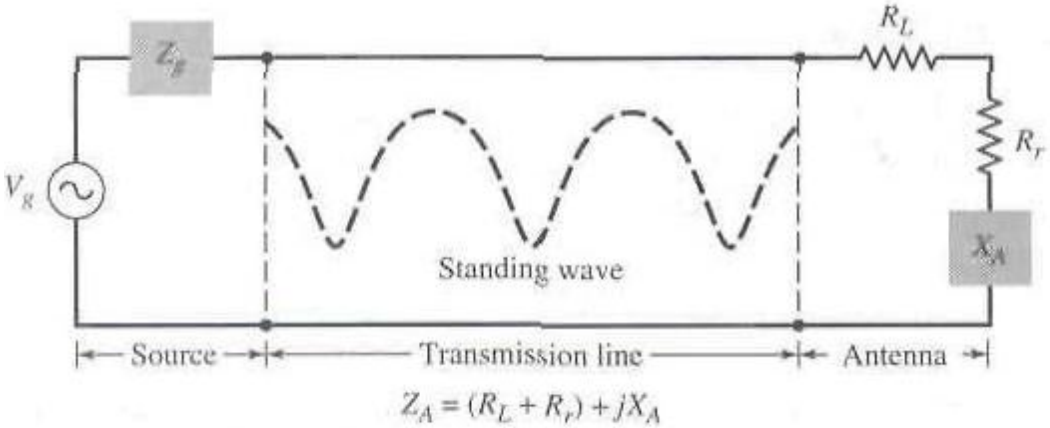


Fig. 2.1 Transmission line equivalent of antenna

RL is the load resistance which is represents dielectric and conductive losses in an antenna structure. Rr is a radiation resistance which represents radiation by antenna. Xa is reactance which represents the imaginary part of resistance of antenna.

Under ideal conditions the total source impedance should be equal to the conjugate of load impedance i.e. total energy generated by source should be transferred entirely to radiation resistance which is radiation of antenna. But actually due to dielectric and conduction losses in the transmission line and antenna and also reflections between transmission line and antenna reduces the radiated power.

Ideal antenna is one that radiates all input power into desired direction. But it is not possible completely. But value approximately near to it can be achieved by various types of antenna. Each antenna has its own property which can help in providing desired results.

2.1.2 Types of antenna

a. Wire antenna:

A lot of wire antennas are available with different shapes and sizes like straight wire which acts ad dipole antenna, helix, loop, etc. loop antennas are of different shapes like circular, rectangular, square or any other shape according to the requirement. Circular loop antenna is mostly used because it is simple to construct.

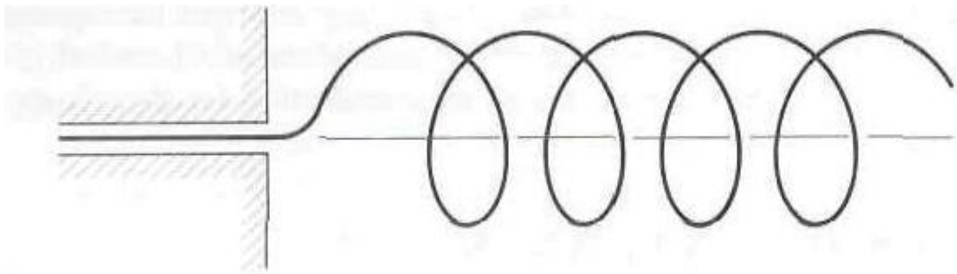


Fig. 2.2 Helix antenna

b. Aperture antennas:

Widely used in aircrafts and space crafts as they can be easily be mounted on them. They can be protected from hazardous environmental conditions by covering them with a dielectric material.

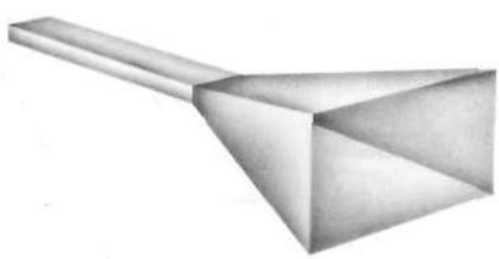


Fig. 2.3 Pyramidal antenna

c. Microstrip antennas:

Mostly used for government and commercial uses. It consists of metallic patch, substrate and ground. The patch can be of rectangular or circular in shape. They are widely used because they are easy to fabricate and analyze, also they have good radiation characteristics. They are comfortable to planar and nonplanar surfaces, low profile; simple and inexpensive also they are easy to fabricate using modern printing technology. These antennas can be used in aircrafts, spacecraft, satellites, missiles, cars, mobiles etc.

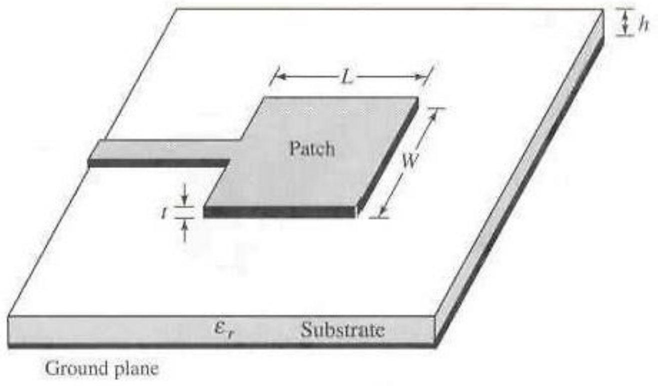


Fig. 2.4 Rectangular patch antenna

d. Array antennas:

At many places we need radiation results that cannot be achieved by a single patch. A group of patches form an array which will give in desired result. All the elements in an array should be arranged in such a way that radiation from each element adds up to give good radiation in a particular direction as desired.

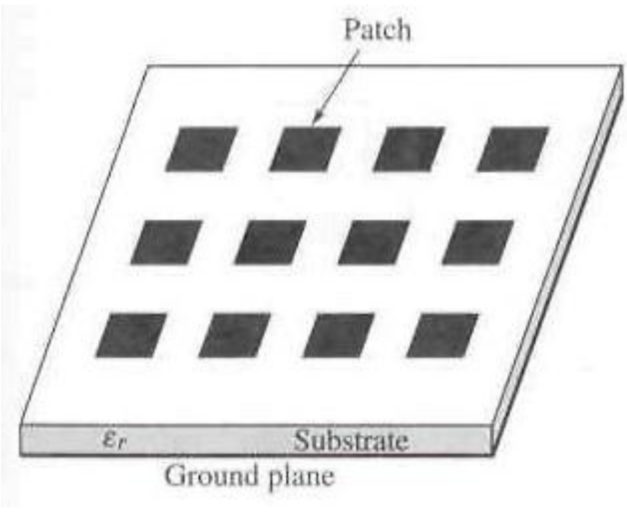


Fig. 2.5 array antenna

e. Reflector antenna:

For very long distance communication (millions of miles) antennas are formed to transmit and receive signals. For example parabolic reflector which is most commonly used. These antennas can be of diameter of 305m. It is because they give large gain to transmit or receive signals after they travel long distances.

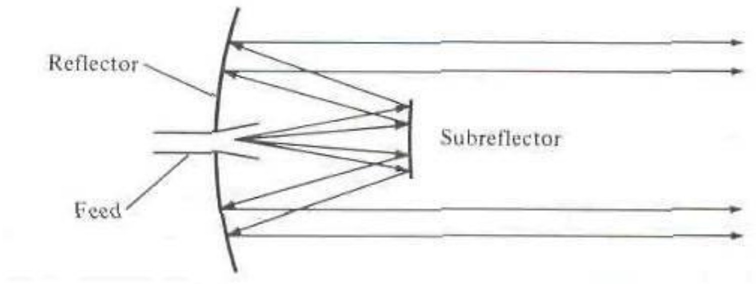


Fig. 2.6 Parabolic reflector

f. Lens antenna:

It is mostly used to collimate incident divergent energy. This results in preventing spreading of energy in undesired directions. They can change much divergent energy into plane waves by choosing right lens material and by proper shaping it. Its work at high frequencies is same as parabolic reflector. But at lower frequency its weight and shape becomes large.

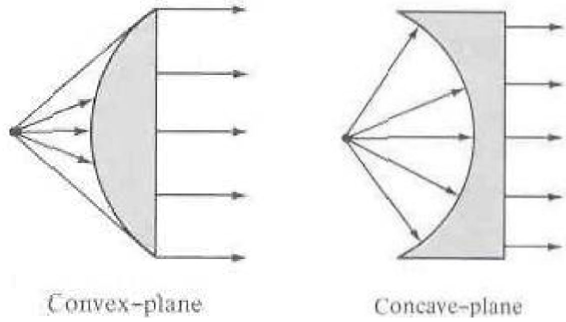


Fig. 2.7 Lens antenna

2.1.3 Radiation Pattern

It is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation pattern is represented as a function of the directional coordinates and it is determined in the far field region. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization."

Amplitude field pattern is defined as the trace of received electric or magnetic field at a constant radius. Amplitude power pattern is a graph of spatial variation of power density along a constant radius. Power pattern is plotted on the logarithmic scale and unit in which it is measured is decibels (dB).

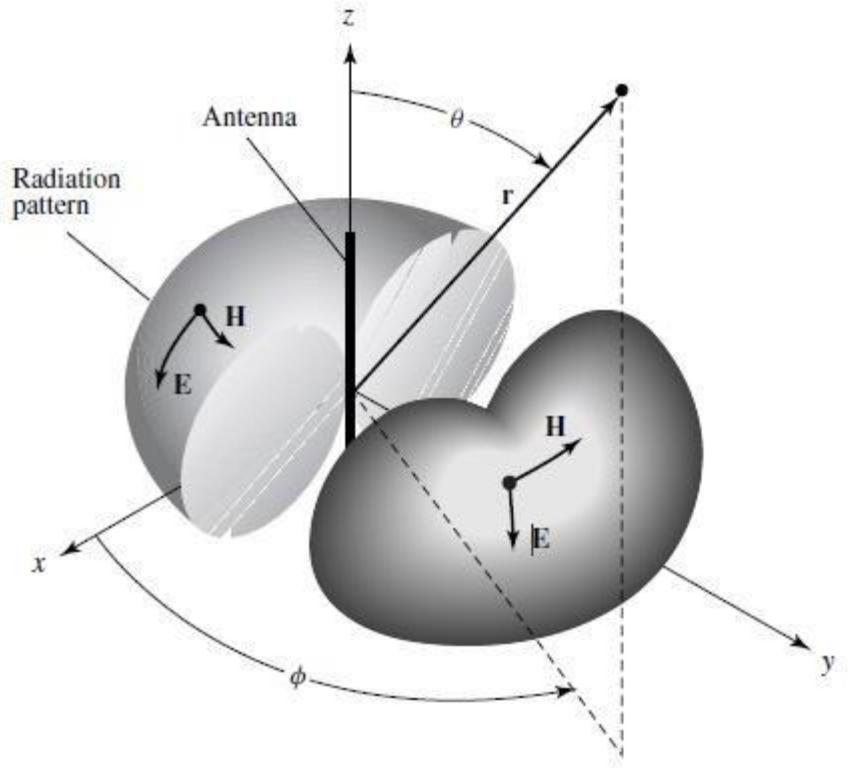


Fig. 2.8 Omnidirectional Radiation Pattern

A plot of magnitude of the electric and magnetic field as a function of the angular space is represented by field pattern (in linear scale). A plot of square of magnitude of the electric or magnetic field as a function of the angular space is called power pattern (in linear scale). The magnitude of the electric and magnetic field as a function of the angular space is called power pattern (in dB).

2.1.4 Radiation pattern lobes:

A portion of radiation pattern which is bounded by the regions of relatively weak radiation intensity is called radiation lobe

The radiation lobe which contains the maximum radiation in desired direction is called major lobe also called main lobe.

A lobe except major lobe is called minor lobe.

A radiation lobe in any other direction other than the desired direction is called side lobe. Mostly side lobe is adjacent to main lobe and it occupies the same hemisphere as the main lobe.

A radiation lobe which makes an angle of 180 degree with the main lobe is called back lobe. Radiations in undesired direction is called minor lobe. They should be reduced as they are losses. Most part of minor lobe is due to side lobes.

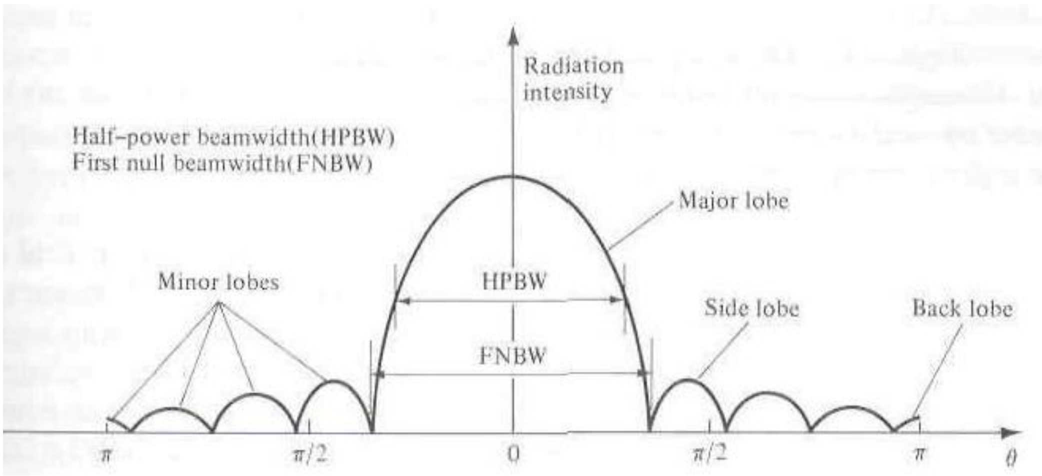


Fig. 2.9 Radiation lobes

2.1.5 Isotropic, Directional and omnidirectional

An antenna having equal radiation in all direction is called isotropic antenna. It is a hypothetical in nature because it cannot be practically made. It is a lossless antenna.

Radiating or receiving electromagnetic waves in a particular direction is called directional antenna. These antennas have their maximum directivity greater than that of half wave dipole.

Antenna with its nondirectional pattern in the given plane (azimuth) and directional pattern in a orthogonal plane (elevation) is called omnidirectional antenna. It is a special case of directional antenna.

2.1.6 Principal patterns

The plane which contains electric field vector and the direction maximum radiation is E plane. The plane which contains the magnetic field vector and the direction of maximum radiation is H plane. There are two main planes : azimuth plane and elevation plane.

2.1.7 Field regions:

The area around antenna is divided into three parts:

a. Reactive near field
b. Radiating near field (Fresnel)
c. Far field (fraunhofer)

Reactive near field is the region of near field region. It is area immediately around the antenna where reactive field is dominant.

Radiating near field (Fresnel) is area between reactive near field and far field. In this field radiation field is dominant and angular field distribution is dependent upon the distance from antenna.

Far field (fraunhofer) is the region where angular field distribution is independent of distance from antenna.

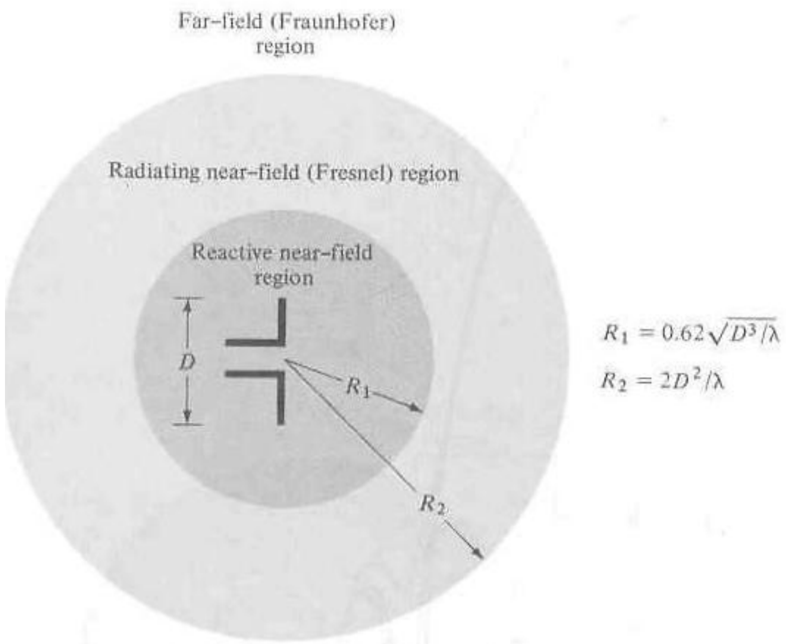


Fig. 2.10 Field region

2.1.8 Radiation intensity:

It is defined as the power radiated by an antenna per unit volume. It is a far field parameter. It can be obtained by product of radiation density and distance's square.

2.1.9 Beam width:

The distance between of two equal points but the both maximum E-Field should be inverted direction of two points.

HPBW

when E-Field is reduced by 50 %. Then angle subtended between two nulls is called half power beam width.

FNBW

Maximum goes to null and there is a minor lobe again maximum goes to null and there is minor lobe so beam width between the first null i.e. known as FNBW.

2.1.10 Directivity:

It is basically the directly proportion of radiation intensity in a particular direction and inversely proportional of the average radiation intensity in everywhere. The strength of power that antenna radiates in a direction in comparison to other direction. If antenna is 100% efficient then directivity should be equal to Gain. But when we design in HFSS then its violets this condition.so, to design the practical antenna directivity should be equal to gain when our requirement is too high. It is the proportion relation of maximum power density to average power.

2.1.11 Antenna efficiency:

It is the efficiency left after subtracting losses from total efficiency.

Total efficiency = Reflection efficiency * conduction efficiency* dielectric efficiency

2.1.12 Gain:

It basically describes that the total electrical power is transferred in radio wave or total radio wave transferred into electrical power. The total process occurs in transmitter or receiver. And that is called gain of the antenna

$$\text{Gain} = 4 * \prod * \frac{\textit{Radiation intensity of an antenna in a given direction}}{\textit{Total power input in the antenna}}$$

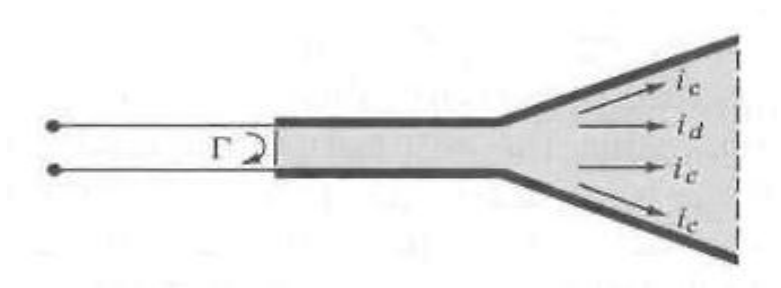


Fig. 2.11 Dielectric, Conduction and Reflection on the device

G and D can be related to each other by the following formula

G = K * D Where: - G is Gain of Antenna

K is Radiation efficiency

D is Directivity

2.1.13 Return Loss:

According to the maximum power transfer theorem, input impedance of the antenna and of the source impedance should be matched for maximum transfer of power. If mismatch occurs between these impedances then reflected process will occur.

