A MICROSTRIP PATCH ANTENNA WITH DUAL L-INVERTED STUBS FOR APPLICATION IN WLAN, USING HFSS.

DISSERTATION II

Submitted in partial fulfillment of the
requirement for the award of the
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IN

(Electronics and Communication Engineering)

By

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ABSTRACT

Twenty century started with the new era known as the modern communication era in which antenna have very important role to perform that is to bring this whole world in one palm by means of communication. The development of micro strip patch antenna is a path breaking development in the modern wireless communication system because of their less complexity, light weight and high reliability. As the result of which several variants of micro-strip patch antenna are developed till now with different types of configurations of which the circular micro strip patch antenna is one.

In this Dissertation-II report the extensive work is done on the multi layered circular micro-strip patch antenna with different configurations having dual L inverted stubs which is based on the cavity model and the proximity feed techniques for WLAN applications. The results obtained after simulating the designed antenna of HFSS are optimum results. Results for the Gain of the antenna, Radiation pattern, S-parameter, Voltage Standing wave ratio are simulated in this work.

CERTIFICATE

I hereby certify that ' **Anil Kumar'** bearing registration number **11008120** has completed objective formulation of thesis titled, "**A Microstrip Patch Antenna With Dual L-Inverted Stubs For Application in WLAN, Using HFSS**', under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of this thesis work has ever been submitted for acquiring degree at any other University.

This thesis work is fit for the submission and the partial fulfillment of the conditions for the award of Masters of Technology in Electronics and Communication Engineering.

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DECLARATION

I hereby certify that the work, which is being presented in this **Dessertation-II** report entitled." **A Microstrip Patch Antenna With Dual L-Inverted Stubs for Application in WLAN Using HFSS** ", for the partial fulfilment of the requirement for the award of Degree of Master of Technology from lovely Professional University under the guidance of Mrs. Isha Puri is a genuine work of my own carried out during the period January to April,2015. The work done in this dissertation -1 report is neither submitted nor taken from any other university.

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The work done in this dissertation-1 is genuine work of student under my guidance and is not copied from any other source.

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IEEE	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEER.
VSWR	VOLTAGE STANDING WAVE RATIO.
HPBW	HIGH POWER BANDWIDTH
LPWB	LOW POWER BANDWIDTH
SWR	STANDING WAVE RATIO
EMW	ELECTROMAGNETIC WAVE

CHAPTER 1
INTRODUCTION TO ANTENNA

1.1 INTRODUCTION

Antenna is a physical conducting material which is used for the transmission and reception of the signals. According to the IEEE Standard Definition [1] antenna is defined as "Ariel means for radiating and receiving radio waves". Antenna is used to transmit energy in the form of electromagnetic wave form (radio waves) and is present at the transmitter as well as at the receiver end. Therefore antenna is an intermediate structure between the free atmosphere and radiation providing devices. The guiding device can be in any form for example coaxial lines, micro strip lines. Electromagnetic energy is transported from transmitter to antenna or from antenna to the receiver by the use of these guiding devices. At the transmitter end antenna is used for transmitting electromagnetic waves and at the receiving end it is used for receiving electromagnetic waves. Antenna used as a transition device between the source and the free atmosphere is shown in the given figure.

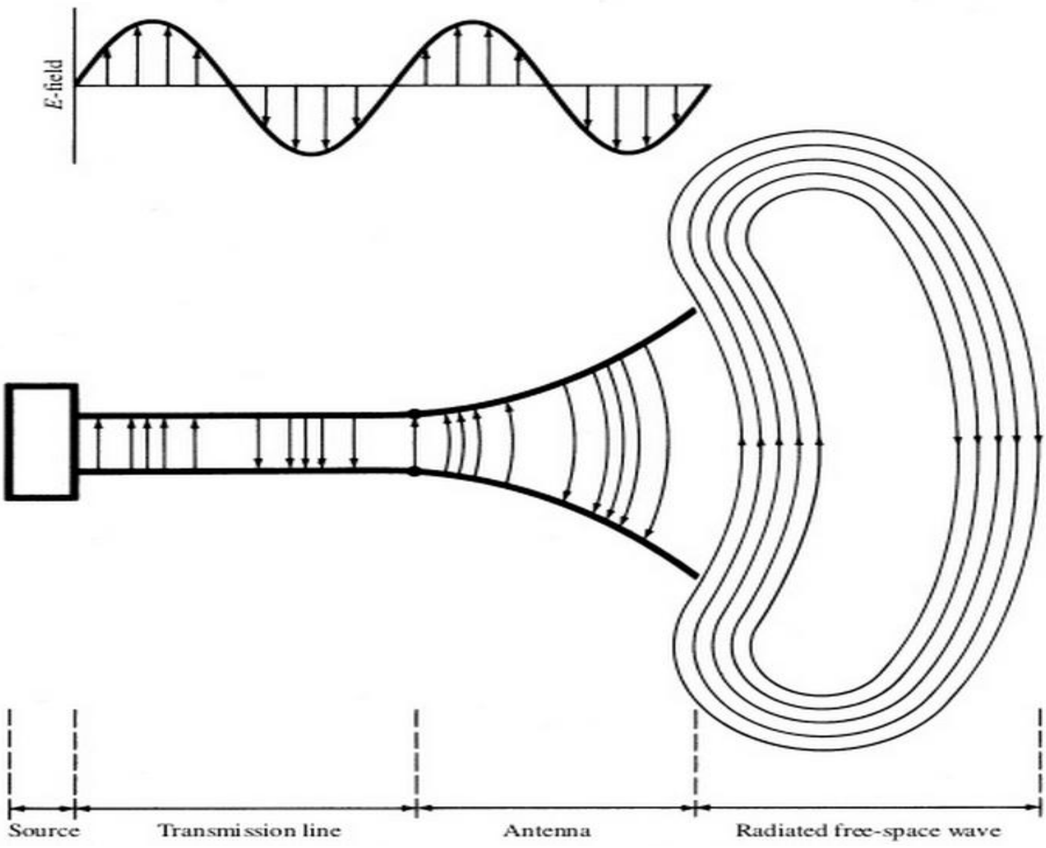


Figure 1.1 Antenna as a Transition Device

The basic question which comes into existence is that how the radiations are established in antennas. Basically to form a radiation there must be the acceleration or deceleration of the charge particles. There are mainly three mechanisms which results in the formation of radiations.

a) Acceleration and deceleration of charge particles inside the conductor results in the formation of radiations.

b) For the charge particles moving with the constant velocity, the radiations are formed if we have conductor with non uniform configuration that is the conductor is abruptly truncated or discontinuous in nature.

c) The charge exhibiting the harmonic motion in time domain also results in the radiations formation.

1.2 ANTENNA PARAMETERS

1.2.1 RADIATION FIELD PATTERN

An antenna radiation pattern is an mathematical function and a graphical representation of the radiation configuration and properties of the antenna as the function of space coordinates [2]. In the far field region the configuration of the radiations becomes somewhat more clear so mostly the radiation pattern properties are studied in the far field region with the help of directional co-ordinates. Study of many properties like the power flux density, radiation intensity of electromagnetic signals, electromagnetic field strength, polarization is done by studying the radiation pattern. Radiation property is studied to find out the three or two dimensional distribution of radiated energy in the free space with respect to the observer present at surface of constant radius or along the path of the antenna. It gives us the measure of the radiation filed strength in given particular direction. Field pattern in terms of amplitude is the measure of the received electric or magnetic field along the constant radius of the surface [2]. Amplitude field pattern is drawn on the linear scale. In case of amplitude power pattern, the graph of the distributed power density with respect to the radius of the surface is measured. We make the use of logarithmic scale to measure the power. We make the use of the logarithmic scale because it considers the detail of even the smallest value of the field pattern. As we know. in radiation pattern, along with the main lobe the side lobs are also present. These side lobes have significant amount of energy. With the use of linear scale for radiation pattern, these side lobes are not considered. Thus the power associated with these lobes is neglected in linear scale. But with the use of logarithmic scale, the power associated with these lobes is also considered.

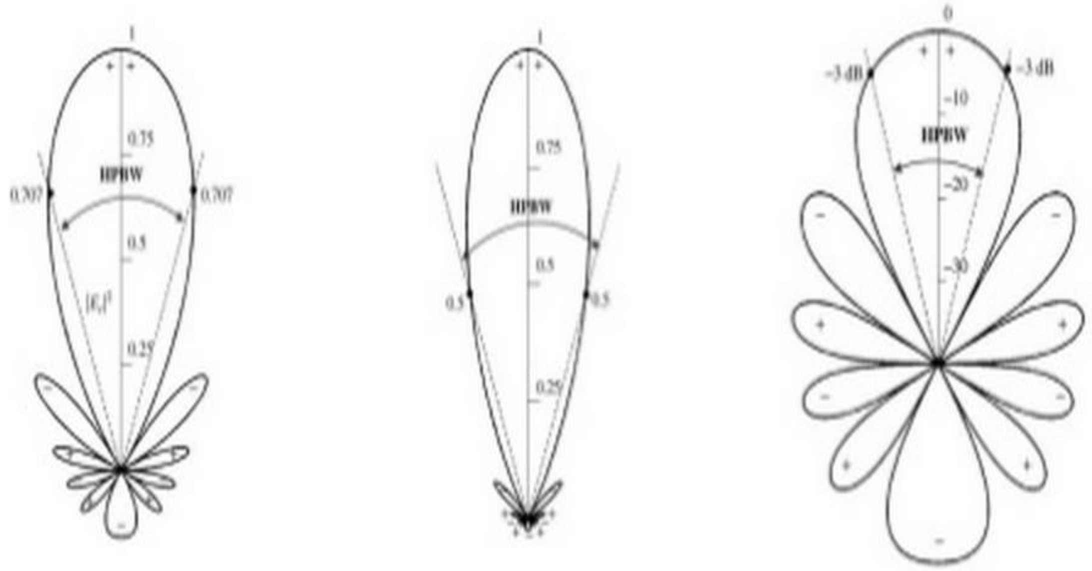


Figure 1.2. Field Pattern, Power Pattern.

The two dimensional radiation pattern for electric field and magnetic field of the typical dipole antenna are given below.

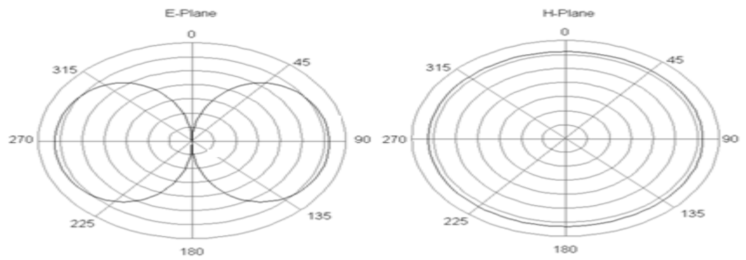


Figure 1.3 Basic Dipole Antenna Radiation Pattern.

1.2.2 PRINCIPLE PATTERN

Performance for some of the linearly polarized antenna are best defined in terms of the H-plane and E-plane of the antenna. Magnetic field is present on the magnetic.

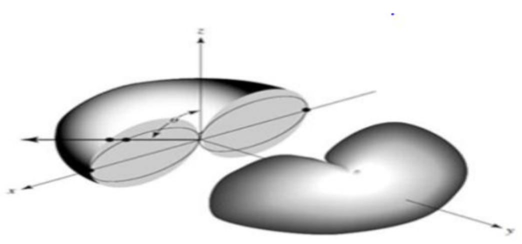


Figure 1.4 Principle Pattern

1.2.3 FIELD REGIONS

Three concentric regions are present around the surroundings of antenna: the reactive near-field, the radiating near-field (Fresnel region) and the far-field (Fraunhofer) regions [2]. These three different types of fields are formed for identifying the structure of the field in each respective region. Reactive near field region falls in the vicinity of the antenna that is antenna is present in reactive near field. The radiating near field region is present at the distance of

$$R = 0.69\frac{\sqrt{D^3}}{\lambda} \tag{1.1}$$

Where

D = Dimension of antenna.

λ = Wavelength of the frequency.

R = Distance between reactive near field region and radiating near field region.

In the reactive field region the electromagnetic radiations are purely reactive that is the energy is stored in this region. In the Fresnel region the radiations are less reactive thus resulting in the formation of the radiations from the stored energy. In the Far field region the reactive field becomes negligible thus the radiations completely dominates in this region. Field structures are studied in these three regions although there are no precise boundaries. In the far-field region, we are at enough distance from the antenna to neglect its size and shape of the antenna. There is assumption that the electromagnetic wave is purely a radiating plane wave (electric field and magnetic fields are having a phase difference in between. Also the electric fields and the magnetic fields are perpendicular to each other and also in the direction of propagation). These field regions gives us the best description for studying our signal. In reactive field region we know the energy is stored within the electromagnetic radiation. In near field region the formation of the radiation pattern starts to take place. This region is less reactive in nature. In far field region, as the reactive field is no more present in this region, we can easily study the spatial configuration of the radiations distributed in this region. Below is the given figure specifying all three different types of regions. As different antenna have different configurations in terms of size. Also, the radiating properties of antenna vary from each other. So, each antenna have its own field regions associated with them. And there is no hard and fast rule that these field regions will exist as per the formula defined for the boundary of the first and the second field region

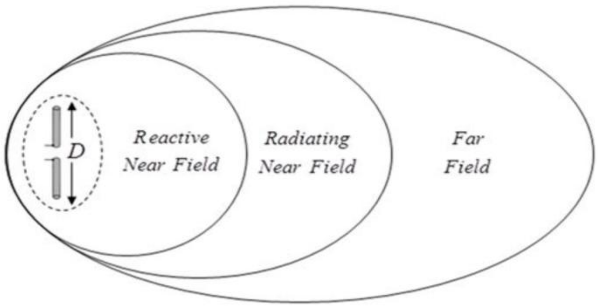


Figure 1.5 Various Field Regions

1.2.4 BANDWIDTH OF THE ANTENNA

Bandwidth of the antenna gives the range of the frequencies up to which our antenna will work efficiently with respect to some of the characteristics. Bandwidth contains the range of the frequencies present on both the sides of the centre frequency over which the antenna parameters like the gain, directivity, input impedance, beam-width are in acceptable range. Beam-width of antenna specifies that our antenna will work properly in this range of frequencies. There is no specified beam-width for any antennas as the requirement varies according the use of antenna for specified purposes. So each antenna has its own beam-width. For example in broadband antenna the band-width is expressed in the form of upper to lower frequency. As 10:1 indicate that upper frequency is ten times more than lower frequency. And in narrowband antenna beam-width is expressed in percentage. The difference between the upper frequency and the lower frequency is measured. After that the percentage is calculated over the central frequency. Pattern bandwidth and the Impedance bandwidth are used to distinguish between the pattern and the input impedance of the antenna. Pattern bandwidth is related to the gain, beam-width, side lobes, polarization and direction of the beam of the antenna. impedance bandwidth is considered for the input impedance and radiation efficiency of the antenna. two dimensional view of the bandwidth is given in the figure below.

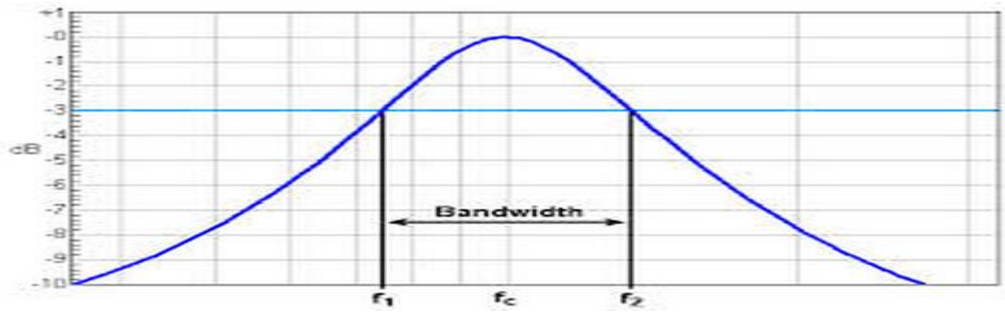


Figure 1.6 Bandwidth of Signal

Bandwidth of the antenna is calculated by the formula

$$\text{BW} = f_h - f_l \tag{1.2}$$

Where

f_h = Upper frequency.

f_l = Lower frequency.

In terms of percentage, bandwidth is given by

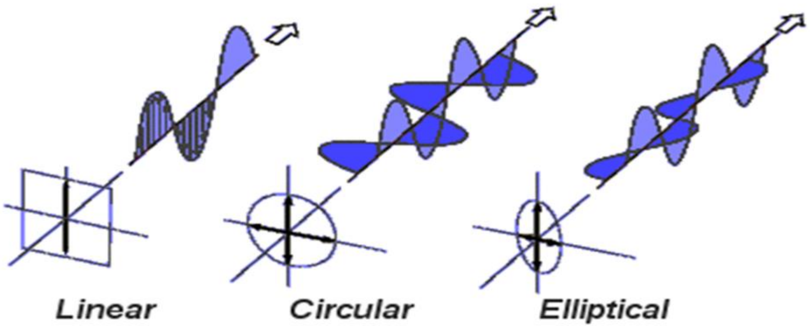
$$\text{BW} = \frac{f_h - f_l}{f_c} \times 100 \tag{1.3}$$

Where

f_c = Central frequency.

1.2.5 POLARIZATION

Polarization is defined as the property of the electromagnetic wave, in terms of wave variation in direction and relative magnitude of the electric/magnetic field vector [2]. Polarization can also be defined in terms of wave transmitted and waves received by the antenna in a given particular direction. Polarization at a point in the far from the region is defined in terms of radiated wave as plane wave whose strength of electric field is same as that of the wave under consideration and whose direction of propagation is present along the radial direction of antenna.



1.7 Polarized Electromagnetic Waves

The above figure shows the three different types of polarization techniques. Linear polarization, circular polarization and elliptical polarization. In case of linear polarization the vector defining the position of the electric field in the space is always present along the line of propagation of the wave. And in case of circular and elliptical polarization the vector defines the circular and elliptical paths respectively. The electric field vector can rotate either in clockwise direction or in counter clockwise direction. For clockwise direction, polarization is defined as right-hand polarization and for counter clockwise direction, the specified polarization is defined as left-hand polarization.

1.2.6 INPUT IMPEDANCE

Input impedance is defined as the impedance possessed by the antenna at its input terminals or the ratio of the voltage to the current at the input terminals as a pair of the antenna and can be given as

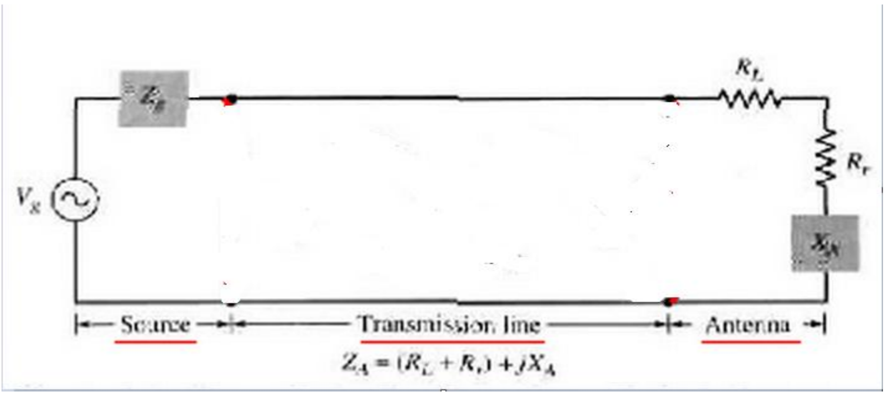


Figure 1.8 Thevenin Equivalent of Antenna

$$R_a = R_r + R_l \tag{1.4}$$

R_l = Resistance loss of antenna.

R_r = Resistance due to radiation of antenna.

R_a = Antenna total resistance.

The equation for the input impedance is

$$Z_{in} = R_{in} + jX_{in} \tag{1.5}$$

Where

Z_{in} = Impedance of antenna terminals

R_{in} = Terminal antenna resistance

The power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses. Maximum power transfer requires matching the impedance of an antenna system. However, the desired matching impedance might not correspond to the dynamic output impedance of the transmitter as analyzed as source impedance but rather the design value typically 50 ohms, required for efficient and safe operation of the transmitting circuitry. When a transmission line is used in between the antenna and the transmitter or receiver one generally would like an antenna system whose impedance is resistive.

1.2.7 BEAMWIDTH

The beam width the pattern is defined as the angular separation between two identical points on opposite side of the pattern maximum [2]. Beamwidth of the antenna is a very important factor. Generally a relation exists between the beamwidth and the side lobes of the antenna. As the value of the beam width increases the value of the side lobes decreases and as the value of the side lobes increases the value of the beam width decreases. Whenever when more than one radiating sources are present in that case the resolution properties of the beamwidth is used to differentiate the different antenna from one another. The most common resolution criterion states that the resolution capability of the antenna to distinguish between two sources is equal to half the first-null beam width (FNBW/2) ,which is usually used to approximate the half-power beam width (HPBW) [2]. The two of the most commonly used beam width are high power beam width (HPBW) and first null beam width (FNBW).

1.2.7.1 HPBW

The angle between the two directions in which the radiation intensity is one half value of the beam. There may be a number of beam width present in an antenna pattern.

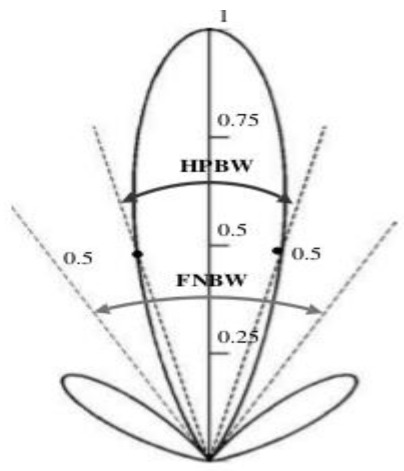


Figure 1.9 HPBW And FNBW

1.2.7.2FNBW

It is the angular separation between the first two nulls of the radiation pattern. Other beam widths are those where the pattern is -10 dB from the maximum, or any other value. The beam width of the antenna is a very important figure of merit and often is used as a tradeoff between it and the side lobe level. As the beam width decreases, the side lobe level increases and vice -versa.

1.2.8 DIRECTIVITY

There are many version of the term Directivity. The term "Directivity" can be defined in many ways. Initially, directivity was known as the "directive gain" which was subsequently changed by the IEEE Standard of Terms for Antennas [1]. Now, Directivity of antenna is the ratio of the radiation intensity in a given direction to the averaged radiation intensity over all directions [2]. In the absence of given direction, the direction having the maximum intensity is considered. The formula for directivity is given as

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \tag{1.7}$$

D = Directivity

U= Dadiation intensity (W/unit solid angle).

P_{rad} = Radiated power (W)

1.2.9 RADIATION POWER DENSITY

As we know, electromagnetic waves are the means of transmitting information from one place to another through the wireless medium or with the help of guiding components like cables etc. So it is natural to consider that the power and energy is present in the electromagnetic wave. Therefore we need some vector to represent this power present in the electromagnetic wave. This vector is known as instantaneous Poynting vector represented by Ŵ [2].The mathematical expression for instantaneous Poynting vector is given as

$$\hat{W} = \check{E} \times \hat{H} \tag{1.8}$$

Ŵ = Poynting vector (instantaneous) (W/m^2).

Ě = Electric-field intensity (instantaneous) (V/m).

Ĥ = Magnetic-field intensity (instantaneous) (A/m)

1.2.10 RADIATION INTENSITY

Radiation intensity is measured in the far field area of the antenna. Radiation intensity is the measure of the amount of power radiated by a given antenna through per unit solid angle [2]. The mathematical formula for radiation intensity is given by

$$U = r^2 W_{rad} \quad (1.9)$$

Where

U = Radiation intensity (W/unit solid angle).

W_{rad} = Radiation density (W/m^2).

r^2 = Square of distance between the antenna and the far-field.(m^2).

1.2.11 ANTENNA EFFICIENCY

Working of the antenna is determined on the basis of its efficiency that is how efficiently an antenna can transmit the electromagnetic waves generated in it. The efficiency of the antenna is considered to sum up all those factors which results in the losses. These losses can occur at the input terminal of the antenna and also because of the mismatching between the feedline and the antenna load. The mathematical expression for these losses is given by [2]

$$e_0 = e_r e_c e_d \quad (1.10)$$

Where

e_0 = total efficiency and is dimensionless.

e_r = reflection efficiency and is dimensionless.

e_c= conduction efficiency and is dimensionless.

e_d = dielectric efficiency and is dimensionless.

Reflection efficiency of the antenna is also measured in terms of Voltage Standing Wave Ratio. Voltage standing wave ratio gives us the ratio of the amount of the power transmitted at the terminal of antenna to the amount of power available at the input terminals of the antenna. If the load of the input terminals of the antenna is not matched with that of the input impedance of the feed in that case the standing waves are formed inside the antenna. Thus, the antenna will act as a energy storing device rather than energy transmitting is case there is mismatch between the load and the feed. Voltage standing wave ratio is expressed in terms of voltage reflection coefficient. Mathematical expression for voltage standing wave ratio is given by

$$VSWR = \frac{(1+|\tau|)}{(1-|\tau|)} \tag{1.11}$$

Where

r = Voltage reflection coefficient expressed at the input terminals of the antenna

$$\tau = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \tag{1.12}$$

Where

Z_{in} = Impedance of antenna.

