*A Term Paper Report on*

# DESIGN OF COMPACT UWB ANTENNA WITH DEFECTED GROUND STRUCTURE USING HFSS

**Submitted in partial fulfillment of**

**the requirement for the award of the degree of**

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**in**

**Electronics and Communication Engineering**

**Under the guidance of**

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**Department of Electronics and Communication Engineering**

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## CERTIFICATE

This is to certify that the term paper entitled **"DESIGN OF COMPACT UWB ANTENNA WITH DEFECTED GROUND STRUCTURE USING HFSS"** is the bonafide work of G.VISHNU SRIVARDHAN (Y17AEC455),D.AKHIL KUMAR (Y17AEC443),CH.MOHITH SRI MITHRA (Y17AEC434),G.RAMA KRISHNA (Y17AEC453),CH.RAJESH VARMA (Y17AEC426) submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology **(B.Tech)** in Electronics and Communication Engineering **(ECE)** by Acharya Nagarjuna University during the academic year 2020-2021.

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# CONTENTS

# ABSTRACT

Microstrip Patch antennas belongs to class of printed antennas having a wide range of beneficial properties including mechanical durability, compactness and cheap manufacturing cost. They have wide ranges of applications in both military and commercial sectors.

In this a Compact UWB antenna with Defected Ground Structure is designed at a range of ultra wide band. The substrate FR4_epoxy is used for designing the proposed antenna with dielectric constant of 4.4 and height of the substrate is 1.6mm. The UWB antenna is simulated by using high frequency structured simulator. The maximum size of antenna is 30x29 mm. The designed antenna resonates at 4.0 and 8.9 GHz with a bandwidth of 3.3 to 10.8GHz, the return loss is -20dB and -43dB respectively and the VSWR is 1.8 and 1.6 for the two resonant frequencies. The proposed antenna is operated for Wireless communication, radar and imaging applications.

# CHAPTER-1

# INTRODUCTION

## 1.1 NEED FOR ANTENNA:

A person, who needs to convey a thought, an idea or a doubt, can do so by voice communication. Generally, if two individuals communicating with each other. Communication takes place through [1] sound waves. However, if two people want to communicate who are at longer distances, then we have to convert these sound waves into electromagnetic waves. The device, which converts the required information signal into electromagnetic waves, is known as an Antenna.

In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity [2] of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication [3], where you cannot expect to lay down a wiring system.

In order to contact a remote area, the wiring has to be laid down throughout [1] the whole route along the valleys, the mountains, the tedious paths, the tunnels etc., to reach the remote location. The evolution of wireless technology has made this whole process very simple. Antenna is the key element of this wireless technology, which gets the transmission as a whole done efficaciously.

## 1.2 WHAT IS AN ANTENNA:

An Antenna is a transducer, [7] which converts electrical power into electromagnetic waves and vice versa.

An Antenna can be used either as a transmitting antenna or a receiving antenna**.**

• A transmitting antenna is one, which converts electrical signals into electromagnetic waves and radiates them.

• A receiving antenna is one, which converts electromagnetic waves from the received beam into electrical signals.

• In two-way communication, the same antenna can be used for both transmission and reception.

Most antennas are resonant, i.e operate effectively under certain frequency bands.

## 1.3 Basic Types of Antennas

Antennas may be divided into various types depending upon:

• The physical structure of the antenna.

• The frequency ranges of operation.

• The mode of applications etc.

### 1.3.1 Physical structure

Following are the types of antennas according to the physical structure. You will learn about these antennas in later chapters.

• Wire antennas

• Aperture antennas

• Reflector antennas

• Lens antennas

• Micro strip antennas

• Array antennas

### 1.3.2 Frequency of operation

Following are the types of antennas according to the frequency of operation.

• Very Low Frequency (VLF)

• Low Frequency (LF)

• Medium Frequency (MF)

• High Frequency (HF)

• Very High Frequency (VHF)

• Ultra High Frequency (UHF)

• Super High Frequency (SHF)

• Micro wave

• Radio wave

### 1.3.3 Mode of Applications

Following are the types of antennas according to the modes of applications-

• Point-to-point communications

• Broadcasting applications

• Radar communications

• Satellite communications

The basic communication parameters are discussed here to have a better idea about the wireless communication using antennas. The wireless communication [6] is done in the form of waves. Hence, we need to have a look at the properties of waves in the communications.

## 1.4 RADIATION MECHANISM:

• The sole functionality of an antenna is power trans-reception.

• Antenna (whether it transmits or receives or does both) can be connected to the circuitry at the station through a transmission line.

• A conductor, which is designed to carry current over large distances with minimum losses, is termed as a transmission line.

• A transmission line conducting current with uniform velocity, and the line being a straight one with infinite extent, radiates no power.

• For a transmission line, to become a waveguide or to radiate power, has to be processed as such

1. If the power has to be radiated, though the current conduction is with uniform velocity, the wire or transmission line should be bent, truncated or terminated.

2. If this transmission line has current, which accelerates or decelerates with a time-varying constant, then it radiates the power even though the wire is straight.

3. The device or tube, if bent or terminated to radiate energy, then it is called as waveguide. These are especially used for the microwave transmission or reception.

This can be well understood by observing the following diagram –

The below diagram represents a waveguide, which acts as an antenna. The power from the transmission line travels through the waveguide[7] which has an aperture, to radiate the energy.

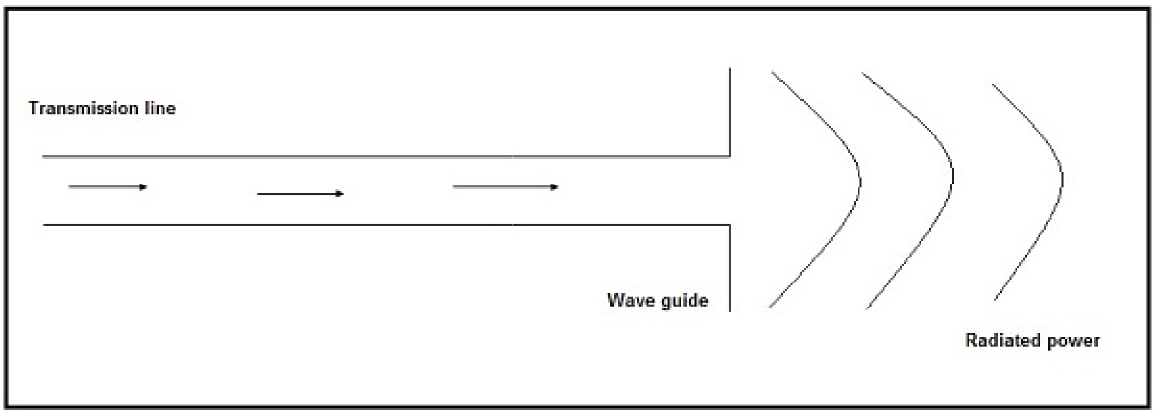



**Figure 1.2 radiation mechanism representation**

# CHAPTER-2

# ANTENNA PARAMETERS

Here, we are going to discuss about the following parameters-

• Frequency

• Wavelength

• Impedance matching

• VSWR & reflected power

• Bandwidth

• Percentage bandwidth

• Radiation intensity

## 2.1 Frequency:

The rate of repetition of a wave over a particular period of time, is called as frequency.

Simply, frequency refers to the process of how often an event occurs.

Mathematically it is represented as:

$$F=1/T \quad \text{------------} \; (1)$$

Where

• f is the frequency of periodic wave.

• T is the time period at which the wave repeats.

The unit of frequency is Hertz, abbreviated as Hz.

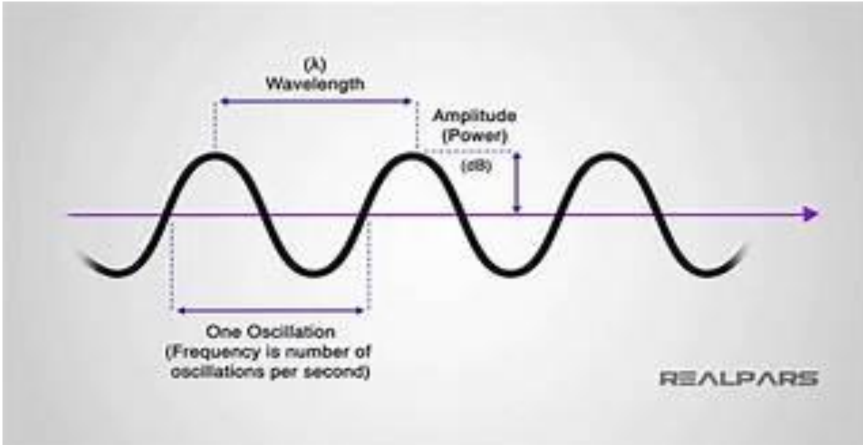



**Fig 2.1 Frequency and wavelength of an Antenna**

## 2.2 Wavelength:

The distance between two consecutive [4] maximum points (crests) or between two consecutive minimum points (troughs) is known as the wavelength.

Simply, the distance between two immediate [2] positive peaks or two immediate negative peaks is nothing but the length of that wave. It can be termed as the Wavelength.

Mathematically it is represented as,

$$\lambda = c/f \quad \text{----------------- (2)}$$

Where-
- $\lambda$ is the wavelength
- c is the speed of light ($3 \times 10^8$ meters/second)
- f is the frequency

The wavelength $\lambda$ is expressed in the units of length such as meters, feet or inches.

## 2.3 Impedance Matching:

Impedance matching is the process of designing the antenna's input impedance (ZL ) or matching it to the corresponding RF circuitry's output impedance (ZO), which would be 50 Ω in most cases

$$SWR = 1 + |\Gamma|/1 - |\Gamma| \quad \text{------- (1)}$$

$\Gamma = ZL - Zo / ZL + Zo$ ------- (2)

A perfect match is obtained when ZL = ZO in Equation 2, which gives Γ a value of zero, and the SWR becomes unity in Equation 1. If the impedance of the line feeding the antenna and the antenna impedance do not match, then the source experiences complex impedance, which would be a function of the line length. Even if the antenna specifications say 50 Ω impedance or matching is achieved using a matching network, the length of the line feeding the [4] antenna is of significance, specifically if it is greater than approximately 1/10th the wavelength of the highest frequency of operation. Matching on the final board will be crucial because antenna impedance can be altered depending on the electrical properties, size and nearness of the adjacent objects mounted on the end product, any enclosures, etc. A Vector Network Analyzer (VNA) can be used to measure the input impedance of the antenna in the end-user environment, as this helps to optimize the antenna for the actual [6] operating conditions. The VNA should be calibrated as close to the measurement plane as possible or at the matching network location. The VNA can be used to measure S11, representing the reflection coefficient. S11 is typically displayed on a Smith chart.