“The relative value of this reflected power to the input or incident power is called the return loss of the antenna. Generally, the threshold for return loss is -10 dB which means

90% of incident power should be transmitted".

Return loss in(dB) = -20 *log(Γ) where Γ is a reflection coefficient

2.1.14 Voltage Standing Wave Ratio:

The VSWR is the degree of impedance mismatch among the transmission line and the load. VSWR is also defined as "the ratio of maximum voltage to minimum voltage".

2.1.14 Axial ratio:

It is the proportional relation of major axis to minor axis of field's polarization. It majorly defines the nature of circular polarization of an antenna in detail.

$$\text{axial ratio} = \left\{ \frac{\text{Major axis}}{\text{minor axis}} \right\}$$

if axial ratio is equal to 1 it is called circular polarized antenna.

If axial ratio is less than 1 it is called elliptical polarized antenna.

Else axial ratio is greater than 1 it is linearly polarized antenna.

2.1.15 Cross polarization and Co-polarization:

Co polarization is polarization of antenna in which it was meant to radiate.

Cross polarization is orthogonal pair of co polarization.

An antenna which is perfectly polarized will have least or zero cross polarization. It is used to measure the correctness of antenna's polarization.

CHAPTER 3

HALF E SHAPED PATCH ANTENNA BACKGROUND AND OVERVIEW

3.1 MICROSTRIP ANTENNA

3.1.1 Basics of microstrip antenna:

Microstrip patch antenna made up of different shape patches places over a substrate which is supported by a ground plane. It can be easily fabricated and printed on a circuit board. It is most widely used antenna. Installation of this antenna is easy due to dimension and price.

It is a planar antenna which consists of a radiating patch. And it is attached on one side with the dielectric substrate, and other side with ground plane. These radiating parts are made of conductors like copper which are commonly photo-etched. The patches are formed in some geometrical shapes like square, rectangular, circular, etc. The fringing fields which is occur in between the patch and the Ground lead to radiation, example as shown in the Fig. 3.1. These antennas radiation pattern is perpendicular to the plane of the radiating patch

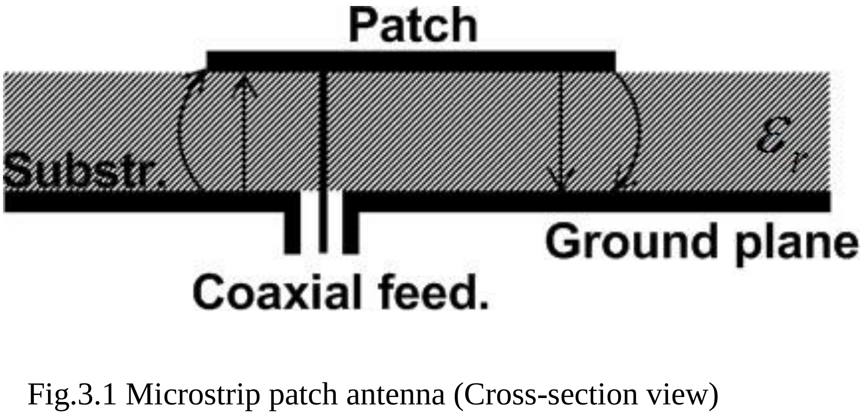


Fig.3.1 Microstrip patch antenna (Cross-section view)

For feeding the patch antennas, different structures can be used, such as coaxial probe, microstrip line, aperture coupling or proximity coupling. The various techniques available for feeding offer a degree of freedom not only while designing, but also in the later stages like while incorporating them in satellite communication antenna. The microstrip patch finds its application in narrowband satellite antenna, because of its low weight, cost, small size and more focused radiation. The existence of ground plane is further beneficial while using in satellite applications, because they prevent the back lobe radiations

Advantages ☺	Disadvantages ☹
Light weight and low volume	Narrow bandwidth
Conformability	Low efficiency
Low cost of fabrication	Low gain
Supports linear and circular polarization	Extraneous radiation from feeds and junctions
High level of integrability	Low power handling capacity
Capable of multiband operations	Surface wave excitation
Mechanically robust	

Table.2 A summary of the advantages & disadvantages of microstrip antennas

3.1.2 Feeding Mechanism:

Coupling of power in or out of an antenna can be done by a variety of techniques that are broadly divided into contacting and non-contacting. Contacting feed means that there is a direct connection of transmission lines, like in coaxial feed or in microstrip lines. The position of the connection within the boundaries of the patch decides the input impedance. Electromagnetic field coupling is used in non-contacting feeds to transfer the power between the radiating patch and the feed lines. Even though this feeding technique provides more degree of freedom as compared to contacting feed, it is harder to design. The most ordinarily used feeding are microstrip lines, coaxial cable etc.

A small length of strip is connected between source to patch. Which is called Microstrip line feed. Basically, feed help to reach the signal up to the patch. it is acting like a path for source and patch which is shown in the Fig. 3.2. Width of the strip is less in comparison to the patch. The advantage of feeding is that the strip can be placed on the same substrate as I did like patch.

Thus, providing a planar assembly. The inset cut of patch is made to create impedance matching between the feed line and the patch. Consequently, it is easier to fabricate and simpler to match by adjusting the point of the inset.

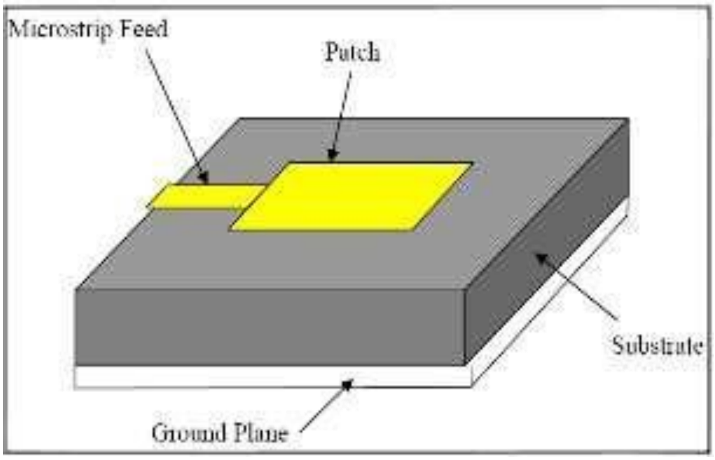


Fig.3.2 Microstrip Feed

Coaxial cable consists of two concentric cylindrical wires which are separated by a dielectric material. In coaxial feed method, the bigger radius of conductor of the coaxial cable is soldered to ground plane while smaller radius conductor is soldered to radiating element. Prime benefit of this feeding system is that the location of the feed can be adjusted to match the impedances to any desired location inside the patch. This technique has lower radiation and is easy to fabricate.