Z_0 = Characteristic impedance of the feed line.

1.2.12 GAIN

Another important parameter which is used to define the validity of antenna is gain. There is a close relation between the directivity and gain of the antenna. Both the efficiency and directional capability of the antenna is considered under gain of the antenna. Gain of the antenna is defined in terms of, "the ratio of intensity of power in a particular direction to that of the radiation that would be obtained if the power accepted by the antenna is radiated isotropically" [2]. Gain is a dimensionless quantity. The mathematical expression for gain is given as

$$\text{Gain} = 4\pi \text{ radiation intensity/total input power} = \frac{4\pi U(\vartheta,\phi)}{P_{in}} \tag{1.13}$$

Where

P_{in} = Incident input power.

Most often, we define gain as the relative gain. In definition of relative gain we calculate the power gain with respect to the reference antenna in a radiating power in as particular direction. We give the same input power to both the antennas that is the antenna whose gain we wish to measure and the antenna which we are using as our reference antenna. Whenever the specific direction of the radiations emitted is not provided to calculate the gain of the antenna, we consider the direction in which maximum radiations are radiated. Gain can also be calculated as the absolute gain which includes both the relative gain and the losses because of reflection.

1.3 MICROSTRIP PATCH ANTENNA

The twentieth century has seen the boom in the modern wireless communication system in which antenna is like the backbone for communication to take place. It is always desirable to have such antennas which have low profile, low cost, highly efficient and easy to install features. All these features are fulfilled by microstrip patch antennas and can easily fit to our demands. This is the reason that extensive work is going on to develop new methods and configurations to design highly efficient microstrip patch antennas. In the recent years several different types of microstrip patch antenna are designed and practically implemented in various communication systems. Rectangular [4] and circular [10] micro strip patch antennas are the widely studied microstrip antennas.

1.4 BREAKTHROUGH IN MICROSTRIP PATCH ANTENNA

With the advancement of the technology in the space, aircraft, satellite and missile applications, there was a need to develop a antenna having a very effective aerodynamics configuration along with other properties like the cost, weight, performance and ease to installation. As the result of these strict specific demands, the microstrip patch antennas came into existence. Microstrip patch antennas can be easily installed on the planar and non planar surfaces. The manufacturing of these antennas is very simple as these antennas can be manufactured by using modern day printed circuit board technology. The introduction of the microstrip patch antennas into the communication system saw the boom in the production of microstrip patch antennas. In the early days rectangular microstrip patch antennas were widely studied because of the ease with which they can be designed and the versatility they offer in return. Now a day we have wide varieties of microstrip patch antennas out of which rectangular and circular microstrip patch antennas are favorite ones. The configurations of the patch can be easily changed for the specific applications and they are versatile for polarization, impedance matching, radiation pattern and resonance frequency. The circular microstrip patch antennas can be easily fabricated because we need to deal with only one parameter that is with radius of the patch of circular microstrip patch antenna. By changing only the radius of the patch, we can operate out designed antenna at different resonating frequencies where as the operating mode remain the same. As, in the present world, wireless communication is integral part of our life. And micrstrip patch antennas are playing a very important role in making this communication possible. Now, we can see microstrip patch antennas fabricated on each and every device used for wireless communication.

1.5 Microstrip Patch Antenna General Structure

A micro strip antenna are basically made up of three main components namely, ground which usually form the base of the antenna, substrate which is placed on the ground plane, patch which form the main radiating part. Patch is present on the substrate that is substrate is present in between the ground and patch .Patch is generally made up of the copper or any other radiating material. Patch can take an shapes. Most commonly used shapes are square, rectangular, circular, triangular, and elliptical or some other. Fobroad-band applications we insert certain shaped slots to increase the bandwidth and gain of the micro strip patch antenna

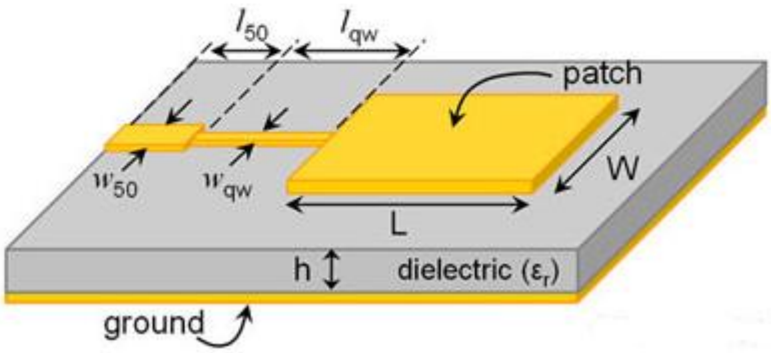


Figure 1.10 General Microstrip Patch Antenna

1.6 ADVANTAGES OF MICROSTRIP PATCH ANTENNA

Microstrip antennas are used in wireless devices such as cellular phones, and also employed in Satellite communications. Some of their main advantages are given below:

a) Light weight and low fabrication cost. The micro strip patch antennas are mostly of very light weight. Also the fabrication cost is very less thus favoring the designing of micro strip patch antennas.
b) Circular polarization and linear polarization is supported by micro strip patch antenna.
c) Micro strip patch antenna are easily integrated with the microwave operating systems.
d) Multi frequency operations are supported by micro-strip patch antenna.
e) Micro strip patch antenna can be easily mounted on any type of solid material having any shape because of its small configuration.
f) Dual and more frequency operation possible.

1.7 Disadvantages of Microstrip antenna.

Some of the disadvantages of microstrip patch antenna are

a) Narrow bandwidth.
b) Low efficiency and Gain.
c) Feeds and junction gives some unnecessary radiations that is leakage in radiations takes place from feed and junctions .

(d) Low power handling capacity.

(e) Surface wave excitation results in the production of spurious waves on the surface.

However, we can compromise on the disadvantages of microstrip patch antennas because of the advantages which microstrip patch antennas can offer to us.

1.8 CIRCULAR MICROSTRIP PATCH ANTENNA

This is another type of microstrip patch antenna other than conventional rectangular micro strip patch antenna whose configuration is circular in shape or disk like shape [10]. In circular micro strip patch antenna either we have the patch of circular in shape or the whole structure configuration is kept cylindrical in shape having a circular patch mounted over the substrate. In circular microstrip patch antennas the substrate is present in between the two conducting surfaces. These conducting surfaces are the ground and the patch. This substrate forms the prefect cavity between the patch and the substrate. Multiple configuration array can also be supported in circular microstrip patch antennas. As the substrate in circular microstrip patch antenna is of considerable thickness, therefore we need the proper feeding techniques so that the losses should be minimized. Circular patch antenna treats the substrate present in between the patch and the ground as the circular cavity. The height of the substrate is less the wavelength of the free space signal. The mode supported by the circular patch antenna is the TM^z mode where 'z' is perpendicular to the patch. In case of circular micro strip patch antenna we need to control only one dimension, that is only radius of the patch. By changing the dimensions of the patch of the antenna we can achieve the different resonating frequencies over which this antenna can work properly. Most of the trend in designing the microstrip antennas is now shifted towards designing of circular microstrip antennas. Circular microstrip antennas are widely used in wireless communication. One of the main advantage of circular microstrip antenna is their operation on dual or more frequencies. Because of their this feature circular microstrip antennas are getting lot more attention and are being widely studied. New, many different models and techniques are now being studied and formulated to make the calculation easier as compared to existing models.

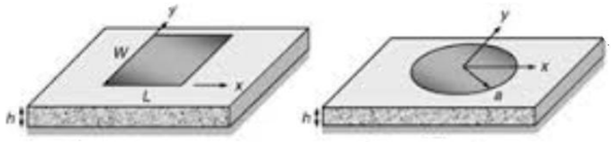


Figure 1.11 Equivalent Structure of Circular Patch Antenna

1.9 FEEDING TECHNIQUE APPLIED IN MICROSTRIP PATCH ANTENNAS

Micro strip patch antennas can be fed by a variety of methods. Classification of these methods is done in two categories contacting and non-contacting. Contacting method is one in which the radio frequency power is fed directly to the radiating patch using a connecting element such as a micro strip line. Whereas in non-contacting method the electromagnetic field coupling is done to transfer power between the micro strip line and the radiating patch. There are mainly four types of feeding techniques employed in micro strip patch antenna namely the micro strip line, coaxial probe (both of these feeding techniques are contacting schemes of providing feed), aperture coupling and proximity coupling (both of these feeding techniques are non-contacting schemes of providing feed).

1.9.1 MICROSTRIP LINE FEEDING TECHNIQUE

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in figure below. The conducting strip is smaller in width as compared to the patch. The microstrip feed run along the surface of the substrate. The main advantage of this type of feeding method is that the feed can be attached on the surface of same substrate to provide a planar structure. But is case of this feed the reflection losses (leakage) are very much because of the broader width of the microstrip feed and because of the interaction between the feed line and the surface of the substrate.

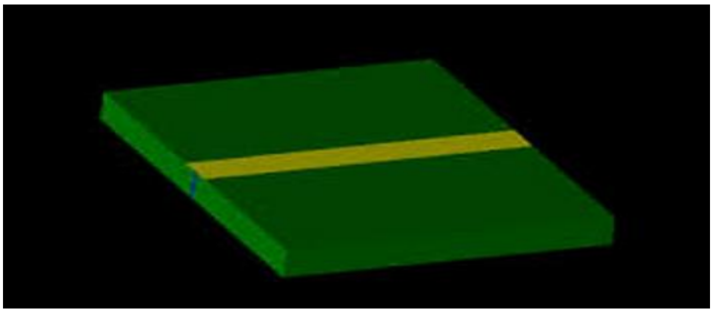


Figure 1.12 Microstrip Feed Line

1.9.2 COAXIAL FEEDING TECHNIQUE

The Coaxial feed or probe feed is one of the most common techniques used for feeding microstrip patch antennas. In this type of feeding technique the coaxial cable containing the inner conducting part passes through the dielectric and touches the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired position inside the patch in order to obtain impedance matching. This feeding is done very easily and has low spurious effects of radiations The only disadvantage of this type of feeding is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate. In case if the substrates are thicker then the increased probe length makes the input impedance more inductive, leading to matching problems. We can place the coaxial feed at any place connecting the patch to match the impedance. A conventional coaxial cable is shown in the figure below

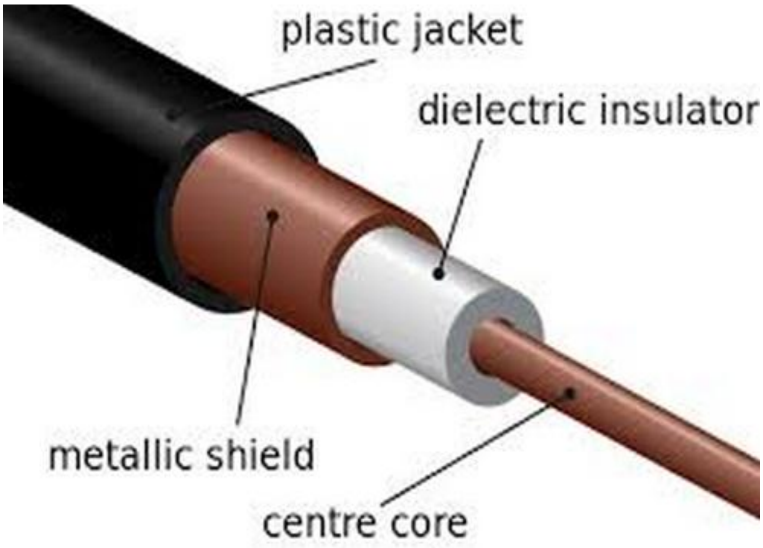


Figure 1.13 Coaxial Wire

1.9.3 APERTURE COUPLED FEEDING TECHNIQUE

In aperture coupling the radiating micro strip patch element is attached on the top of the antenna substrate, and the micro strip feed line is present at the bottom of dielectric material in order to obtain aperture coupling. We choose the dielectric constant and the thickness independently to optimize the distinct electrical functions of radiation and circuitry. Coupling aperture is done beneath the patch, thus resulting in low cross-polarization due to symmetry of the configuration.

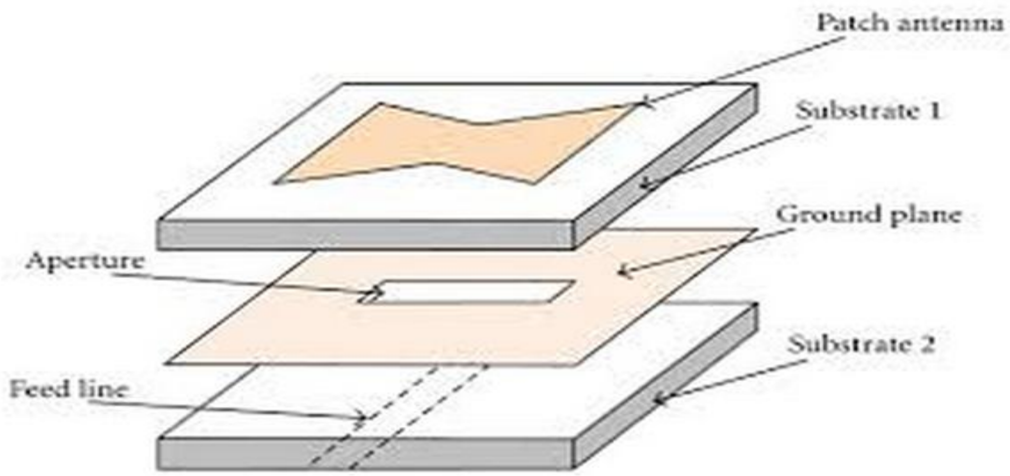


Figure 1.14 Aperture Coupling Feed

Generally, a material having a larger dielectric value with considerable thickness is used at the base and low dielectric constant material is used for the top substrate to optimize radiation from the patch. High band width is obtained by this type of feeding technique.

1.9.4 PROXIMITY COUPLING FEEDING TECHNIQUE

This type of coupling is also called as electromagnetic coupling feed. In this type of feeding technique the micro strip feed line is present in between the two dielectric substrates and the radiating patch is present at the top of the substrate. The main advantage of this feeding technique is that it removes the spurious feed radiations and provides very high bandwidth.

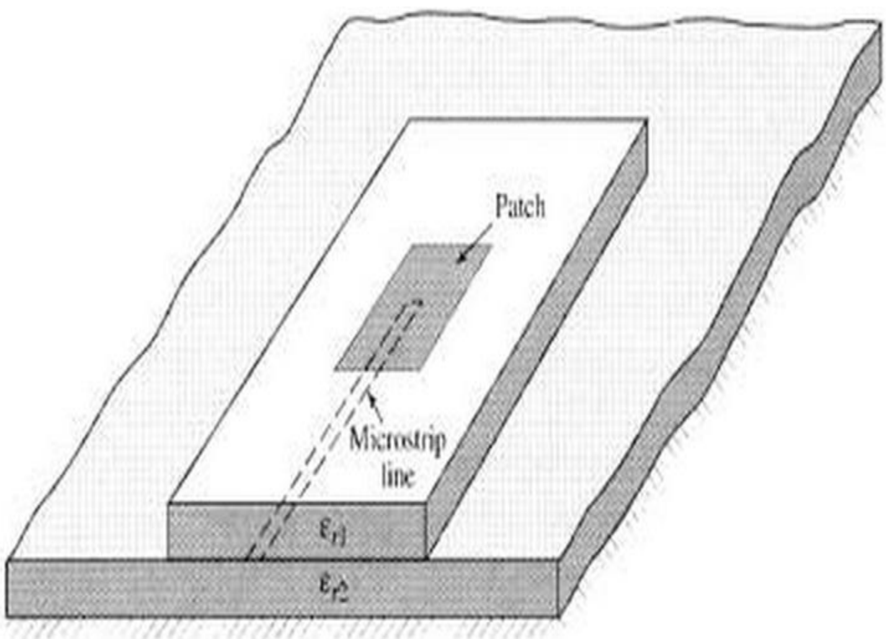


Figure 1.15 Proximity Coupled Feed

1.10 DIFFERENT TYPES OF MICROSTRIP PATCH ANTENNA

1.10.1 SLOTTED MICROSTRIP PATCH ANTENNA

There are many ways to design the slotted microstrip patch antenna. Slotting in microstrip patch antenna is mainly done to achieve for impedance matching, polarization, increasing bandwidth and for resonance frequency. Slotting can be done in many forms according to the specific need. Generally for achieving broad-band in the range of 3Ghz and above we put slots like (a) E shaped slot (b) H shaped slots (c) T shaped slots (d) inverted L-shaped slots or simply placing the rectangular slots on the patch. Slots can vary the current and frequency distribution of the applied input voltage thus resulting in increasing the bandwidth. Some of the slotted micro strip patch antenna configurations are given below

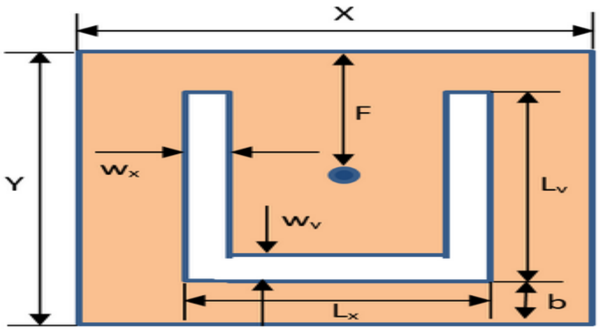


Figure 1.16 U-Shaped Rectangular Microstrip Patch Antenna

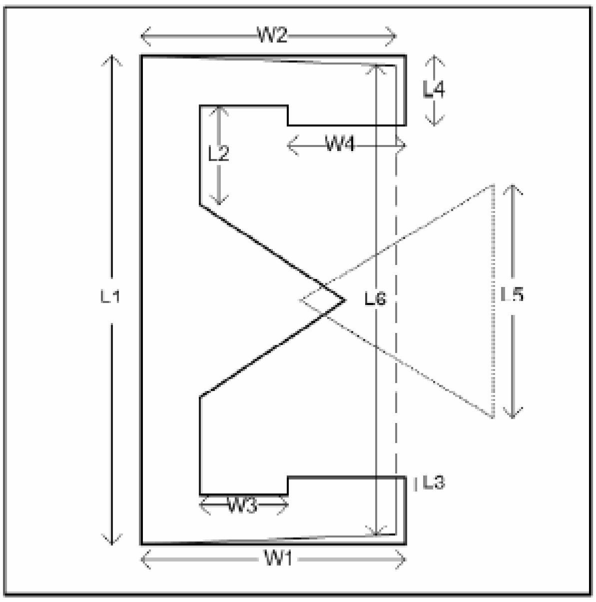


Figure 1.17 M-Slotted Microstrip Patch Antenna.

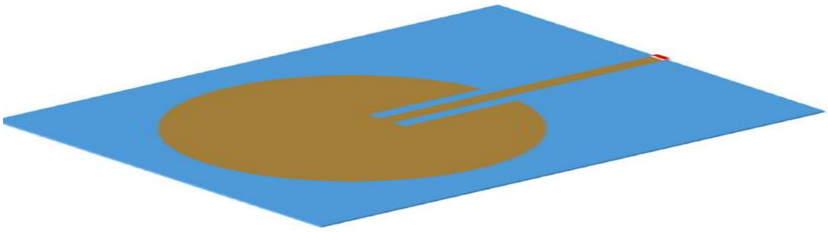


Figure 1.18 Circular Slotted Microstrip Patch Antenna

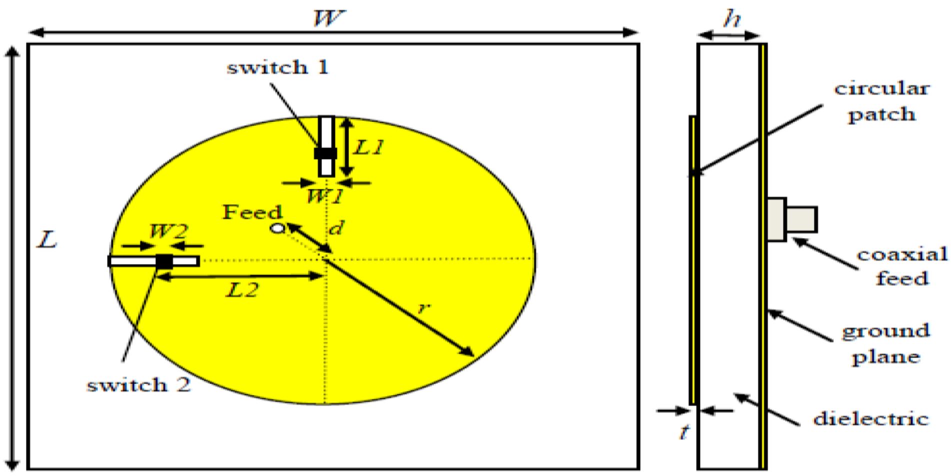


Figure1.19 Circular Patch Antenna With Switchable Polarization

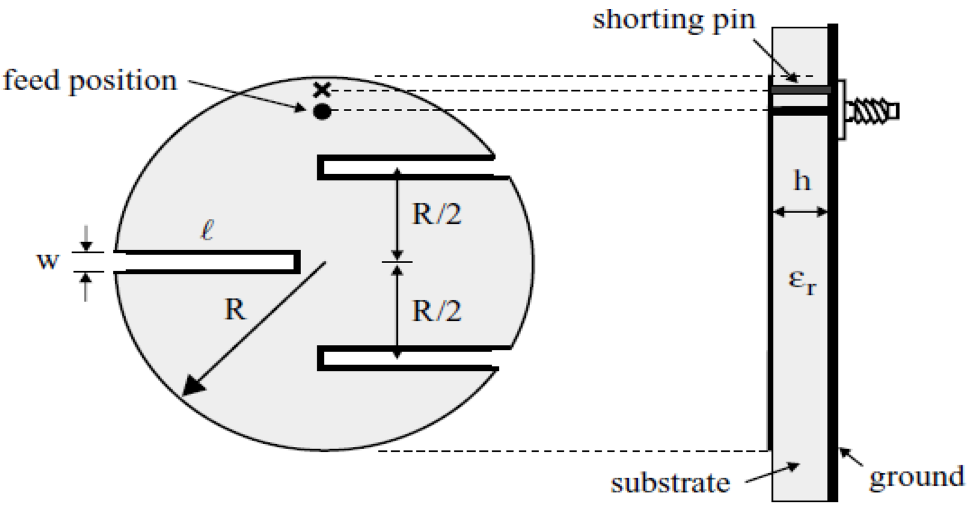


Figure 1.20 Meandered Circular Microstrip Patch Antenna With Sorting Pin

These are few slotted microstrip patch antenna structures which we just saw above. We can make numerous number of slotted structures according to our application and according to our preferred suitable design.

1.11 STUBS IN CIRCULAR MICROSTRIP PATCH ANTENNA

In the designing of the circular micro strip patch antennas the substrate height is kept large as compared to other conventional microstrip patch antennas. So, as the height of the substrate increases more are the chances of impedance mismatch between the load and the source. Therefore in cases like these we make the use of the external materials which helps in impedance matching between the load and the source. Such components are called stubs. We make the use of the values of the voltage standing wave ratio and the value of the characteristic impedance of the feeding line to calculate the impedance values and location of the position of the stub to be inserted from the Smith chart. We place the stub at such a position where the admittance is pointed towards the load. By placing the stubs at the proper position we can effectively reduce the impedance mismatch thus resulting in reduction of losses such as radiation loss, surface wave loss etc.

1.12 RESONATING INPUT RESISTANCE IN CIRCULAR MICRO STRIP PATCH ANTENNA

As we know that the input impedance in case of circular microstrip patch antenna is real and it does not depend upon the position of the feed point on the surface of the patch. The

$$G_t = G_{rad} + G_c + G_d \qquad (1.14)$$

Where

G_t = Total loss.

G_{rad} = Radiation losses.

G_d = Dielectric losses.

The input resistance set in the circular microstrip patch antenna is because of the probe.

1.13 EFFICIENCY, BANDWIDTH AND QUALITY FACTOR

Each antenna has its own quality factor. Antenna losses are calculated by calculating quality factor. Mostly, the losses which occur in antenna are dielectric losses, radiation losses, surface wave losses and conduction losses. The conduction and dielectric losses are because of the faulty dialectic materials which results in the ohmic resistance. The radiation loss is because of the mismatch between the feed and the antenna. Surface waves results in the coupling among the components present on the surface of the antenna thus resulting in losses[15] All these losses are closely related to each other. Quality factor is used to calculate all these losses. The general equation for quality factor (Q_t) is given as [16]

$$\frac{1}{Q_t} = \frac{1}{Q_{rad}} + \frac{1}{Q_c} + \frac{1}{Q_d} + \frac{1}{Q_{sw}} \qquad (1.15)$$

Where

Q_t = Overall quality factor.