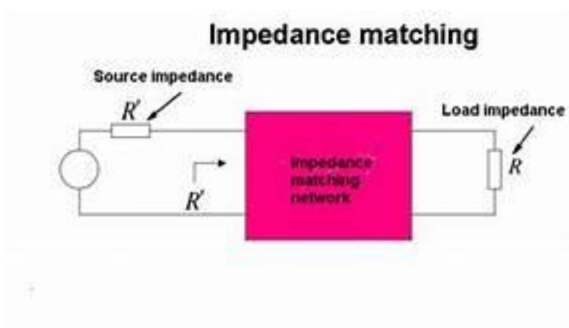



**Fig 2.3 Impedance matching**

## 2.4 VSWR & Reflected Power:

The ratio of the maximum voltage to the minimum voltage in a standing wave is known as Voltage Standing Wave Ratio.

If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power [7] will not be radiated effectively. Instead, some of the power is reflected back.

The key features are-

• The term, which indicates the impedance mismatch is VSWR.

• VSWR stands for Voltage Standing Wave Ratio. It is also called as SWR.

• The higher the impedance mismatch, the higher will be the value of VSWR.

• The ideal value of VSWR should be 1:1 for effective radiation.

• Reflected power is the power wasted out of the forward power. Both reflected power and VSWR indicate the same thing.

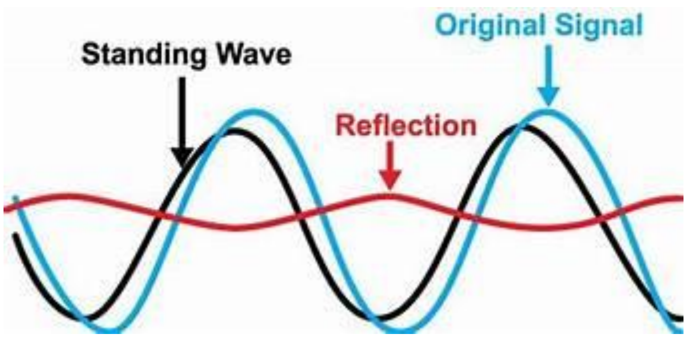



**Fig 2.4 Standing Wave**

## 2.5 Bandwidth:

A band of frequencies in a wavelength, specified for the particular communication, is known as bandwidth.

The signal when transmitted or received, is done over a range of frequencies. This particular range of frequencies [2] are allotted to a particular signal, so that other signals may not interfere in its transmission.

• Bandwidth is the band of frequencies between the higher and lower frequencies over which a signal is transmitted.

• The bandwidth once allotted, cannot be used by others.

• The whole spectrum is divided into bandwidths to allot to different transmitters.

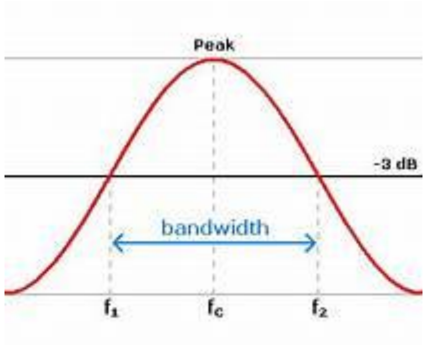



**Fig 2.5 Bandwidth**

## 2.6 Percentage Bandwidth:

The ratio of absolute bandwidth to the center frequency of that bandwidth can be termed as percentage bandwidth.

Percentage Bandwidth= (Fh-Fl)/Fc ---------------- (3)

Where,

• Fh= higher frequency

• Fl=lower frequency

• Fc=center frequency

## 2.7 Radiation Intensity:

"Radiation intensity is defined as the power per unit solid angle"

Radiation emitted from an antenna [4] which is more intense in a particular direction, indicates the maximum intensity of that antenna.

Radiation Intensity is obtained by multiplying the power radiated with the square of the radial distance.

$$U = r^2 W\text{rad} \text{ ----------------- } (4)$$

Where

• U is the radiation intensity

• r is the radial distance and

• Wrad is the power radiated.

the radiation intensity of an isotropic source is given by

*U=Prad/4pi ------------------- (5)*

The unit of radiation intensity is Watts/steradian or Watts/radian^2.

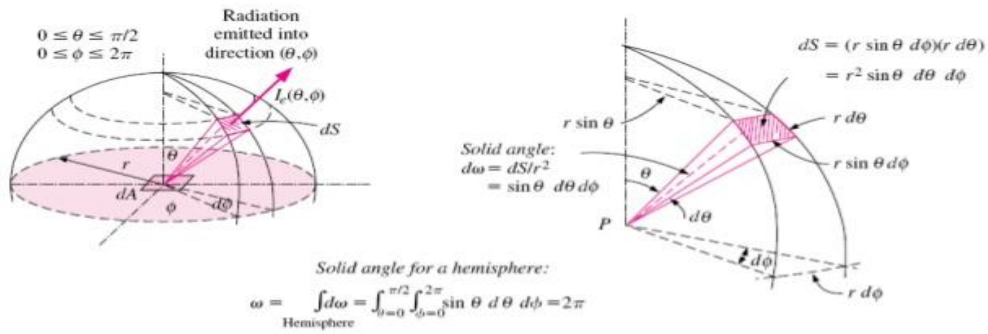



**Fig 2.7 Radiation intensity**

## 2.8 Directivity:

The ratio of maximum radiation intensity of the subject antenna to the radiation intensity of an isotropic or reference antenna, radiating [1] the same total power is called the directivity.

• An Antenna radiates power, but the direction in which it radiates matters much.

• The antenna, whose performance is being observed, is termed as subject antenna.

Its radiation intensity is focused in a particular direction, while it is transmitting or receiving. Hence, the antenna is said to have its directivity in that particular direction.

• The ratio of radiation intensity in a given direction from an antenna to the radiation intensity averaged over all directions, is termed as directivity.

• If that particular direction is not specified, then the direction in which maximum intensity is observed, can be taken as the directivity of that antenna.

Mathematically it is represented as,

$$\boxed{D = \frac{U}{U_0} = \frac{4\pi U}{P_{\text{rad}}}} \quad \text{-------------------- (6)}$$

If direction is not specified then,

$$\boxed{D_{\max} = D_0 = \frac{U|_{\max}}{U_0} = \frac{U_{\max}}{U_0} = \frac{4\pi U_{\max}}{P_{\text{rad}}}} \quad \text{---------------------- (7)}$$

Where ,

• $D$ = directivity (dimensionless)

• $D_0$ = maximum directivity (dimensionless)

• $U$ = radiation intensity (W/unit solid angle)

• $U_{max}$ = maximum radiation intensity (W/unit solid angle)

• $U_0$ = radiation intensity of isotropic source (W/unit solid angle)

• $P_{rad}$ = total radiated power (W)

## 2.9 Antenna Efficiency:

The efficiency of an antenna is a ratio of the power delivered to the antenna relative to the power radiated from the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna or reflected [3] away due to impedance mismatch. One nice property of antennas is that the efficiency is the same whether we are using the antenna as a transmit or receive antenna. Hence, we could define antenna efficiency [6] as the ratio of "potential power received from all possible angles", but that's more complicated. Just remember transmit and receive antenna efficiency is the same, and since it is easier to understand efficiency in terms of power radiated vs. power supplied, we'll simply use that definition. This property of antennas is known as antenna reciprocity. The antenna efficiency (or radiation efficiency) can be written as the ratio of the radiated power to the input power of the antenna:

$$\varepsilon_R = P_{rad}/P_{input} \text{ ----------------------- } (8)$$

## 2.10 Aperture Efficiency:

Aperture efficiency of an antenna, is the ratio of the effective radiating area (or effective area) to the physical area of the aperture.

An antenna has an aperture through which the power is radiated. This radiation should be effective with minimum losses. The physical area [6] of the aperture should also be taken into consideration, as the effectiveness of the radiation depends upon the area of the aperture, physically on the antenna.

The mathematical expression for aperture efficiency is as follows :

$$\varepsilon_A = A_{eff}/A_p \text{ ----------------- } (9)$$

where

- $\varepsilon_A$ is Aperture Efficiency.
- $A_{eff}$ is effective area.
- $A_p$ is physical area..

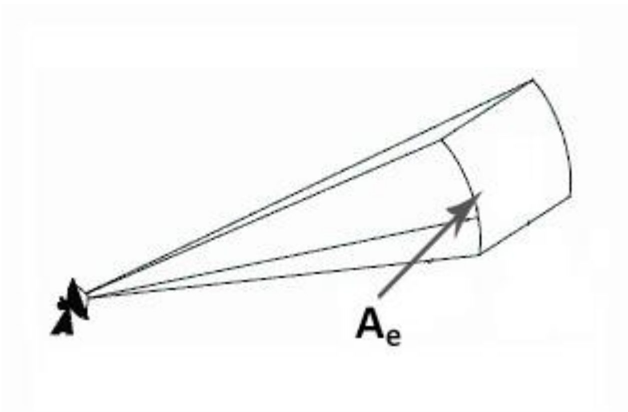



**Fig 2.10 Antenna effective aperture**

## 2.11 Gain:

Gain is a measure that takes into account the efficiency of the antenna as well as its directional [1] capabilities. Gain of an antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna [6] were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π.” In equation form this can be expressed as

$$\text{Gain} = 4\pi\frac{\text{radiation intensity}}{\text{total input (accepted) power}} = 4\pi\frac{U(\theta.\phi)}{\text{Pin}} \text{ (dimensionless)} \quad \text{------------} (10)$$

In most cases we deal with relative gain, which is defined as “the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction.” The power input must be the same for both antennas. The reference antenna is usually a dipole, horn, or any other antenna whose gain can be calculated or it is known. In most cases, however, the reference antenna is a lossless isotropic source. Thus

$$G = \frac{4\pi U(\theta,\varphi)}{\text{Pin (lossless isotropic source)}} \text{ (dimensionless)} \quad \text{-----------------} (11)$$

When the direction is not stated, the power gain is usually taken in the direction of maximum radiation.

## 2.12 RADIATION FIELDS:

Another important topic of consideration is the near field and the far field regions of the antenna.

The radiation intensity when measured nearer to the antenna, differs from what is away from the antenna. Though the area is away [2] from the antenna, it is considered effective, as the radiation intensity is still high there.

### Near Field:

The field, which is nearer to the antenna, is called as near-field. It has an inductive effect and hence it is also known as inductive field, though it has some radiation components.

### Far field:

The field, which is far from the antenna, is called as far-field. It is also called as radiation field, as the radiation effect is high in this area. Many of the antenna parameters along with the antenna directivity and the radiation pattern of the antenna are considered in this region only.

## Field Pattern:

The field distribution can be quantifying in terms of field intensity is referred to as field pattern. That means, the radiated power [5] from the antenna when plotted, is expressed in terms of electric field, E (v/m). Hence, it is known as field pattern. If it is quantified in terms of power (W), then it is known as power pattern.

The graphical distribution of radiated field or power will be as a function of

• spatial angles (θ, Ø) for far-field.

• spatial angles (θ, Ø) and radial distance(r) for near-field.

The distribution [2] of near and far field regions can be well understood with the help of a diagram.