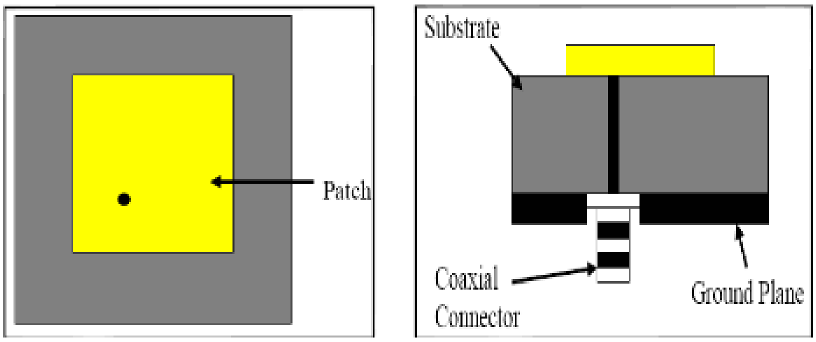


Fig.3.3 Coaxial Feed

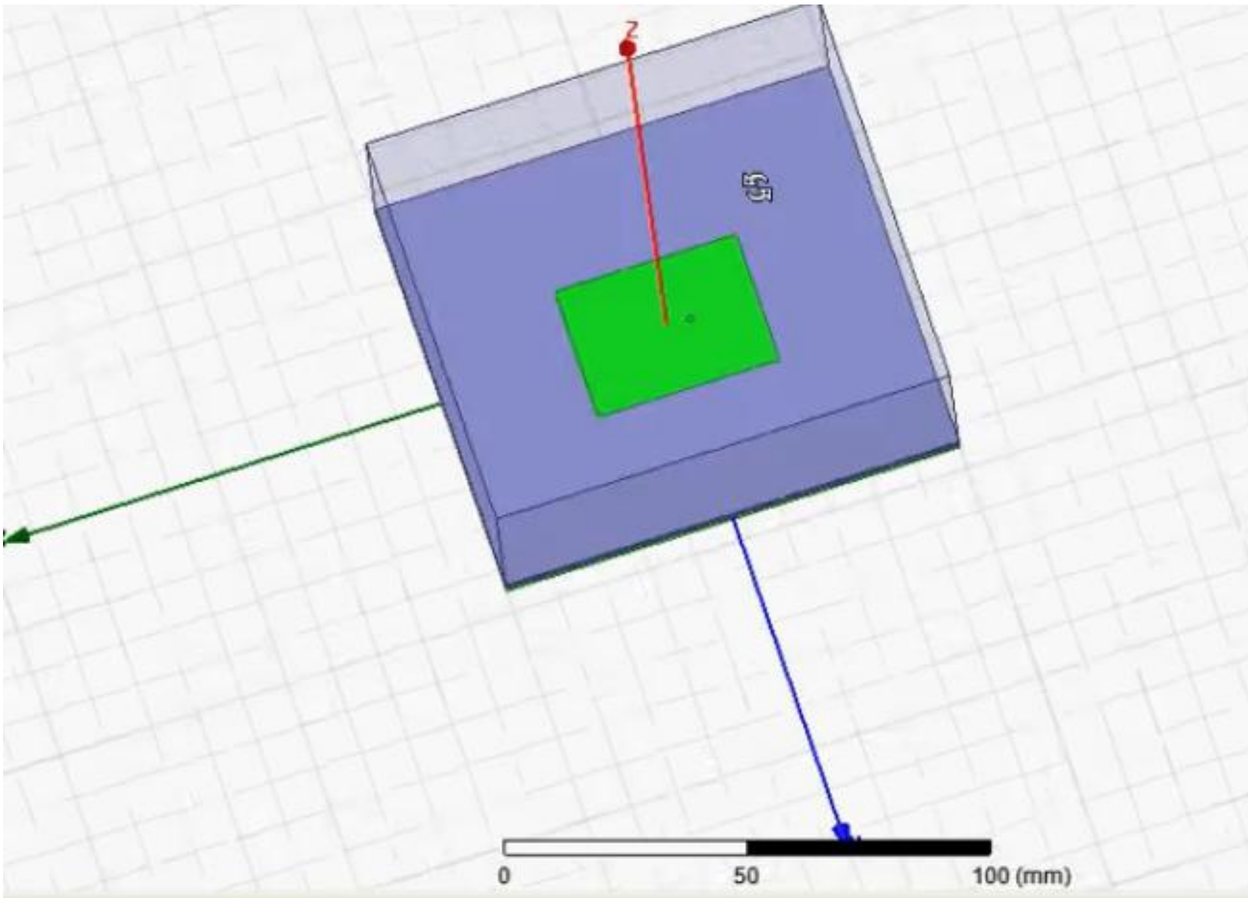


fig 3.4 Microstrip antenna

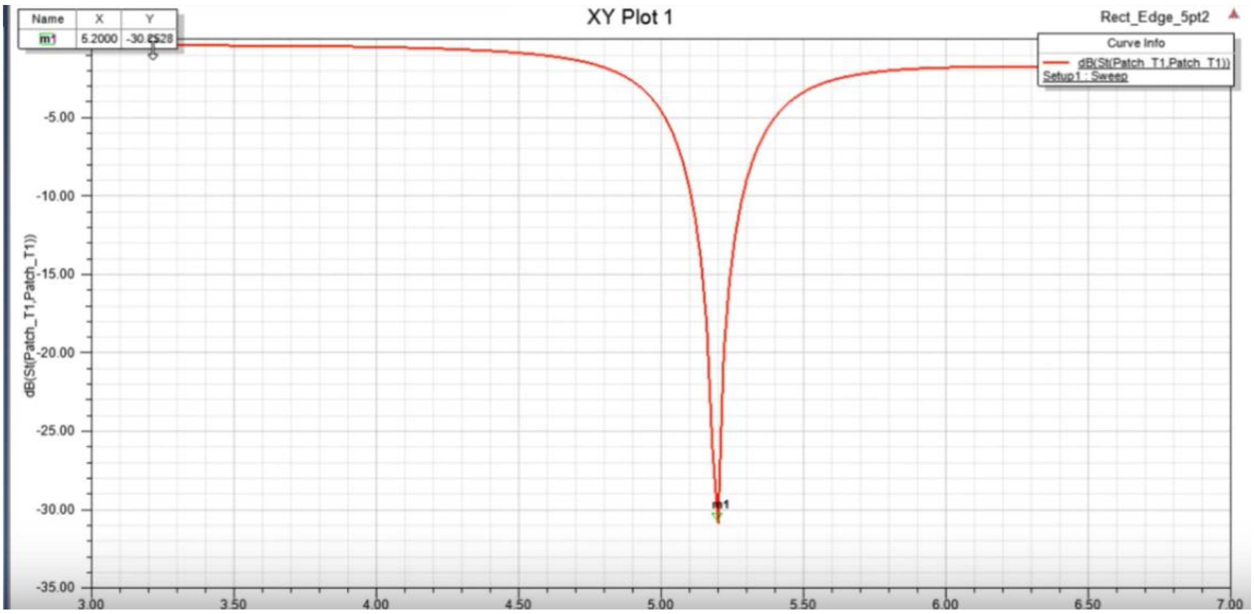


Fig 3.5 S11 parameter of microstrip antenna

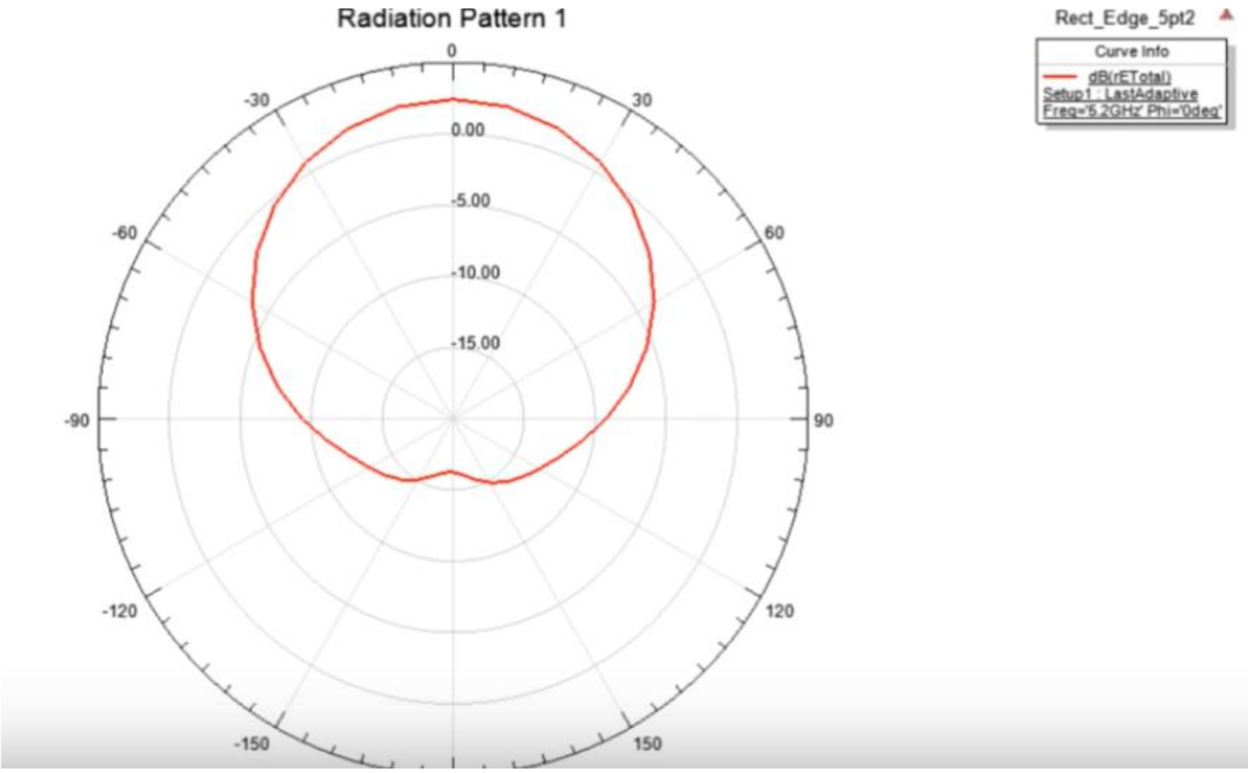


Fig 3.6 2dB plot

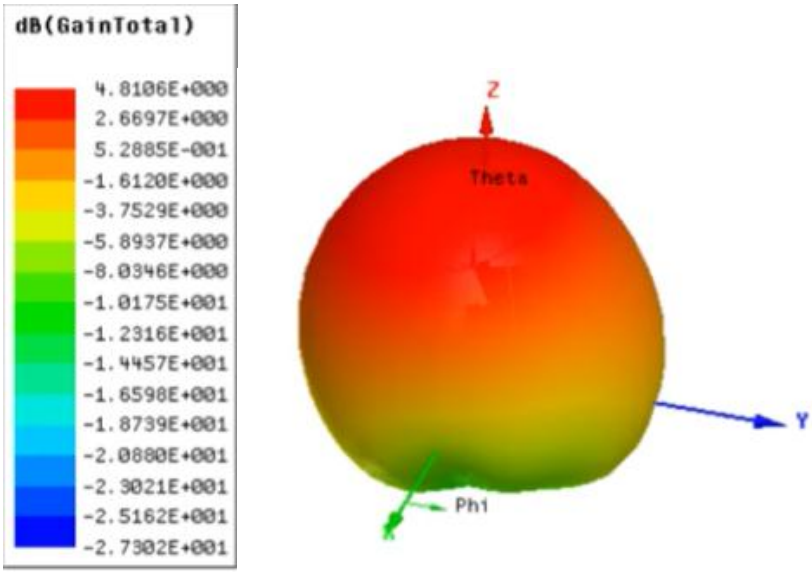


Fig 3.7 3dB radiation pattern

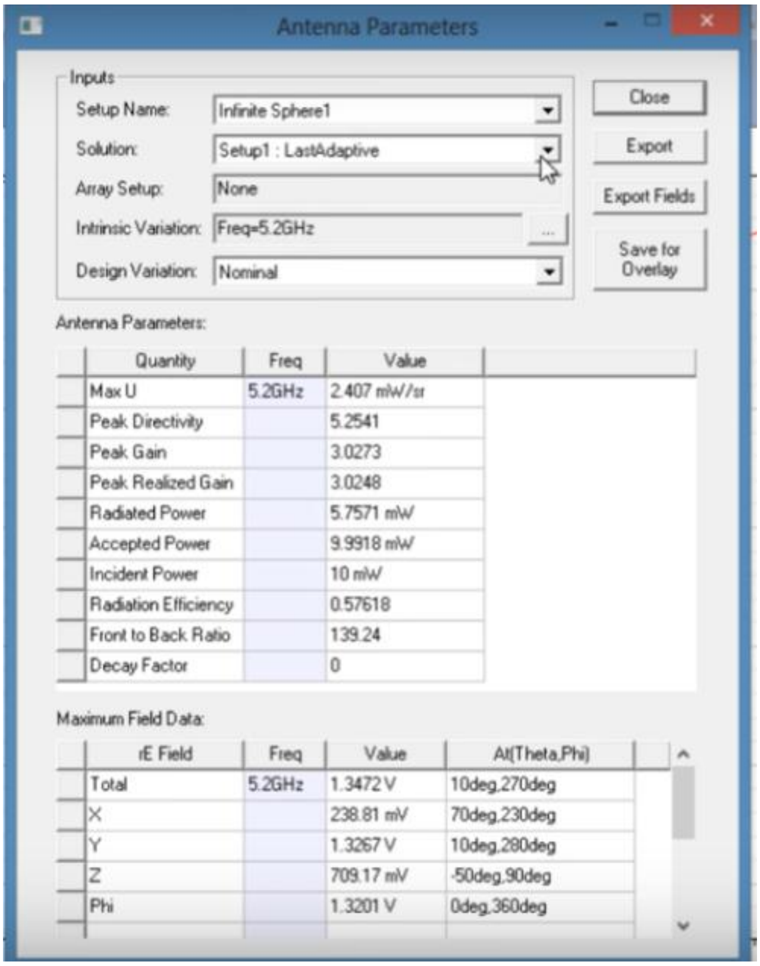


Fig 3.8 antenna parameters

3.2 POLARISATION

Polarization of electromagnetic wave indicates the plane in which it is vibrating. Electromagnetic wave consists of electric and magnetic wave making an angle of 90 degree with each other. It is used to know the signal characteristics. It is of three types:

- Linear polarization
- Circular polarization
- Elliptical polarization

1. Linear polarization:

If time and phase difference of two components is equal to n pie then the wave is called linearly polarized wave where n is whole number. If the electric field or magnetic field vector at a given point in space is always oriented along the same straight line at every point of time then a time harmonic wave is said to be linearly polarized. For field to be linearly polarized it should fulfill following criteria:

a. Two linear orthogonal components that are in phase or out of phase in time domain or

b. Only one component

2. Circular polarization:

A polarization is circular polarized if magnitudes of two components are same and phase difference is odd multiple of 90 degree.

If electric field or magnetic field vector at a given point forms a circle as a function of time. For the field to be circularly polarized following conditions should be fulfilled:

a. Two components must have same magnitude,

b. Field must have two orthogonal components,

c. Two components must be odd multiples of 90.

The direction of rotation can be determined by rotating phase leading component behind the phase lagging component and tracing the field formed during this rotation as the wave goes away from the observer. If the rotation of the field traced is in clockwise direction then the wave is clockwise or right hand circularly polarized but if reverse happens that is the field traced is anticlockwise so wave is counterclockwise or left hand circularly polarized wave.

3. Elliptical polarization:

A polarization is elliptically polarized if magnitudes of two components are not same and phase difference is odd multiple of 90 degree.

If the tip of the vector field whether electric or magnetic traces an elliptical path in space then the time harmonic wave is called elliptically polarized. The vector field changes with time continuously and in this change it traces an elliptical path. If the vector field rotates in clockwise direction then the path traced is called right hand or clockwise elliptical polarized else it is called left hand or counter clockwise elliptical polarized. To form an elliptical polarization following conditions should be fulfilled:

a. The field must contain two orthogonal linear components;

b. Both components magnitudes can be same or different;

c. 1. If magnitude is not same then phase difference must not be multiple of 180 degree

2. If magnitude is same then phase difference should not be odd multiple of 180 degree.

3.3 MIMOANTENNA

Communication industry mainly focuses on high data transfer. Mimo is foundation of mobile and wireless networking. Monopole resonator antenna is used to radiate Omni directionally and are used in multi broadcasting. Mimo antenna as the name suggest it has multiple input and it gives multiple output. Hence more than one feed line is provided to the network and this helps in giving better results. It is a beneficial because each patch gets equal input and so the radiate with full energy. These antennas give good efficiency as they every patch radiates with its full capacity. The output gained is directional and focused. The radiation pattern obtained is highly focused and gain is high. As compared to single feed antennas mimo gives high returns and this high return is good for communication. Satellites will give very focused and accurate information if mimo are used as antennas.

3.4 ANTENNA OVERVIEW

Main challenge lies in the proper designing of array elements in any array designing. Element performance is directly proportional to the array performance hence selecting a right element is an important work. Choosing a single layer with single feed element that gives circular polarization in result and that to for two frequency band is not easy especially if the frequency ratio is low. Previously circular polarized antennas were fairly narrow band i.e. bandwidth less than 2%, axial ratio less than 3db and S11 less than -10db. To add dual band performance in a circularly polarized patch antenna a lot of different techniques were tried which includes stacked patch antenna, slotted patch shapes and slotted ground planes. Majority of these designs have an issue that they require multiple layers or very thin slots that cannot be scaled in X band frequencies effectively. Designs which don’t have these issues affect the result i.e. they reduce antenna directivity. This happens because the slot radiates behind the antenna. Rest other antennas has an issue that frequency ratio between the two operating bands was very big.

So finally a design E shaped patch antenna which gives circular polarization in result was accepted. This antenna fulfills the requirements like bandwidth is increased by using a thick, low permittivity substrate. Main benefit of this patch is that they can be provided with single feed on a single layer and this also reduced many of the fabrication complexity. The E shaped patch was very helpful in achieving 17% of the axial ratio and S11 parameter.

Any other shape like L would be difficult to fabricate and it might lead to any sort of mechanical failure. Circular polarized half E shaped patch antenna provided wide bandwidth and is easy to fabricate hence future it is taken into regard.

Circular polarized half E shaped patch design:

The circular polarized half E shaped patch fulfills the above listed requirements. The design has reduced the size up to 50% of the currently used size and the bandwidth is also good. In the patch a small sorting bar is also placed across the slot of half E. this bar is placed to change the polarization of antenna. Without this bar the radiation pattern would be linearly polarized in y direction but now it gives circular polarization. The bar enables new mode to radiate in x direction. By proper tuning a proper circular polarization is also achieved.

The design is made in X band. The main objective was to achieve good S11 parameter with high gain. The substrate used id Roger RT Duroid 5880LZ. Its permittivity is 1.96. it has many other qualities like it gives nearly 0 z axis coefficient in thermal expansion and it is light weight. This avoids failure during thermal expansion. The dimensions of antenna are checked until good results are obtained.

The beam gets tilted as we move to higher order model. Distribution of field causes changes in electric field phase at antenna aperture. This beam tilt at transmitter frequency in this antenna is due to same phase variation at the aperture. This beam squint problem in circularly polarized half E shaped patch antenna was removed as we increase the order of array. This antenna gives good dual band results with a small size.

After selection of half E shaped circularly polarized antenna element, a proper array number must also be chosen which can give highest possible antenna gain after a grating lobe effect. To steer the high gain antenna beam mars rover system uses mechanical gimbals.

It is expected that in future rovers will use the similar kind of gimbal. The complex feed network needed in electronically steered phased array antennas is avoided by this mechanically steered system. Our requirement to a broadside directed array is reduced, feed network design is also simplified, and we obtain equal phase and magnitude on excitation.

The key behind choosing this antenna configuration to get maximum possible antenna directivity is that it uses most of the antenna's aperture efficiently. It also avoids grating lobe effects. One more important aspect in development of this antenna was to prevent each element from touching each other.

Why Roger is used instead of FR4?

Dielectric constant is a material property. FR4 is cheap, readily available and easily processed material. Its relative dielectric constant is 4. It's not best material for patch antenna. Many patches show better efficiency when there is air instead of FR4. On fabrication it might give a smooth surface than roger as it is hard material.

Roger is better than FR4 and it has more consistent properties for microwave but it is more expensive. Its dielectric constant is 2.2. Ceramic is used for GPS antenna patch. It has other electrical and mechanical properties.

It has properties like low density, lightweight material. It is good for weight sensitive and high performance applications. It has very low dielectric constant and it is uniform over a wide range of frequency. They can be easily cut, sheared and machined to shape.

KEY BENEFITS:

- Uniform electrical properties over wide range of frequency
- Light weight and low density
- Lowest dielectric constant available
- Low z axis radiation.

CHAPTER 4

SOFTWARE USED AND FABRICATION TECHNIQUES

4.1 SOFTWARE USED

For stimulation of antenna HFSS is used. It is high performance full wave EM wave stimulator. It stimulates arbitrary 3 dimensional volumetric passive devices. Its advantage is that it is familiar with Windows GUI. It has many features simulation, automation, solid modeling, visualization and easy to learn. It gives three dimensional modular window of electromagnetic field problems. Solutions are quick and accurate. It uses FEM, brilliant graphics and adaptive meshing to provide solutions and unmatched performance to all the 3D problems of electromagnetic field. It helps to calculate parameters such as resonant frequency, s parameter, vswr, polar plots etc.

It is simulating system which works on mesh element tetrahedron. It helps in solving any 3D geometry especially complex shapes and curves.

HFSS full form is high frequency structure simulator. For electromagnetic simulation it uses finite element method (FEM).

It has increased its evolution with time with the help of input from many industries and users. It is a tool for good output in development, research and virtual prototyping.

HFSS window has many panels as follows:

- **Project manager:** it helps in listing the structure of project. It contains design tree which makes it possible.
- **Message manager:** it tells about any error or changes needed before stimulation. It acts like a warning window.
- **Property window:** to change model attributes or parameters this window is helpful.
- **Progress window:** it displays progress of stimulation.
- **3D modeler window:** it contains active design's model and model tree.

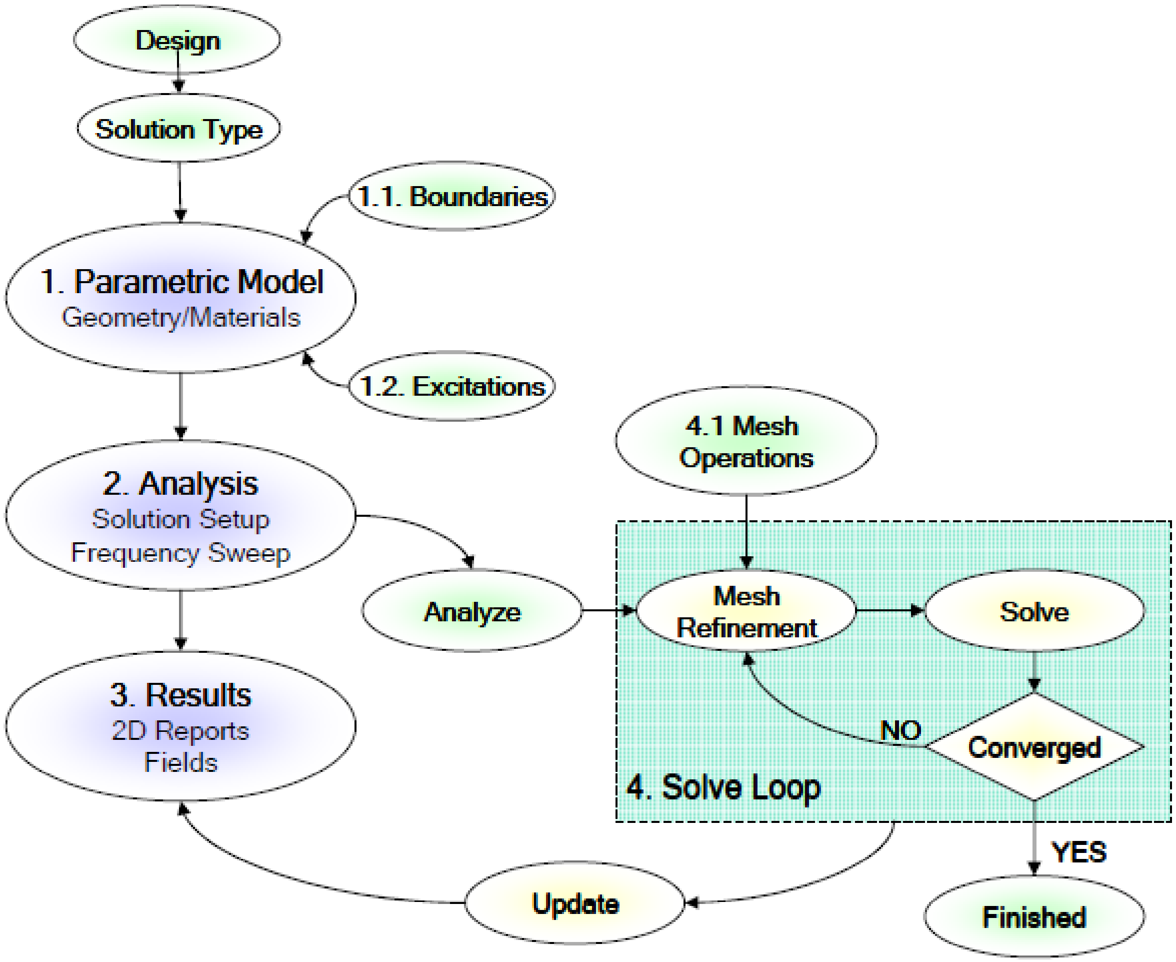
Flow chart of simulating result in HFSS

To design a structure in HFSS. We have to follow some procedure which is categories in different Windows model. These windows model is given in below.

- **Parametric Model Generation**
- **Analysis Setup**
- **Results**

- **Solve Loop**

To understand the processes, we have to see through Flow chart which is shown below.



Plotting data

Data plotting can have many forms. The most frequently used format is 2-Dimensional Cartesian plotting, but we can also the capability to draw in 3-Dimensional. All the parameter that can be plotted on different graphs, is shown below.

Eigenmode solution

- Eigenmode Parameters (modes)

Driven Modal Solution

- S-parameters
- Y-parameters
- Z-parameters
- VSWR
- Gamma (complex propagation constant)
- Port Zo

Driven Terminal Solution

- S-parameters
- Y-parameters
- Z-parameters
- VSWR
- Power (at port)
- Voltage Transform matrix (T)
- Terminal Port Zo

Fields

- Mag_E
- Mag_H
- Mag_Jvol
- Mag_Jsurf
- Local_SAR (Specific Absorption Rate)
- Average_SAR
-

Types of plot: -

- Rectangular Plot
- Polar Plot

- 3D Rectangular Plot
- 3D Polar Plot
- Smith Chart
- Data Table
- Radiation Pattern

4.2 FABRICATION METHODOLOGY

Different ways exists for fabrication of microstrip patch antenna. For the fabrication of strip antenna a mask was designed using gerber file.

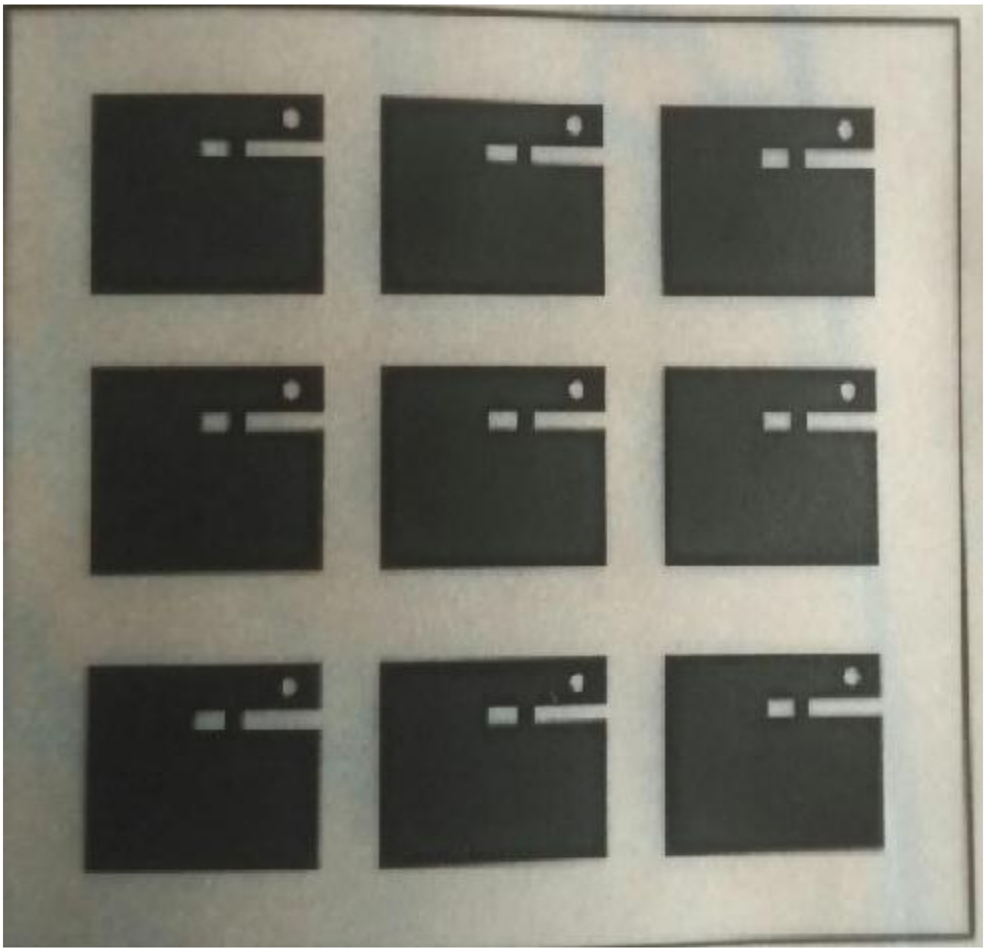


Fig. 4.2 Gerber file of patch

Fig. 4.3 Gerber file of ground

Photolithography technique was used to transfer mask image on electroplated copper PCB board. PCB sheet's cut size was cleaned to remove the surface impurities with the help of organic solvent. Then it is dried with the help of hot air gun. Then a coating of positive photo resist is done on it. This substrate is pre baked at 90 degree Celsius so that solvent gets removed and film is stuffed. The substrate is exposed to indigenous developed mask aligner which has an inbuilt exposure system.