Q_{rad} = Radiation losses quality factor.

Q_c = Conduction losses quality factor in ohm.

Q_d = Dielectric losses quality factor.

Q_{sw} = Surface wave quality factor.

Surface losses are very less in case of thin substrates and can be neglected. But in case of thick substrates, surface wave losses comes into picture as the thickness of the substrate is increased so these losses are considered in case of thick substrates. The mathematical expressions for the above mentioned losses are given as

$$Q_c = h\sqrt{\pi f \mu\sigma} \qquad (1.16)$$

$$Q_d = 1/\tan\delta \qquad (1.17)$$

$$Q_{rad} = 2\omega\varepsilon_r K/hG_t/l \qquad (1.18)$$

Where

σ = Conductivity of the patch conductor.

δ = Substrate material loss tangent.

h = Height of the substrate.

G_t/l = Overall conductance per unit length.

The height of the substrate and Q_{rad} inversely proportional to each other that is more the height of the substrate less is the radiation quality factor. Q_{rad} is dominant in case of thin substrates. There exists a relation between the bandwidth of the antenna over the certain specific frequency band and input impedance. We make the assumption that the value of the voltage standing wave ratio at the input terminals is in optimum range. There the fractional bandwidth at the input terminals is given by

$$\Delta f/f_0 = VSWR\text{-}1/Q_t\sqrt{VSWR} \quad (1.19)$$

1.14 INPUT IMPEDANCE OF CIRCULAR MICROSTRIP PATCH ANTENNA

The input impedance comprises of both the resistance because of the resonance frequency and because of the input feed position. It consists of both the real and imaginary parts that is it is complex in nature. The real and imaginary parts of the input impedance is the function of the frequency and vary as per the frequency variation. In case of the thick substrates the feed reactance is not negligible and is taken into consideration. Matching is done by setting the proper value of feed reactance and thereby we determine the resonant frequency. In case of cavity model, the current flowing in the feed is in the same direction as that of the magnetic walls surrounding the substrate thus resulting in impedance matching. Also by placing the feed point far away from one of these magnetic walls we can ensure that the magnetic field because of the feed and that of the magnetic wall does not overlap . Therefore at the feed position the magnetic energy density associated by it is only because of the current which is flowing inside the feed. There the feed point is chosen deliberately far from the magnetic walls so that the stored magnetic energy density value remains only double with respect to that of the feed only. Thus the large value of reactance is present when the feed is near to the magnetic wall and small value of reactance is present when the feed point is far from the magnetic wall. Mathematical expression for calculating the approximate value of feed reactance is given as

$$x_f = \eta\, kh[\ln(kd/4) + 0.557]/2\pi \quad (1.20)$$

1.15 CIRCULAR MICROSTRIP PATCH ANTENNA FOR WLAN APPLICATION

Circular microstrip patch antennas are more favored for wireless communication purposes mostly in the WLAN applications because of the dual operating frequency of the microstrip patch antennas. Dual operating frequencies are easily achieved in case of circular microstrip patch antennas by placing the slots at the suitable positions on the surface of the patch. By changing the dimensions of the slots, the bandwidth can be easily changed. The bandwidth increment can be easily achieved in circular microstrip by implying the slotting technique. Also, by varying the position and dimension of the slots we can increase the gain and can achieve polarization in a particular direction. As

5.99GHz is newly introduced frequency in WLAN frequency band so more possible designs of circular microstrip patch antenna are in demand which can operate at this frequency along with other operating frequency.

CHAPTER 2

LITERATURE REVIEW

Before getting started with the thesis work the first step which one should take is Literature review. One should have crystal clear in depth knowledge about his purposed thesis project. We should be able to distinguish that which is useful data for us and which is not. There are many mediums for literature review. IEEE papers, conferences journals, internet, libraries, books etc are the main sources from where we can do literature review. All the collected data must be preserved carefully as they form the basis of our thesis work. We should go through all the available literature related to our thesis project and should form the notes and should write down the important points. List of some of the papers which are taken from the IEEE explore and from other journals and books related to my thesis project is given below.

[3] Nayyer Fazal and Shaid Bashir,**17,2012** (Department of Electrical engineering technology Peshawar, Pakistan) is designed as pent band micro strip patch antenna that resonates at GSM (Global system for mobile communication), GPS(L), GPS(L2), WLAN(wireless local area Network) and UWB . Micro-strip line is used as a feeding technique in this antenna. Slots are used to achieve the multi-band operation. A conducting strip is also used at the bottom side of antenna. The return loss of the antenna is less then 10dB in all the five bands and work efficiently in all the purposed bands. Because of its small size it can be used in all the portable devices which are designed for wireless communication.

[4] Amit A. Deshmukh and K. P. RaV,Feb 2010, Antenna is triple band and which is designed by using the combination of open-circuit quarter-wavelength stub, a pair of rectangular slots and a resonant U-slot. To achieve the working of this micro-strip antenna for four bands a new configuration is realized by inserting two half U-slots inside a stub-loaded rectangular micro-strip patch. The experiments performed for working of this antenna on multi-band are fulfilling all the necessary conditions and are experimentally verified, and close agreement was obtained among the simulated, measured, and theoretical results.

[5] Dalia Nashaat, Hala A. Elsadek, Esmat Abdallah, Hadia Elhenawy and Magdy F. Iskander, 7/09/2009. As we know with the advancement of technology and with more and more functions getting merged into one we need to increase the band-width of the antenna in wireless communications . Up to now we were concentrating on the Planar monopole antennas which are suitable for mobile applications and hence there is need of improvement in band-width of the antenna. Designing of this antenna is done in three steps. In first step the design of the compact antenna is done which is ultra-wide bandwidth (UWB). Ultra wide-band is achieved by using semicircular microstrip monopole antenna with modified ground plane and a semi circular patch like umbrella shape. The bandwidth produced by this antenna is from 2 to 30 GHz with discontinuities from 7GHz to 10GHz, from 12.5 GHz to 17.5GHz. The size is reduced by around 50% from conventional rectangular shape patch. Second step is concerned with using meta material for improving the performance of antenna The meta material structures used are Metallo-electromagnetic band gap structure (MEBG) and spiral artificial magnetic conductors (SAMC). Finally the antenna designed provides an impedance bandwidth (S]]<-10dB) of more than 29GHz corresponding to over 900% increase over the original bandwidth.

[6] Naser Ghassemi, Shahram Mohanna, J. Rashed-Mohassel, M. H. Neshati ,4/08/2008. Work done in this paper presents the newly evolving designing method of micro-strip antenna with multilayer aperture coupled with a non symmetric U-shaped feed line. Two slots are used to excite the rectangular patch . These slots are preset on the ground plane of micro strip antenna. The position and dimensions of the slots effects the parameters of the antenna. After getting results antenna has VSWR < 2 from 2.6 GHz to 5.4 GHz (70%) and the gain of the structure is more than 7 dB from 2.7 GHz to 4.4 GHz (48%).

[7] Shan-Cheng Pan, and Kin-Lu Wong, 2/08/1998. In this article, they present several novel designs of single-feed micro-strip antennas using a shorting-pin loading technique for providing dual-frequency operation with a relatively large frequency ratio of 2.0 - 4.9 Optimum resulta are obtained at the working frequency range of designed antenna.

[8] F. Jolani and A. M. Dadgarpour and H. R. Hassani,2008. This paper presents the small sized antenna designed for WLAN applications. M slot is inserted in the patch with sorting wall. Antenna size is reduced by the use of shorted triangular parasitic patch and a folded patch. After selecting a proper sorted wall the simulated results are proper well up to ore agreement and the bandwidth of the antenna is 21.17% covering the 4.93–6.09

GHz band. The antenna size is of order 0.1094λo × 0.1094λo × 0.0544λo (6 × 6 × 3mm3). 75% surface size reduction is done in this antenna as compared to other normal micro-strip antenna having the same patch operating at the same frequency. Radiation pattern used over all the bandwidth is H-plane.

[9] M. T. Islam, M. N. Shakib and N. Misran,**2008**. In this paper E-H shaped broad-band micro-strip patch antenna is designed. In this antenna the probe used for feeding purpose is L-shaped. Impedance band-width antenna gain and the radiation pattern of the antenna is investigated by designing the prototype of antenna. The designed antenna is covering the bandwidth from. radiation pattern of the purposed antenna is stable in nature.

[10] W. Ren, 2011 the designer of the purposed dual-band slot antenna is working on 2.4/5 GHz WLAN. Ring slot and the circular shaped ring slot is used as slots in this antenna which are working at 2.4 GHz and 5 GHz bands respectively. The size of antenna is very small as per given dimensions (40mm × 40mm × 1mm). This antenna covers all the bandwidth specified by IEEE 802.11b/g (2.4–2.485 GHz) and IEEE 802.11a (5.15–5.825 GHz) with optimum results.

[11] J. J. Tiang, M. T. Islam, N. Misran and J. S. Mandeep, November 2009. This purposed micro-strip antenna is working for dual frequencies. The feeding technique which is used in this antenna is micro-strip feed which is in close proximity with the circular slot patch. The bandwidth covered by this antenna is from 26.2% and 22.2% respectively. The purposed antenna used in RFID applications.

[12] By Lin Peng, Cheng-Li Ruan, 11 July 2012. The purposed micro-strip antenna is fed with micro-strip line which is designed for operating on dual frequencies having two parasitic invert L stubs for 2.4/5-GHz. The substrate used in this antenna is FR4 having relative permittivity of 4.4. The thickness of the substrate is 1mm. The main purpose of the inverted L-shaped stub slots is to generate the frequency of 2.4Ghz/5.8Ghz which is used for the WLAN applications.

[13] J. A. Ansari, Anurag Mishra, N. P.Yadav, P. Singh, B. R. Vishvakarma, 9 June 2012. In the present paper a dual frequency resonance antenna is achieved by introducing L- shaped slot in circular disk patch. The resonance frequency is found to be 5.087 and 8.455GHz and the 10dB bandwidth of the proposed antenna for lower and upper resonance frequency is found to be 4.39 and 4.66% respectively. It is easy to adjust the higher and lower band by changing the dimensions of notch and slot introduced in the antenna. The frequency ratio is found to be 1.6621. The gain and efficiency of the proposed antenna is found to be 9.50dB at lower resonance however it is 7.0 dB at upper resonance frequency whereas the efficiency at lower and upper resonance is found to be 94.6 and 88.2%.The theoretical results are compared with IE3D simulation results which are in good agreement.

[14] Ganga Prasad Panday, Binod kumar Kanaujia, A.K.Gautam, Surendra K. Gupta,**June 2012**. In this paper the L-strip proximity coupled slot loaded circular micro-strip antenna is designed and its results are analyzed IE3D simulation software validated by MoM. 3.74 GHz frequency is used and gives ultra wide-band operation. Three different layers of the substrate are taken of variable height in which the L-Strip feed is present underneath the third layer of substrate.

[15] Shrikant Panday, Sudeep Baudha, Rahul Singh Rathore, August 2014. In this paper Rectangular Line Slot antenna working on dual frequencies is studied using HFSS simulator. Dual band operation is obtained by the use rectangular line slot patch geometry. The operating frequency of this antenna is 2.4 GHz . After varying the slot broadness the second frequency achieved is 3.3 GHz.

[16] Nagendra kushwala, Raj Kumar, R V S Krishna,**5 July 2012**. In this paper the Ultra Wide-Band antenna is presented having the rectangular slot and an asymmetrical cut in the ground plane. A co-planer waveguide feed with the hexagonal patch is used to excite the slot. A wider impedance bandwidth is achieved because of the inductive reactance creation by the asymmetric slot present. The operating frequency taken is from 2.9Ghz to 14.75GHz.

[**17] A.K.Verma, Nasimuddin, 7,2008**. In this paper the improved cavity model concept called modified Wolff model is used. The study of the parameters of circular antenna like resonance frequency, bandwidth and input impedance is done at the frequency of 2GHz. The parameters thus obtained are the studied by field theoretic methods.

[18] H.A.Osman, E.A.Abdallah and A.A Abdel Rhim, July 2011. In this paper the frequency of 5.2GHz is used to study the novel electromagnetically coupled circular disk patch antenna. Size reduction by 85% is achieved in this antenna by clipping the radiating patch in a particular fashion. The bandwidth thus ranges from 4.8GHz to 6.15GHz.

[19] B.J.Kwaha, O.N.Inyang and P.Amalu, 2014. A Fortran program is used to obtain the basic parameters of circular micro-strip patch antenna. These parameters include the conductance, effective radius of the patch, actual radius of the patch, directivity, input resistance and quality factor. Reduction of the patch radius takes place as the frequency increases as 0.2374cm for 10GHz and 0.05079GHz for 45.0GHz.

[20] R.Dhanalakshmi, Santhosh Kumar and S.Srinivas, 5 Februry 2013. In this paper EGB process is utilized along the slotting process to increase the gain. EGB stands for the engineered meta-material which is used for the process of gain enhancement. Substrates such as the FR4 and Rogers is used which have low dielectric constants. Cylindrical EGB structures are created at the surface of the substrate material to attain high gain.

[21] Nagendra Prasad Yadav, Babau R. Vishvakarma, 2014. L-strip proximity feed is used in circular disk patch antenna which is based on the cavity model in which three layers of substrate material are used. The L-strip feed is used to decrease the distance between the patch and the micro-strip feed. The L-strip feed is present beneath the third layer and the radiating circular patch is mounted over it. As the feed is not in direct contact with the patch it is known as the proximity feed. The resonance frequencies are 5.19GHz and 10.44GHz for the respective lower resonance frequency and upper resonance frequency. When the notch is cut we get the shift in the frequency in both the lower and upper frequency. We can easily adjust the higher and lower bands by changing the dimension of L-strip. The conducting material used for circular patch and ground is copper. With the change in the dimensions of the L-strip feed we see the significant amount of change in the bandwidth of the proposed antenna. The theoretical results and in good approximation with the simulated results.

CHAPTER 3
ABOUT THE THESIS

3.1 SCOPE OF THE STUDY

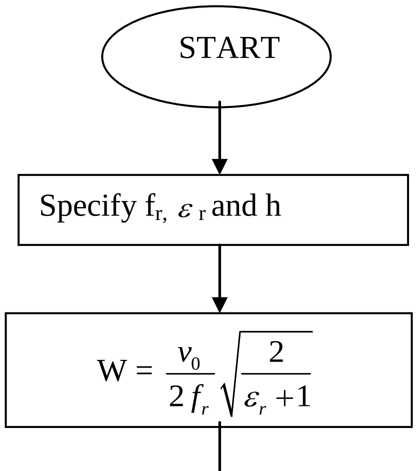
Now from several decades we are designing the micro-strip patch antenna mostly for the wireless communication systems. We keep on experimenting with the dimensions of the micro-strip patch antennas so that we can achieve our particular requirements. In some cases we need our antenna to be smaller in dimension and vice-versa. Some antenna are designed to provide the narrow bandwidths and some are designed to provide the larger bandwidth. Slotting is one way to achieve all our particular requirements. Slotting can be done in different forms and at any place in the micro-strip patch antenna design. A lot of work is already done on the rectangular micro strip patch antenna. In rectangular micro strip patch antenna we need to control the two dimensions of the patch that is length and breadth of the patch. By changing the dimensions of the patch the operating order of modes also get changed. But in case of circular patch antenna we need to control only one dimension that is the radius of the circular patch. So by changing the dimension of the circular patch there is no effect on the operating order of mode. The operating modes do no change by changing the dimension of the circular patch but the resonating frequency does gets changed. The modes supported by the circular micro-strip patch antenna are TM^Z mode. Here 'z' is at ninety degree to patch. As my thesis project is to design the circular micro strip patch antenna in which the multi layering of the substrate material is done. Here three layers of substrate are used. With the increase in the layers of the substrate we can increase the bandwidth. Also by placing the circular micro-strip patch antenna either outside or inside of the conical plane can modify the radiation pattern up to some extent of the micro-strip patch antenna.

3.2 OBJECTIVE OF THE STUDY

The aim of this thesis is to design a multilayered circular microstrip patch antenna for dual WLAN frequencies. The designed antenna is based on the cavity modal. As the substrate thicknesses is large because of the presence of the multilayer so we have make the use of dual L-inverted stubs for impedance matching purposes. The feeding technique applied is the coaxial feed joining the coaxial feed point to the other end of the feed under the patch. The L-shaped strip is beneath the patch thus acting as a proximity coupled feed. The distance between the feeding point and the magnetic wall is kept enough so that there is no coupling of the magnetic energy of the substrate magnetic wall with that of the feeding point magnetic field. The designed antenna is working properly at the two WLAN frequencies that is the designed antenna is dual frequency operating antenna. In the beginning of the thesis work the circular micro strip patch antenna was designed for application in satellite communication. This work was done for the implementation of the base paper. The main motive of the thesis work is to design the circular microstrip patch antenna for the antenna for dual WLAN frequencies. One of the frequency is newly introduced frequency (5.9GHz) in WLAN frequency band. Firstly, designing of the circular micro-strip patch antenna without any slots is done. This designed antenna is working at the operating frequency of 5.9GHz. After the introduction of the slots there is increment in the bandwidth of the frequency also dual frequency operation is achieved. There is considerable increment of the gain, bandwidth after the introduction of the slots. The value for voltage standing wave ratio is less than one for both the operating frequencies.

3.3 RESEARCH METHODOLOGY

After going through the proper literature related to circular microstrip patch antenna, the antennas designed on the basis of cavity model are easy to implement and are accurate ones. So the multilayered circular microstrip patch antenna is designed on the basis of cavity model. Also the feeding technique employed is probe feed at one end of the micro strip feed line and other end is under the patch acting as proximity coupled feed. Maximum possible distance is maintained between the feed point and the patch for proper coupling of energy. The other end of the feed is present underneath the patch thus resulting in proximity coupled feeding technique. The flow chart below gives us the designing procedure of circular patch.



$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{\varepsilon_r - 1} + \frac{\varepsilon_r - 1}{2}[1 = 12\frac{h}{W}]^{\frac{-1}{2}}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)}\frac{(\frac{W}{h} + 0.264)}{(\frac{W}{h} + 0.8)}$$

$$\text{Area of Patch}, \ A_e = \sqrt{\frac{W * l}{\Pi}}$$

END

3.3.1 CAVITY MODEL

Circular micro-strip patch antenna can act as a cavity model which are loaded by dielectric material. In the cavity model we can easily find out the field between the ground plane and the patch material which is normalized to both planes. In the cavity model both the ground plane and the patch are conducting materials with the thick substrate present in between them. In cavity model the electric field is present between the two conductors that is between ground and patch and the magnetic field is considered along the perimeter of the patch. When the micro-strip patch is energized, the charge distribution is established on the upper part and on the lower part of the patch and also at the surface of the ground. Two mechanisms are established when the patch is excited. These mechanisms are Attractive mechanism and Repulsive mechanism. Attractive mechanism controls the opposite polarity charges which are present at the lower surface of the patch and at the surface on the ground. The repulsive mechanism is between the like charges on the bottom side of the patch which tries to push the charges which are present at the bottom of the patch around its edge towards the top surface. These mechanisms results in the current densities at the bottom and top surface of the patch. As the attractive mechanism dominates thus most of the current density and the charge distribution is present underneath the patch.

In this thesis work, circular microstrip patch antenna is designed on the basis of cavity model. There are mainly three types of models of analysis for microstrip patch antennas.

These are the transmission line model [3], full wave model [4] and the cavity model [5]. In transmission line model microstrip antenna is represented as a two slots and a transmission line of low impedance is used to separate the two slots. Transmission line model is simple to design but is less accurate. Full wave model is which includes the integral equations is or the moments method is based on method of moments(MoM). The full wave models can be treated as single elements, stacked elements, arbitrary shaped elements and are very versatile because of its accuracy. Out of these three models cavity model is the most precise one but its little difficult then the other two models to apply. The substrate between the ground and the patch is treated as the cavity in the cavity model. The patch is kept circular in shape so we need to adjust only the radius of the patch to change the gain of the antenna whereas the dimension of the feed is changed for coupling energy more effectively from the feeding point up to radiating patch. It is seen that in case of circular micro strip patch antenna, more the distance is present between the radiating patch and the feeding point, more effectively the coupling of energy takes place. There is need of using L-strip micro strip feed to minimize the distance between the patch and the feeding point. Attractive and repulsive mechanisms are established to control the charge distribution on application of excitation in case of cavity model. The attractive mechanism is established between the opposite charges which are present on the bottom of the patch and on the surface of the ground whereas the repulsive mechanism is established between the same charges present at the bottom of the patch which pushes some of the charges along the edge and towards the top surface of the patch. Corresponding charge densities are established on the surfaces of ground and patch. Because of the movement of these charges the charge densities are established at the top J_t and bottom J_b surface of the patch.

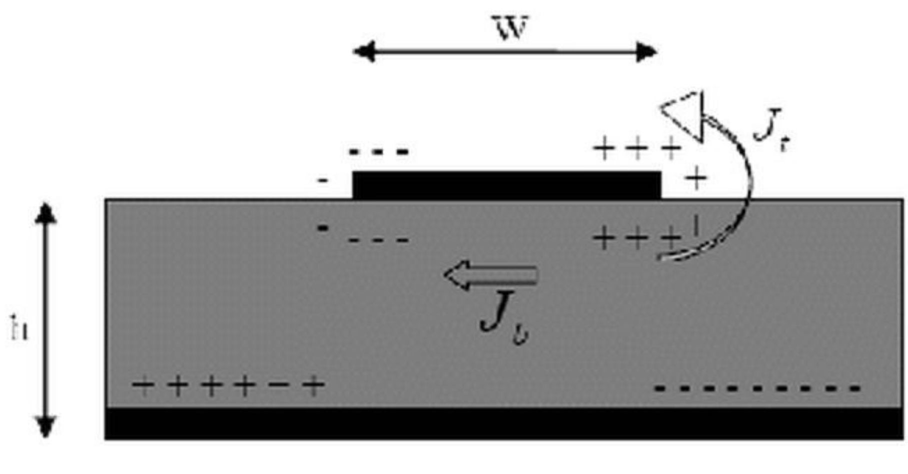


Figure 3.1 Charge Distribution and Current Density in Cavity Model

As the height to width ratio is kept small for most of the micro strip patch antennas so the current density and the charge flow will be more at the bottom of the surface as compared to the side. Since, there is no flow of the current on the side walls so we can say that the walls are perfectly covered by the magnetic field as a result of which this model results in good normalized magnetic and electric field distribution under the surface of the patch. The walls of the substrate act as the magnetic field walls as the magnetic field density is present along the whole walls of the substrate resulting in magnetic field current. The feeding point need to be present far from the magnetic field walls so that the coupling between the feeding point magnetic current and the magnetic field current density along the wall is avoided. In case of circular micro strip patch antenna the substrate sandwiched between the ground and cavity is treated as the cavity thus the modes supported are TM^z mode. Here 'z ' is at ninety degree to the patch. Ground and patch are two conductors and the cavity is present in between having the walls of perfect magnetic field.

3.3.2 PROXIMITY COUPLED FEEDING TECHNIQUE

When the feed line does not touch the radiating patch directly but instead the patch is excited indirectly by the feed which is present in close proximity to patch or present beneath the patch on the substrate surface is known as proximity coupled feed. In our design the L-strip is used to reduce the distance between the micro-strip feed and the radiating patch. The part of the L-strip is present beneath the third layer of the substrate to provide the sufficient field to the radiating circular patch for its excitation. The length of the L-strip feed present underneath the substrate is not more than quarter wave. The L-strip which is present under the substrate provides sufficient capacitance to overcome the inductance present because of the vertical portion of L-strip.

3.4 SOFTWARE USED

HFSS stands for "High Frequency Structure Simulator" is one of the several commercial tools used for designing and simulating various types of antenna and designing of other complex radio frequency complex electronic circuits including filters ,transmission lines, and packaging. HFSS is very interactive software package for calculating the behavior of electromagnetic radiations present inside the simulated designed structure. We make the use of HFSS for calculating

a) basic electromagnetic field quantities,
b) open boundary problems and radiated near and far fields.
c) Characteristic port impedances and propagation constants.
d) Generalized S-parameters and S-parameters renormalized to specific port impedances.

3.4.1 3-D MODELER WINDOW

The 3D Modeler window comprises of the three dimensions that is x-axis, y-axis and z-axis. The three dimensional structure is designed in this window that is it is the space where the model geometry of antenna is created. It is present next to the command window. A lot of space is assigned to modeler window so that we have larger space and better view to create the three dimensional geometry very easily.