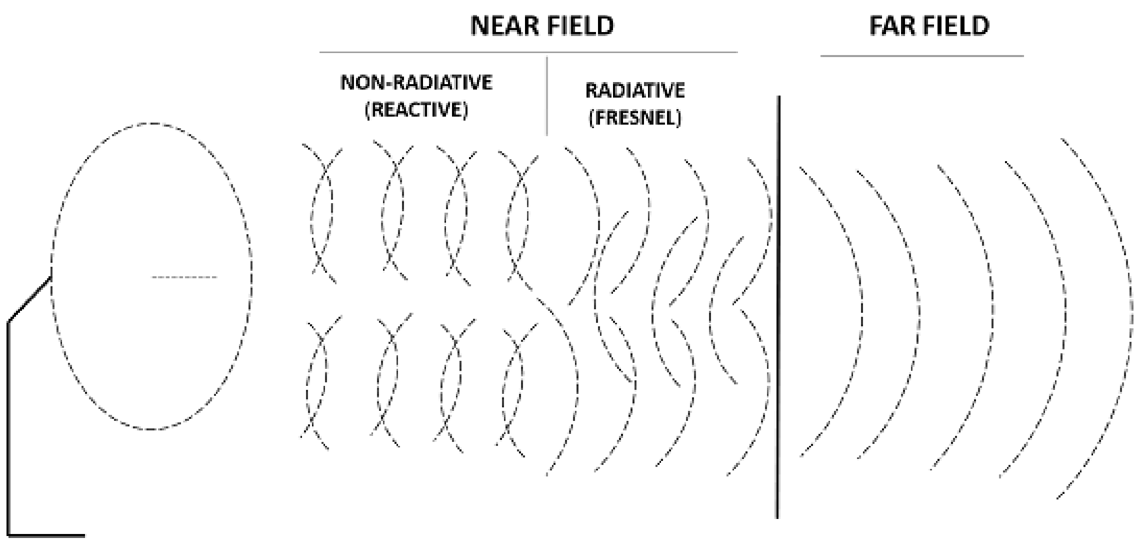



**Figure 2.12 representation of field pattern**

The field pattern can be classified as-

• Reactive near-field region and Radiating near-field region – both termed as near- field.

• Radiating far-field region – simply called as far-field.

The field, which is very near to the antenna is reactive near field or non-radiative field where the radiation is not pre-dominant. The region next to it can be termed as radiating near field or Fresnel's field as the radiation [3] predominates and the angular field distribution, depends on the physical distance from the antenna.

The region next to it is radiating far-field region. In this region, field distribution is independent of the distance from antenna. The effective radiation pattern is observed in this region.

## 2.13 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the farfield region and is represented [1] as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization." The radiation property of most concern is the two- or three dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. A convenient set of coordinates is shown in Figure . A trace of the received electric (magnetic) field at a constant radius is called the amplitude field pattern. On the other hand, a graph [6] of the spatial variation of the power density along a constant radius is called an amplitude power pattern. Often the field and power patterns are normalized with respect to their maximum value, yielding normalized field and power patterns. Also, the power pattern is usually plotted on a logarithmic scale or more commonly in decibels (dB). This scale is usually desirable because a logarithmic scale can accentuate in more details those parts of the Pattern that have very low values.

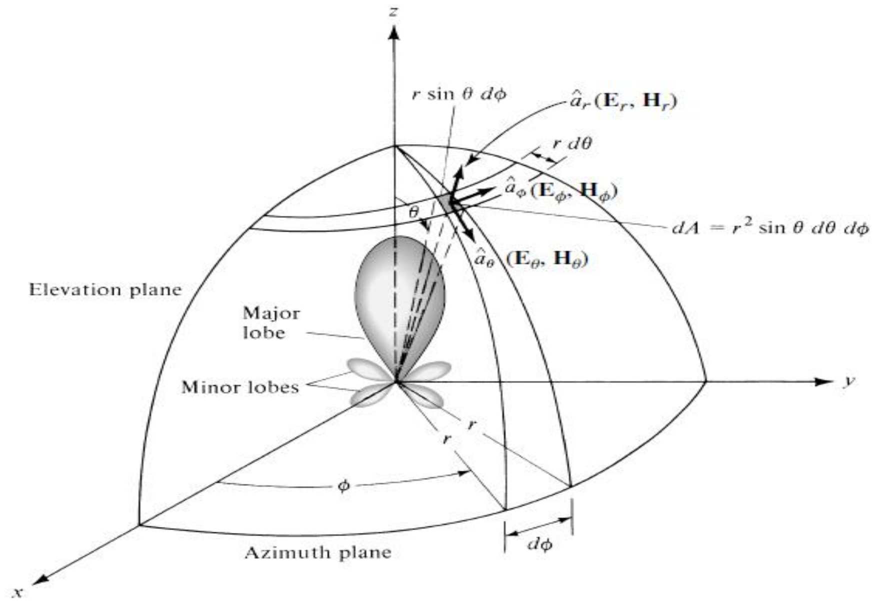



**Figure 2.13.1 Coordinate system for antenna analysis**

For an antenna, the

a. field pattern (in linear scale) typically represents a plot of the magnitude of the electric or magnetic field as a function of the angular space.

b. power pattern (in linear scale) typically represents a plot of the square of the magnitude of the electric or magnetic field as a function of the angular space.

c. power pattern (in dB) represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular space.

To demonstrate this, the two-dimensional [4] normalized field pattern (plotted in linear scale), power pattern (plotted in linear scale), and power pattern (plotted on a logarithmic dB scale) of a 10-element linear antenna array of isotropic sources, with a spacing of $d = 0.25\lambda$ between the elements, are shown in Figure. In this and subsequent patterns, the plus (+) and minus (−) signs in the lobes indicate the relative polarization [2] of the amplitude between the various lobes, which changes (alternates) as the nulls are crossed. To find the points where the pattern achieves its half-power (−3 dB points), relative to the maximum value of the pattern, you set the value of the

a. field pattern at 0.707 value of its maximum, as shown in Figure)

b. power pattern (in a linear scale) at its 0.5 value of its maximum, as shown in Figure

c. power pattern (in dB) at −3 dB value of its maximum, as shown in Figure

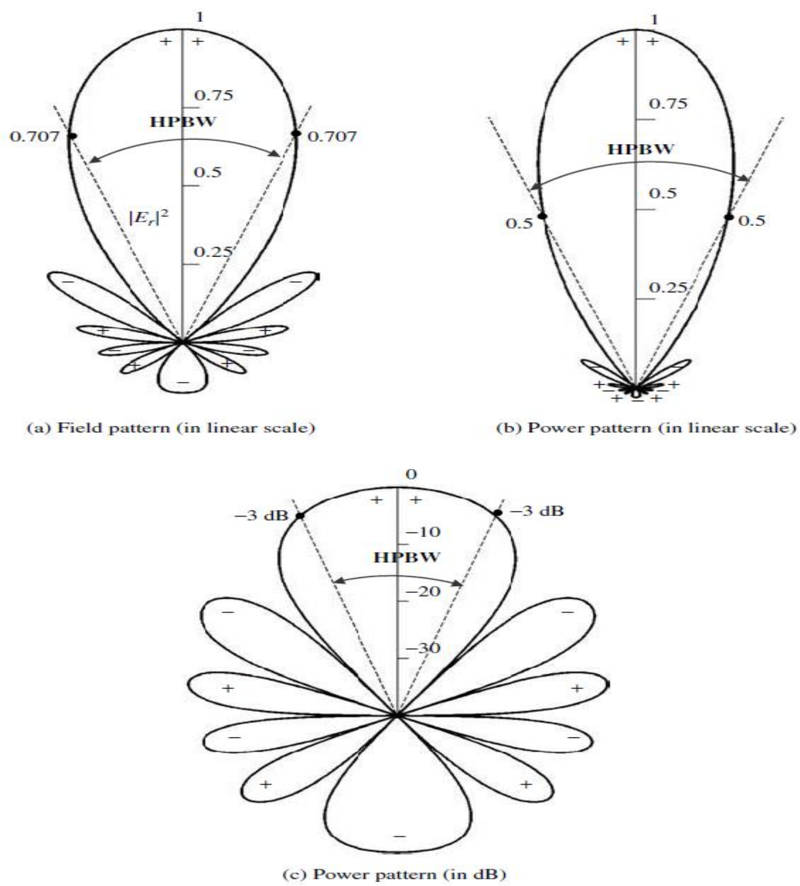



**Figure 2.13.2 field patterns**

Two-dimensional normalized field pattern (linear scale), power pattern (linear scale), and power pattern (in dB) of a 10-element linear array with a spacing of d = 0.25λ.

## 2.14 Radiation Pattern Lobes:

Various parts of a radiation pattern are referred to as lobes, which may be sub classified into major or main, minor, side, and back lobes. A radiation lob*e* is a “portion of the radiation pattern bounded by regions of relatively [5] weak radiation intensity.” Figure (a) demonstrates a symmetrical three dimensional polar pattern with a number of radiation lobes. Some are of greater radiation intensity than others, but all are classified as lobes. Figure (b) illustrates a linear two-dimensional [7] pattern where the same pattern characteristics are indicated.

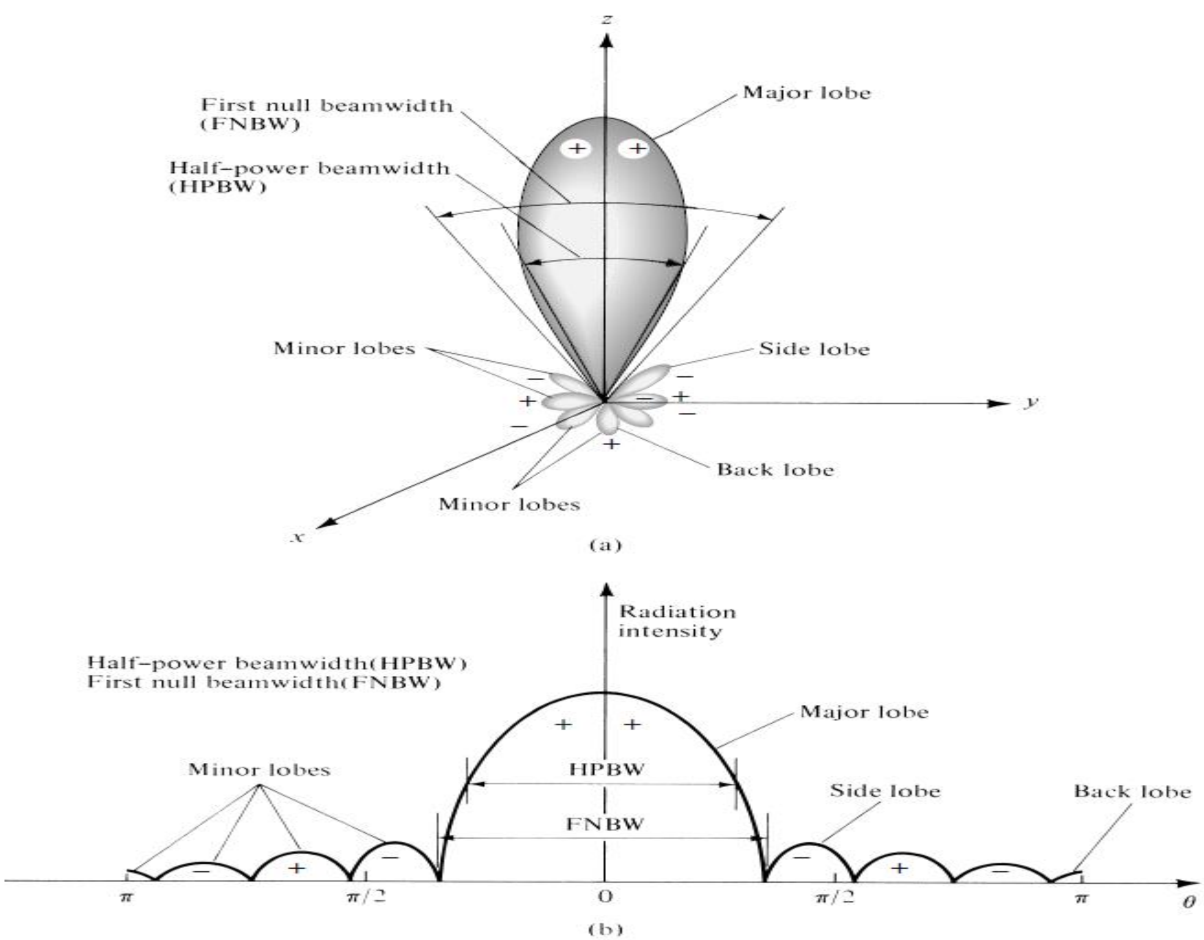



**Figure 2.14(a) Radiation lobes and beam widths of an antenna pattern.**
**(b) Linear plot of power pattern and its associated lobes and beam widths.**