Fig. 4.4 solution for substrate formation

In 20% KOH solution the exposed substrate was developed. Once the images are transferred onto the substrate it is placed in oven at 130 degree Celsius. For hard baking it is heated for 30 minutes. The unwanted part that is exposed is removed in $FeCl_3$ solution. The etched pattern of copper is washed in DI water. Then it is air dried. This processing gives best quality antenna.

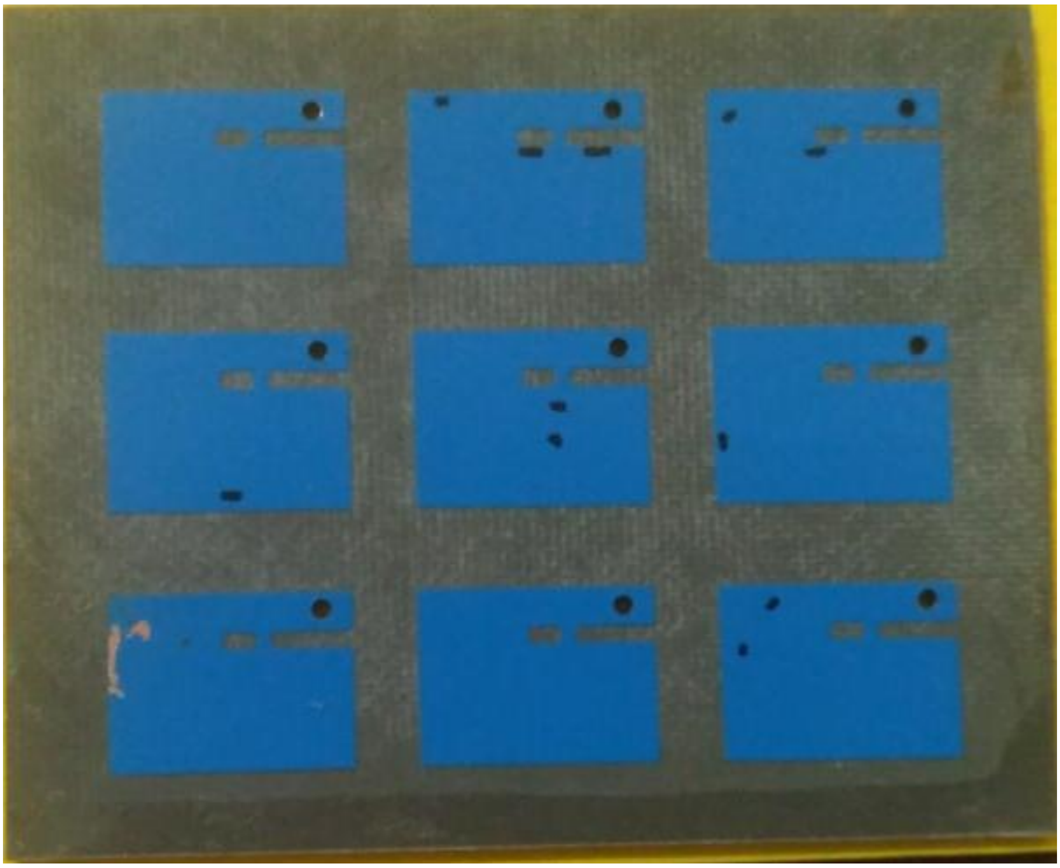


Fig. 4.5 antenna formed

The fabricated antenna is then soldered to attach input ports to it. This antenna is multiple input antenna so all 9 patches are provided with 9 input ports.

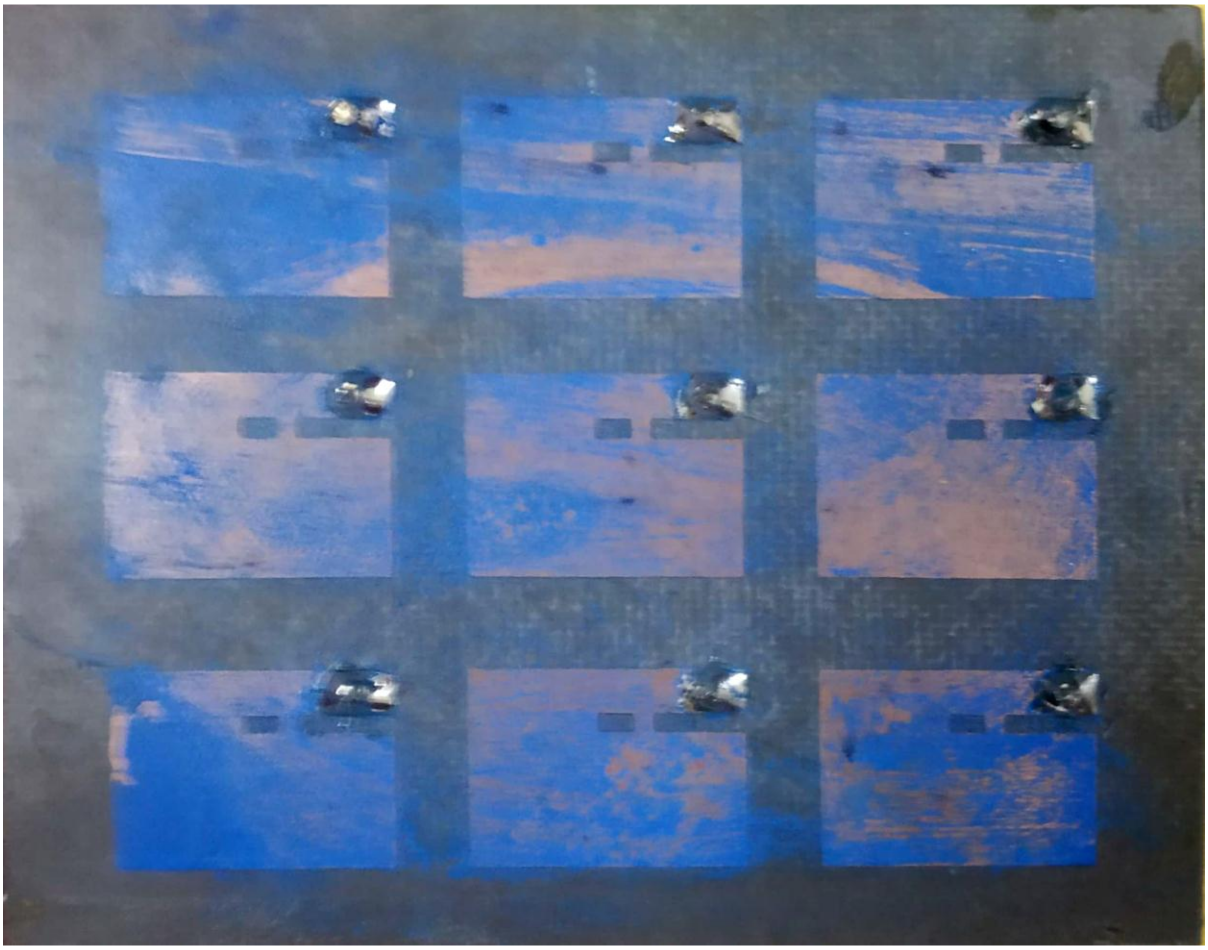


Fig. 4.6 front of antenna

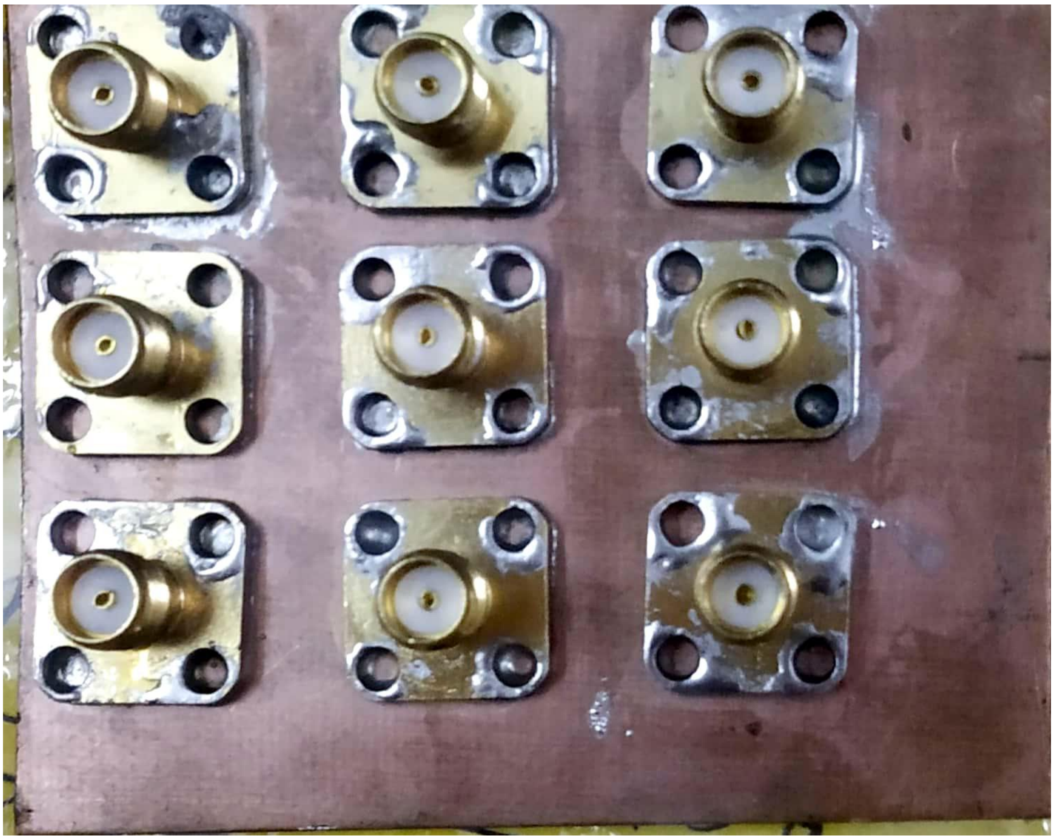


Fig. 4.7 Back of antenna

CHAPTER 5

ANTENNA DESIGN

The circular polarized half E shaped patch fulfills the above listed requirements. The design has reduced the size up to 50% of the currently used size and the bandwidth is also good. In the patch a small sorting bar is also placed across the slot of half E. this bar is placed to change the polarization of antenna. Without this bar the radiation pattern would be linearly polarized in y direction but now it gives circular polarization. The bar enables new mode to radiate in x direction. By proper tuning a proper circular polarization is also achieved.

The design is made in X band. The main objective was to achieve good S11 parameter with high gain. The substrate used id Roger RT Duroid 5880LZ. Its permittivity is 1.96. it has many other qualities like it gives nearly 0 z axis coefficient in thermal expansion and it is light weight. This avoids failure during thermal expansion. The dimensions of antenna are checked until good results are obtained.

The beam gets tilted as we move to higher order model. Distribution of field causes changes in electric field phase at antenna aperture. This beam tilt at transmitter frequency in this antenna is due to same phase variation at the aperture. This beam squint problem in circularly polarized half E shaped patch antenna was removed as we increase the order of array. This antenna gives good dual band results with a small size.

After selection of half E shaped circularly polarized antenna element, a proper array number must also be chosen which can give highest possible antenna gain after a grating lobe effect. To steer the high gain antenna beam mars rover system uses mechanical gimbals. It is expected that in future rovers will use the similar kind of gimbal. The complex feed network needed in electronically steered phased array antennas is avoided by this mechanically steered system. Our requirement to a broadside directed array is reduced, feed network design is also simplified, and we obtain equal phase and magnitude on excitation.

The key behind choosing this antenna configuration to get maximum possible antenna directivity is that it uses most of the antenna’s aperture efficiently. It also avoids grating lobe effects. One more important aspect in development of this antenna was to prevent each element from touching each other.

5.1 Single patch half E circular polarized antenna:

In this thesis I have made a single patch half E antenna. The Two dimensional Radiation Pattern of single patch antenna is circularly polarized. This patch of copper is placed over the substrate. Substrate used is Roger RT/duroid of relative permittivity 2.33. Substrate thickness is 1.6 mm and its dielectric loss tangent is 0.0012. Substrate dimension is 20mm*16mm*1.6mm. The antenna discussed above has been designed as shown below:

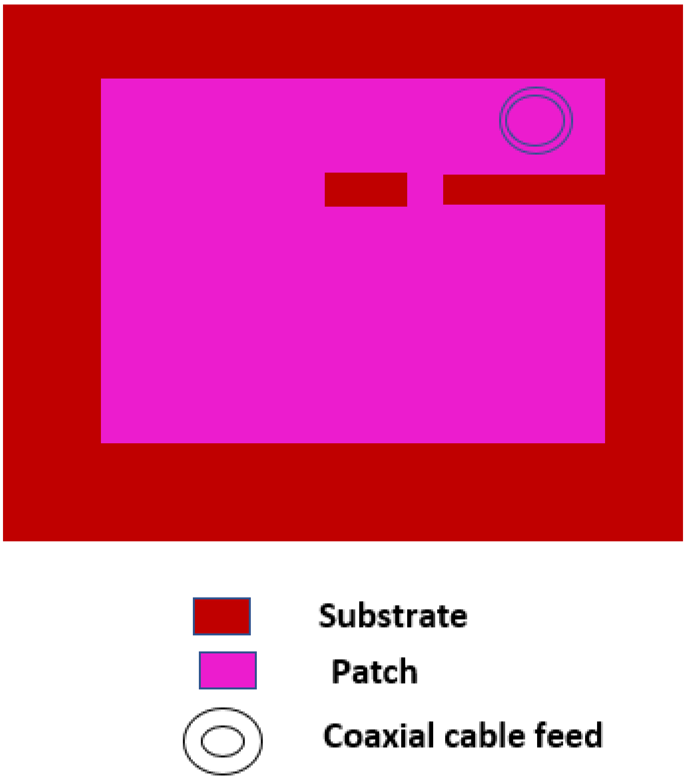


Fig 5.1 single patch half E shaped antenna

In the above figure I have placed the copper patch of dimension 15mm*11mm over the substrate which is of dimension 20mm*16mm*1.6mm. The patch is made of copper which is made perfect electric using the software HFSS. A cut of 9mm*1mm is made in the patch which gives it an appearance of half E. A small strip of 1mm*1mm is placed to make the linear polarized field to circular polarized field in x direction. Feeding is done with the help of coaxial cable. The feed line consists of three cylinders. The first cylinder is of material pec which has relative permeability and permittivity 1. Its dimension is radius 0.5 mm and height 1.2 mm. the second cylinder is also of pec material with dimension radius 0.5mm and height 1.6mm. The third cylinder is of Teflon material whose permittivity is 2.1 and permeability is 1. Its dimension is radius 2mm and height 1.2mm. The antenna also has a ground plane which is provided with perfect electric field. The ground is of dimension 20mm*16mm.

The whole antenna is provided with energy through a waveport. The waveport is of 2mm radius. The whole system is placed inside the radiation box.

Table 3: Proposed single patch half E shaped antenna

PARAMETERS	VALUE(MM)
Substrate length	20
Substrate width	16
Substrate height	1.6
Patch length	15
Patch breadth	11
Cut length	9
Cut breadth	1
Slit length	1
Slit breadth	1
Coaxial 1 height	0.5
Coaxial 1 radius	1.2
Coaxial 2 height	0.5
Coaxial 2 radius	1.6
Coaxial 3 height	2
Coaxial 3 radius	1.2
Ground length	20
Ground breadth	16
Waveport radius	2

5.2 2×2 array half E circular polarized antenna:

I have made 2×2 array half E antenna. Its 2-Dimensional Radiation Pattern is circularly polarized. This patch of copper is placed over the substrate. Substrate used is Roger RT/duroid of relative permittivity 2.33. Substrate thickness is 1.6 mm and its dielectric loss tangent is 0.0012. Substrate dimension is 45mm*37mm*1.6mm. The antenna discussed above has been designed as shown below:

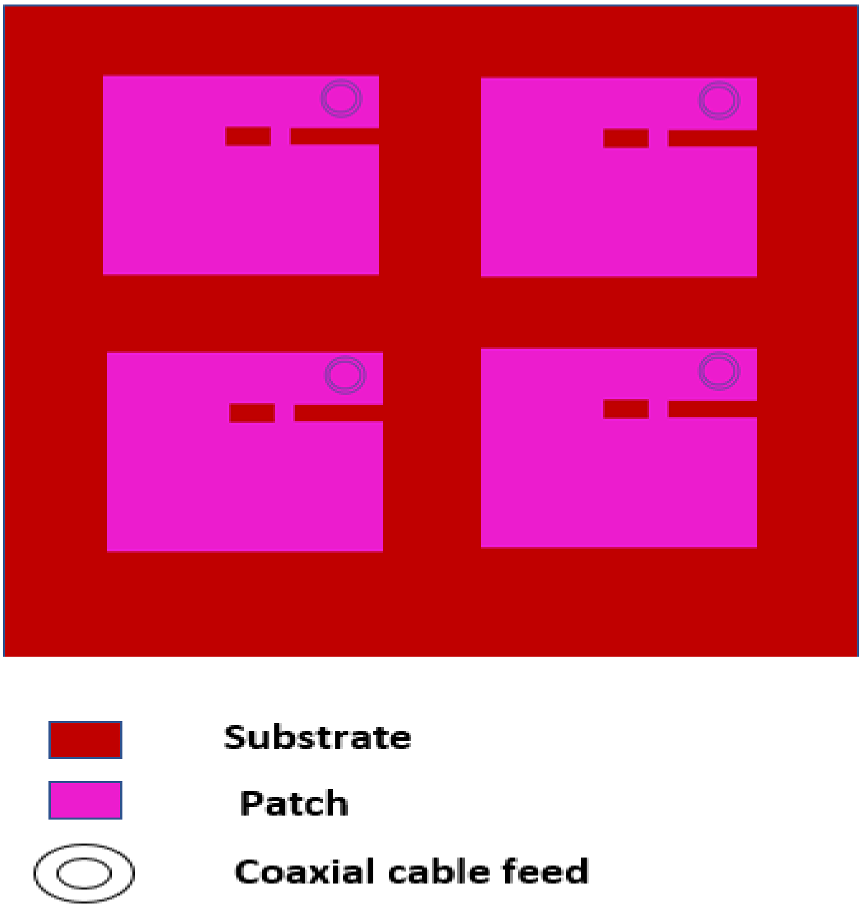


Fig 5.2 2×2 array half E shaped antenna

In the above figure I have placed the four copper patches each of dimension 15mm*11mm over the substrate which is of dimension 45mm*37mm*1.6mm. The patch is made of copper which is made perfect electric using the software HFSS. A cut of 9mm*1mm is made in each patch which gives it an appearance of half E. A small strip of 1mm*1mm is placed to make the linear polarized field to circular polarized field in x direction. Feeding is done with the help of coaxial cables. Each patch has its own coaxial feed line. Each feed line has its own wave port too. The feed line consists of three cylinders. The first cylinder is of material pec which has relative permeability and permittivity 1. Its dimension is radius 0.5 mm and height 1.2 mm. the second cylinder is also of pec material with dimension radius 0.5mm and height 1.6mm. The third cylinder is of Teflon material whose permittivity is 2.1 and permeability is 1. Its dimension is radius 2mm and height 1.2mm. The antenna also has a ground plane which is provided with perfect electric field. The ground is of dimension 20mm*16mm. the whole antenna is provided with energy through a waveport. The waveport is of 2mm radius.