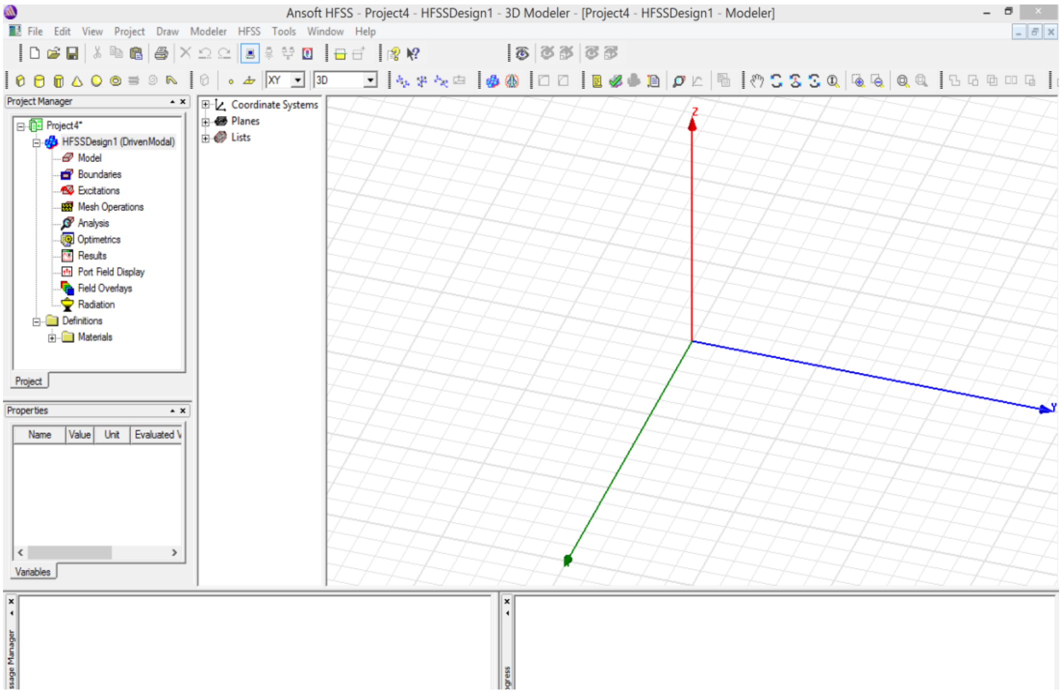


Figure 3.2 3- D Modeler Window

3.5 PREFECT E VERSES PREFECT H SYMMETRY BOUNDARIES

In general, we use the following guidelines to decide which type of symmetry boundary to use, a perfect E or a perfect H:

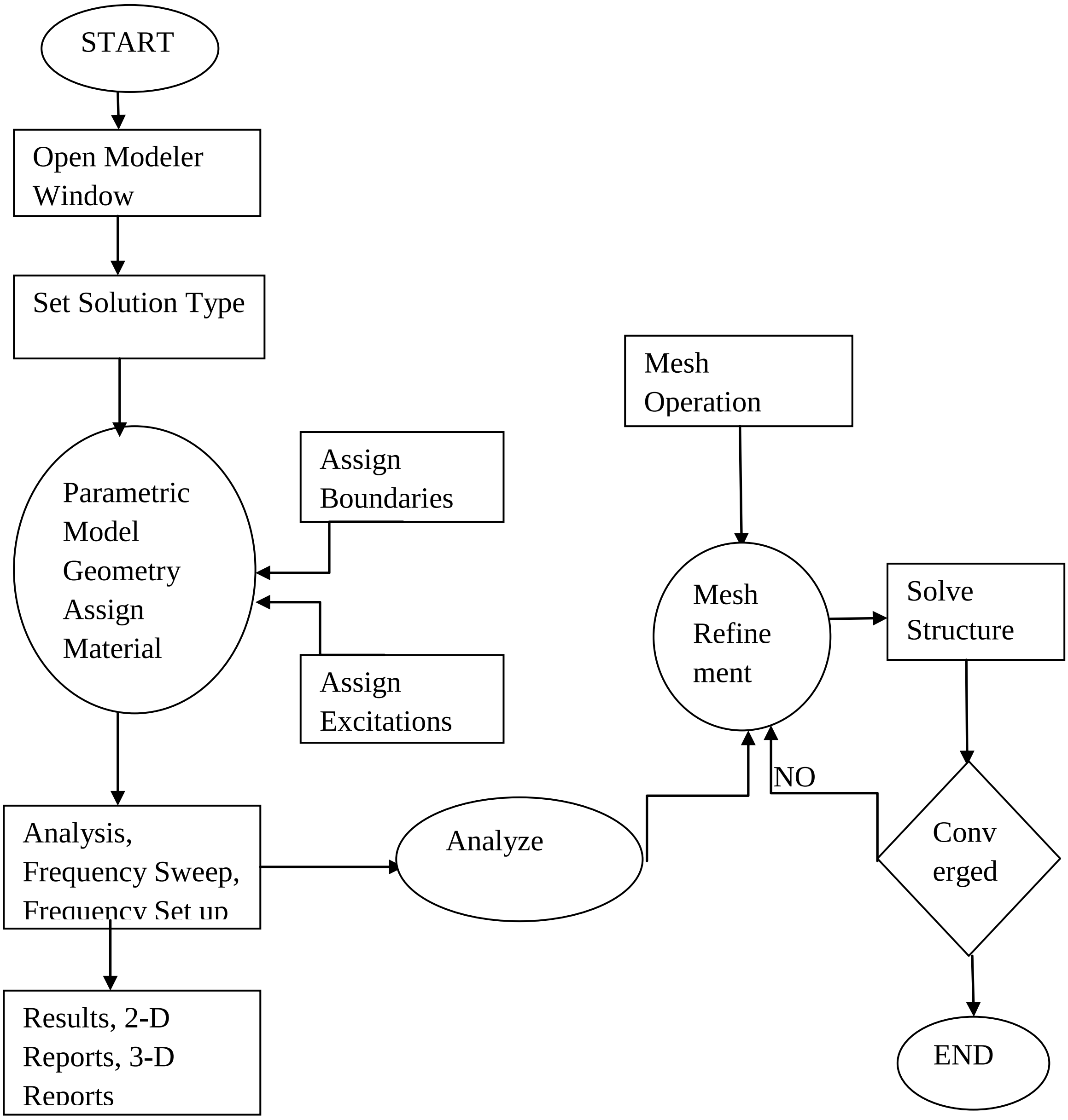
a) If the symmetry is such that the E-field is normal to the symmetry plane, use a perfect E symmetry plane.

b) If the symmetry is such that the E-field is tangential to the symmetry plane, use a perfect H symmetry plane.

Generally in case of antenna we use the prefect E boundary on the surface of patch and ground. Infinite radiation is given to the air box. The main purpose of giving infinite radiation is to decrease the effect of the radiations present in the vicinity of the antenna. Also for calculating the gain and radiation pattern we need to provide the boundary in which our antenna is placed. Port excitement is done to provide the inflow of the field to excite the patch. Port excitation can be provided either by wave port or lump port. In can of excitation provided by coaxial feed we use the lumped port.

3.6 DESIGNING STEPS IN HFSS TOOL

Flow chart is given to show the stepwise designing of antenna on HFSS tool



CHAPTER 4

FORMULATION AND DESIGNING

4.1 ABOUT MICRO STRIP FEED LINES

Microstrip lines are used to transmit the power or to take out the power in case of solid state devices. The advantage of microstrip lines is that they are laid on the surface of the solid state devices without disturbing the working of the device. Microstrip lines operates in TEM that is transverse electric and magnetic mode. The major drawback of microstrip lines is that they suffer from the radiation losses. To overcome this loss we make the use of very thin materials with high dielectric values. Because of the easy fabrication feature and easy interconnection feature, microstrip lines are mostly preferred.

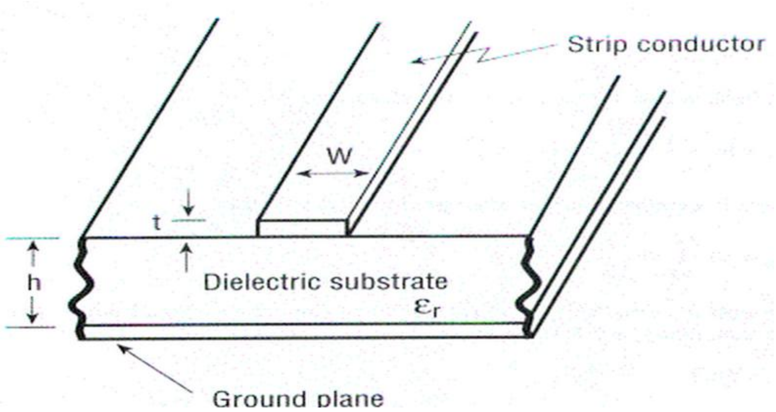


Figure 4.1 Micro Strip Feed line

4.2 MICRO STRIP FEED LINES CHARACTERISTIC IMPEDANCE

Microstrip line impedance depends upon the strip thickness, width, and the distance between the strip line and ground. There are many methods to calculate the impedance of microstrip lines. One of the important equation to find the characteristic impedance of the microstrip line is [2]

$$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln[\frac{5.98h}{0.8w + t}] \qquad \text{for}(h<0.8w) \qquad (4.1)$$

Where

ε_r = Relative dielectric constant value of the material.

h = Distance between ground and microstrip line.

w = Microstrip line width.

t = Microstrip line thickness.

4.3 MICRO STRIP FEED LINES LOSSES

Microstrip lines are prone to many losses. Some of these losses are because of the impedance mismatching and some are because of the geometric configuration of the microstrip line itself. Some of the losses depends upon the conductors and substrates electrical properties. Generally, two types of losses are present. Ohmic losses present between the micro strip line and ground and losses in the substrates due to dielectric. The attenuation factor (α) consider both of these losses. The mathematical expression for attenuation factor (α) is given as [2]

$$\alpha = -\frac{dP}{2P(z)} = \alpha_d + \alpha_c \tag{4.2}$$

Where

α_d = Attenuation constant because of dielectric.

α_c = Attenuation constant because of ohmic.

The mathematical expressions for α_d and α_c are given as

$$\alpha_d = \frac{w}{2}(\sqrt{\mu\varepsilon}) \tan\theta \tag{4.3}$$

$$\alpha_c = \frac{8.68 R_s}{Z_0 w} \quad \text{dB/ cm for } \frac{w}{h} > 1 \tag{4.4}$$

4.4 RADIATION LOSSES

Microstrip lines also exhibits radiation losses in spite of ohmic and dielectric losses. Radiation losses are strictly related to substrate dielectric constant and its thickness and also on the geometry of the substrate. Radiation loss gives us the ratio of the total power radiated to the total power dissipated. The mathematical expression is given by [2]

$$\frac{P_{rad}}{P_t} = 240\pi^2 \left(\frac{h}{\lambda_0}\right)^2 \frac{F(\varepsilon_{re})}{Z_0} \tag{4.5}$$

Where

$F(\varepsilon_{re})$ gives us radiation factor.

$$F(\varepsilon_{re}) = \frac{\varepsilon_{re-1}}{\varepsilon_{re}} - \frac{\varepsilon_{re-1}}{2\varepsilon_{re}\sqrt{\varepsilon_{re}}} \ln \frac{(\sqrt{\varepsilon_{re}})+1}{(\sqrt{\varepsilon_{re}})-1} \tag{4.6}$$

Where

ε_{re} = Effective dielectric constant of the substrate.

4.5 FORMULA USED FOR DESIGNING CIRCULAR PATCH ANTENNA

Driving formula for the patch used in the microstrip patch antennas [2] need the values of substrate dielectric constant, the frequency on which we want our antenna to work and the height of the substrate. The width and length of the patch are thereafter derived by using the specific formulas for respective dimensions.

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \frac{\sqrt{2}}{\sqrt{\varepsilon_r + 1}} \tag{4.7}$$

Where

W = Width of the patch.

f_r = Operating frequency in hertz.

ε_0 = Dielectric constant of the substrate.

μ_0 = Permeability of the substrate.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{w}]^{\frac{-1}{2}} \tag{4.7}$$

Where

ε_{reff} = Effective dielectric constant of the substrate.

$$\frac{\Delta l}{l} = 0.412 \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \tag{4.8}$$

Where

Δl = Effective increase in the length.

$$L = \frac{1}{2 f \sqrt{\varepsilon_{reff\,\mu_0}}\, \varepsilon_0} - 2\Delta l \tag{4.9}$$

Where

L = Actual length of the substrate.

$$A_e = \sqrt{\frac{L \times W}{\pi}} \tag{4.10}$$

Where

A_e = Area of the circular patch.

As it is tedious to work with these equations. So we make the use of the Matlab to get the calculations easily done. All the formulas are written in Matlab as a program and then the values are taken as per the specifications.

```
clc;
clear all;
c=3*10^8;
fo=input('Enter frequency of operation (fo) in GHz=' );
Er=input('Enter Dielectric constant of the substrate(Er)=' );
h=(c*.3)/(2*fo*sqrt(Er-1)); %height of the substrate.
h=h*1000;
disp('h=' );
disp(h);
Wp=(c/(2*fo))*sqrt(2/(Er+1));%formula to calculate width of patch
Wp=Wp*1000;
Wph=Wp/h;
disp('Wp=' );
disp(Wp);
Eeff=((Er+1)/2)+((Er-1)/2)*(1/(sqrt(1+(10*(h/Wp)))));%formula to
calculate effective dielectric of substrate
disp('Eeff=' );
disp(Eeff);
Lef=c/(2*fo*sqrt(Eeff));%formula to calculate effective length of patch
Lef=Lef*1000;
dL=((0.412*h)*(Eeff+0.3)*(Wph+0.264));
dL=dL/((Eeff-0.258) *(Wph+0.8));%formula to calculate effective increase
in length
Lp=Lef+(2*dL); %length of patch in(mm)
disp('Lp=' );
disp(Lp);
w=((50/60)*sqrt((Er+1)/2))+((Er-1/Er+1)*(0.23+(0.11/Er)));
B=(377*pi)/(2*50*sqrt(Er));
wstrip=(2*h/pi)*(B-1-(log((2*B)-1))+(Er-1/2*Er)*((log(B-1))+0.39-
(0.61/Er)));%formula to calculate width of feed line
disp('wstrip=');
disp(wstrip);
Ls=(6*h)+Lp; %length of substrate in(mm);
disp('Ls=' );
disp(Ls);
Ws=(6*h)+Wp; %width of substrate in(mm);
disp('Ws=' );
```

4.6 GETTING STARTED WITH DESIGNING ON HFSS SOFTWARE

The designing of circular micro strip patch antenna is done on High Frequency Structure Simulator(HFSS). First of all we will open the project window and will create the new project. On project window we have model window which contain three dimensional axis that is x-axis, y-axis and z-axis. We can draw the three dimensional structure here in modeler window. Also, the choices are provided for setting units. we can design our structure in mm, cm etc. For less complexity and to make our design less bulky we consider the 'mm' unit for designing purposes. The circular antenna is designed for 10 GHz frequency.

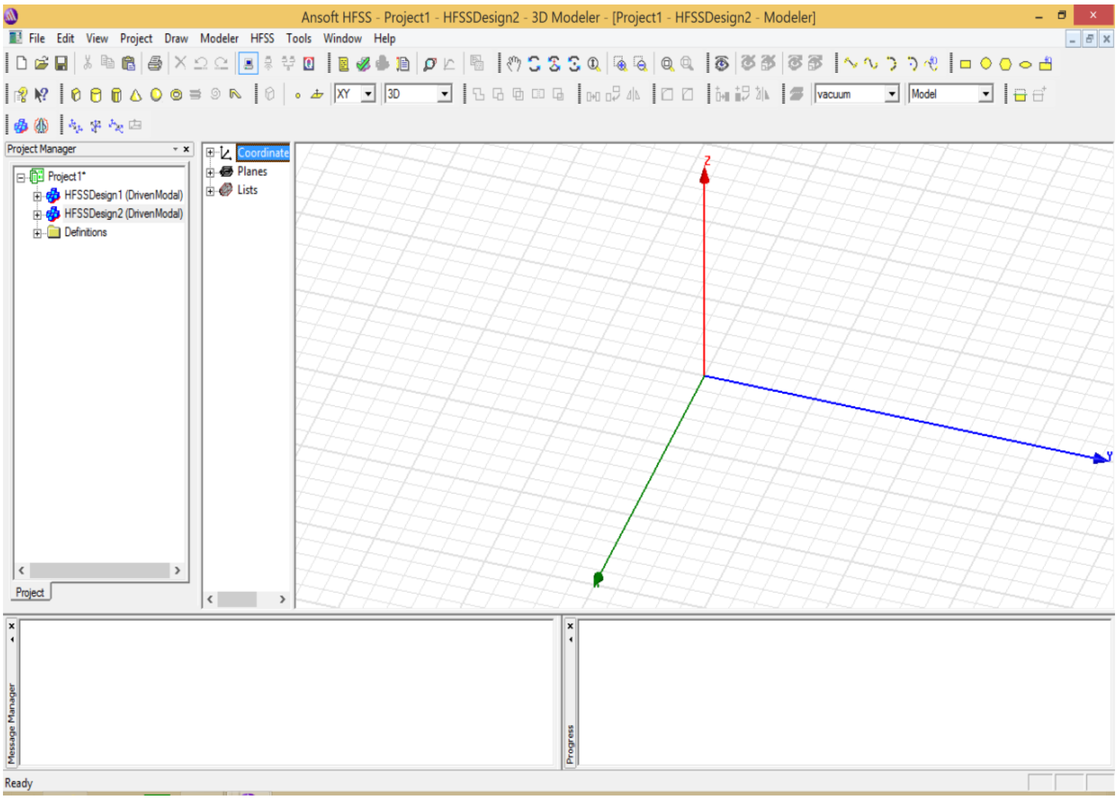


Figure 4.2 Modeler Command Window Used For Designing Purpose

When the modeler command window gets opened we will set up the units for our design in the modeler unit. After clicking on modeler unit, a box will appear which has wider options of units. We can choose any units for our new design. The units used in this design are in mm. We have option for what kind of structure we want to draw. We can draw structures in the form of box, rectangular, cylindrical, circular and many more forms listed in the modeler window. As our design is in cylindrical shape we will click draw cylinder and will give the values for the initial and final co-ordinates. After giving the specified values for the co-ordinate system the 3-D structure of the design will be formed. We can see the structure in any orientation that is in 360 degree orientation in X-axis, 360 degree orientation in Y-axis and similarly in 360 degree orientation in Z-axis.

4.7 PATCH ANTENNA FOR SATELLITE COMMUNICATION

Design specifications of the circular microstrip patch antenna for satellite communication. Here the designing of the circular micro strip patch antenna for satellite communication is done. As the operating frequency for satellite communication is high so the distance between the feeding point and the patch is less. By doing this maximum excitation is provided to the patch as there is proper coupling between the input and output that is between feedline and antenna structure.

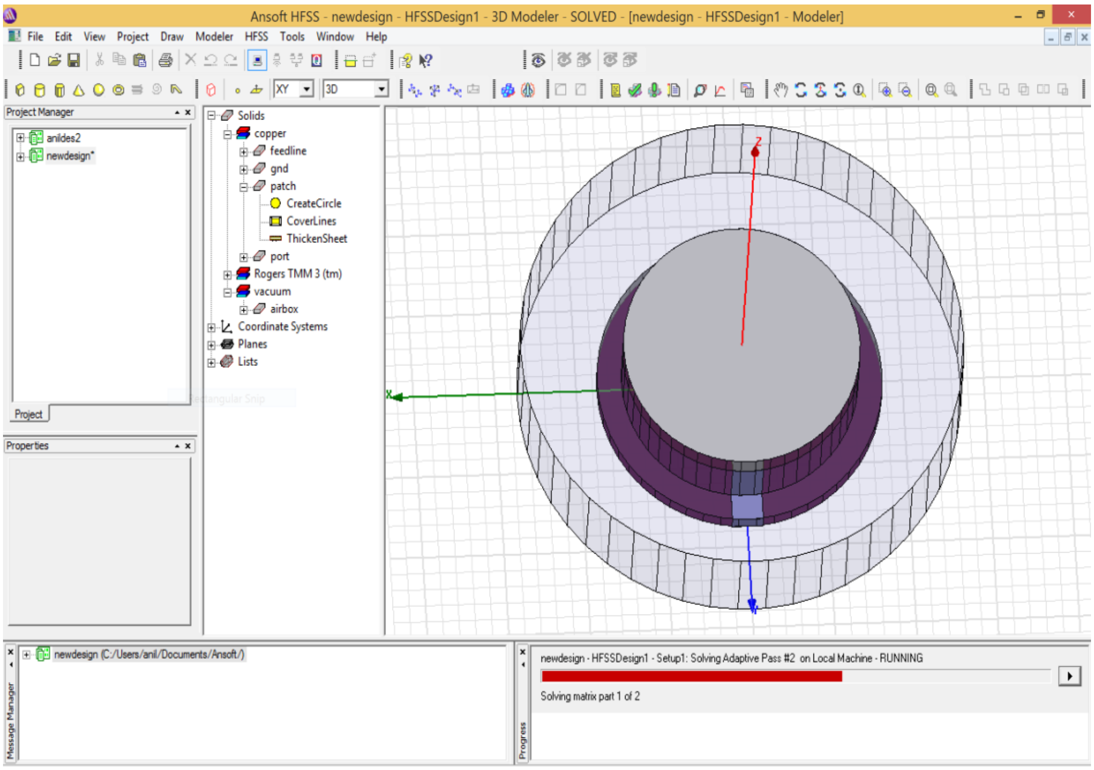


Figure 4.3 Top view of Antenna for Satellite Communication.

Ground radius	17.48375 mm
Radius of first layer of substrate	17.48375 mm
Radius of second layer of substrate	14.505 mm
Dielectric material used	Rogers RT/duroid 5870
Relative permittivity	2.33
Radius of patch	14.505 mm
Length of feedline	13.98375 mm
Width of feedline	3.7862 mm

Table 4.1 Design specification of circular micro strip patch antenna for satellite communication

Here, in this design the distance between the feeding point and the patch is kept small so that our designed antenna can work properly at high frequency. Here the feeding technique used is proximity coupled feeding technique. The horizontal portion of the L-strip feed is kept beneath the surface of the patch present over the surface of the third layer of substrate. This horizontal part of the strip of the microstrip feed is acting as a proximity coupled feed not touching the patch directly but is present beneath the patch under third layer of substrate.

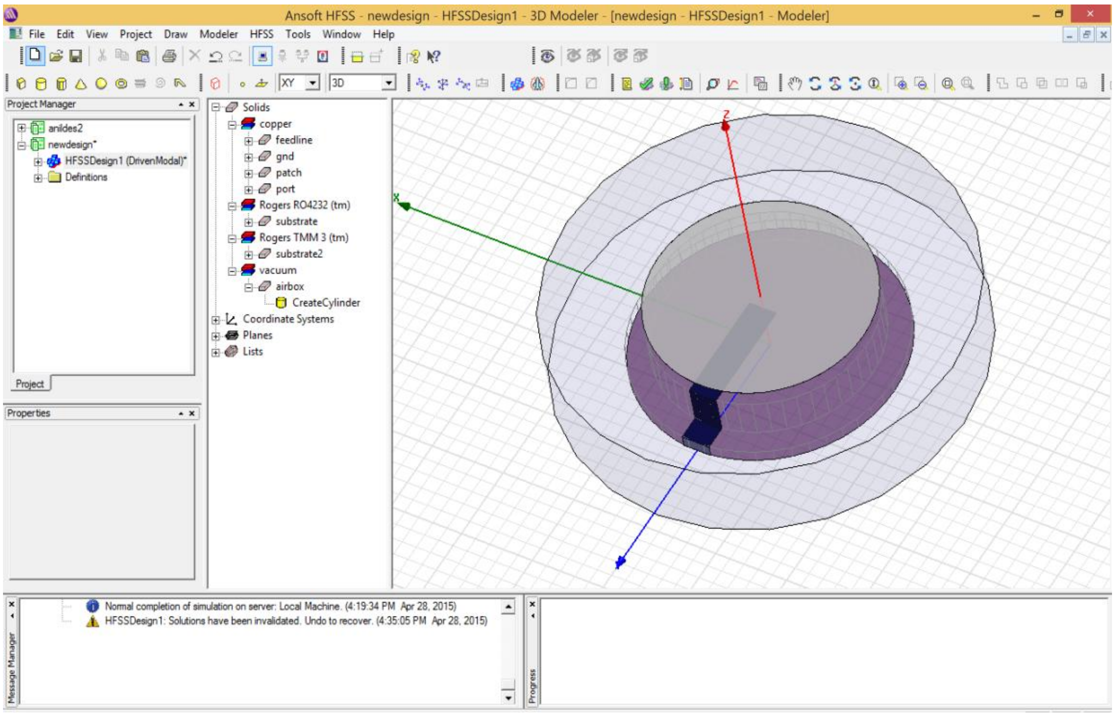


Figure 4.4 Horizontal Part of Feedline Under Surface Patch.