## 2.15 Isotropic, Directional, and Omni directional Patterns

An isotropic radiator is defined as “a hypothetical lossless antenna having equal radiation in all directions.” Although it is ideal and not physically realizable, it is often taken as a reference for expressing the directive properties of actual antennas. A directional antenna is one “having the property of radiating or receiving electromagnetic waves more effectively in some directions [3] than in others. This term is usually applied to an antenna whose maximum directivity is significantly greater than that of a half-wave dipole.” Examples of antennas with directional radiation patterns are shown in Figures. It is seen that the pattern in Figure is non directional [1] in the azimuth plane [$f(\varphi)$, $\theta = \pi/2$] and directional in the elevation plane [$g(\theta)$, $\varphi$ = constant]. This type of a pattern is designated as omnidirectional, and it is defined as one “having an essentially non directional pattern in a given plane (in this case in azimuth) and a directional pattern in any orthogonal plane (in this case in elevation).” An omnidirectional pattern is then a special type of a directional pattern.

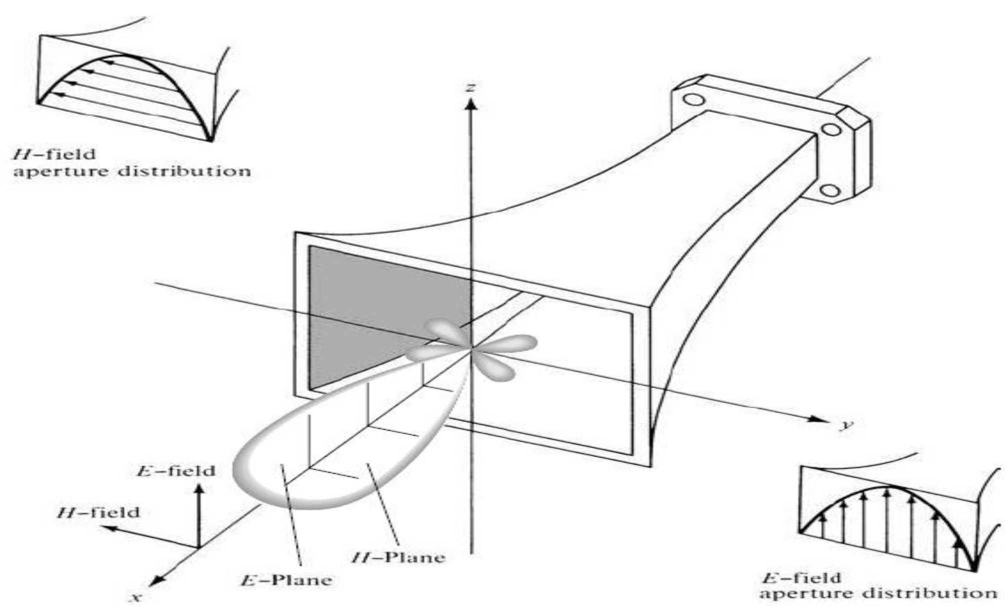


**Figure 2.15 Principal *E*- and *H*-plane patterns**

## 2.16 Principal Patterns

For a linearly polarized antenna, performance is often described in terms of its principal *E*-and H-plane patterns. The E-plane is defined as “the plane containing the electric field vector and the direction of maximum radiation,” and the H-plane as “the plane containing the magnetic-field vector [5] and the direction of maximum radiation.” Although it is very difficult to illustrate the principal patterns without considering a specific example, it is the usual practice to orient most antennas so that at least one of the principal plane patterns coincide with one of the geometrical principal planes. For this example, the *x*-*z* plane (elevation plane; $\varphi = 0$) is the principal *E*-plane and the *x*-*y* plane (azimuthal plane; $\theta = \pi/2$) is the principal *H*-plane. Other coordinate [4] orientations can be selected. The omnidirectional pattern of Figure has an infinite number of principal E-planes (elevation planes; $\varphi = \varphi c$) and one principal *H*-plane (azimuthal plane; $\theta = 90^\circ$).

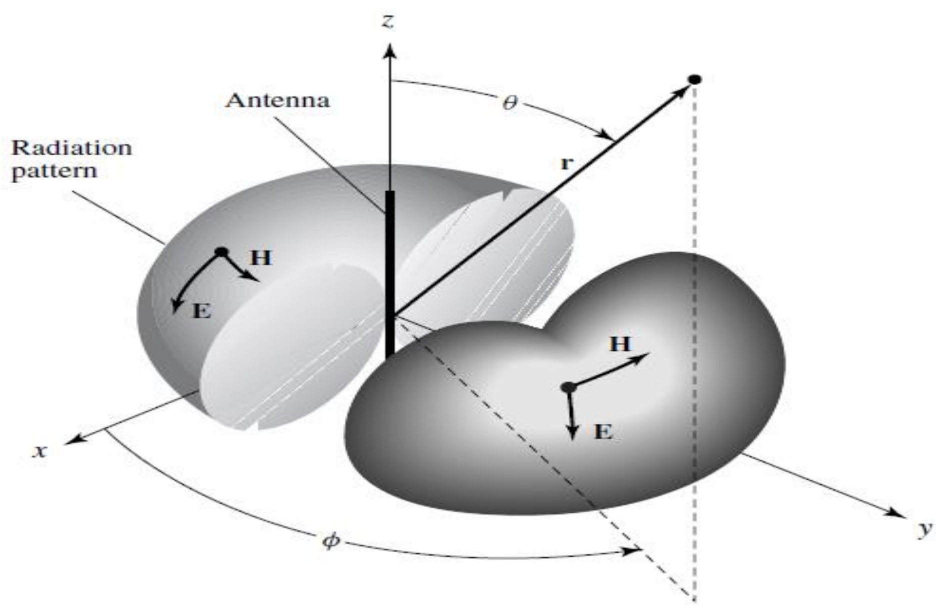



**Figure 2.16 Omni directional antenna pattern.**

# CHAPTER-3
# Types of Antennas

Antennas have to be classified to understand their physical structure and functionality more clearly. There are many types of antennas depending upon the applications applications.

| Type of antenna | Examples | Applications |
|---|---|---|
| Wire Antennas | Dipole antenna, Monopole antenna, Helix antenna, Loop antenna | Personal applications, buildings, ships, automobiles, space crafts |
| Aperture Antennas | Waveguide (opening), Horn antenna | Flush-mounted applications, air-craft, space craft |
| Reflector Antennas | Parabolic reflectors, Corner reflectors | Microwave communication, satellite tracking, radio astronomy |
| Lens Antennas | Convex-plane, Concave-plane, Convex-convex, Concaveconcave lenses | Used for very highfrequency applications |
| Micro strip Antennas | Circular-shaped, Rectangularshaped metallic patch above the ground plane | Air-craft, space-craft, satellites, missiles, cars, mobile phones etc. |
| Array Antennas | Yagi-Uda antenna, Micro strip patch array, Aperture array, Slotted wave guide array | Used for very high gain applications, mostly when needs to control the radiation pattern |

**Table(1) Types of antennas**

## 3.1 Wire Antennas

Wire antennas are familiar to the layman because they are seen virtually everywhere on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas [5] such as a straight wire (dipole), loop, and helix which are shown in Figure. Loop antennas need not only be circular. They may take the form of a rectangle, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicity in construction.

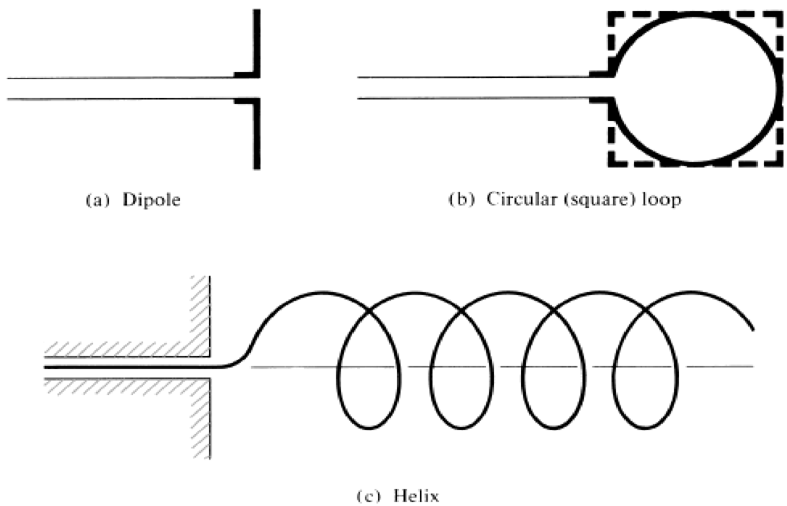



**Fig 3.1 Wire Antennas**

## 3.2 Aperture Antennas

Aperture antennas may be more familiar to the layman today than in the past because of the increasing demand for more sophisticated forms of antennas and the utilization of higher frequencies. Some forms [1] of aperture antennas are shown in Figure. Antennas of this type are very useful for aircraft and spacecraft applications, because they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. In addition, they can be covered with a dielectric material to protect them from hazardous conditions of the environment.