5.3 3×3 array half E circular polarized antenna:

A 3×3 array half E antenna whose radiation pattern is circularly polarized is made. This patch is of copper is placed over the substrate. Substrate used is Roger RT/duroid of relative permittivity 2.33. Substrate thickness is 1.6 mm and its dielectric loss tangent is 0.0012. Substrate dimension is 65mm×52mm×1.6mm. The antenna discussed above has been designed as shown below:

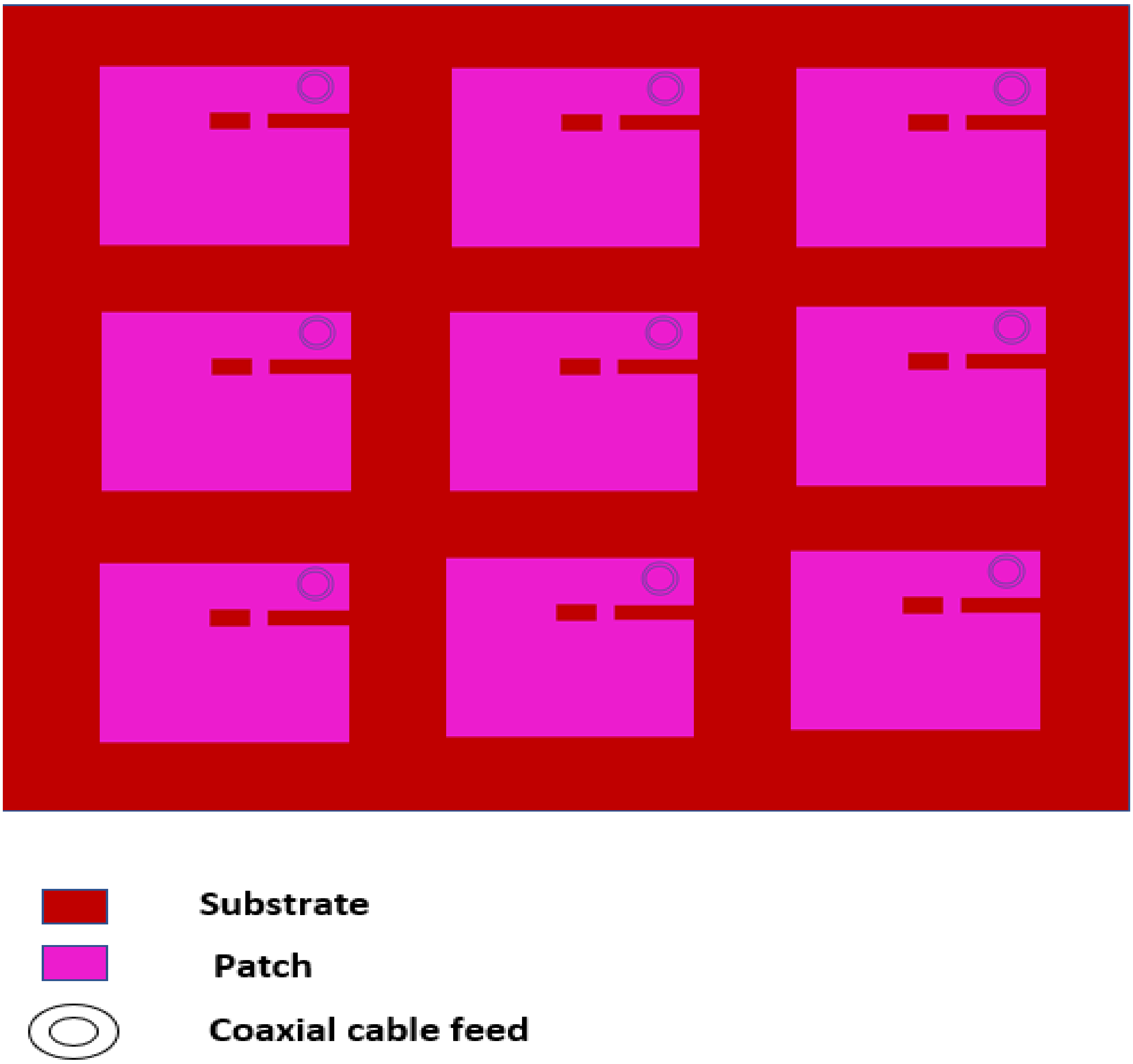


Fig 5.3 3×3 array half E shaped antenna

The whole system is same as the above discussed two models with a difference that substrate is of dimension 65mm×52mm×1.6mm. Total 9 patches are formed to gain this configuration

CHAPTER 6

STIMULATION AND RESULTS

6.1 Single patch half E circular polarized antenna:

Single patch half E circular polarized antenna is designed at a center frequency 9.2 GHz. Fig 6.2 shows the frequency response of simulated result S11 parameter

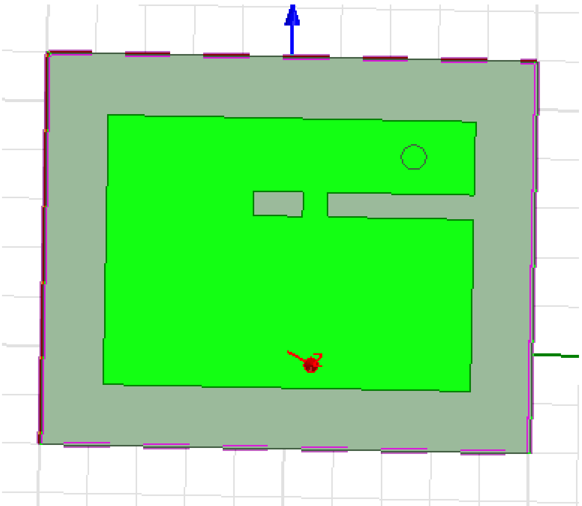


Fig 6.1 single patch Half E circular polarized antenna

The return loss is -19.21dB. Frequency band is from 8.97GHz to 9.34 GHz.

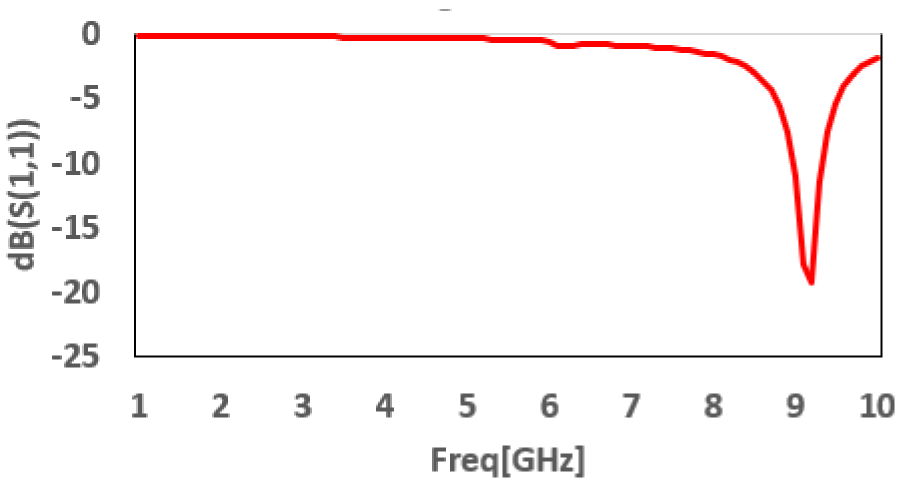


Fig 6.2 Stimulated return loss (dB)

The 3-dimensional gain at 9.2 GHz is shown in figure 6.3 and 2-dimensional gain is shown in figure 6.4 of proposed antenna. The total gain of single patch half E shaped circular patch antenna is 7.9 dB.

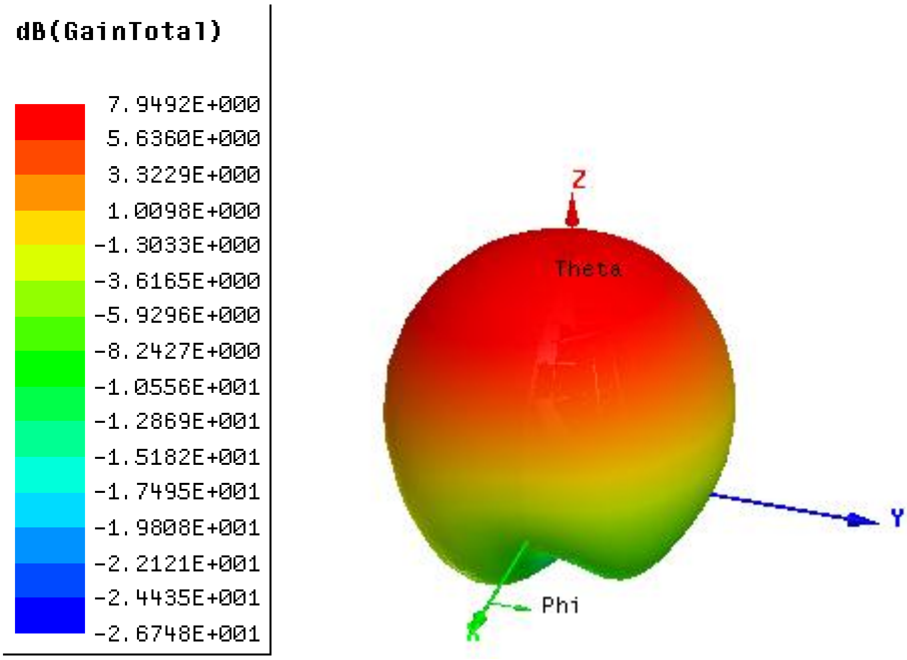


Fig 6.3 3D polar gain

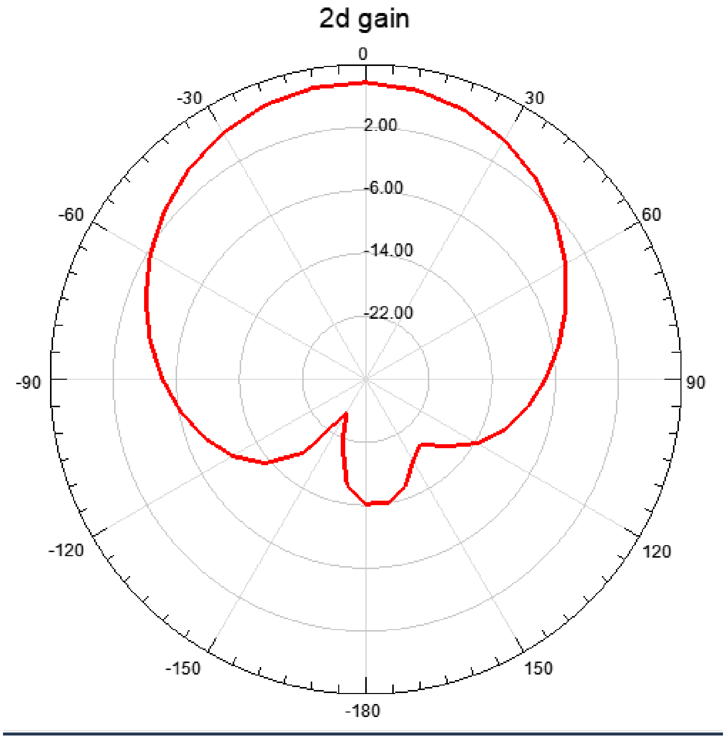


Figure 6.4 2-Dimensional Radiation Pattern of Proposed antenna

Fig 6.5 shows the Radiation efficiency. The total radiation efficiency is 96% which is good enough for further use. It will totally convert radio frequency power to radiated power.

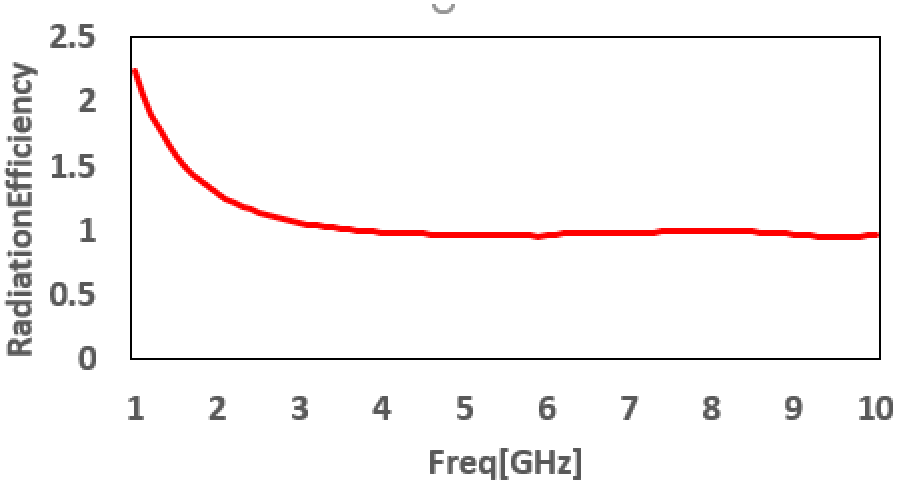


Fig 6.5 radiation efficiency

Figure 6.6 shows vswr. The exact value of vswr is 1.24 at 9.2 GHz. If the vswr is less than 2 then it is satisfactory for all antenna application because it is a perfect match.

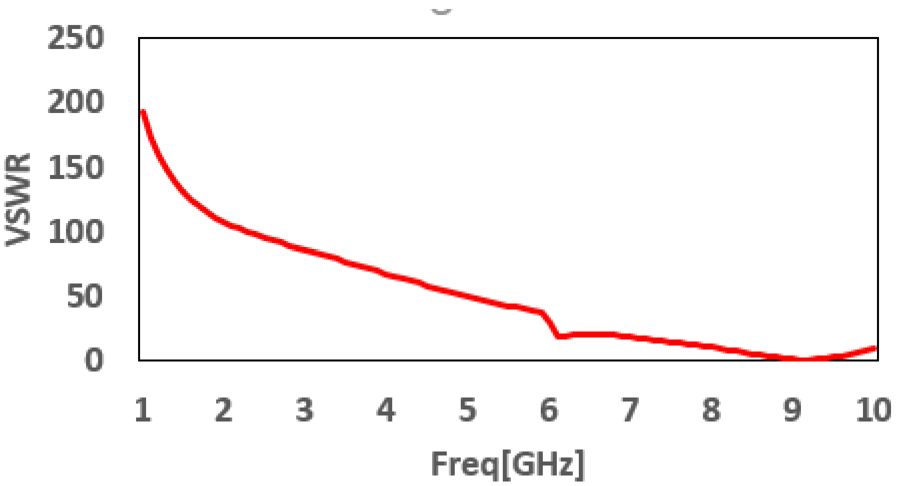


Fig 6.6 VSWR

Figure 6.7,6.8,and 6.9 shows electric field distribution, magnetic field distribution and current density of antenna at phi=0 respectively.