4.8 DESIGN CIRCULAR MICRO STRIP PACTH ANTENNA FOR WLAN

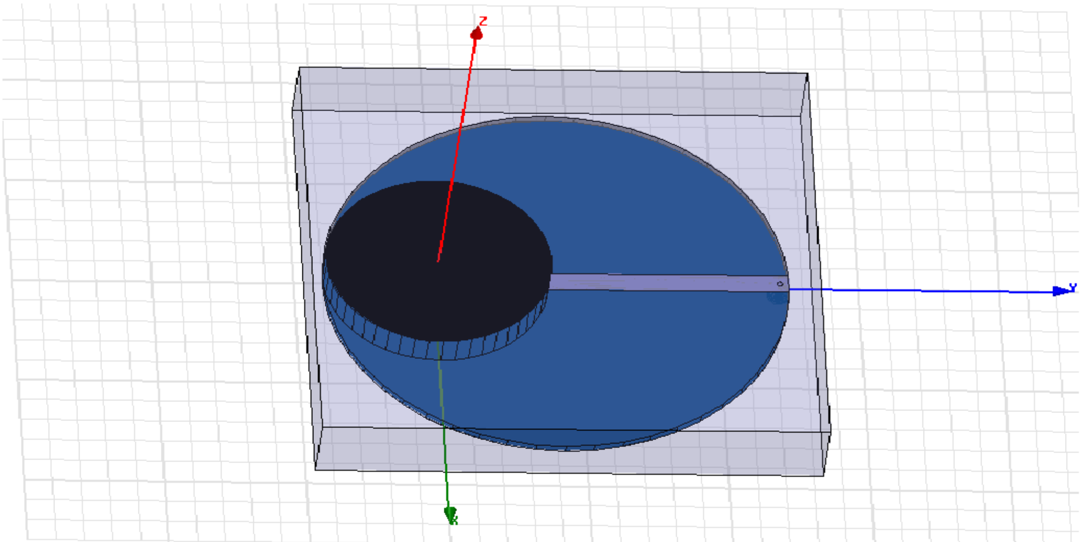


Figure 4.5 Circular Patch Antenna for WLAN Applications

Design specifications of the circular micro strip patch antenna for WLAN applications is provided in the given table. The feeding point is present at the distance of 61mm at the other end of the feed line.

Ground Radius	41.27mm
Patch Radius	20mm
Substrate Second and Third layer Radius	20mm
Total Height	8mm
Relative Permittivity	1.7
Feedline Length	62.54mm
Feedline width	4mm
Dielectric Material	Foam

Table 4.2 Design Specifications of the Circular Microstrip Patch Antenna for WLAN Applications

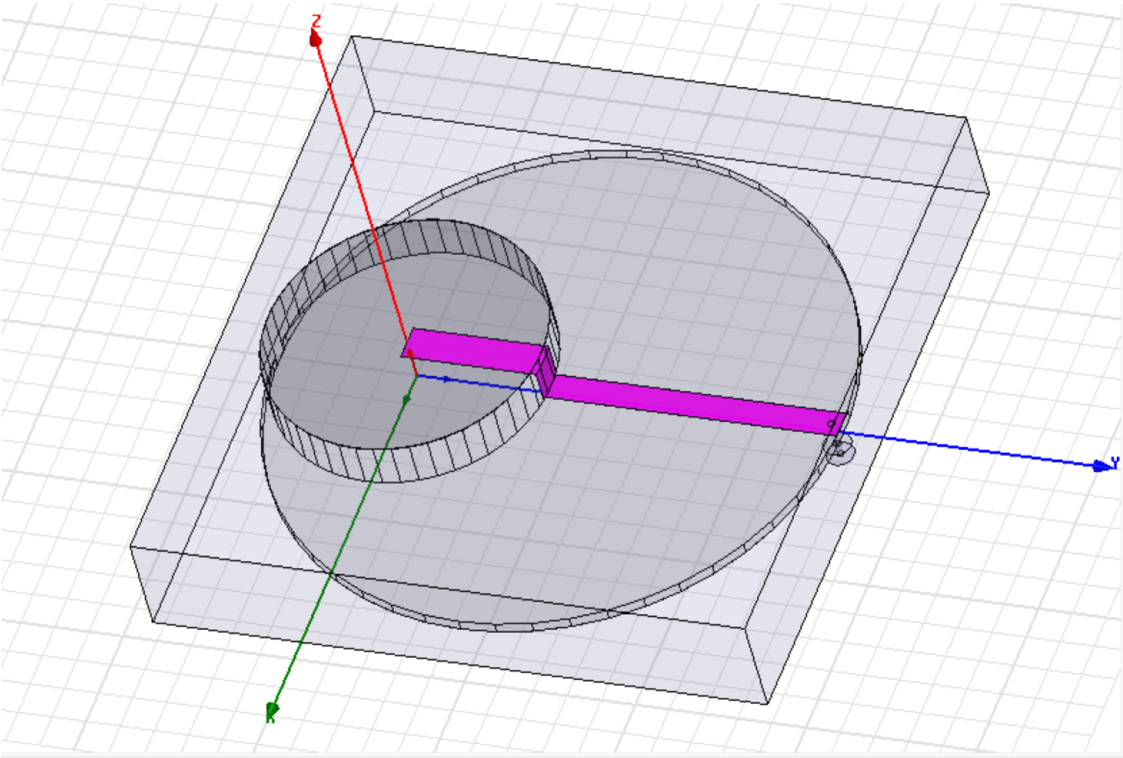


Figure 4.6 L-Shaped Microstrip Feedline With Coaxial Feed

4.9 DESIGNING STEPS FOR CIRCULAR PATCH ANTENNA

The following steps are followed in designing the circular microstrip patch antenna

a) First of all we open the modeler window on HFSS software and then set the preferred units.
b) Then setting the radius value for ground plane we draw the circle for ground.
c) The first layer of the substrate is of the same radius as that of the ground.

d) Then, over first layer of substrate we draw the second and third layer of substrate and the patch over the third layer of substrate.

e) The radius for the second layer of substrate, for third layer of substrate, and for patch is kept same.

f) Now, we draw the microstrip feedline running over first layer of the substrate, the vertical part of feedline along the height of the second layer of the substrate, and then the horizontal part of feedline is present between the second layer and third layer of the substrate. There is no direct contact between the microstrip feed and patch.

g) At the free end of the microstrip feed the feeding point is chosen at the extreme end of the feedline. The feed is provided with the help of coaxial cable.

h) Finally, we draw the air box around the designed structure to isolate our structure from the outside environment. We can see the respective layers in the figure 4.5 given above.

4.10 CIRCULAR PATCH ANTENNA WITH L-INVERTED STUBS

Stubs are being used to match the impedance and increase gain, the directivity, the bandwidth and make the antenna working for dual frequencies.

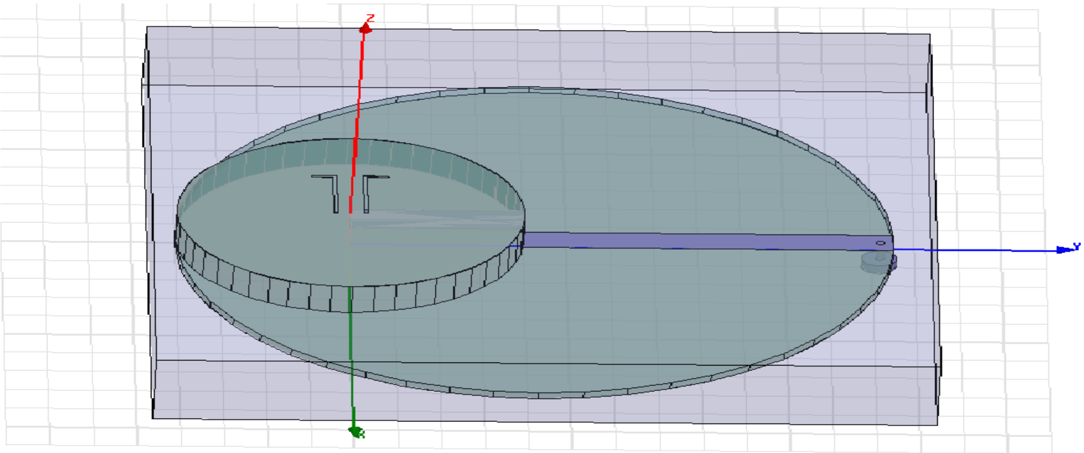


Figure 4.7 Dual L-Inverted Stubs of Same Dimensions

As we know, impedance matching is very important in case of microstrip feed lines. If the improper impedance matching is present in the designed structure in that case there will be more losses in the form of return losses. Therefore, we make the use of the stubs for the impedance matching purpose. First of all the stubs of same dimensions are introduced on the surface of the patch more towards the load. After that the adjustment in positions is done to find the matching where the return losses are minimum.

Length	10mm
Width	1mm
Positi0n	(0, ±1.5 , 8)mm

Table 4.3 Stubs With Same Dimensions

4.11 THE CIRCULAR PATCH ANTENNA WITH VARIBLE DIMENSIONS OF DUAL L-INVERTED STUBS

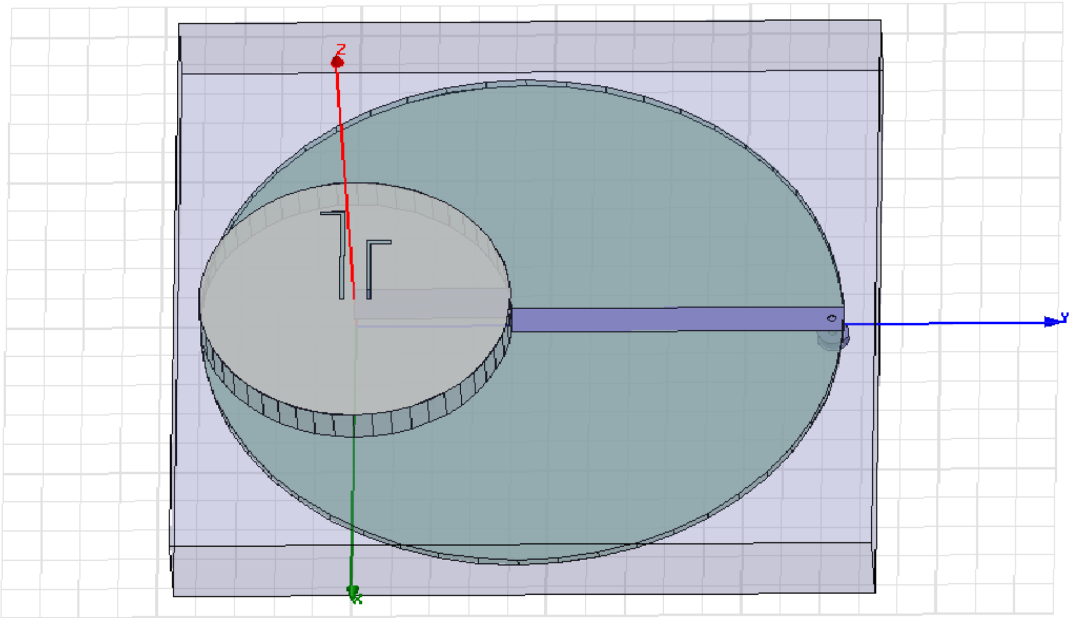


Figure 4.8 Variable Dual L-Inverted Stubs

In this design the two L shaped stubs of unequal dimensions are used. When the stubs of unequal dimensions are used, in that case the more impedance matching is achieved between the source and load. Also there is increment in gain and directivity. The low value for voltage standing wave ratio is achieved in this case. Thus we can say that there is no formation of standing waves inside the antenna structure. The radiations are radiated effectively with high directivity.

Length of Right Hand Stub	10mm
Length of Left Hand Stub	15mm
Width of Both Stubs	1mm

Table 4.4 Dimensions of Variable L-Shaped Stubs

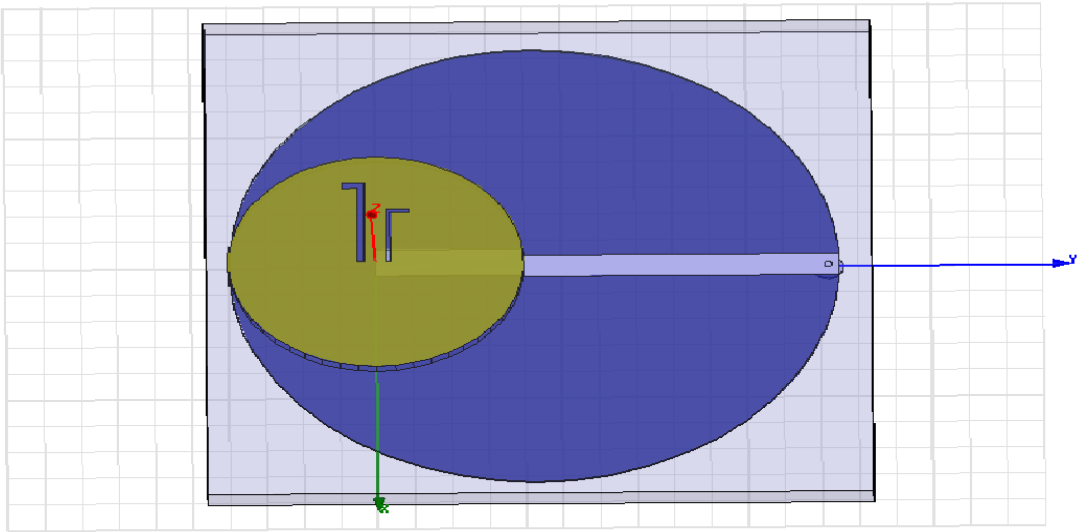


Figure 4.9 Variable Length And Width Stubs

Length of Left Hand L-Shaped Stub	15mm
Length of Right Hand L-Shaped Stub	10mm
Width of Left Hand Stub	3mm

Table 4.5 Dimensions of Stubs With Left Hand Stub Having Large Width and Length

Here, by increasing the length and width of left hand side L-inverted stub, there is increase in gain. Also the voltage standing wave ratio is minimum for both the operating frequencies. And there is enhancement in directivity.

CHAPTER 5

SIMULATED RESULTS AND ANALYSIS

5.1 ANALYSIS: ASSIGNING BOUNDRIES AND EXCITATIONS

After 3-D model is designed we will assign the boundaries to the patch and the air box. We have boundaries and excitations dialog boxes from which we can choose the respective value to be given to our patch, ground and air box. Perfect E boundary is assigned to the patch to create perfect conducting surface.

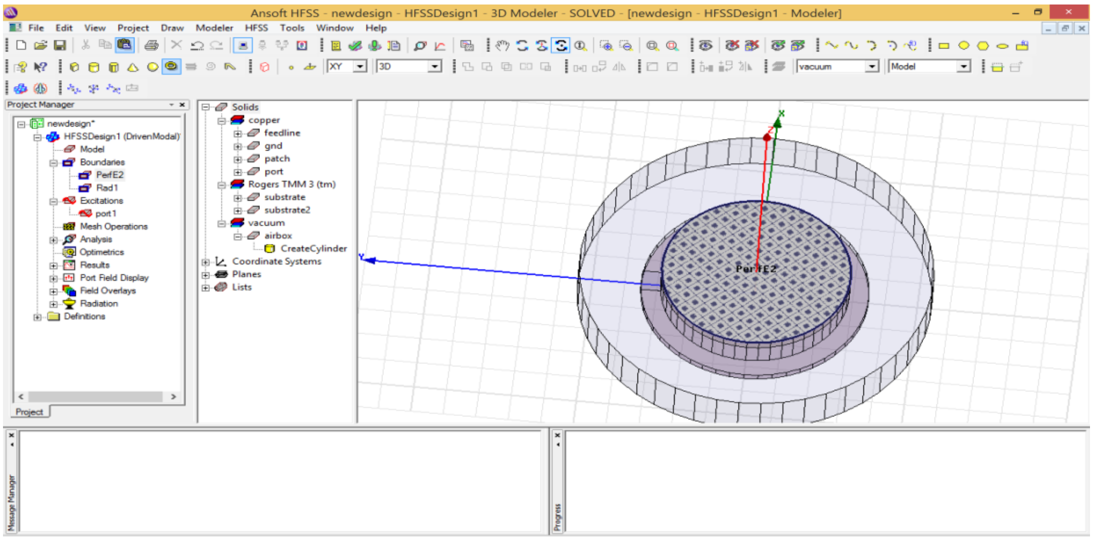


Figure 5.1 Perfect E Assignment to Patch

Radiation is given to the air box to nullify the effect of radiations present in the vicinity of the antenna.

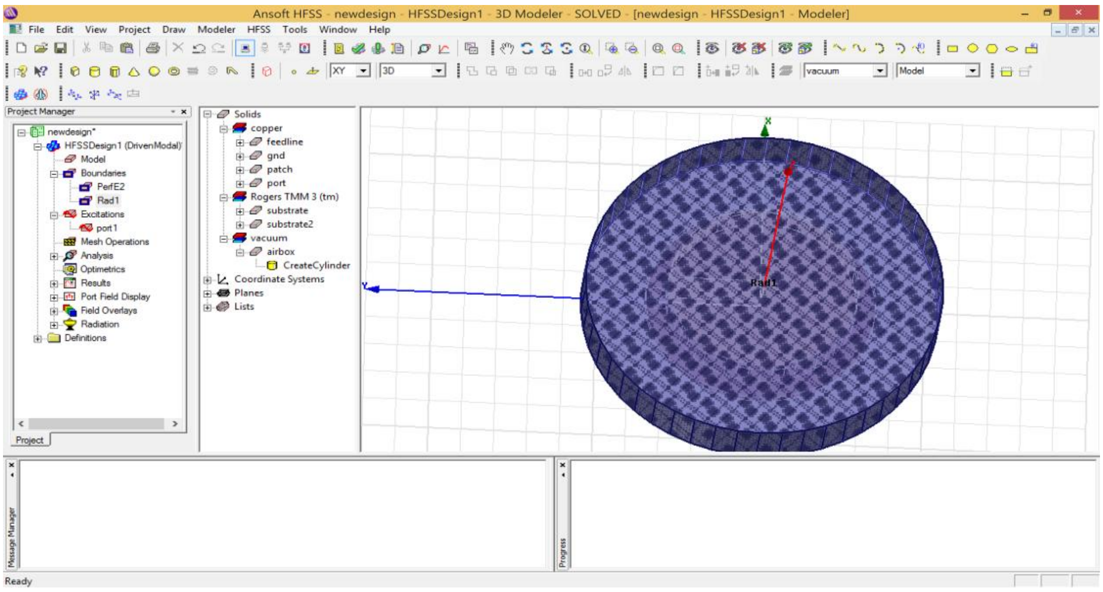


Figure 5.2 Radiation Given to Air Box

Lump port is is assigned at the free end of the microstrip feed. Perfect H boundary is present by default at the edges of lump port. The S-parameter are calculated at the lump port only. Figure 4.8 showing lump port assignment.

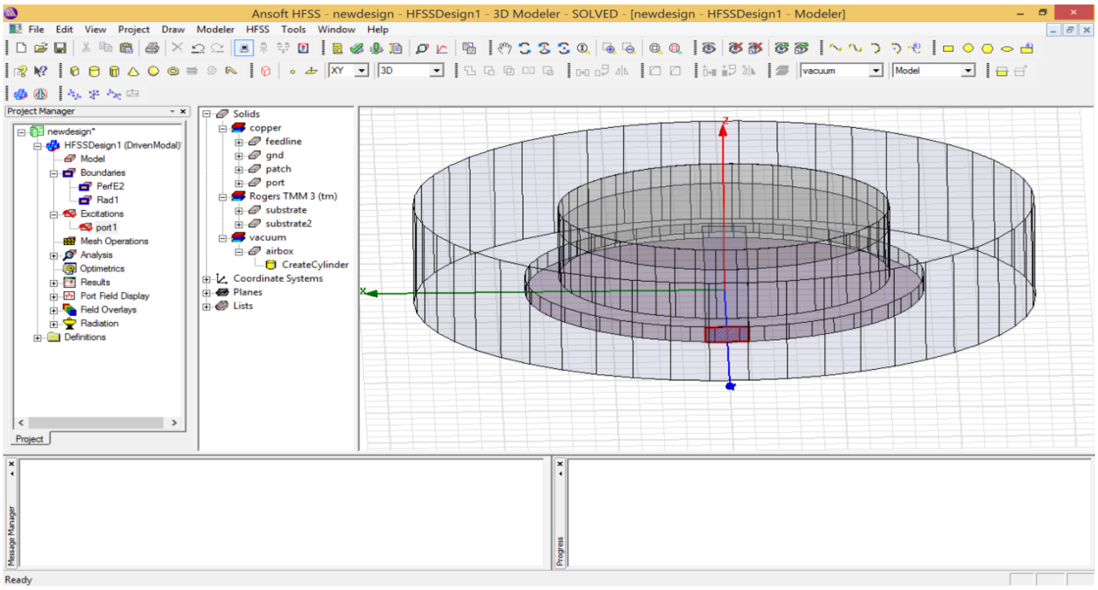


Figure 5.3 Lump Port Assignment

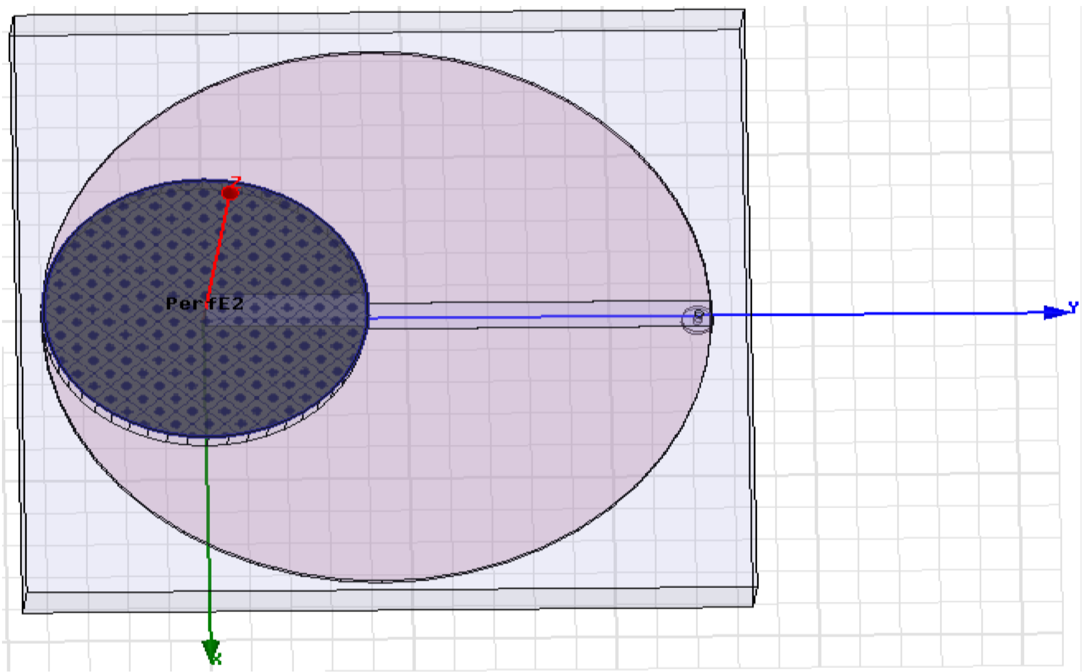


Figure 5.4 Perfect E

We provide the perfect electric field to the patch because it is required by patch for the emission of radiations. Perfect E results in the evenly distribution of the electric field along the whole surface of the patch.