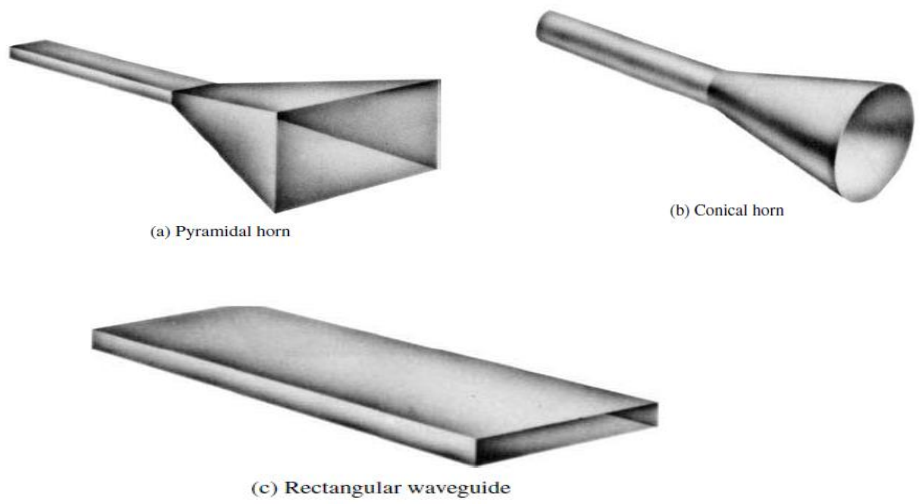



**Figure 3.2 Aperture antenna configurations**

## 3.3 Array Antennas

Many applications require radiation characteristics that may not be achievable by a single element. It may, however, be possible that an aggregate [7] of radiating elements in an electrical and geometrical arrangement (an array) will result in the desired radiation characteristics.

The arrangement of the array may be such that the radiation from the elements adds up to give a radiation maximum in a particular direction or directions, minimum in others, or otherwise as desired. Typical examples of arrays are shown in Figure. Usually the term array [4] is reserved for an arrangement in which the individual radiators are separate as shown in Figures. However the same term is also used to describe an assembly of radiators mounted on a continuous structure, shown in Figure.

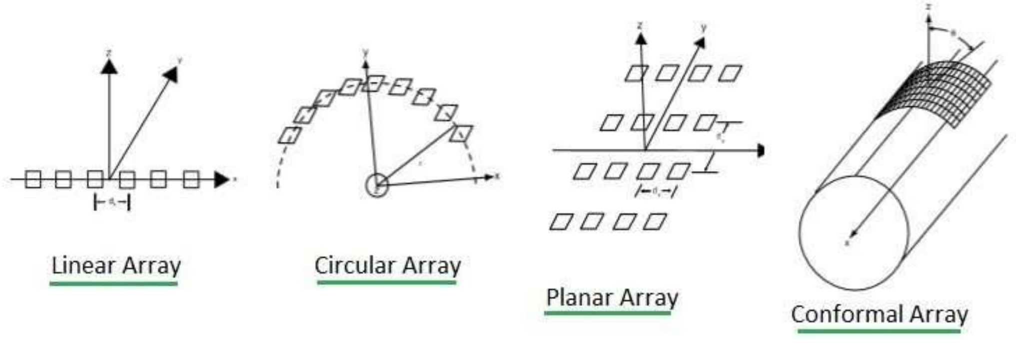
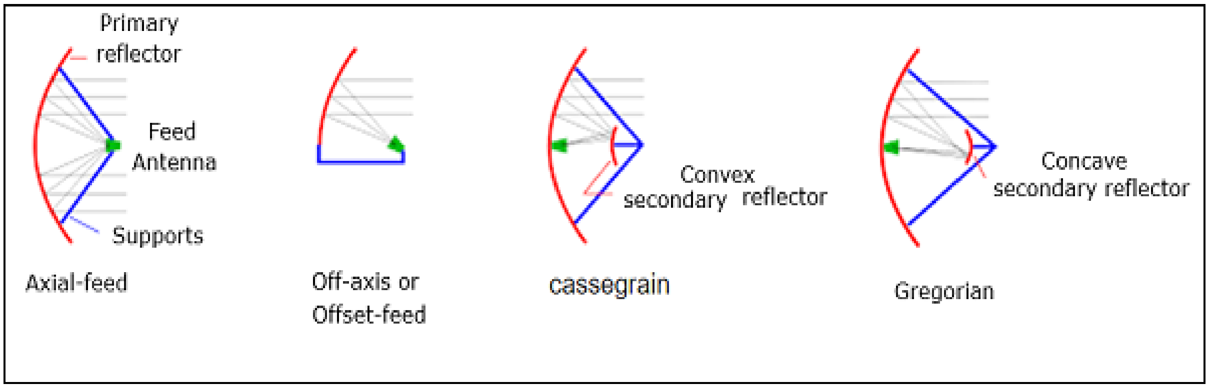



**Fig 3.3.1 Array Antennas**

## 3.4 Reflector Antennas

The success in the exploration of outer space has resulted in the advancement of antenna theory. Because of the need to communicate over great distances, sophisticated forms of antennas had to be used in order to transmit and receive signals that had to travel millions of miles. A very common [3] antenna form for such an application is a parabolic reflector shown in Figures. Antennas of this type have been built with diameters as large as 305 m. Such large dimensions are needed to achieve the high gain [6] required to transmit or receive signals after millions of miles of travel. Another form of a reflector, although not as common as the parabolic, is the corner reflector, shown in Figure.



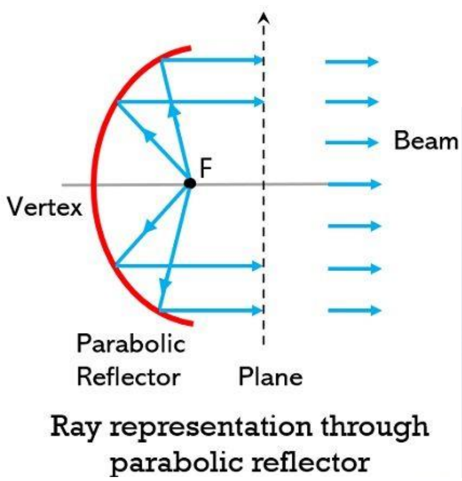




**Fig 3.4 Reflector antennas**

## 3.5 Lens Antennas

Lenses are primarily used to collimate incident divergent energy to prevent it from spreading in undesired directions. By properly shaping the geometrical configuration and choosing the appropriate material of the lenses, they can [1] transform various forms of divergent energy into plane waves. They can be used in most of the same applications as are the parabolic reflectors, especially at higher frequencies. Their dimensions and weight become exceedingly large at lower frequencies. Lens antennas are classified according to the material from which they are constructed, or according to their geometrical shape. Some forms are shown in Figure. In summary, an ideal antenna [3] is one that will radiate all the power delivered to it from the transmitter in a desired direction or directions. In practice, however, such ideal performances cannot be achieved but may be closely approached. Various types of antennas are available and each type can take different forms in order to achieve the desired radiation characteristics for the particular application.

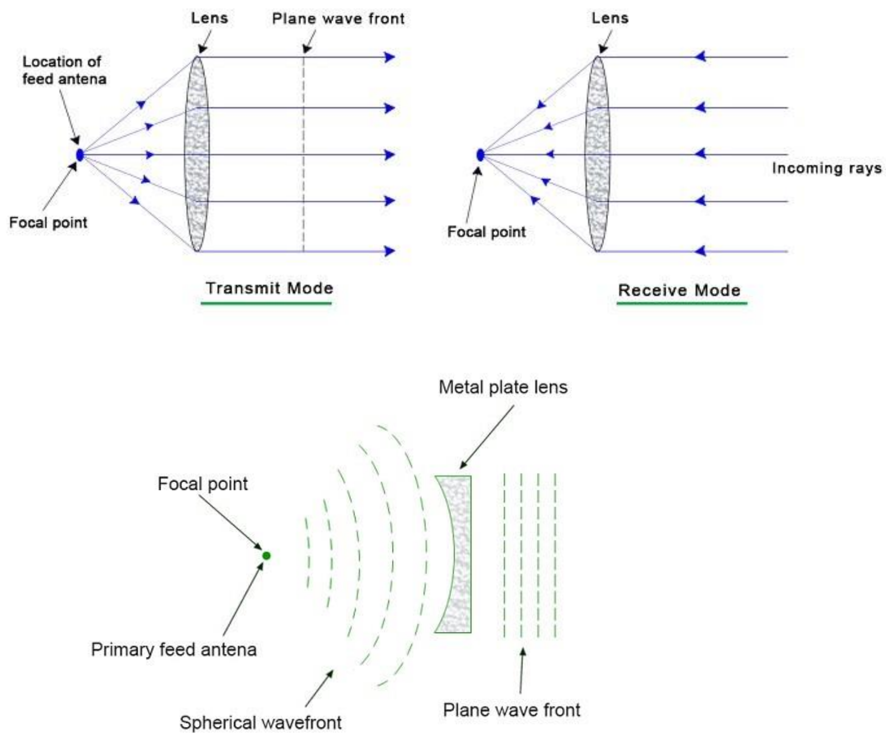



**Fig 3.5 Lens Antennas**

## 3.6 Microstrip Antennas

Microstrip antennas became very popular in the 1970s primarily for space borne applications. Today they are used for government [5] and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations, as shown in Figure. However, the rectangular and circular patches, shown in Figure are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The microstrip antennas are low profile, conformable to planar and non planar surfaces, simple and inexpensive to fabricate using modern [4] printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

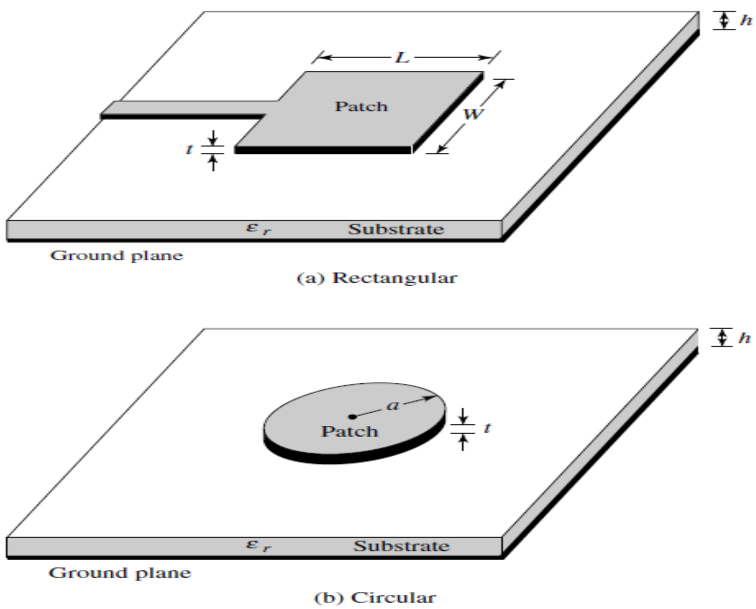



**Figure 3.6 Rectangular and circular microstrip (patch) antennas**

## 3.7 Electrically Small Antennas

In Electrically small antenna dipole, loop & patch length would be considered less than $1/10^{th}$ of its wavelength. The present dissertation deals with electrically small antennas, namely antennas which are small compared to the wavelength. An important point regarding electrically small antennas is that their performances are closely related to their electrical size. The product of the bandwidth and the gain is a function of the size of the antenna, so that the gain can only be increased [7] at the expense of the bandwidth, and vice versa. In this thesis, the goal was thus to miniature is various antennas by keeping their characteristics as close as possible to the theoretical maxima.