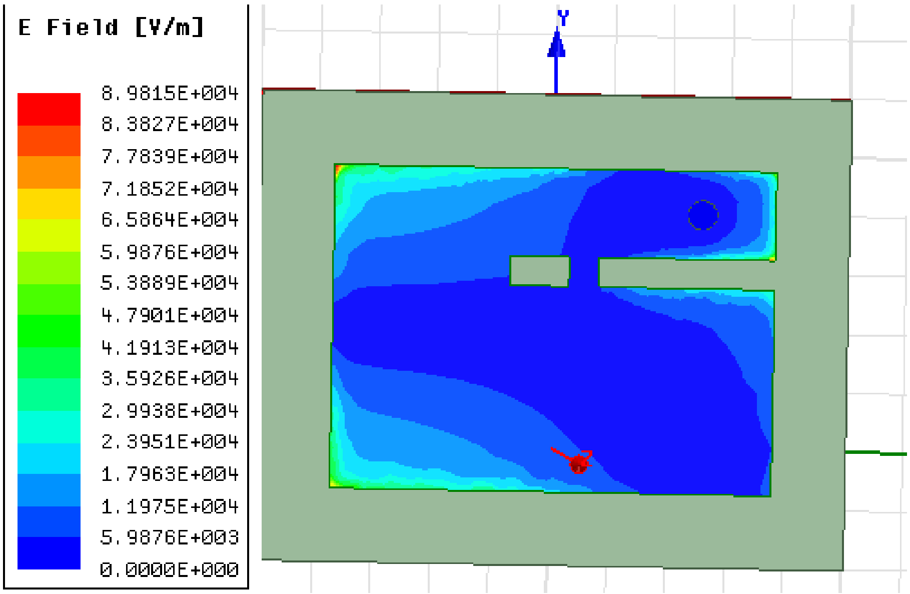


Fig 6.7 electric field distribution

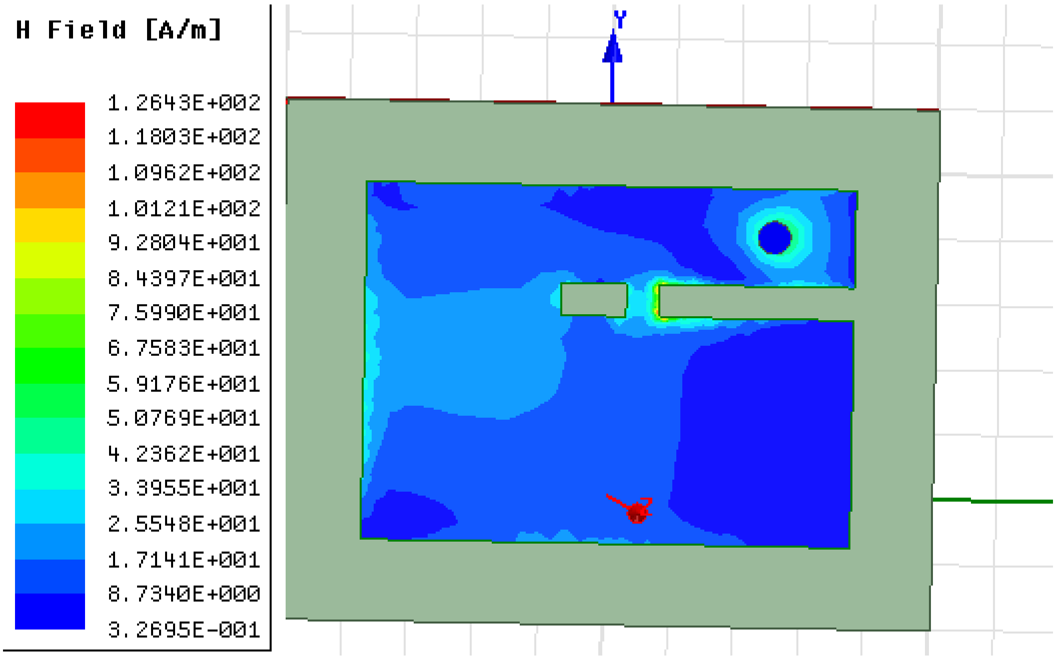


Fig 6.8 magnetic field distribution

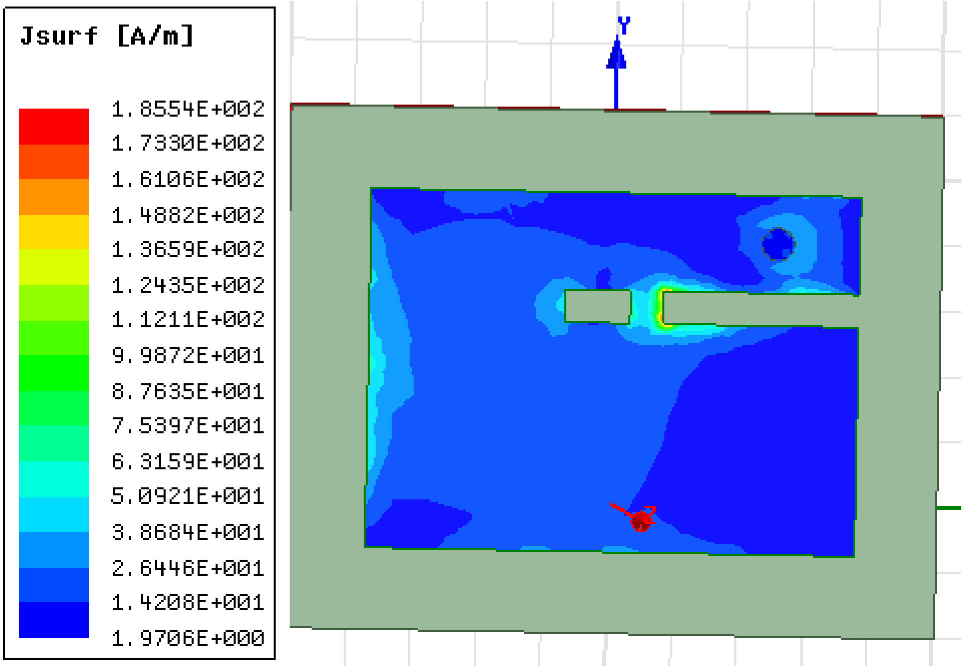


Fig 6.9 current density

6.2 2×2 array half E circular polarized antenna:

2×2 array half E circular polarized antenna is designed at a center frequency 8.6 GHz. Fig 6.10 shows the frequency response of simulated result S11 parameter

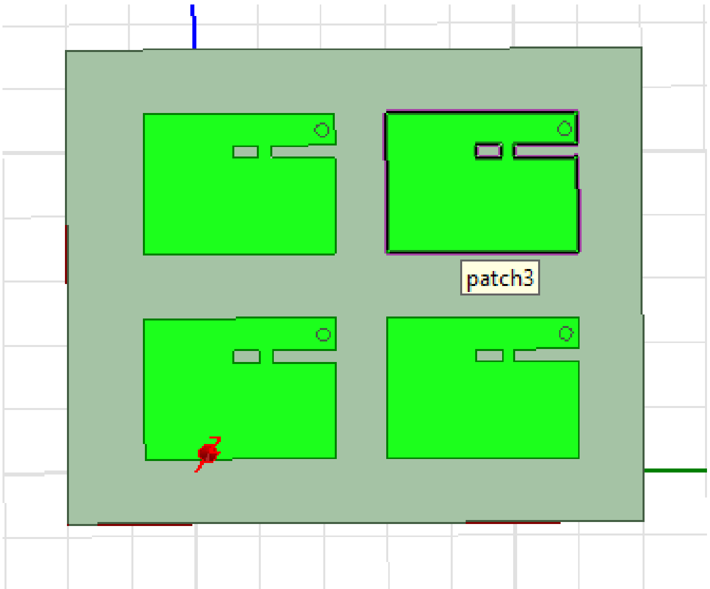


Fig 6.10 2×2 array Half E circular polarized antenna

The return loss is -25.6dB. Frequency band is from 8.38GHz to 8.87 GHz.

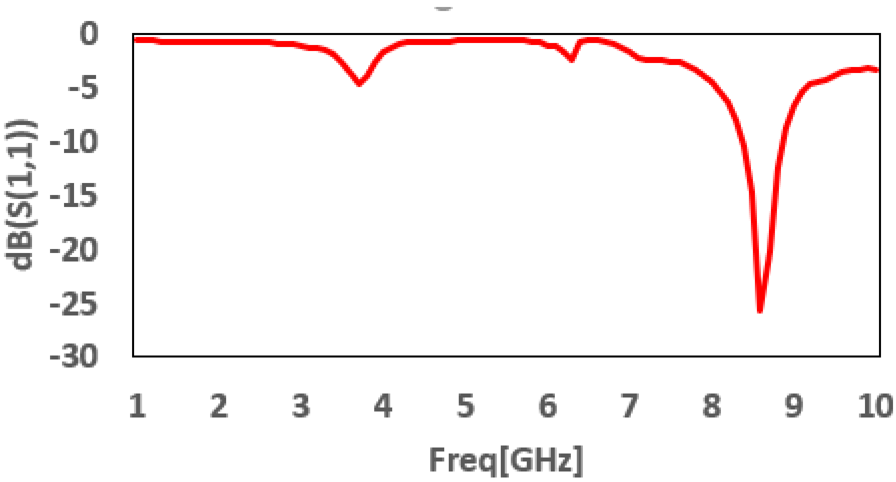


Fig 6.11 Stimulated return loss(dB)

The 3-dimensional gain at 8.6 GHz is shown in figure 6.12 and 2-dimensional gain is shown in figure 6.13 according to prototype model. Total gain of single patch half E shaped circular patch antenna is 11.1 dB.

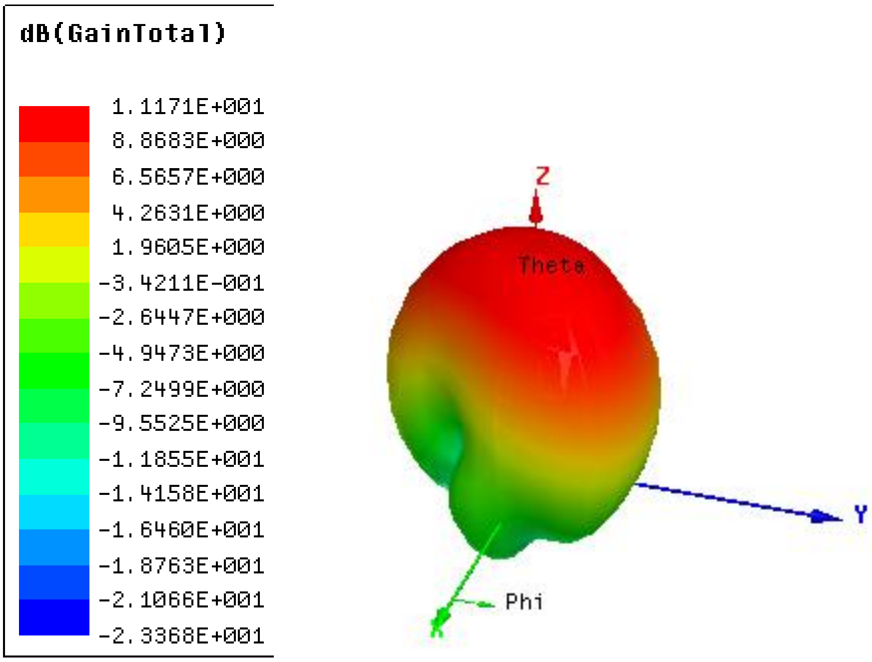


Figure 6.12 3-Dimensional Radiation Pattern of Proposed case

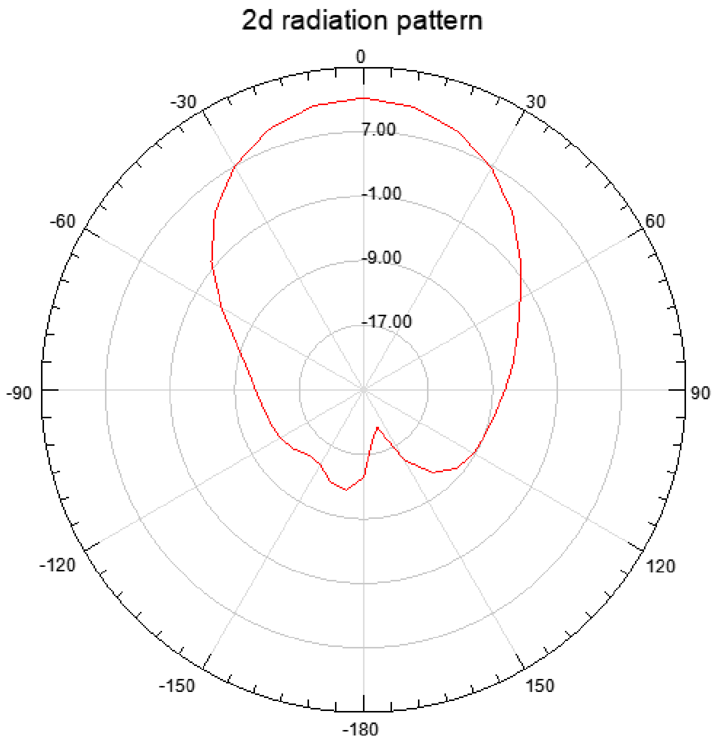


Fig 6.13 2D radiation pattern

Figure 6.14 shows the radiation efficiency. The total radiation efficiency is 98% which is good enough for further use. It will totally convert radio frequency power to radiated power.

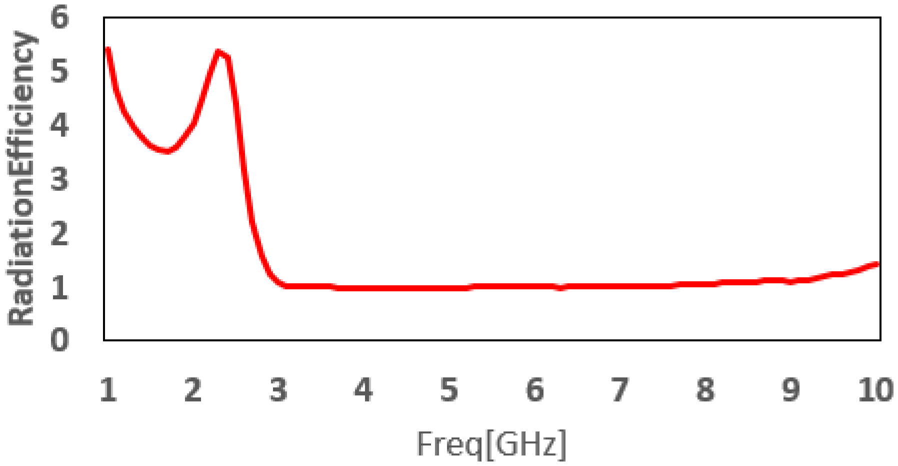


Fig 6.14 radiation efficiency

Figure 6.15 shows vswr. The exact value of vswr is 1.1 at 8.6 GHz. If the vswr is less than 2 then it is satisfactory for all antenna application because it is a perfect match.

Fig 6.15 VSWR for patch 1: 1.1

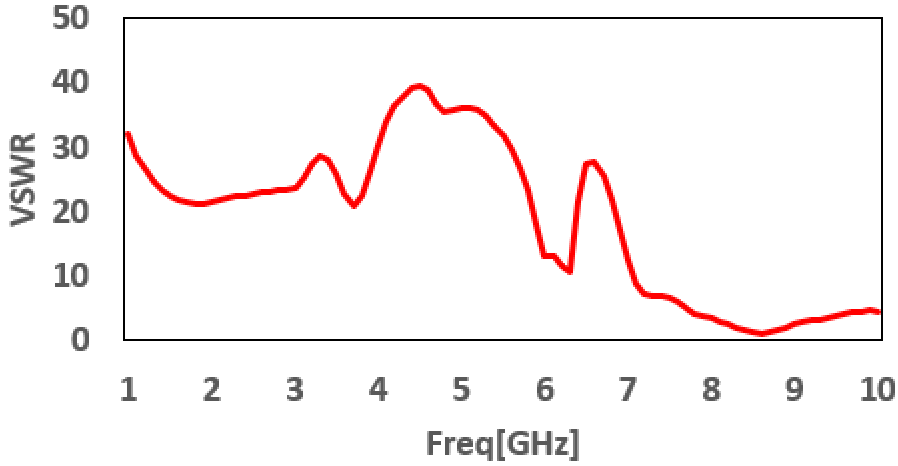


Fig 6.16 patch 2: 1.1

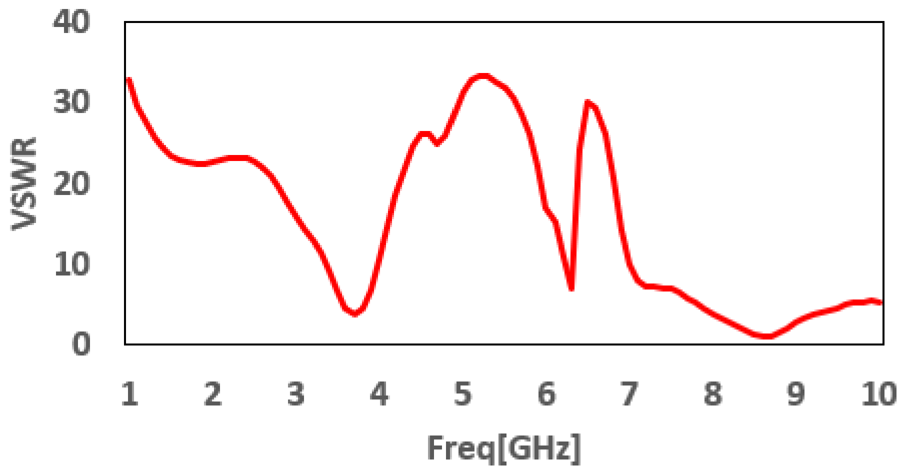


Fig 6.17 For patch 3: 1.1

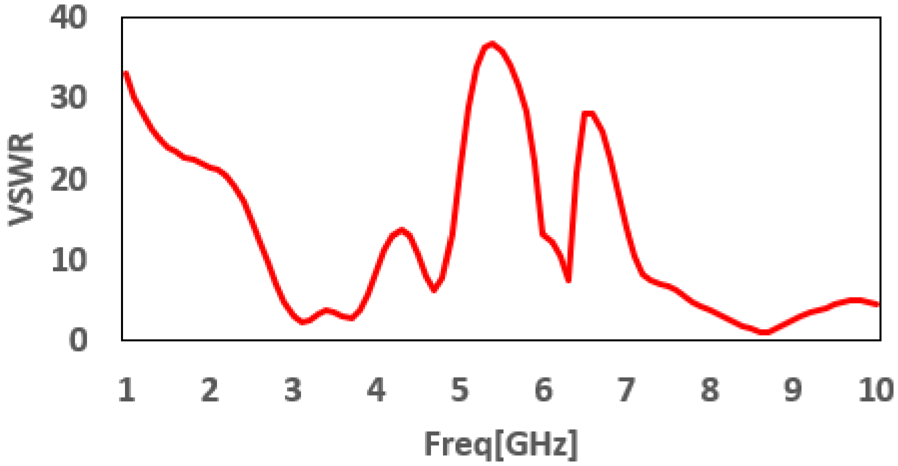


Fig 6.18 For patch 4: 1.1

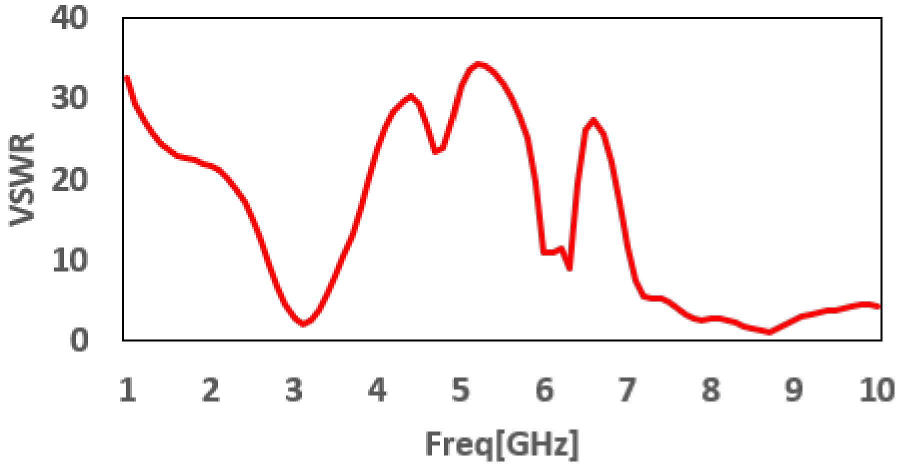


Figure 6.19,6.20,and 6.21 shows electric field distribution, magnetic field distribution and current density of antenna at phi=0 respectively.