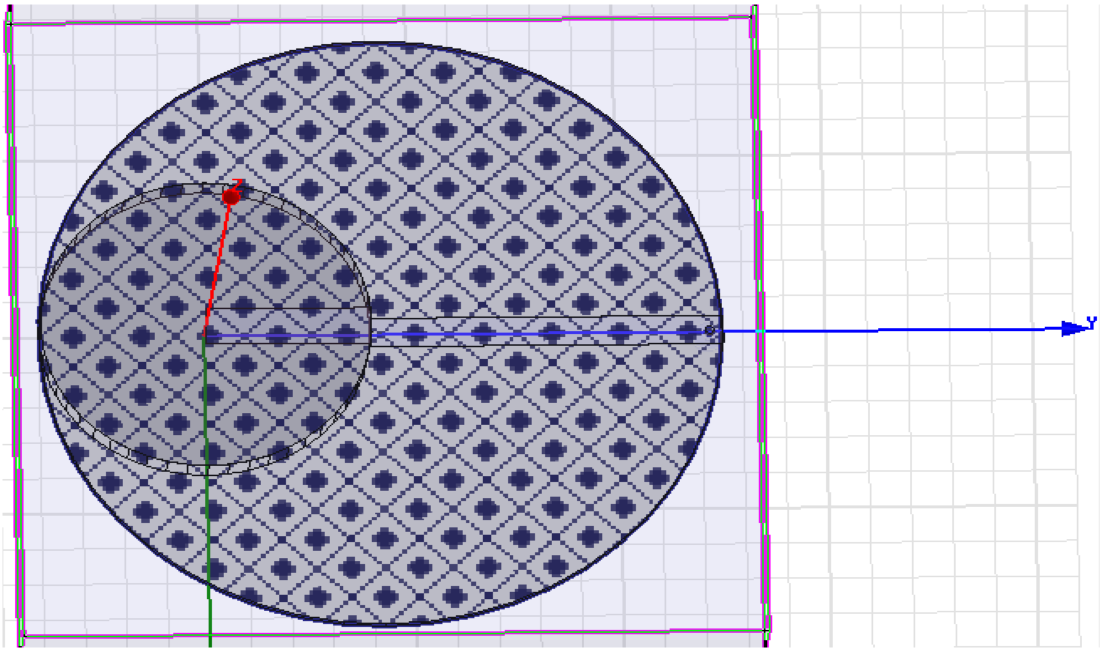


Figure 5.5 Perfect E Assignment to The Ground

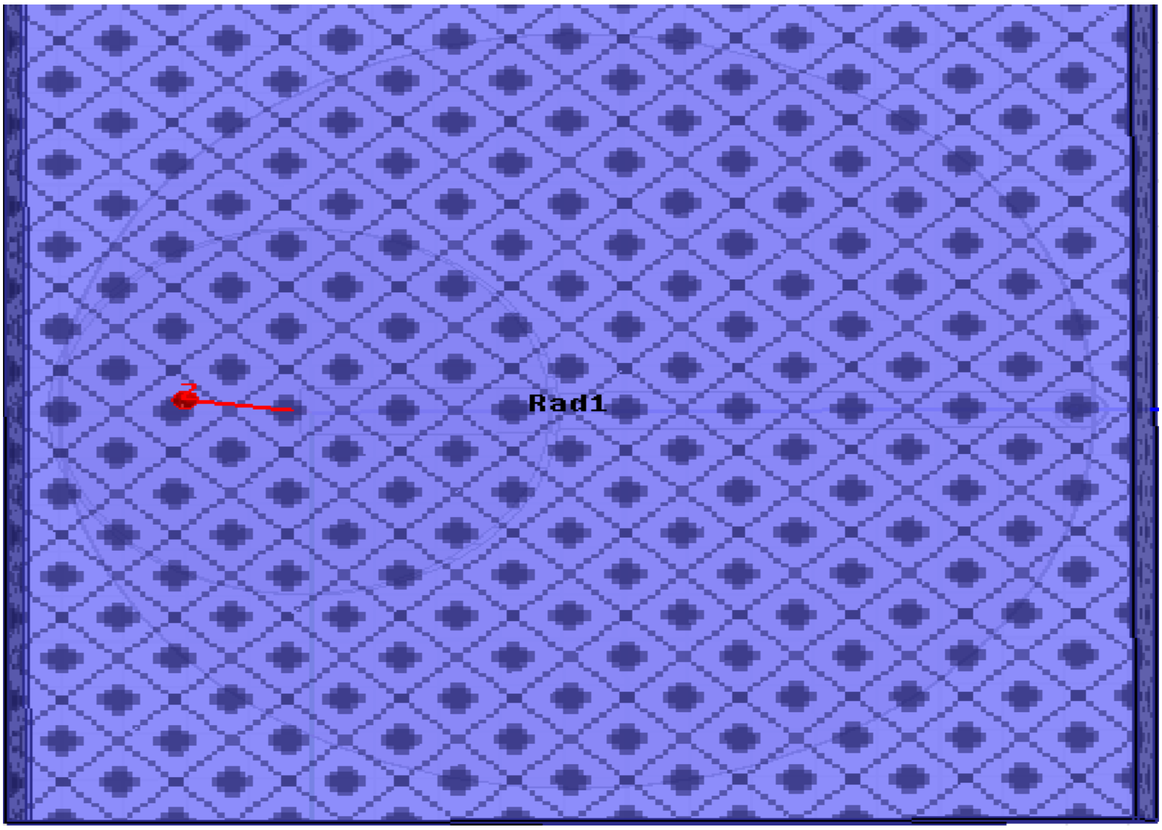


Figure 5.6 Radiation Given to the Airbox

Same boundary conditions are provided for all the circular micro strip patch antenna with L-inverted stubs designed for WLAN applications..

5.2 SIMULATED RESULTS OF CIRCULAR MICRO STRIP PATCH ANTENNA FOR SATELLITE COMMUNICATION

5.2.1 SCATTERING PARAMETER

In linear electrical networks scattering parameter is used to describe their electrical behavior. We use the S-parameters for the electronic circuits working at high frequencies mainly at radio frequency. S11 parameter defines the total reflection coefficient of voltage at the input end. Figure 4.9 shows the simulated S-parameter graph for the circular micro strip patch antenna.

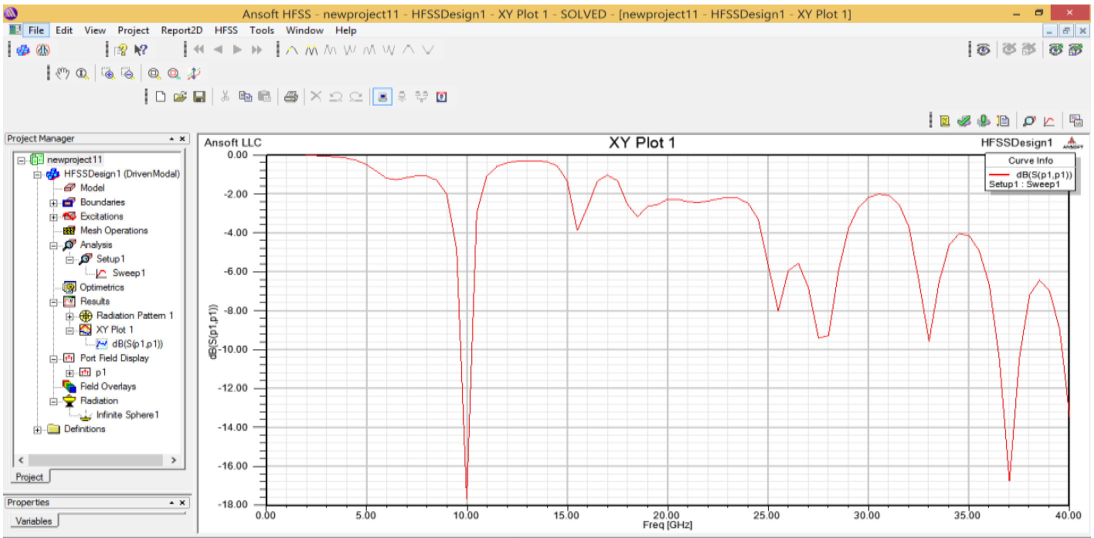


Figure 5.7 S-Parameter

5.2.2 VOLTAGE STANDING WAVE RATIO

For the micro strip lines the optimum value of VSWR is less than two decibels to transmit the radiations effectively.

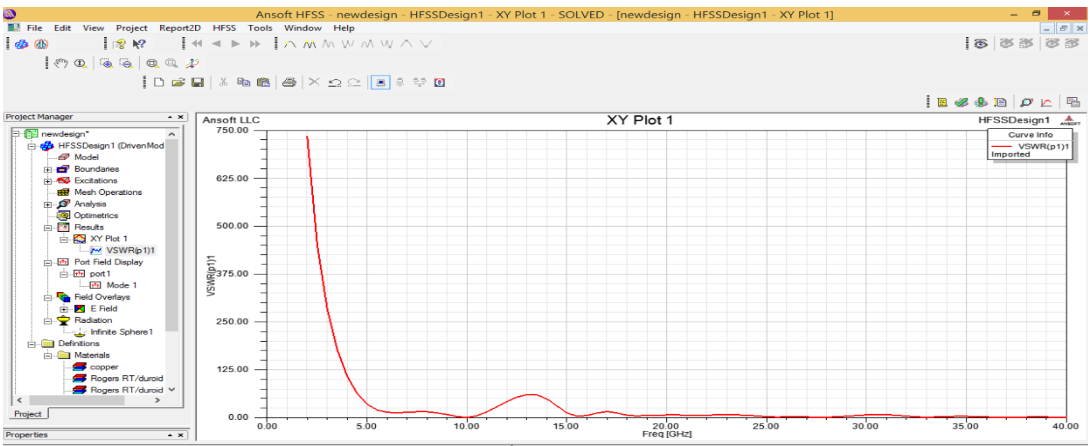


Figure 5.8 Voltage Standing Wave Ratio

Radiation pattern gives us the information about the configuration of the radiation in the far filed region. It is in the spatial far filed region that the radiations takes some particular shape with respect to the antenna position.

5.2.3 RADIATION PATTERN

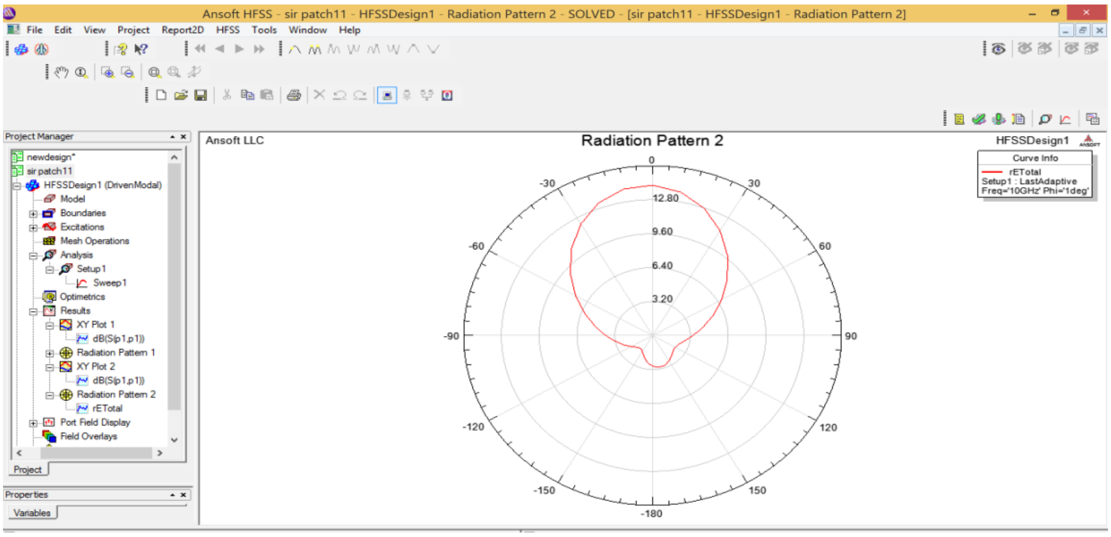


Figure 5.9 Radiation Pattern

5.2.4 GAIN

The energy radiated by an Omni directional antenna when compared to the energy radiated by an local antenna in a particular direction gives the value of gain. Thus by gain we can measure the directivity of the antenna that is how efficiently the radiations are transmitted in an particular direction. Figure 4.12 gives us the graph for gain in dB.

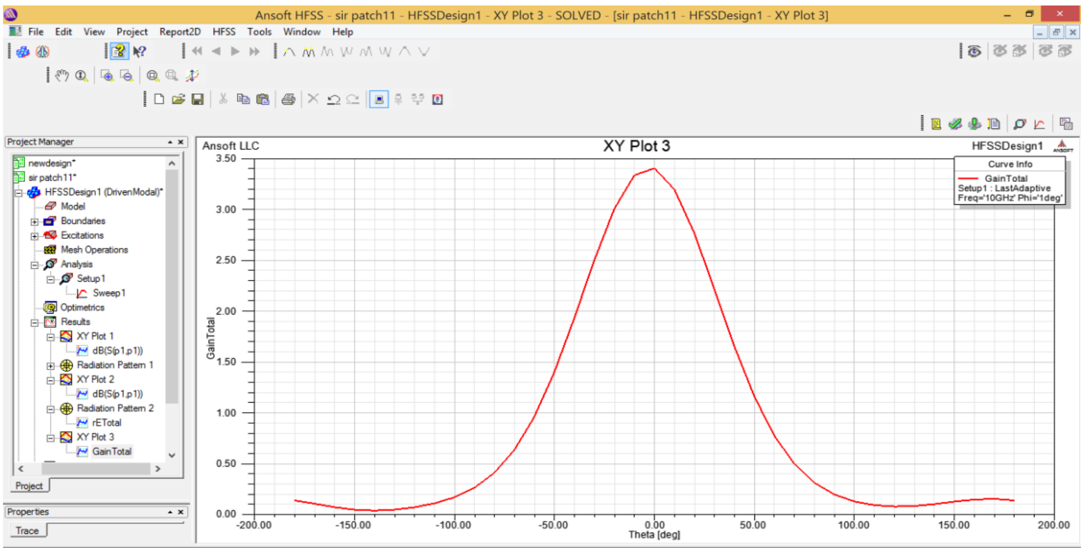


Figure 5.10 Gain of Circular Micro Strip Patch Antenna

5.3 SOLUTION AND SWEEP SET UP BOX

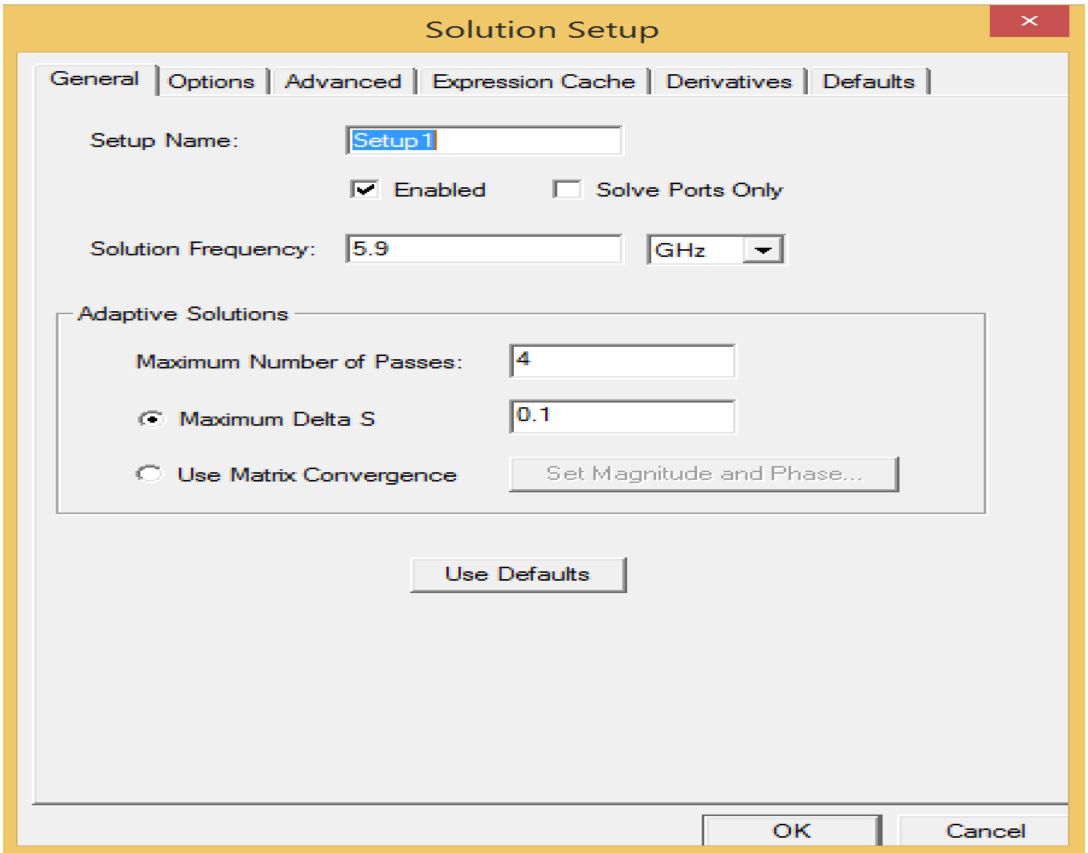


Figure 5.11 Solution Set up Box

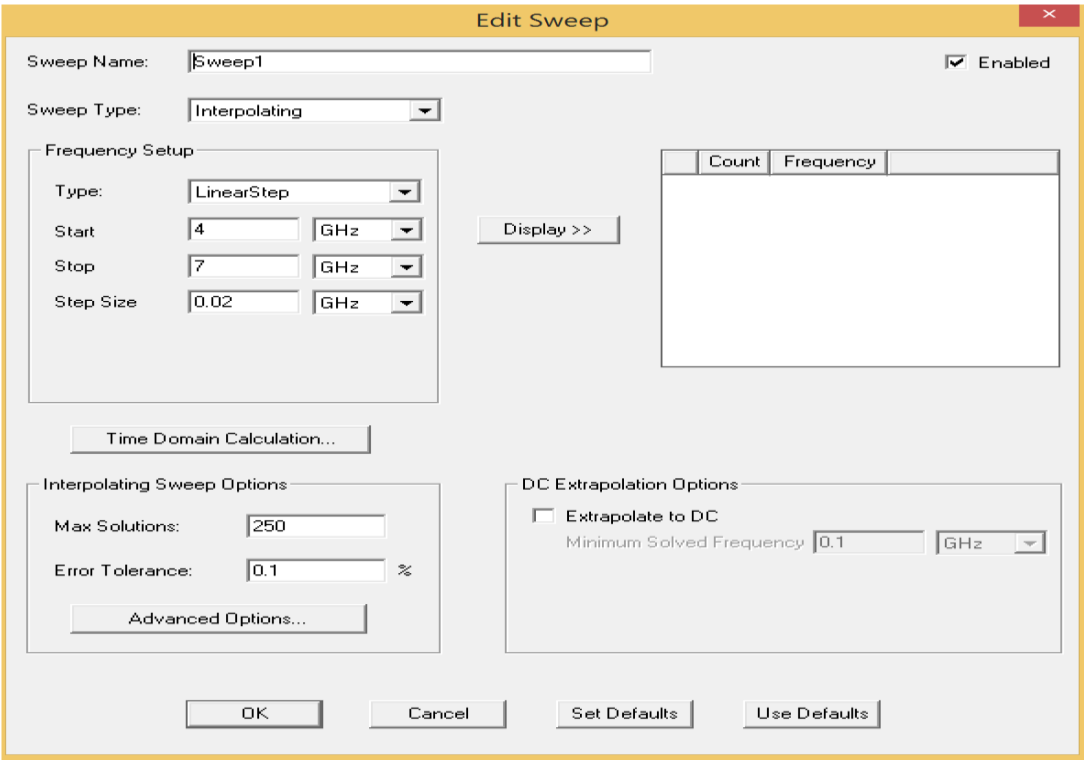


Figure 5.12 Sweep Set up Box

5.4 CIRCULAR PACTH ANTENNA FOR WLAN APPLICATION

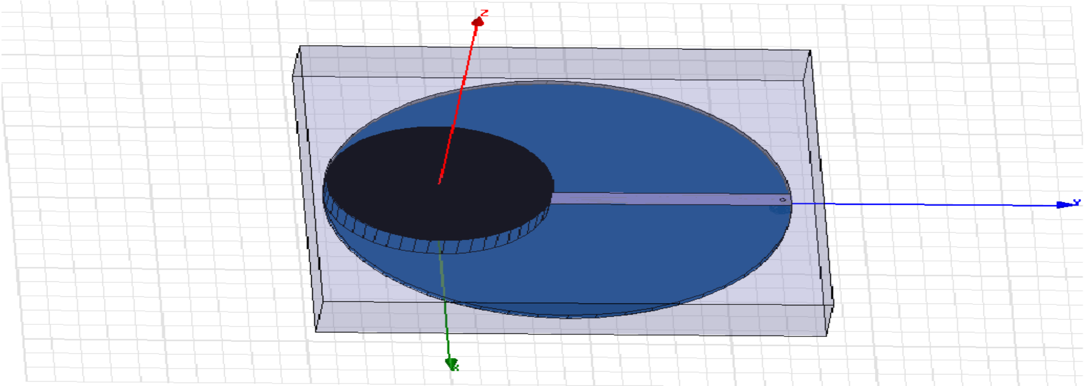


Figure 5.13 Circular Patch Antenna For WLAN Application

5.5 SIMULATED RESULTS

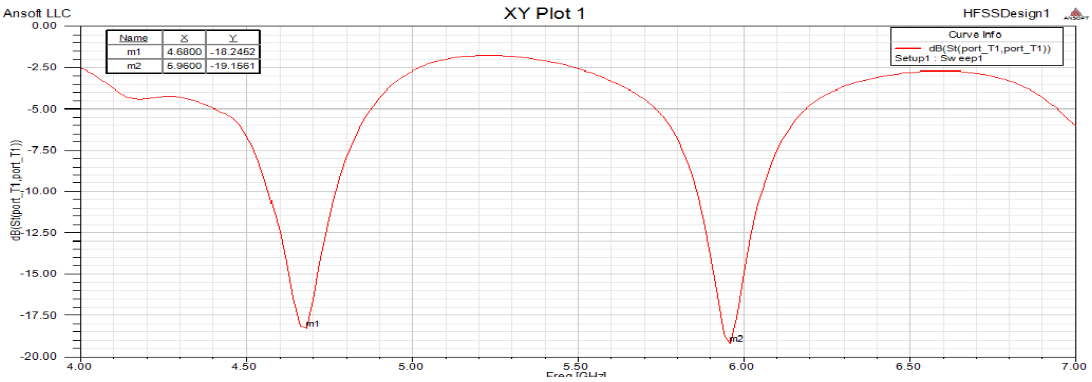
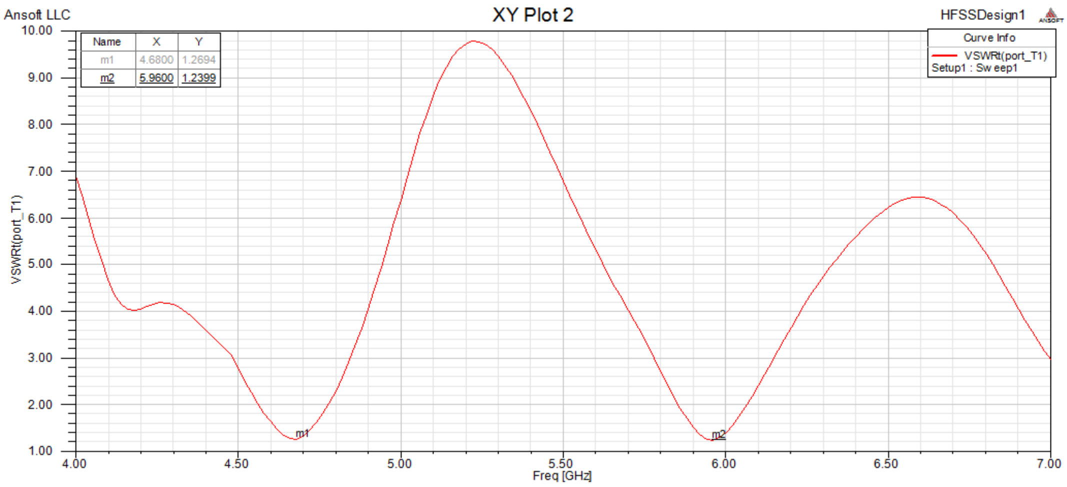


Figure 5.14 Scattering Parameter of Circular Patch Antenna



5.15 VSWR of Circular Microstrip Patch Antenna

The VSWR value tells us about how efficiently the designed antenna is radiating radiations efficiently into the space. Whenever there is mismatch in impedance between the source and load, there is formation of standing waves inside the structure of antenna.

So in that case the antenna works as a energy storing device rather than an energy radiating device. Here, the VSWR value for both the frequencies is less than two. In case of microstrip patch antennas it is desirable to get the value for voltage standing wave ratio less than two decibel. As the obtained value for our circular microstrip patch antenna is less than two so we can say that there is proper matching between the load and the source and our designed antenna is working properly for both the frequencies.