# CHAPTER-4

# MICROSTRIP ANTENNA

## 4.1 Overview of Microstrip Antenna

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on microstrip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals [4] for the last ten years, on these antennas shows the importance gained by them. The microstrip antennas are the present day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the microstrip antenna and its design considerations were discussed in the subsequent chapters. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch

Microstrip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's.

The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip [6] resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough.

## 4.2 Introduction

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure . The patch is generally made of conducting material [3] such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

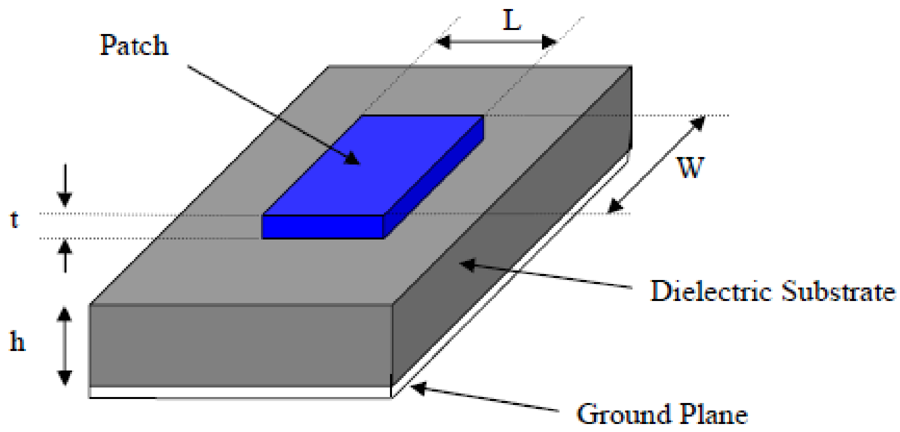



**Figure 4.2.1 Structure of a Microstrip Patch Antenna**

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 5.3.1 For a rectangular patch, the length L of the patch is usually $0.3333\lambda < L < 0.5\lambda$, where $\lambda_0$ is the free-space [5] wavelength. The patch is selected to be very thin such that $o << t << \lambda$. The height $h$ of the dielectric substrate is usually $0.003\ \lambda_0 \leq h \leq 0.05\lambda$. The dielectric constant of the substrate ($\varepsilon_r$ ) is typically in the range $2.2 \leq \varepsilon_r \leq 12$ .

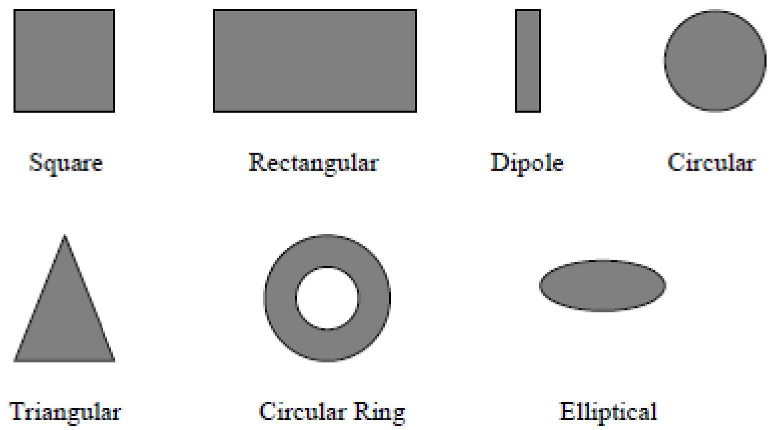



**Figure 4.2.2 Common shapes of microstrip patch elements.**

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, higher dielectric constants must be used which are less [7] efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

The frequency of operation of the patch antenna of Figure 1 is determined by the length L. The center frequency will be approximately given by:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

The above equation says that the microstrip antenna should have a length equal to one half of a wavelength within the dielectric (substrate) medium. The width W of the microstrip antenna controls the input impedance. Larger widths also can increase the bandwidth. For a square patch antenna fed in the manner above, the input impedance will be on the order of 300 Ohms. By increasing [2] the width, the impedance can be reduced. However, to decrease the input impedance to 50 Ohms often requires a very wide patch antenna, which takes up a lot of valuable space. The width further controls the radiation pattern. The normalized radiation pattern is approximately given by:

$$E_\theta = \frac{\sin\left(\frac{kW \sin\theta \sin\phi}{2}\right)}{\frac{kW \sin\theta \sin\phi}{2}} \cos\left(\frac{kL}{2} \sin\theta \cos\phi\right) \cos\phi$$

$$E_\varphi = -\frac{\sin\left(\frac{kW \sin\theta \sin\phi}{2}\right)}{\frac{kW \sin\theta \sin\phi}{2}} \cos\left(\frac{kL}{2} \sin\theta \cos\phi\right) \cos\theta \sin\phi$$

In the above, k is the free-space wavenumber, given by 2pi/λ. The magnitude of the fields, given by:

$$f(\theta, \phi) = \sqrt{E_\theta^2 + E_\phi^2}$$

The fields of the microstrip antenna are plotted in Figure 2 for W=L=0.5λ.

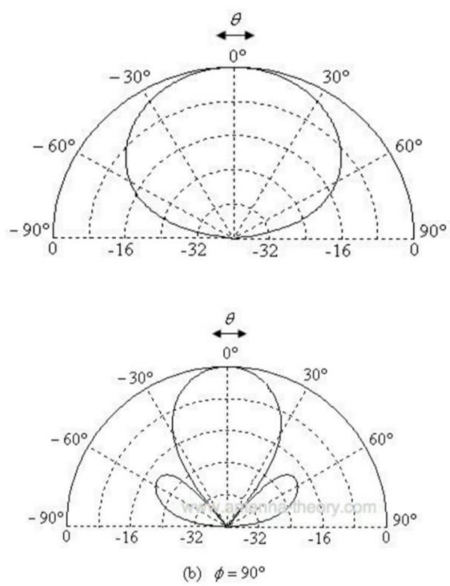



**Fig 4.2.3 Normalized radiation pattern**

## 4.3 Advantages and Disadvantages

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc... The telemetry and communication [4] antennas on missiles need to be thin and conformal and are often Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages discussed by Kumar and Ray are given below:

• Light weight and low volume.

• Low profile planar configuration which can be easily made conformal to host surface.

• Low fabrication cost, hence can be manufactured in large quantities.

• Supports both, linear as well as circular polarization.

• Can be easily integrated with microwave integrated circuits (MICs).

Microstrip patch antennas suffer from a number of disadvantages [1] as compared to conventional antennas. Some of their major disadvantages discussed by Garget are given below:

• Narrow bandwidth

• Low efficiency

• Low Gain

• Extraneous radiation from feeds and junctions

Microstrip patch antennas have a very high antenna quality factor (Q). Q represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately [3] scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by use of photonic band gap structures as discussed by Qian et al. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

## 4.4 Feed Techniques

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

### 4.4.1 Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure. The conducting strip [3] is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

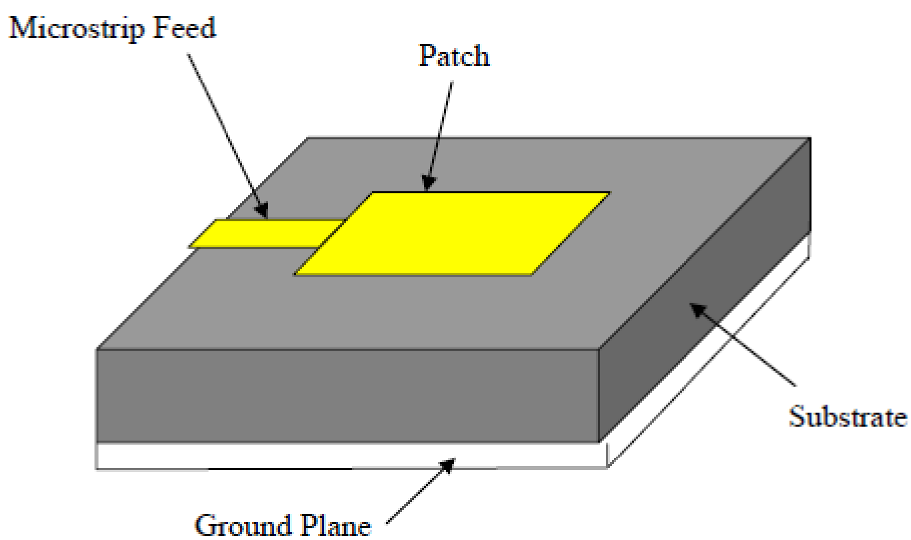



**Figure 4.4.1 Microstrip Line Feed**

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate [2] being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

Resonance frequency of the microstrip line antenna is given as,

$f = c/2L_{es}\sqrt{\varepsilon_{re}}$

The characteristic impedance of microstrip line:

$Z_L = j\omega L_L + 1/(j\omega C_L + 1/j\omega L_L)$

Therefore, the total input impedance (Zin) of antenna can be calculated by equivalent circuit diagram as

$Z_{in} = Z_L + 1/1/(1/j\omega C_c + 1/j\omega L_c + 1/Z_p + 1/Z_{pp} + 1/Z_{cc})$

where Lc and Ccis the inductance and capacitance of SRR's

**4.4.2 Coaxial Feed**

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

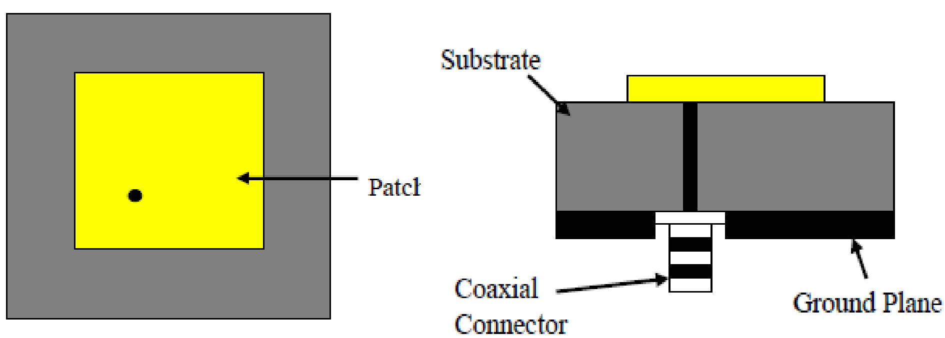



**Figure 4.4.2 Probe fed Rectangular Microstrip Patch Antenna**

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ( $h > 0.02\lambda_o$ ). Also, for thicker substrates, the increased probe length [5] makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problems.