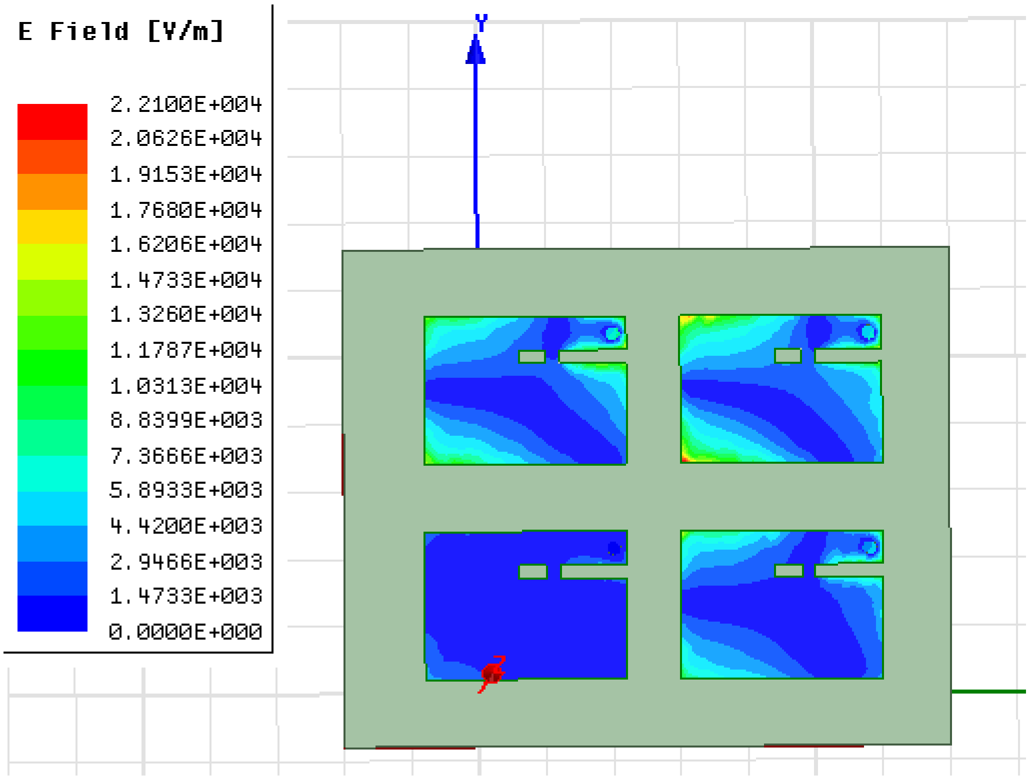


Fig 6.19 electric field density

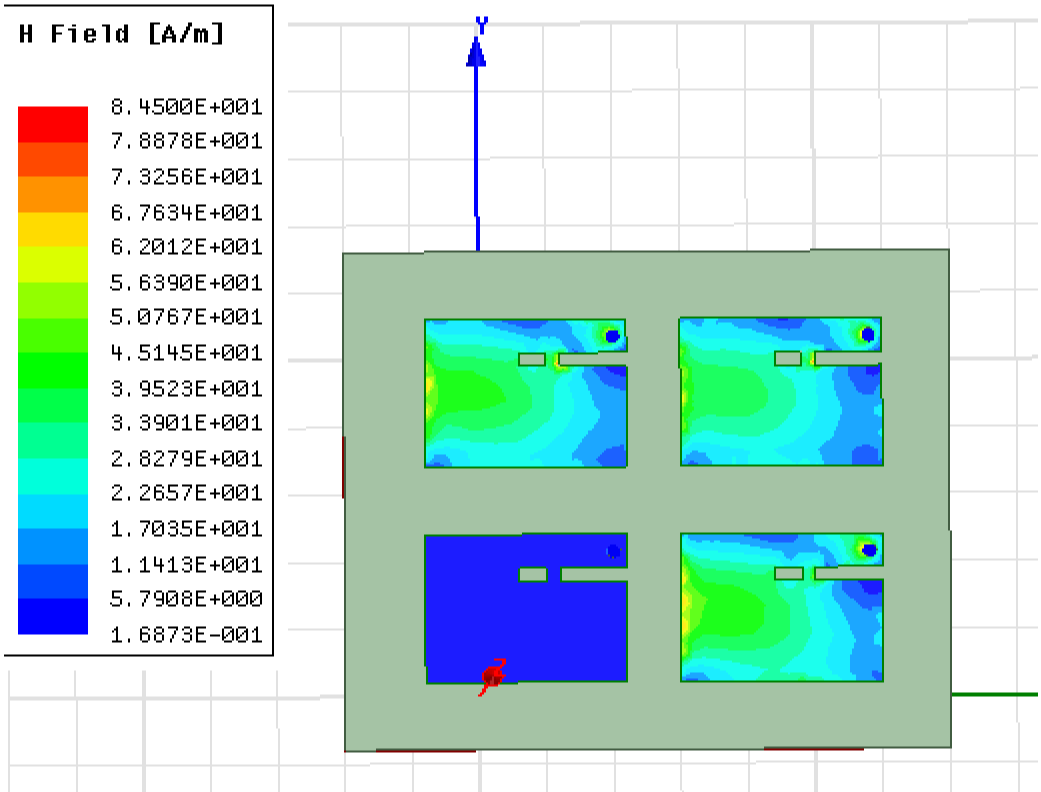


Fig 6.20 magnetic field density

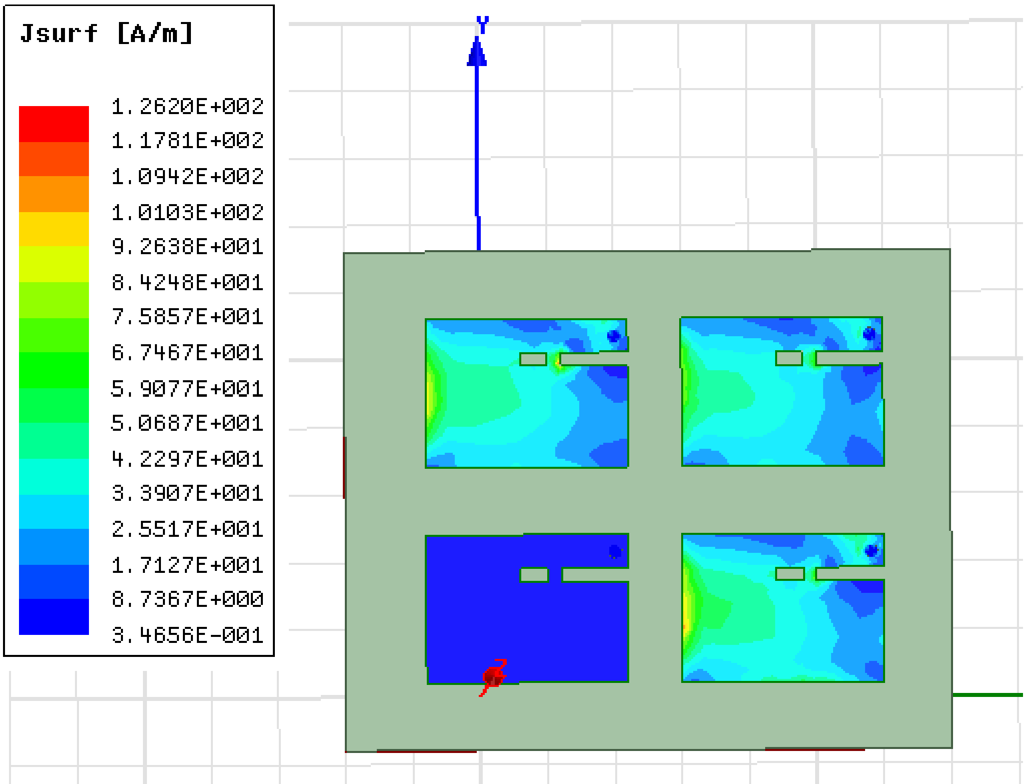


Fig 6.21 current density

6.3 3×3 array half E circular polarized antenna:

3×3 array half E circular polarized antenna is designed at a center frequency 8.6 GHz. Fig 6.22 shows the frequency response of simulated result S11 parameter

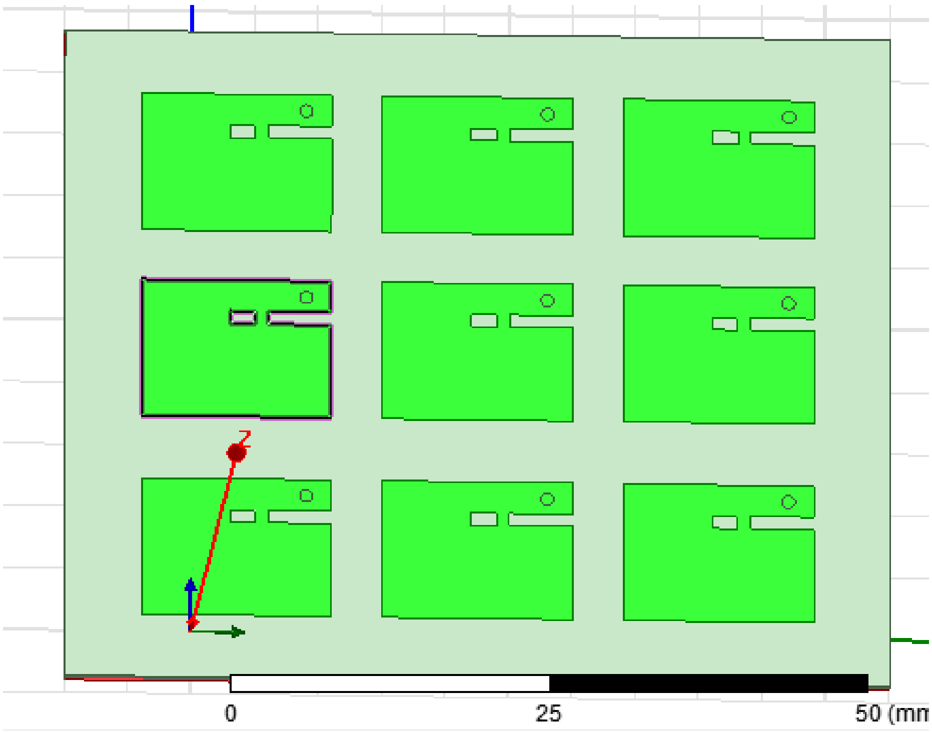


Fig 6.22 3×3array Half E circular polarized antenna

The return loss is -20.37dB. Frequency band is from 8.6GHz to 9.7 GHz.

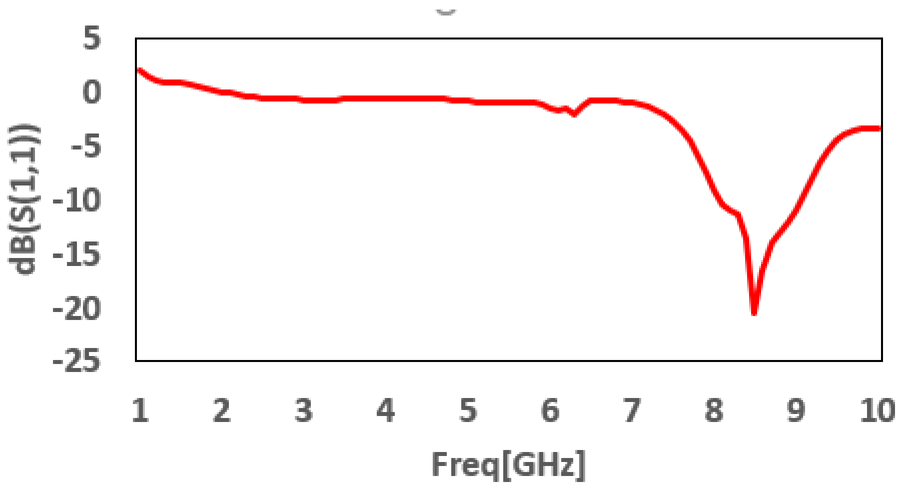


Fig 6.23 Stimulated return loss(dB)

The 3 dimensional gain at 8.6 GHz is shown in figure 6.23 which is given below. The total gain of single patch half E shaped circular patch antenna is 31.74 dB.

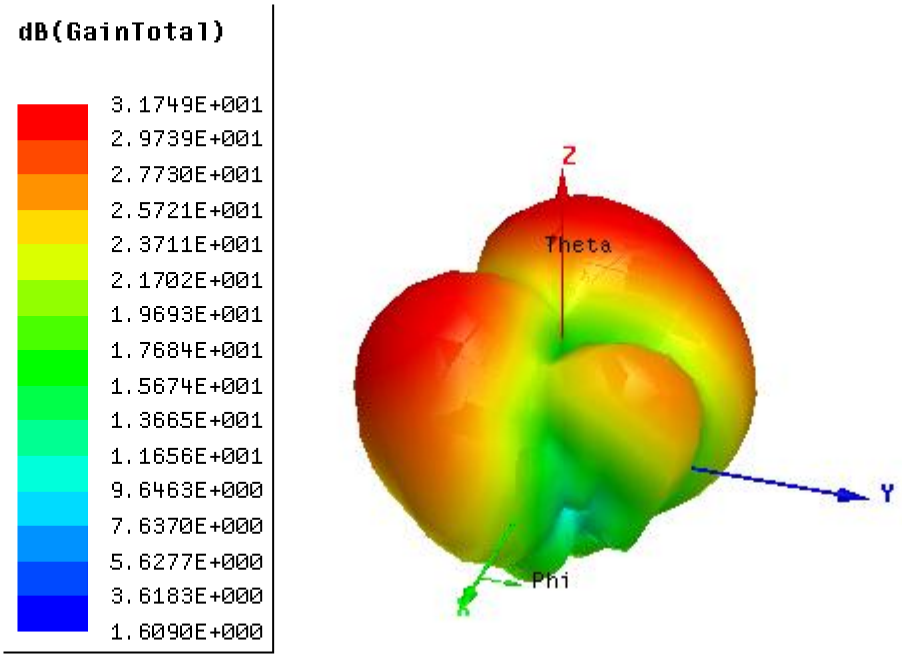


Fig 6.23 3D radiation pattern

Figure 6.24 shows the radiation efficiency. The total radiation efficiency is 96% which is good enough for further use. It will totally convert radio frequency power to radiated power.

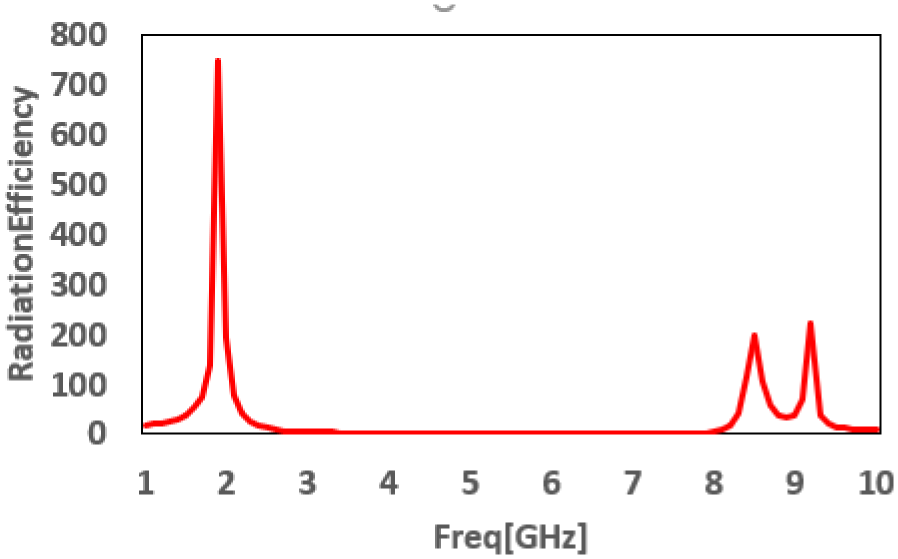


Fig 6.24 radiation efficiency

Figure 6.25 shows vswr. The exact value of vswr is 1.4 at 8.6 GHz. If the vswr is less than 2 then it is satisfactory for all antenna application because it is a perfect match.