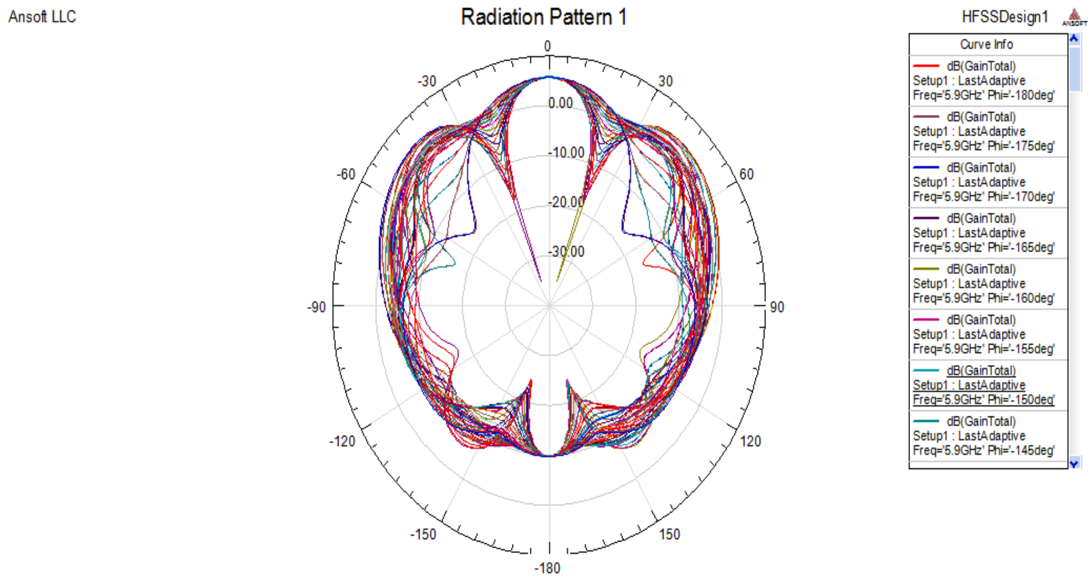
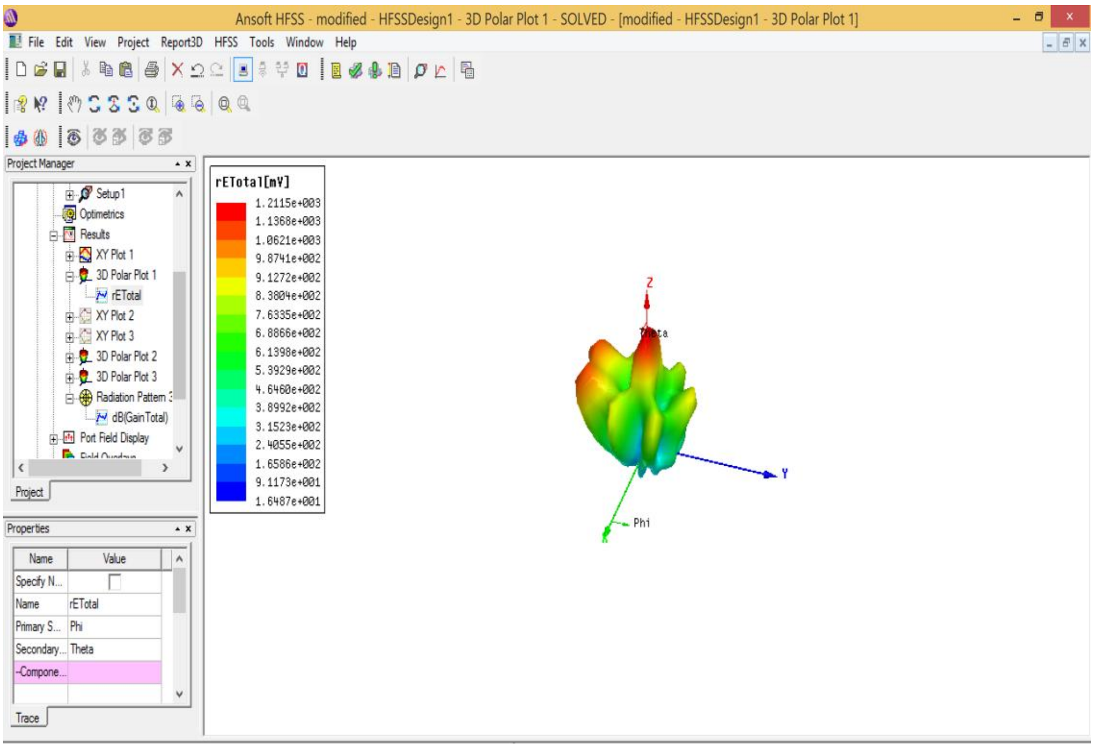


Figure 5.16 Radiation Pattern of Circular Patch Antenna



5.17 3-D Simulated Result for Radiation Pattern

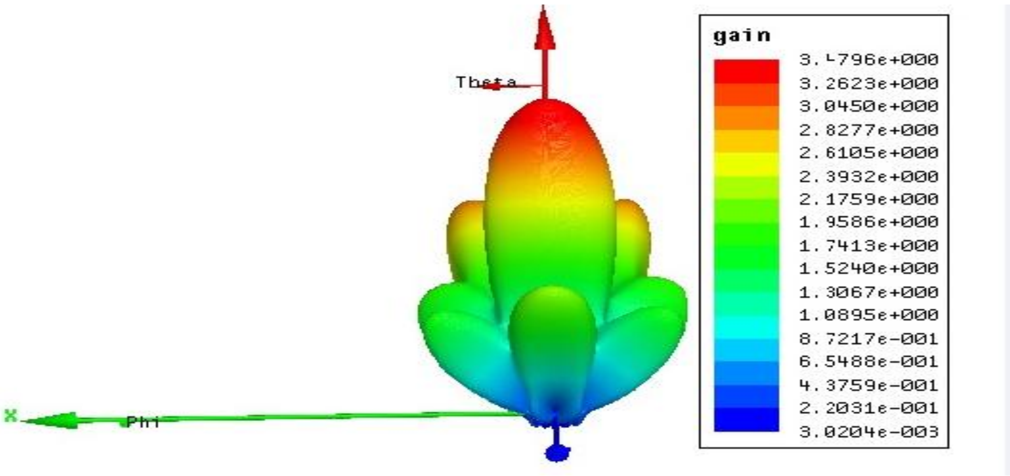


Figure 5.18 Gain for Circular Microstrip Patch Antenna

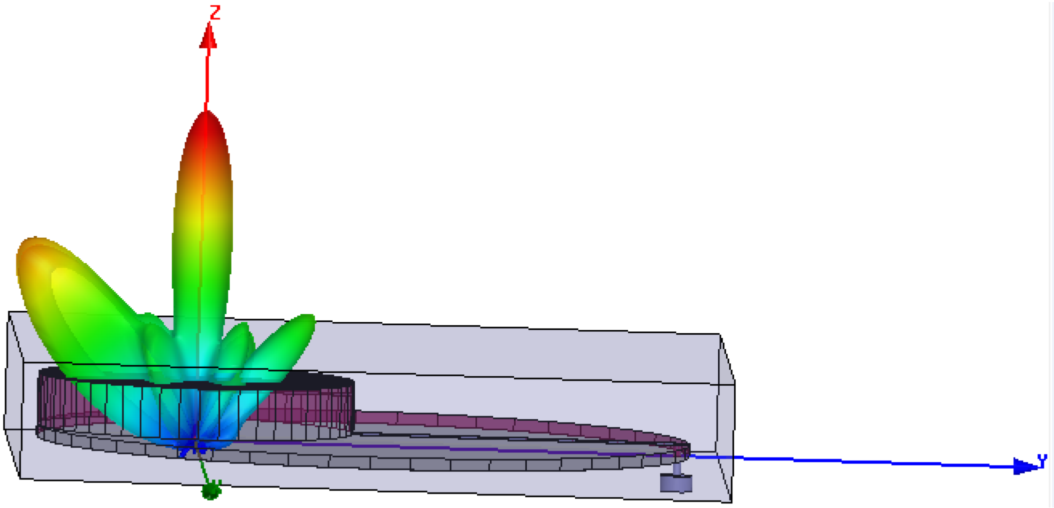


Figure 5.19 Directivity of Radiated Radiations

5.6 SIMULATED RESULTS WITH L-INVERTED STUBS

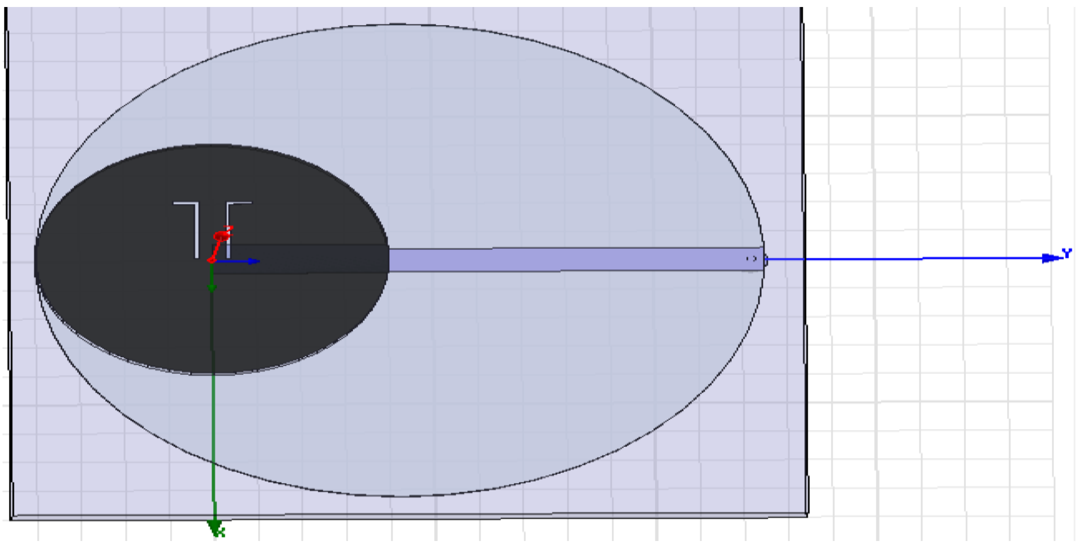


Figure 5.20 Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

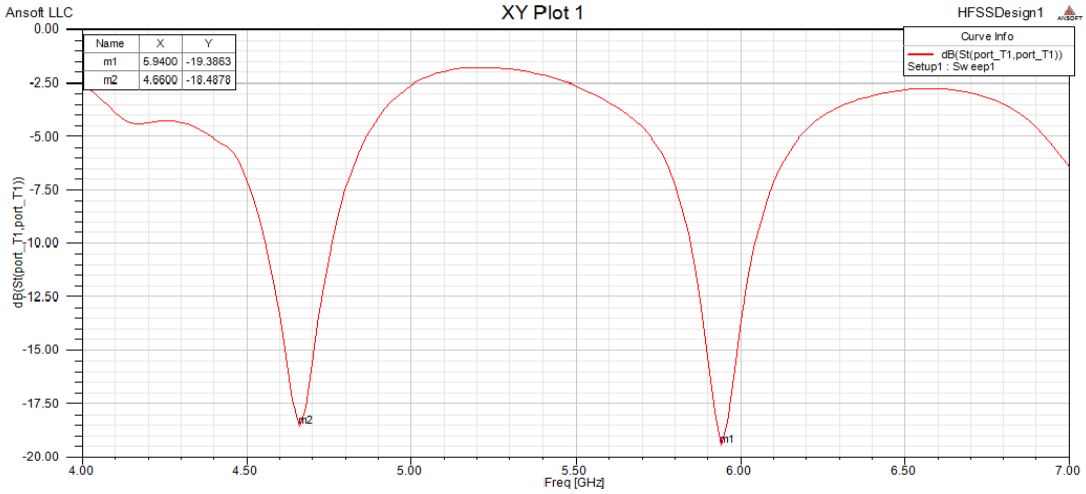


Figure 5.21 S Parameter of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

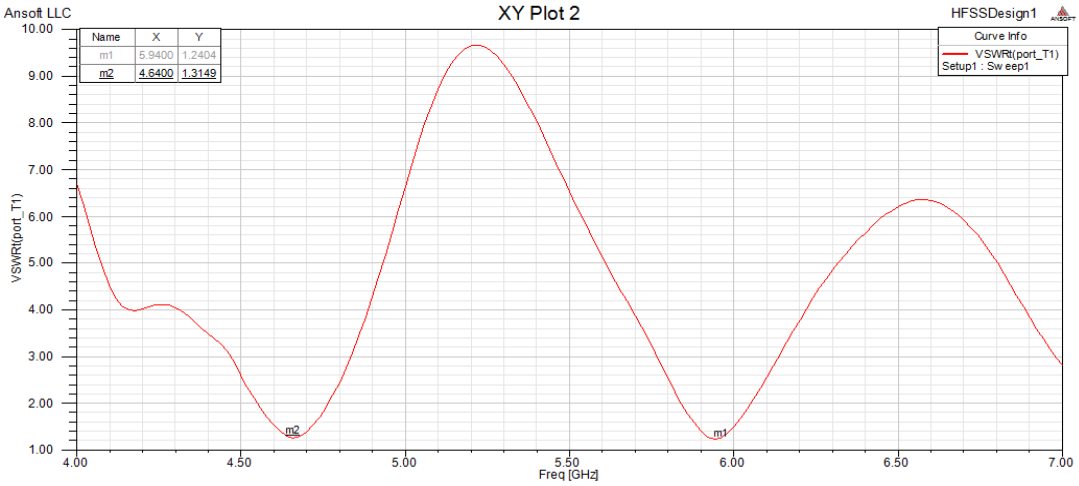


Figure 5.22 VSWR of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

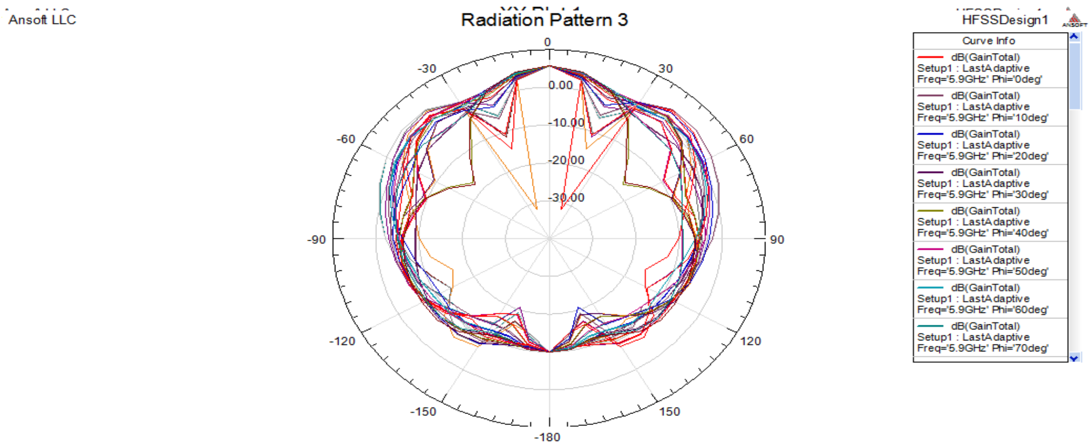


Figure 5.23 Radiation Pattern of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

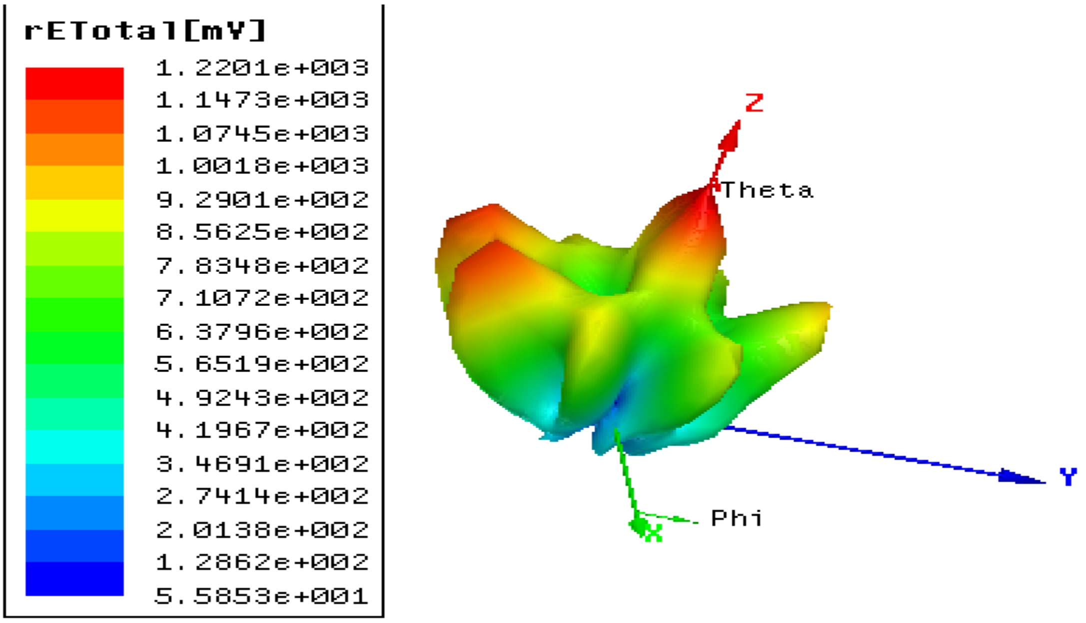


Figure 5.24 3-D Simulated Result of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

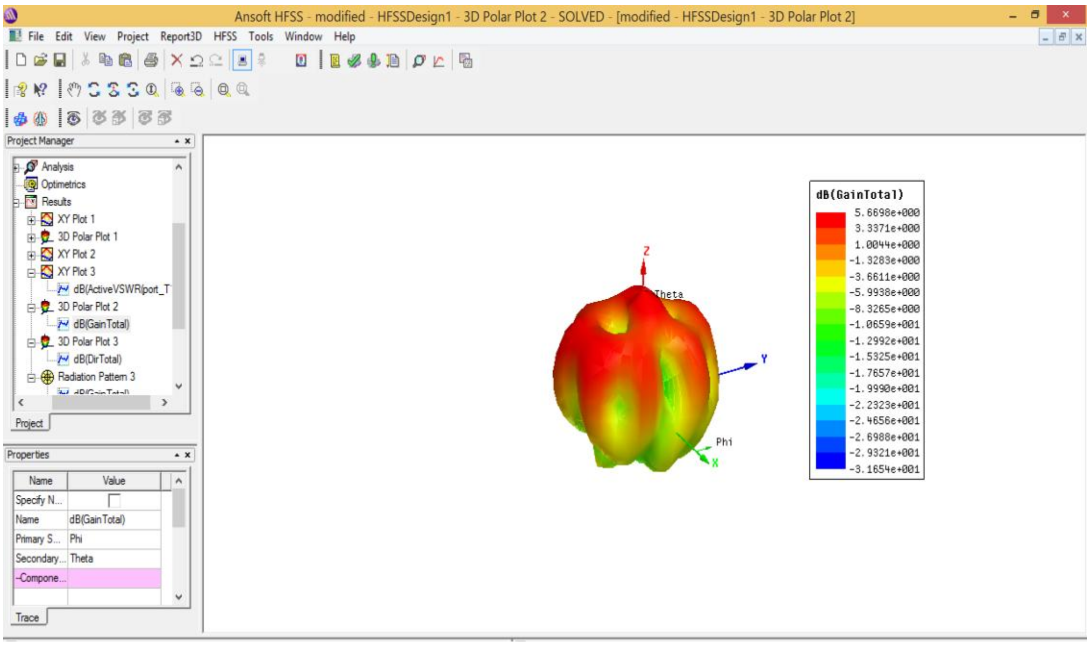


Figure 5.25 Gain of Circular Microstrip Patch Antenna With Dual L-Inverted Stub of Equal Dimensions

We have introduced the L-shaped stubs in the circular microstrip patch antenna for the impedance matching. We can see clearly the effect of stubs in the results for voltage standing wave ratio and the gain of the antenna. By the introduction of the stubs the voltage standing wave ratio value have decreased in large extent for both the operating frequencies. Also, there is increment of gain of the circular microstrip patch antenna by the introduction of the stubs

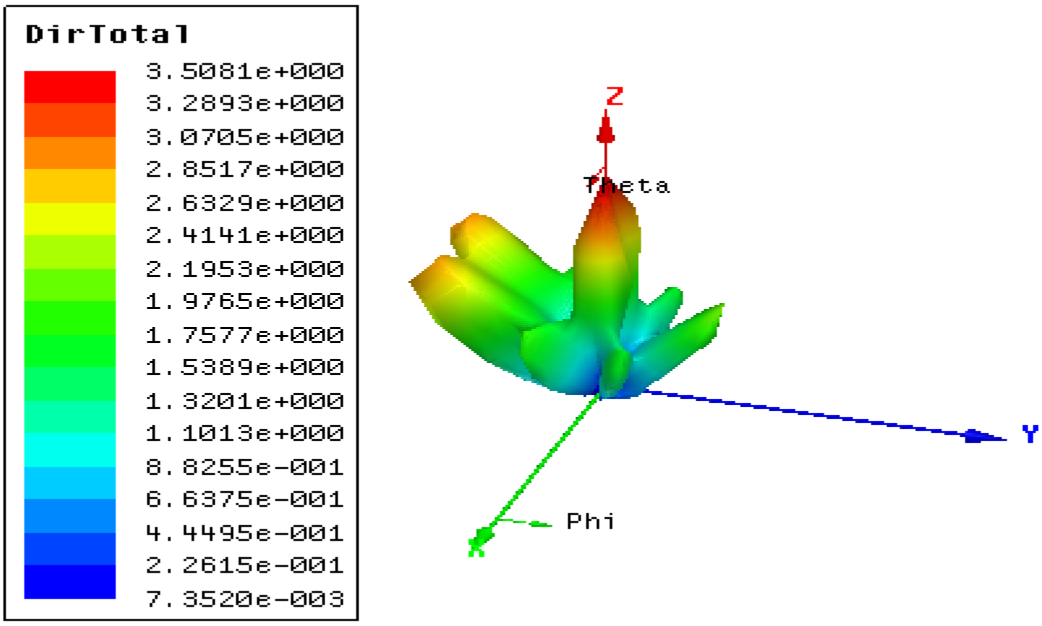


Figure 5.26 Directivity of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

By the insertion of L-shaped stubs there is increment in directivity of the circular microstrip patch antenna

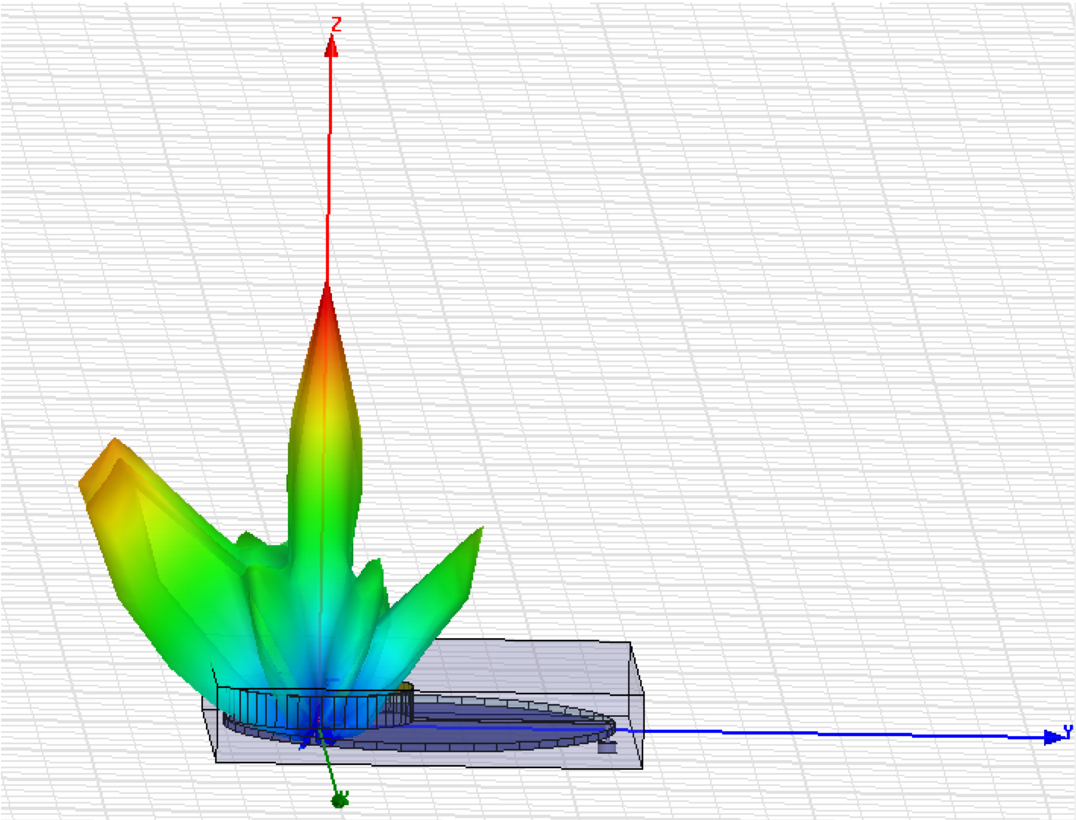


Figure 5.27 Direction of Radiated Field of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Equal Dimensions