### 4.4.3 Aperture Coupled Feed

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

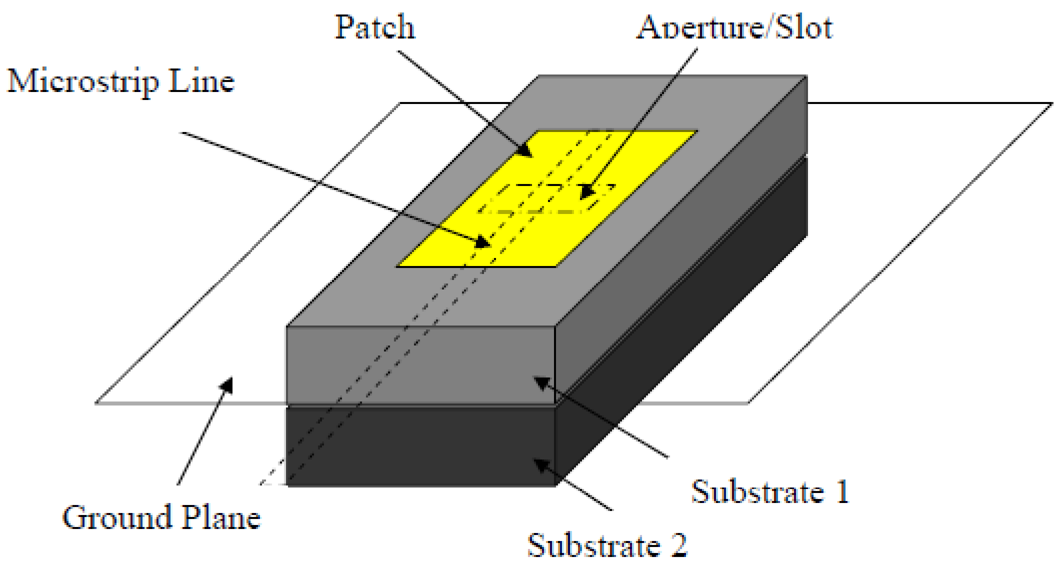



**Figure 4.4.3  Aperture-coupled feed**

The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for [1] the bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

### 4.4.4 Inset feed

Previously, the patch antenna was fed at the end as shown here. Since this typically yields a high input impedance, we would like to modify the feed. Since the current is low at the ends of a half wave patch and increases in magnitude toward [3] the center, the input impedance(Z=V/I) could be reduced if the patch was fed closer to the center. One method of doing this is by using an inset feed(a distance R from the end) as shown in the figure.

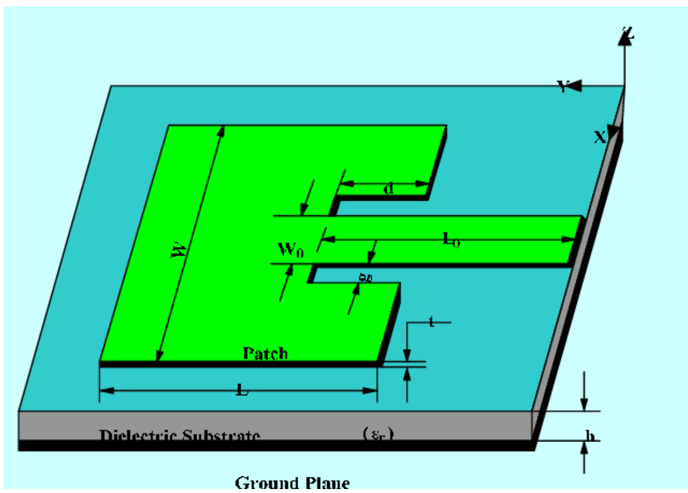



**Fig 4.4.4 Inset feed**

Since the current has a sinusoidal distribution, moving in a distance R from the end will increase the current by cos(pi*R/L) - this is just noting that the wavelength is 2*L, and so the phase difference is 2*pi*R/(2*L) = pi*R/L. The voltage also decreases in magnitude by the same amount that the current increases. Hence, using Z=V/I, the input impedance scales as:

$$Z_{in}(R) = \cos^2\left(\frac{\pi R}{L}\right) Z_{in}(0)$$

In the above equation, Zin(0) is the input impedance if the patch [1] was fed at the end. Hence, by feeding the patch antenna as shown, the input impedance can be decreased. As an example, if R=L/4, then cos(pi*R/L) = cos(pi/4), so that [cos(pi/4)]^2 = 1/2. Hence, a

(1/8)-wavelength inset would decrease the input impedance by 50%. This method can be used to tune the input impedance to the desired value.

### 4.4.5 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) [5], due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

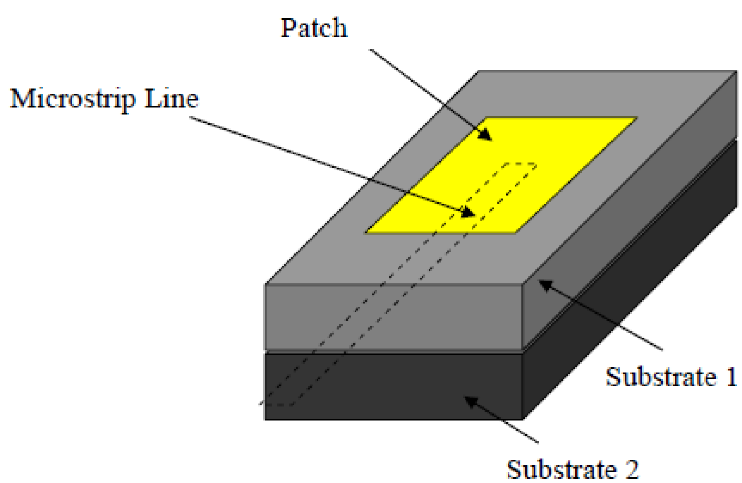



**Figure 4.4.5 Proximity-coupled Feed**

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

# CHAPTER-5

# DESIGN OF UWB ANTENNA WITH DGS

## 5.1 Introduction to HFSS

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high frequency electronic products such as antennas, antenna arrays, RF or microwave components, high speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS to design high-frequency, high-speed electronics found in communications systems, radar systems, advanced [6] driver assistance systems (ADAS), satellites, internet-of-things (IOT) products and other high-speed RF and digital devices.

- In world wide use Ansys HFSS to design high frequency high speed electronics found in communication systems
- HFSS employs versatile solvers and an intuitive GUI to give you unparalleled performance plus deep insight into all your 3D em problems
- HFSS is a full wave 3D which means it solves all of Maxwell's equation .the limit on accuracy is basically dependent on the mesh size. HFSS is very good at extracting s-parameters and fields
- Engineers world wide use ansys HFSS to design high frequency,high speed electrons found in communication system radar system advanced driver assistance system(ADAS), satellites, internet of things(IOT) products and other high speed RF and digital devices.

### 5.1.1 Mathematical Method used in HFSS:

HFSS uses a numerical technique called the finite element method.this is procedure where a structure is subdivided into many smaller subsection called finite element. The finite element used by HFSS are tetrahedron and entire collection of tetrahedral is called mesh.solution is found for the fields within the finite element and these fields are interrelated so that Maxwell's equations are satisfied across buildings ,yield a field solution for the entire original structure.once the field solution has found the s matrix solution is determined.

## 5.2 Applications of HFSS

HFSS is high frequency structure simulator it is high performance full wave electromagnetic field simulator 3D volumetric passive device modelling that takes advantages of familiar Microsoft Windows graphical user interface .it integrates simulation, visualization, solid modelling and automaton in easy to learn environment. Typical uses

1.package modelling
2.PCB board modelling
3.EMI
4.antenna mobile communications
5.connectors

## 5.3 Introduction to UWB Antenna:

Ultra Wideband is a communication technology used in wireless networking to achieve high bandwidth connections with low power spectral density. UWB [7] has traditional applications in non co-operative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications.As of september 2019, UWB support has started to appear in high end smartphones.

- It has a frequency range from 3.1 to 10.6 GHz.
- It has high data throughput for communication devices.
- It has high precision for location and imaging devices.
- It has high resolution for sensing devices.
- It uses Ultra Low Power(mW).
- It has limited interference with conventional radio systems.
- It has short signal pulses over a broad spectrum.
- It has high wireless data rates in excess of 100Mbps.
- Data rates drop considerately at longer distances.

Nowadays, designing a compact system that supports high data rate and multiple wireless metric capabilities with effective electromagnetic spectrum utilization is needed. UltraWide-band technology incorporates compact techniques such as diversity, multiplexing, and beam forming have been proved to enhance wireless system performance in an environment where interference, fading. Multi-path tends to degrade the signal quality, reduce the effective data rate and many subscribers in the cell. Why COMPACT? It is all about the channel capacity of the system [2] whereby the channel capacity depends on bandwidth and signal to noise ratio.

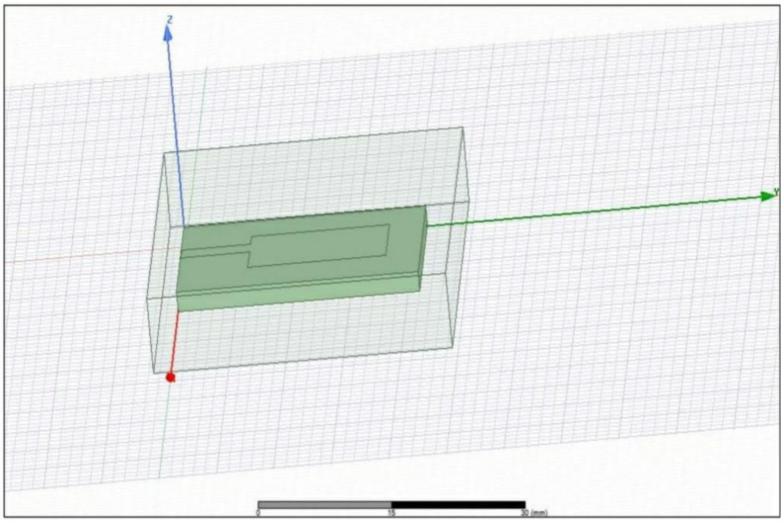
Imagine a single antenna system in which we have an antenna that transmits and receive a signal. There are some multi-path propagation and channel fading condition which will deteriorate the signal to noise ratio (SNR).

- UWB microwave imaging procedure is a radiation less, high-resolution and affordable cost method which is extensively employed in recent years for timely detection of tumors .

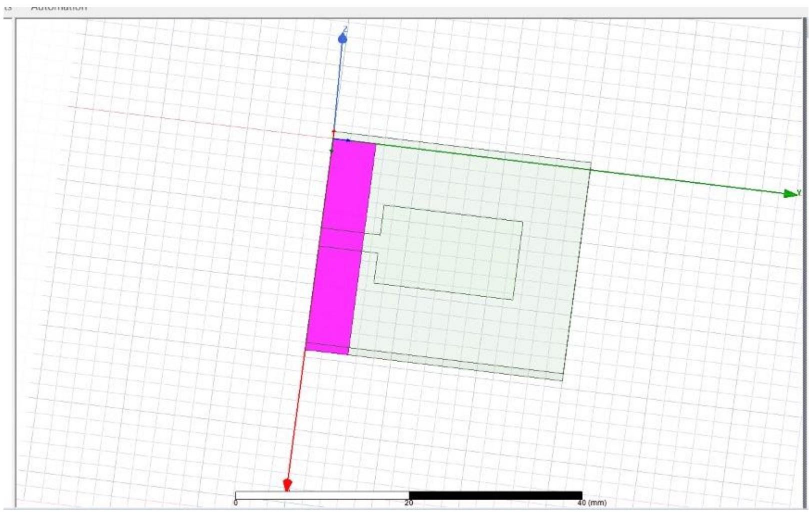
- UWB is a short range carrier less communications technique that propagates information as short pulses.