Fig 6.25 For patch 2: 1.3

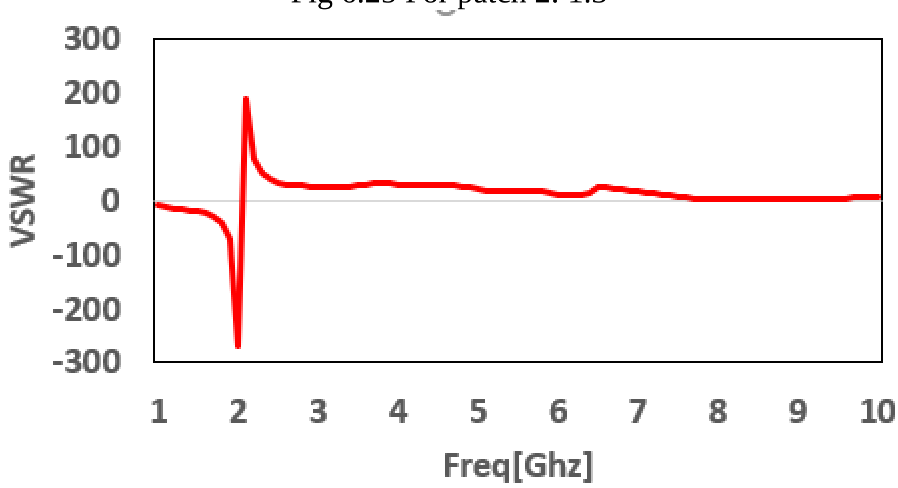


Fig 6.26 For patch 10: 1.4

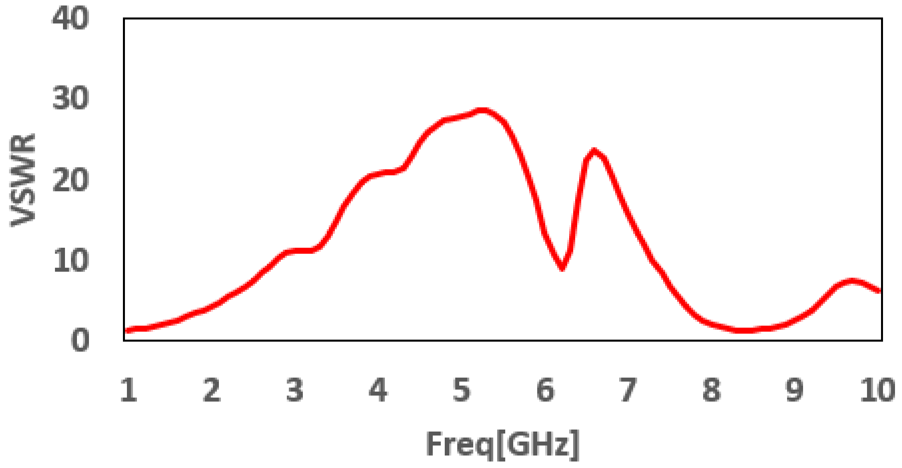


Fig 6.27 full antenna vswr

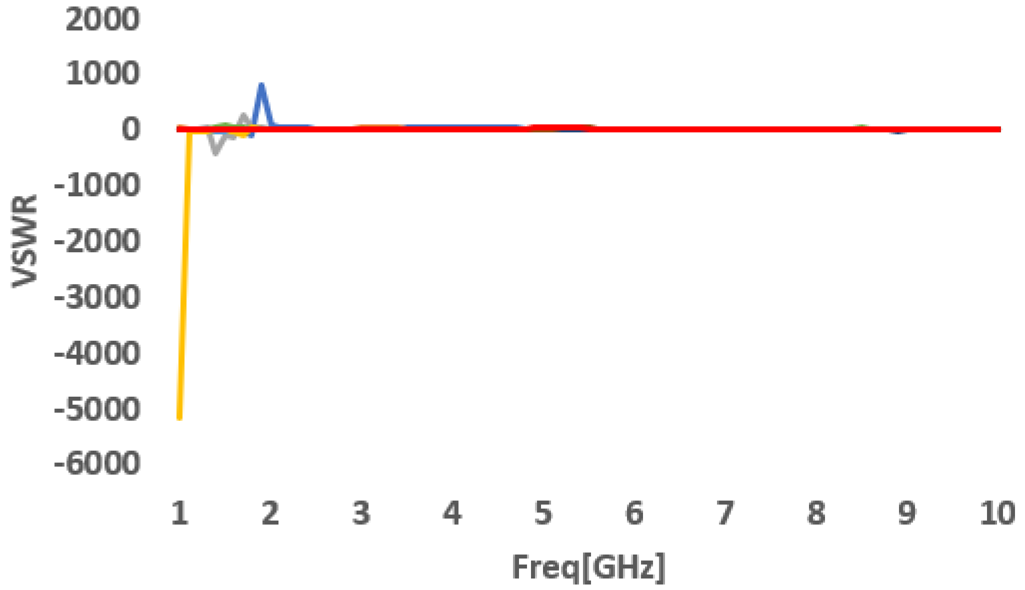


Figure 6.28, 6.29 and 6.29 shows electric field distribution, magnetic field distribution and current density of antenna at phi=0 respectively.

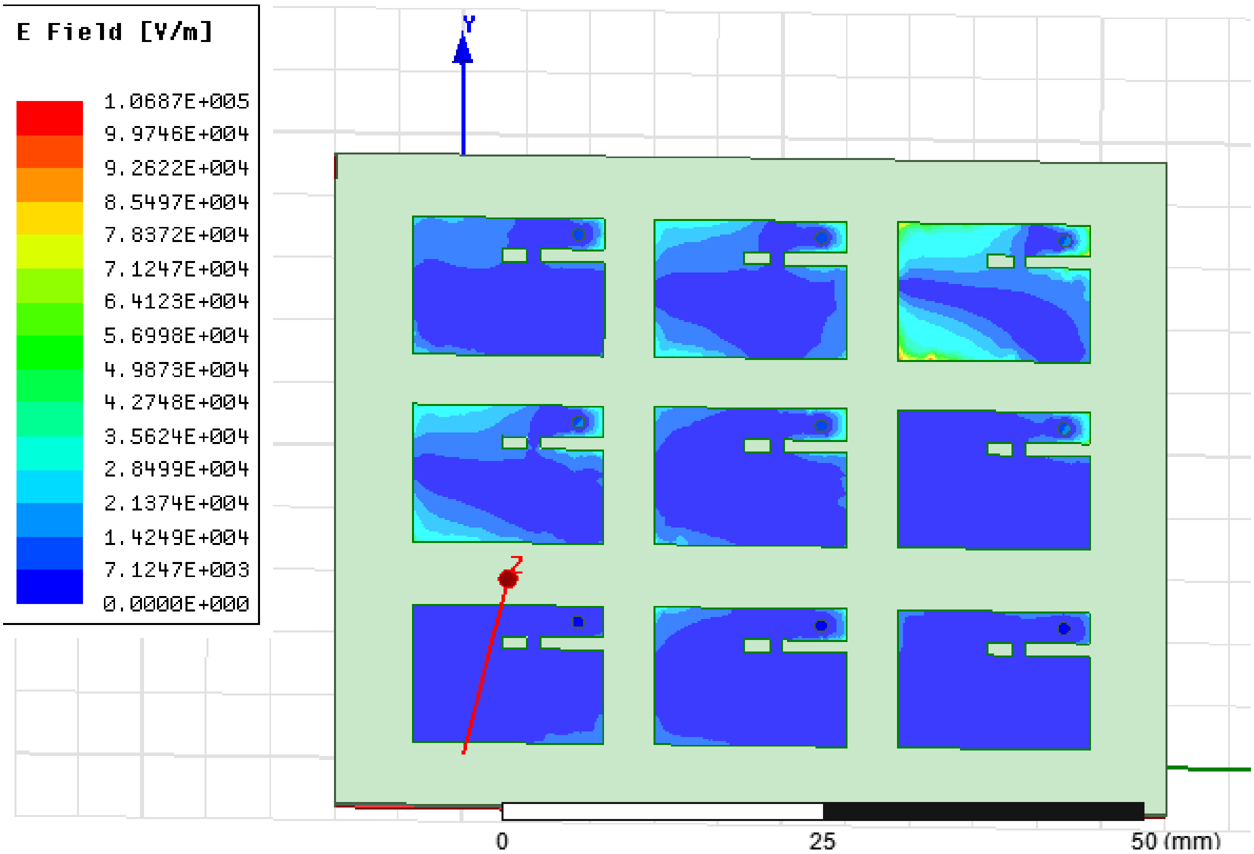


Fig 6.28 electric field density

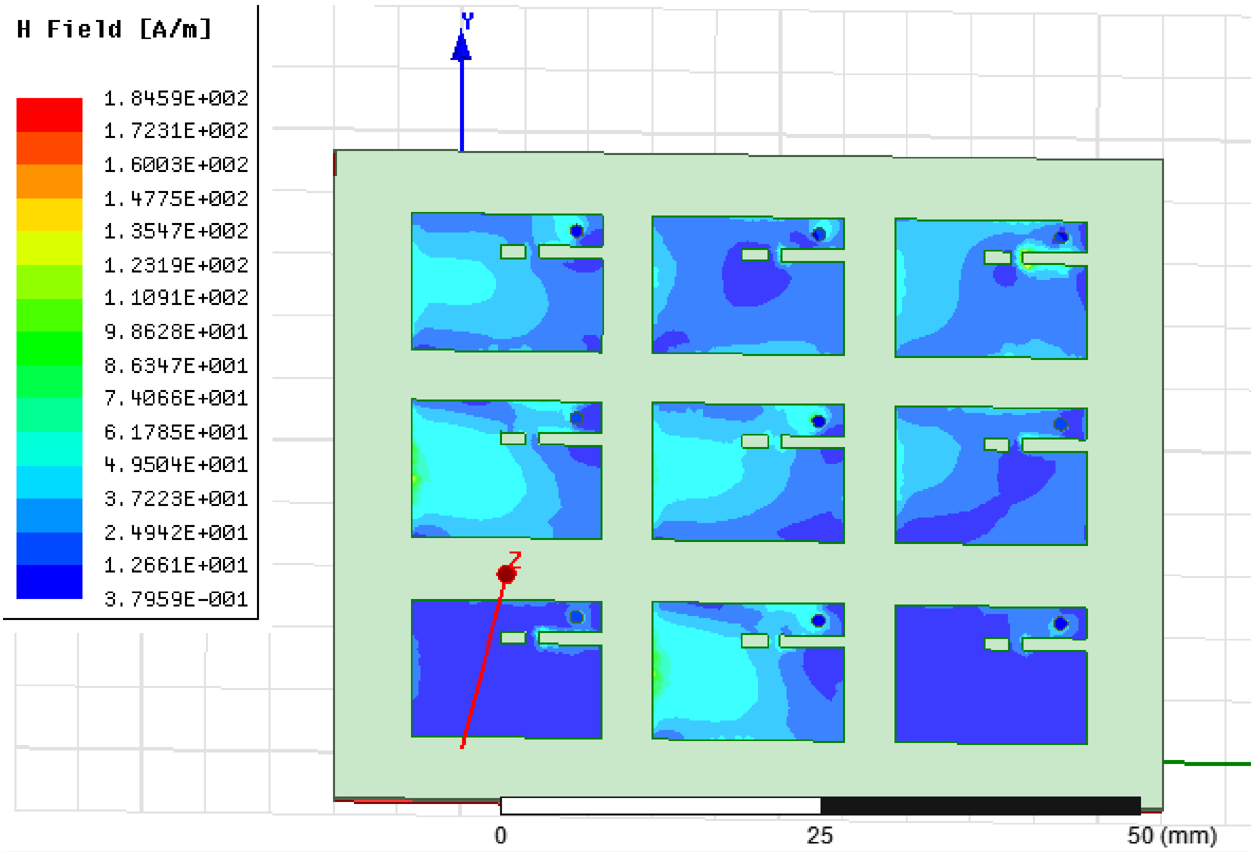


Fig 6.29 magnetic field density

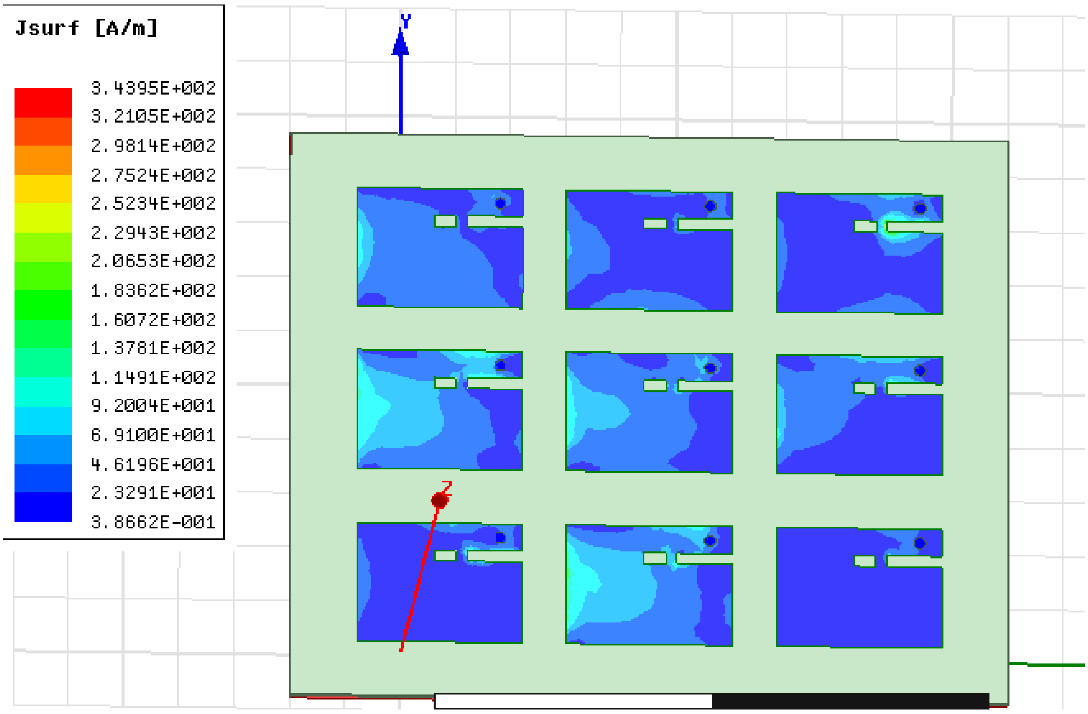


Fig6.30 current density

Parameters	Single patch	2*2 array antenna	3*3 array antenna
Resonant frequency(GHz)	9.2	8.6	8.6
Return loss ;S11(dB)	-19.21	-25.6	-20.37
Efficiency	96	98	96
Gain	7.9	11.1	31.7
VSWR	1.2	1.1	1.4

Table 4: Comparison between all three antennas

6.4 MEASURED RESULTS:

Antenna design with 3×3 half E shaped patch circularly polarized antenna has best result overall so only this design is fabricated. After fabrication the results are measured using the available instruments. The S11 parameter of practical antenna comes to be 8.9GHz. The coordinates are 8.9GHz, -16.174dB. The measured results are as follows:

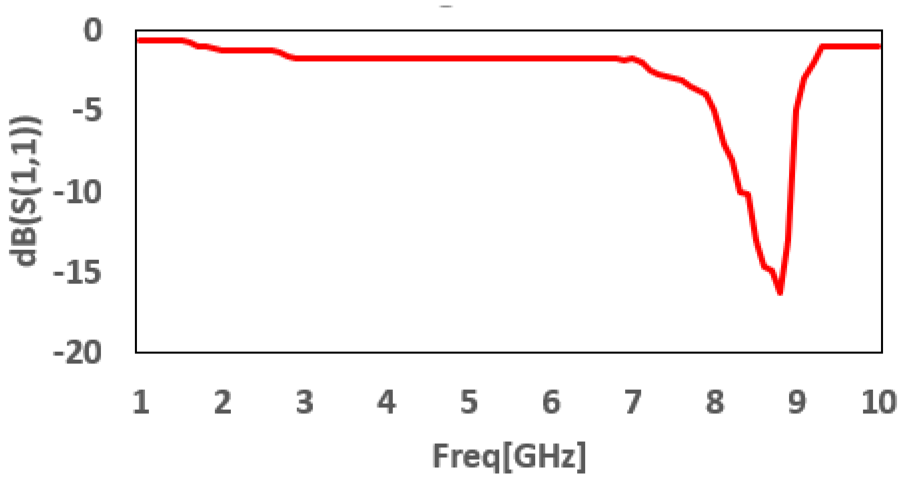


Fig 6.32 reading of antenna

6.5 COMPARISION:

A comparison is made between the simulated and fabricated results to further observe the difference between the two in fig.6.33. As we can observe the results are almost in agreement. Some frequency shift may be due to the fabrication errors or even the flexibility of the antenna. This shift in frequency was due to unpredictable losses.

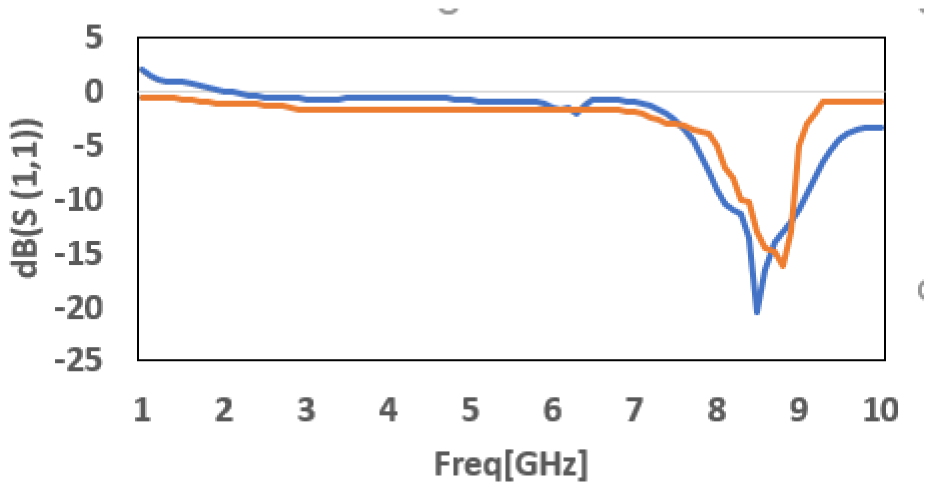


Fig. 6.33 Comparison of stimulated and practical antenna

Percentage Error = [[Experimental – Theoretical]/ Theoretical] ×100

=[[8.9-8.6]/8.6]×100 = 3.4%

3.4% error is between the stimulated value and the practical value.

6.6 CONCLUSION:

An antenna with high power handling capability and high and high is designed. Antenna has a gain of 31dBi which can help in direct to earth communication mostly used in mars rovers. The antenna designed has high gain, small size/compact, low cost and also it gives circular polarized radiation. This design gives good radiation pattern and return loss. These components are then stimulated in software HFSS. Such antennas can help greatly in

knowing more about mars and its probability of living there. Like recently rovers has found berries like fruits and rabbits like animal. It may be by some error also but if we achieve a good communication link between mars and earth then we can find out more and achieve more in this field. This research opens door to long distance communication and also it makes or India to progress in this field. More research can be done by increasing the number of patches and recording the results. More high the gain results more successful is the antenna returns.

6.6 FUTURE WORK:

Every research has some scope for its improvement. In this thesis, numerous features of satellite antennas were discussed. However, there are still some areas which can be improved and need more research. Satellite application is a continuously evolving field, so satellite antennas will continue to be in the scope of the research. Irrespective of the application few requirements like miniaturization, conformability, better radiation characteristics and cost reduction will always be the aim in this research.

1. The copper tape used as the conductor in the fabrication of the antenna is not very dependable. The tape peels off or breaks due to bending or careless handling. Therefore making the antenna less durable or temporary. To avoid this, the new printable technology like Inkjet or 3D printing can be used. In these technologies the conductive links are printed in the required patterns directly onto the substrate. Or we can use the flexible yarned conductors, but they are not easily available.
2. It will always be an aim to achieve a better performance of the antenna. For that human errors during the fabrication process need to be avoided or at least minimized. Hence, the fabrication field needs more development so that we get accurate results.

3. Material selection plays a vital role in the performance and reliability of the antenna. More research needs to be done on the materials to be used for these applications. Factors like availability, flexibility, conductivity, permittivity, thickness need special focus.
4. The most commonly used feeding is metallic SMA connector is used, but they are large and heavy, so small and lightweight connectors can be suggested in future for a satellite antenna.
5. Further experiments are needed to be done with increase in patch number. Due to lack of time it was not possible. But this research will be taken forward to check for the best possible results.
6. Conventional soldering is not that reliable on the fabrics as is can burn the fabric and the connections is very fragile. So new techniques could improve the fabrication process.

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