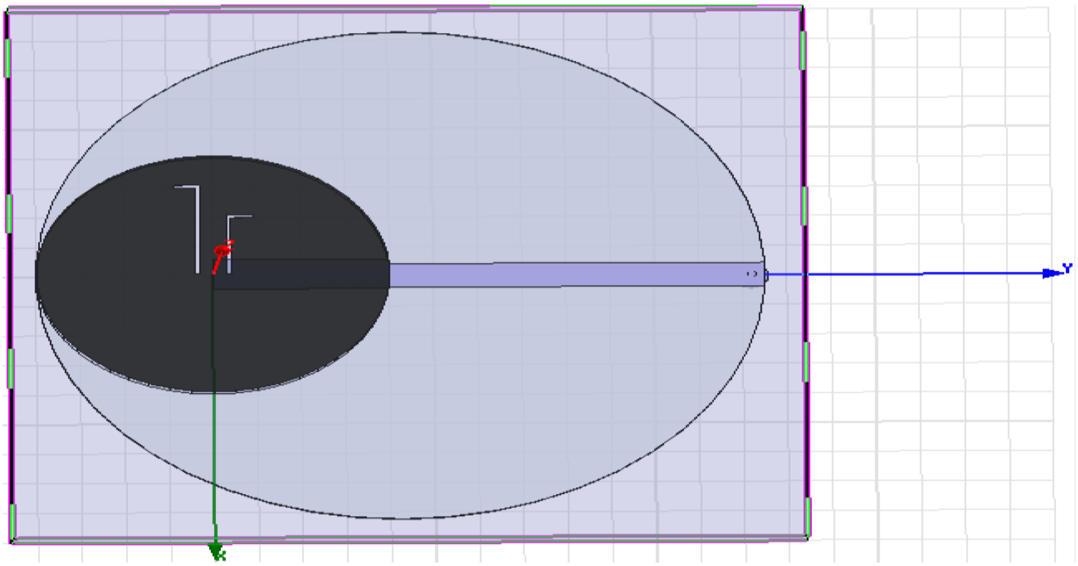


Figure 5.28 Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

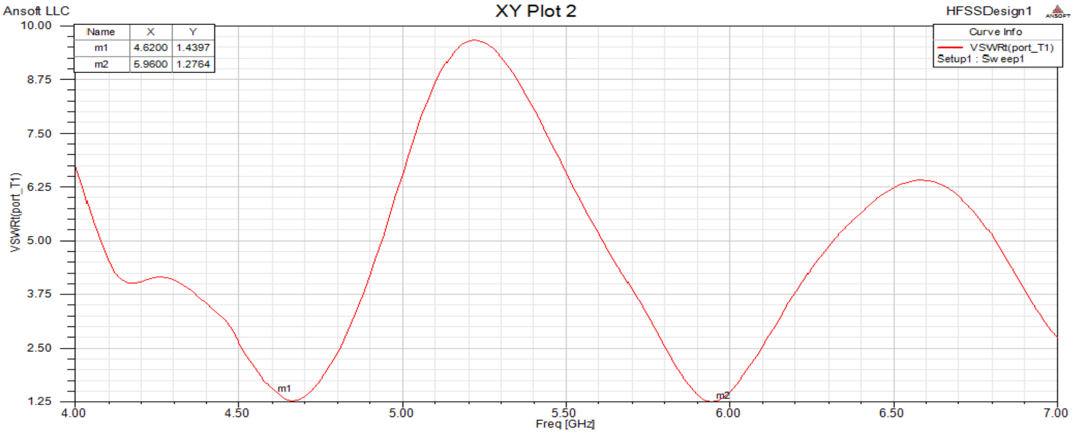


Figure 5.29 VSWR of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

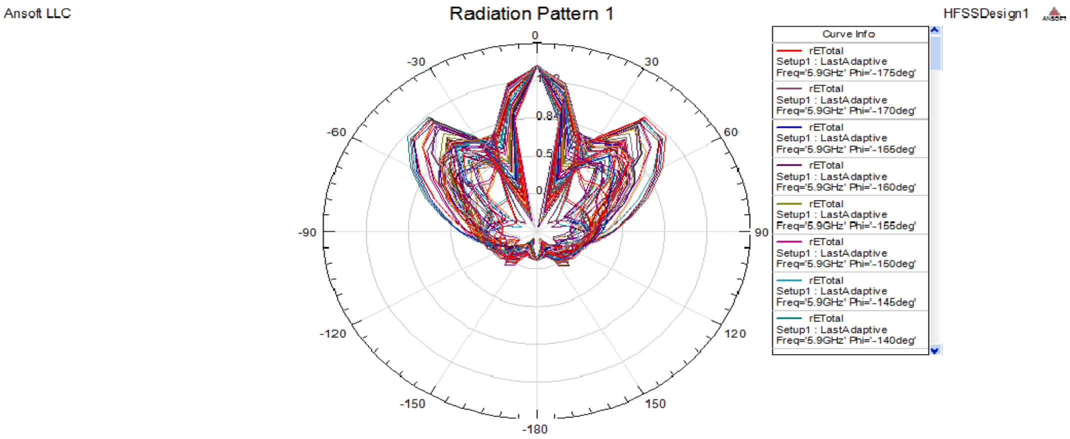


Figure 5.30 Radiation Pattern of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

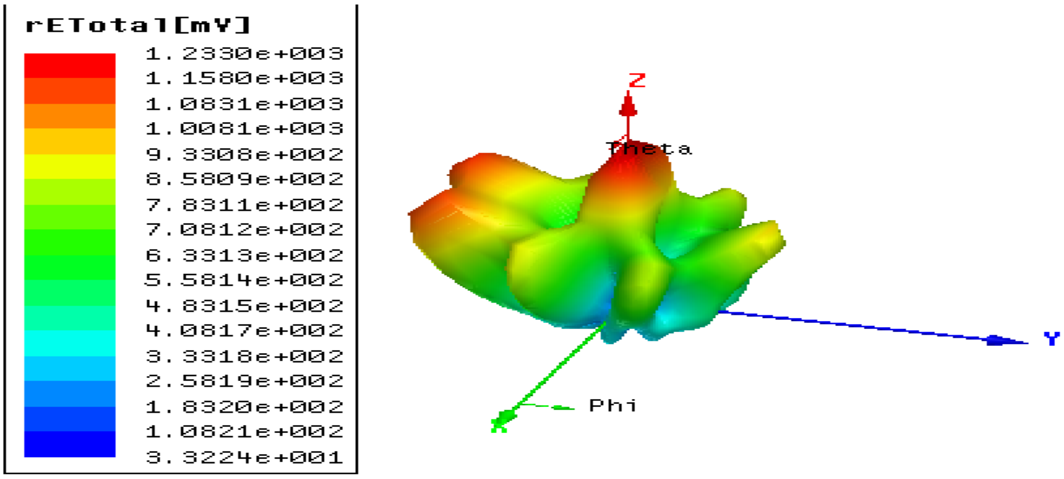


Figure 5.31 3-D Radiation Pattern for Dual L-Inverted Stubs of Unequal Dimensions

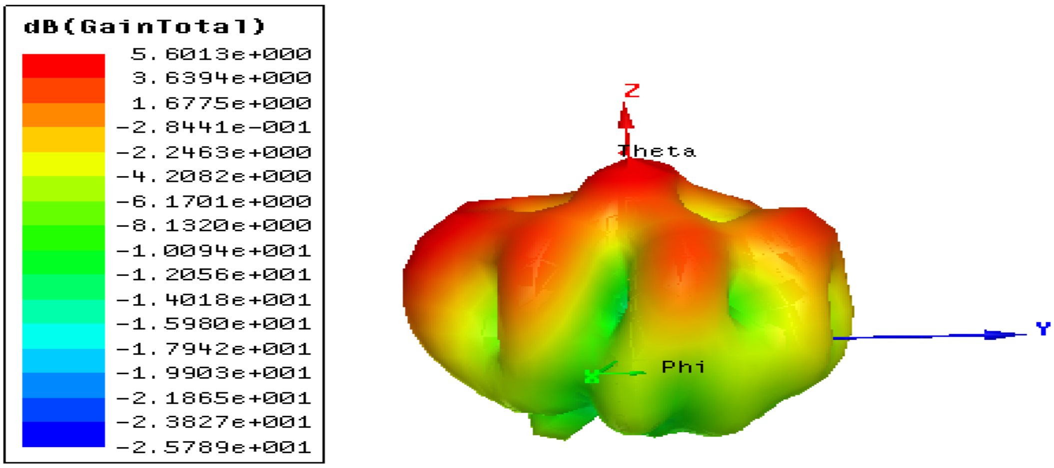


Figure 5.32 Gain of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

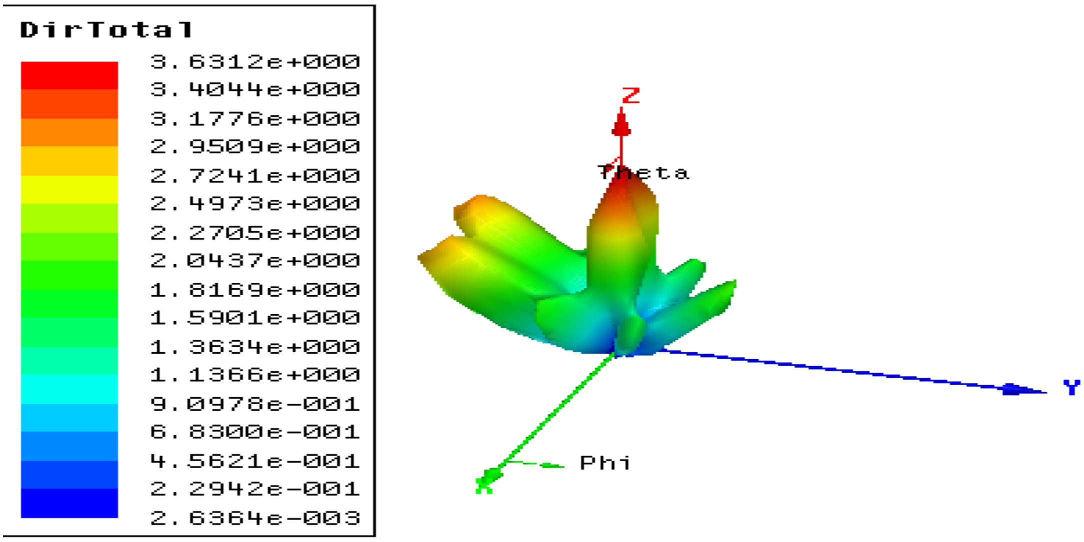


Figure 5.33 Directivity of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

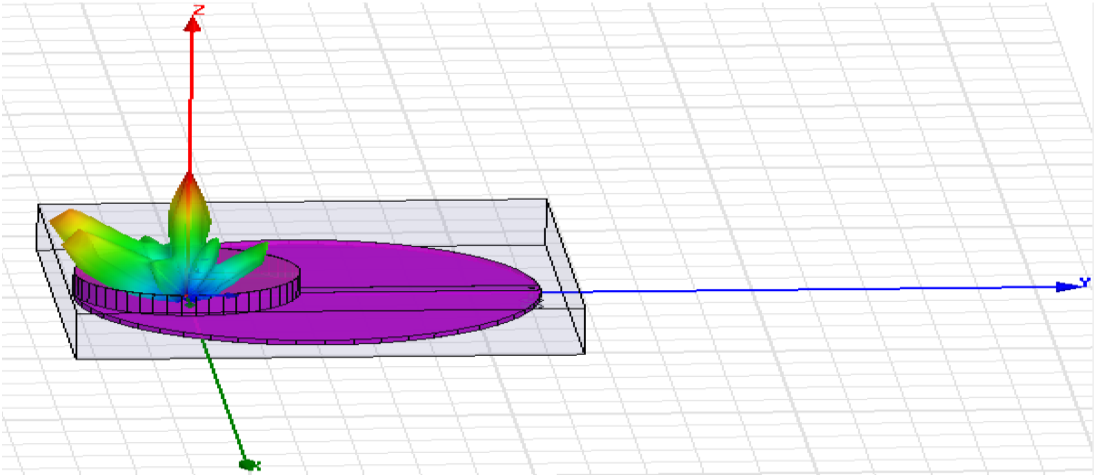


Figure 5.34 Direction of Radiated Field of Circular Microstrip Patch Antenna With Dual L-Inverted Stubs of Unequal Dimensions

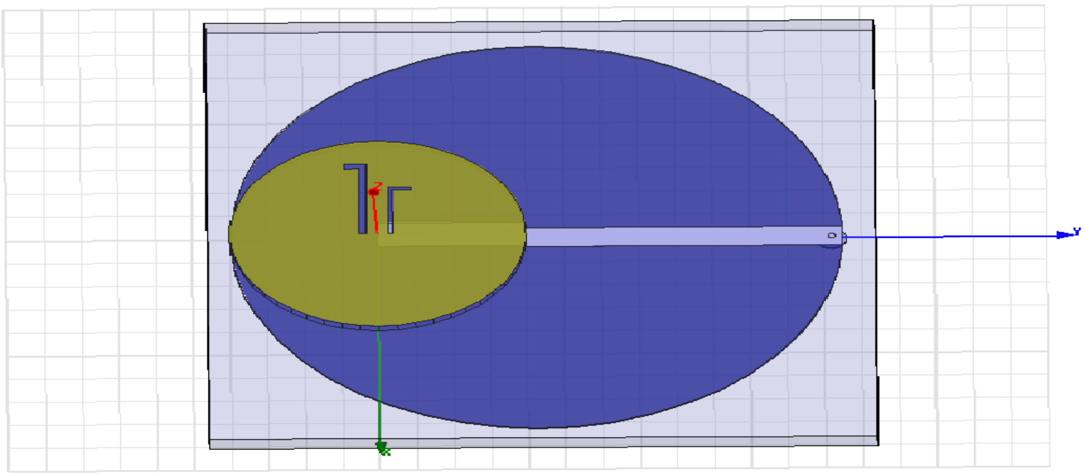


Figure 5.35 Circular Microstrip Patch Antenna With Variable Width and Length of Dual L-Inverted Stubs

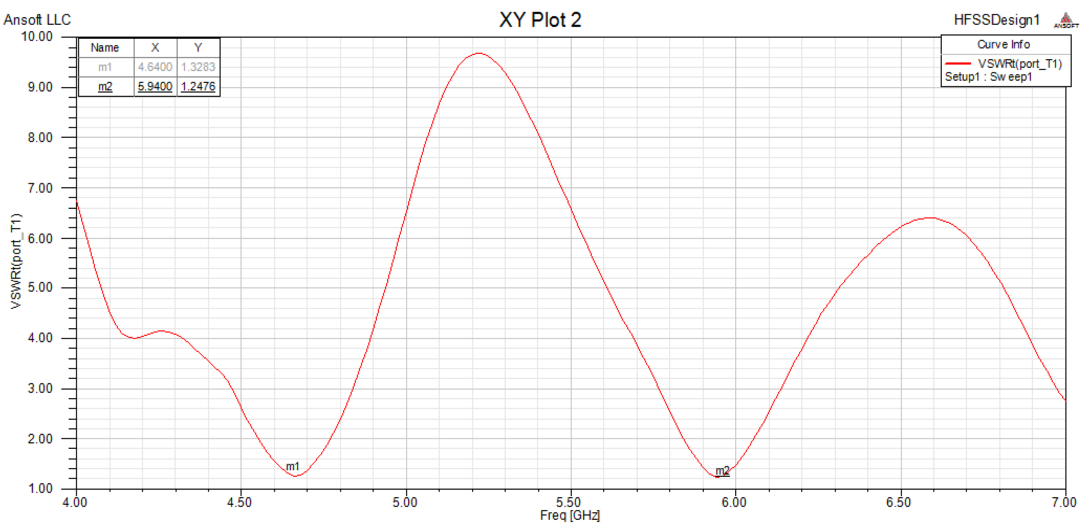


Figure 5.36 VSWR for Variable Width of Dual L-Inverted Stub

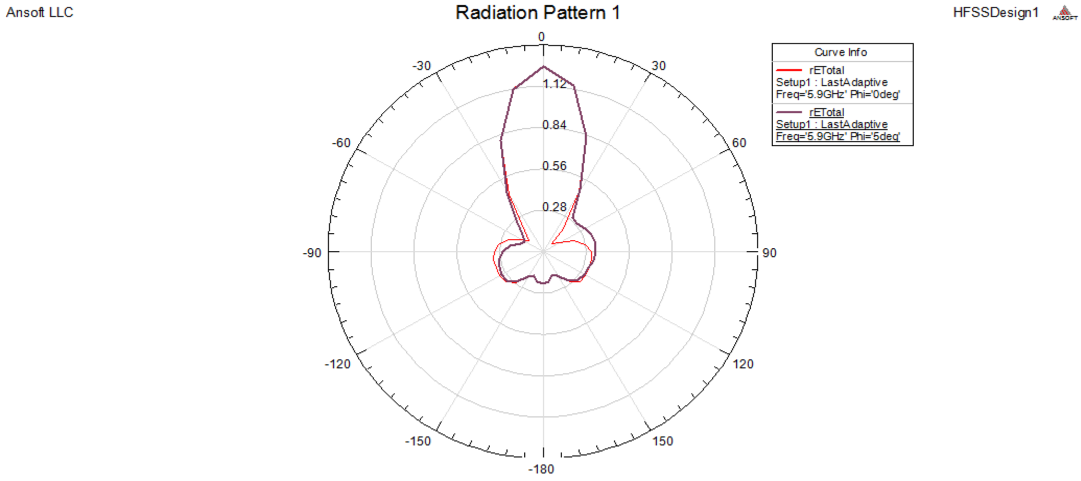


Figure 5.37 Radiation Pattern for Variable Width of Dual L-Inverted Stubs

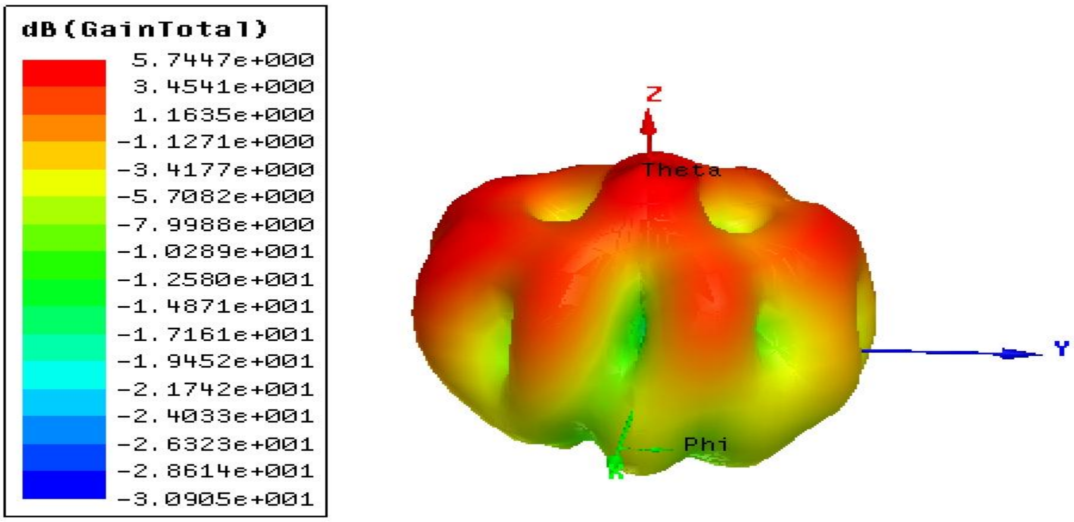


Figure 5.38 Gain of Circular Microstrip Patch Antenna With Variable Width of Dual L-Inverted Stub

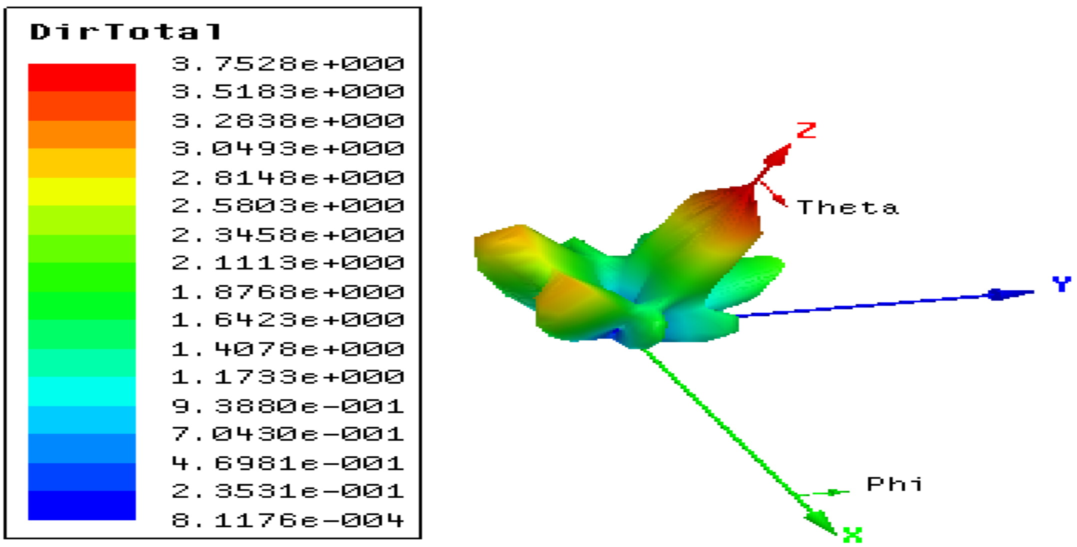


Figure 5.39 Directivity for Variable Width of Dual L-Inverted Stub

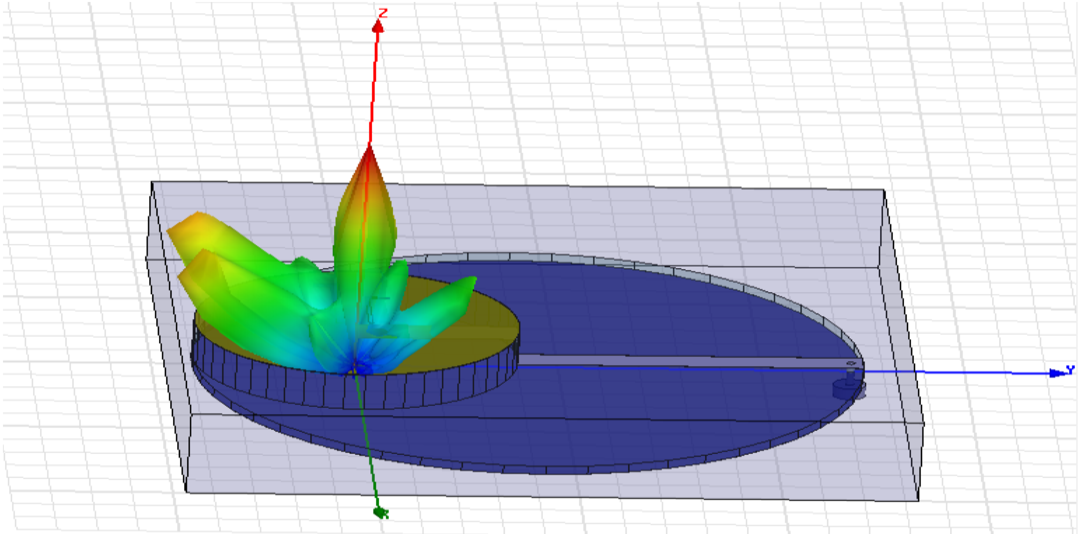


Figure 5.40 Direction of Radiated Radiations for Variable Width of Dual L-Inverted Stub

5.7 RESULTS EVALUATION

ANTENNATYPE	VSWR(f_1) (DB)	VSWR(f_2)	GAIN	DIRECTIVITY	BW (GHz)
CIRCULAR	1.2399	1.2694	3.7103	1.2115e+003	2.576
WITH EQUAL STUBS	1.2404	1.3149	5.6698	3.5081	2.5747
WITH UNEQUAL STUBS	1.2764	1.4397	5.6013	3.6312	1.5016
WITH UNEQUAL STUBS, ONE STUB HAVING LARGE WIDTH	1.2276	1.2283	5.7447	3.7528	2.5856

Table 5.1 Evaluated Results For Circular Microstrip Patch Antenna With Different Configuratuons

From the above table we can conclude that the gain and directivity is high for the circular microstrip patch antenna with unequal stubs in which the left ahnd stub is having larger length as well as the larger width as compared to the right hand side stub. The low value of the voltage standing wave ratio is also obtained in this case. So, there is proper impedance matching between the source and load because of the insertion of the stubs. Also, the bandwidth value is large in this case as compared to other cases. Here, we can conclude that, the stubs of unequal dimensions can result in better impedance matching as compared to the inserted stubs of same dimensions. Here, we have two cases in which we have used stubs of unequal dimensions and in both the cases the simulated results are better than that of the simulated results of equal dimensions stub as well as compared to the circular microstrip patch antenna having no stubs.

5.8 CONCLUSION

In this thesis, the dissertation-I work was based on the designing of the circular microstrip patch antenna for the satellite communication. The circular microstrip patch antenna is modified on the basis of cavity model and in terms of dimensions to make it operational for dual WLAN frequencies. As, 5.9GHz frequency is newly included in WLAN frequency band and lot of work is going on in designing those antennas which can be operational on this frequency. Thus our designed antenna is working properly on this newly introduced WLAN frequency along with another frequency. Further, as in case of circular microstrip patch antenna the impedance matching problem between the source and load persists, so we have introduced dual L-inverted stubs for proper impedance matching. Different configurations of stubs are introduced and their results are simulated. We can see the change in the antenna parameters by changing the position and dimensions of the stubs on the surface of patch. With the introduction of stubs there is significant increment of gain, directivity. and radiated radiations. But most importantly, the voltage standing wave ratio value should be improved with the use of stubs and clearly there is significant improvement in the value of voltage standing wave ratio in circular micro strip patch antenna with stubs as compared to the antenna having no stubs. Also, the gain of the antenna with stubs is large as compared to antenna having no stubs.

5.9 FUTURE SCOPE

As the work on circular microstrip patch antenna with dual L-inverted stubs is already studied in this thesis work and the simulated results with different configurations of L-inverted stubs are compared in terms of gain, bandwidth, voltage standing wave ratio and directivity. Further, more work can be done with the introduction of stubs and slots and see whether there is change in the values in the parameters of the antenna which we have studied. Also, with the increase in the height of the substrate we can increase the bandwidth of the operating frequency. In future, different designing techniques can be adopted for designing purpose.

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