## 5.4 DESIGN OF UWB ANTENNA:

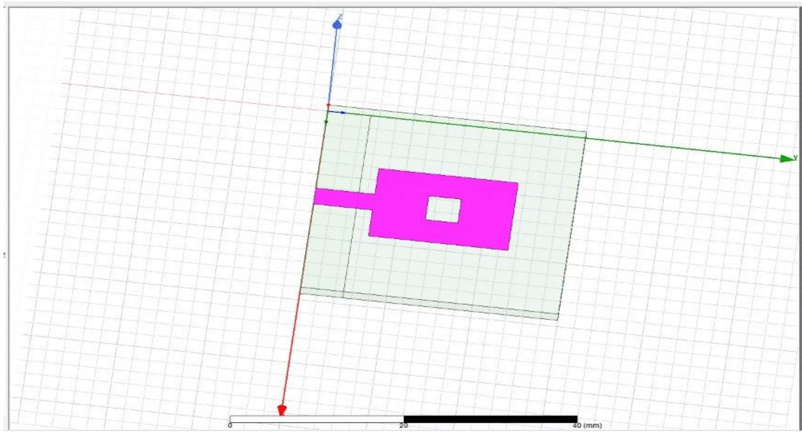
**Stage 1: Design of patch antenna with truncated ground.**



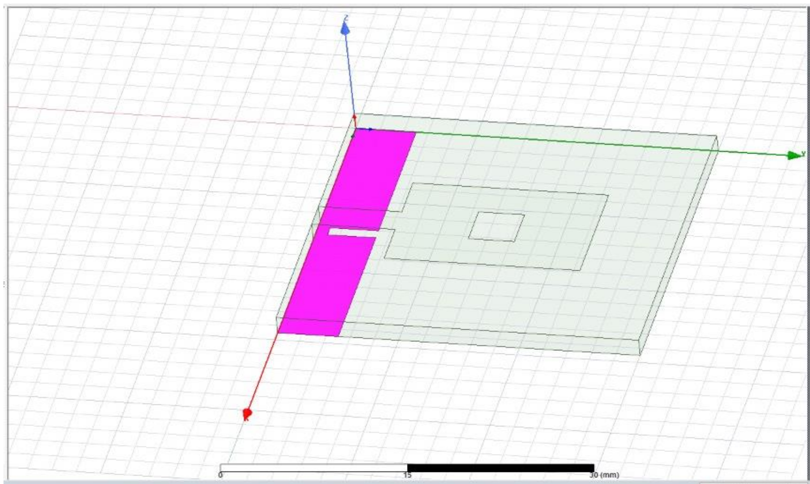
**Stage 2: Cutting the ground**



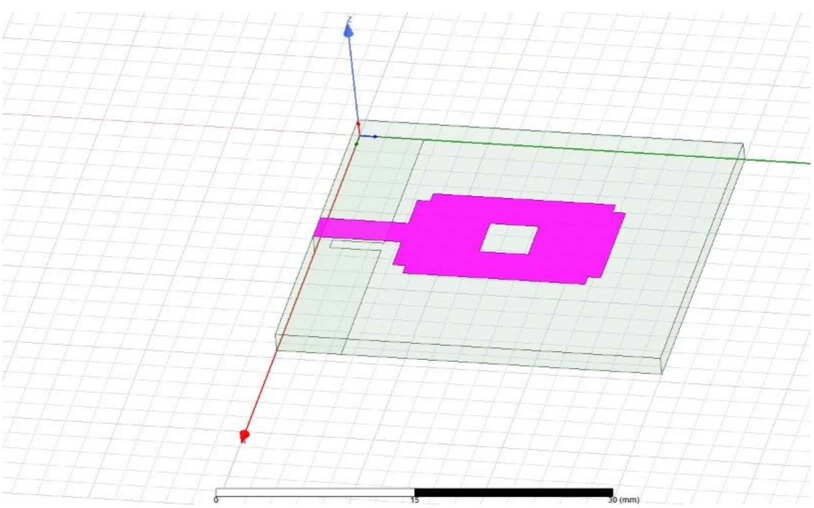
**Stage 3: Cutting a slot at centre of Patch**



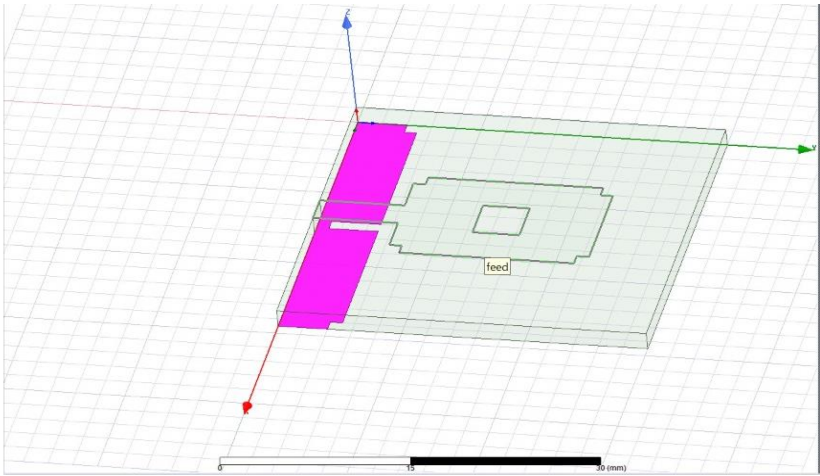
**Stage 4: Cutting a I-shaped a central slot in ground**



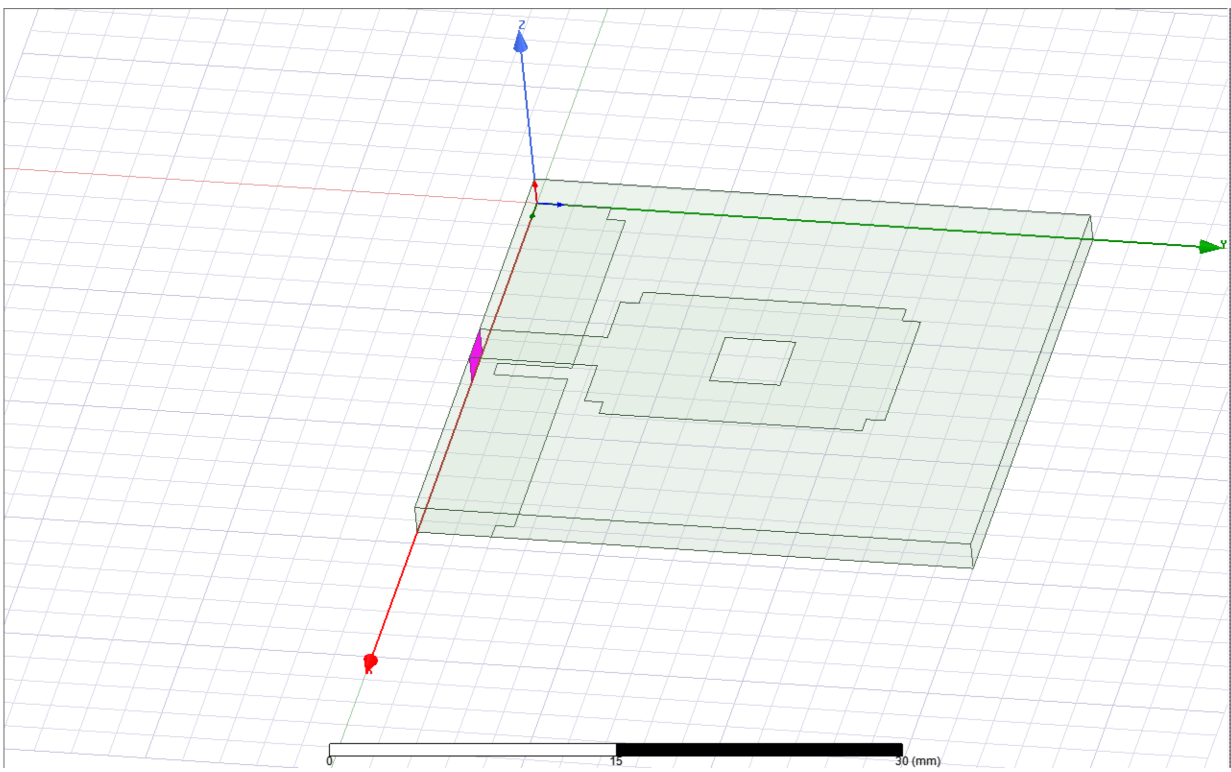
Stage 5: Cutting edges of the patch



**Stage 6: Cutting edges of the ground**



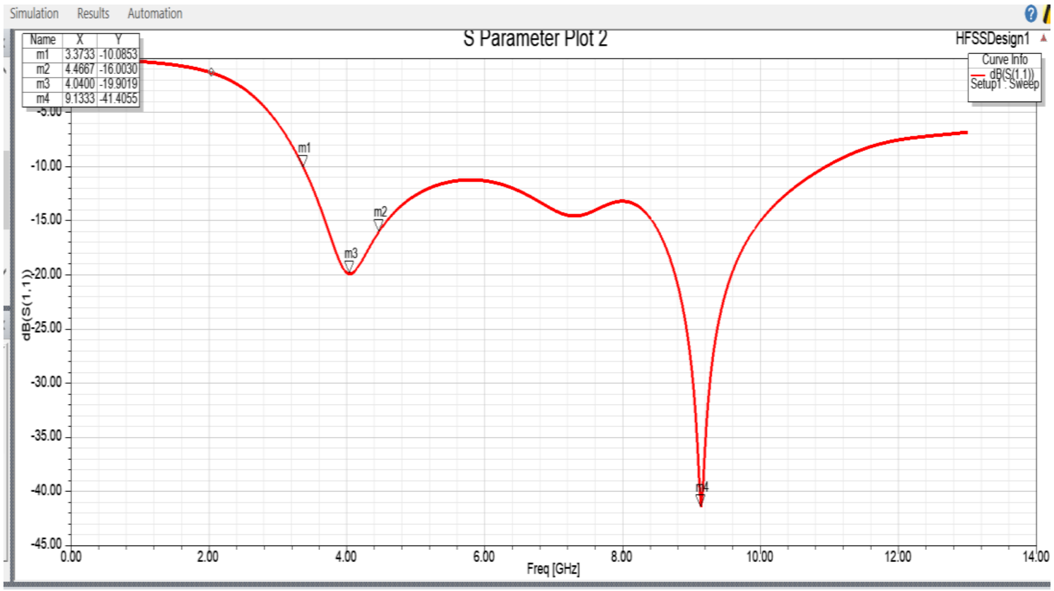

Finally the proposed antenna is as follows:



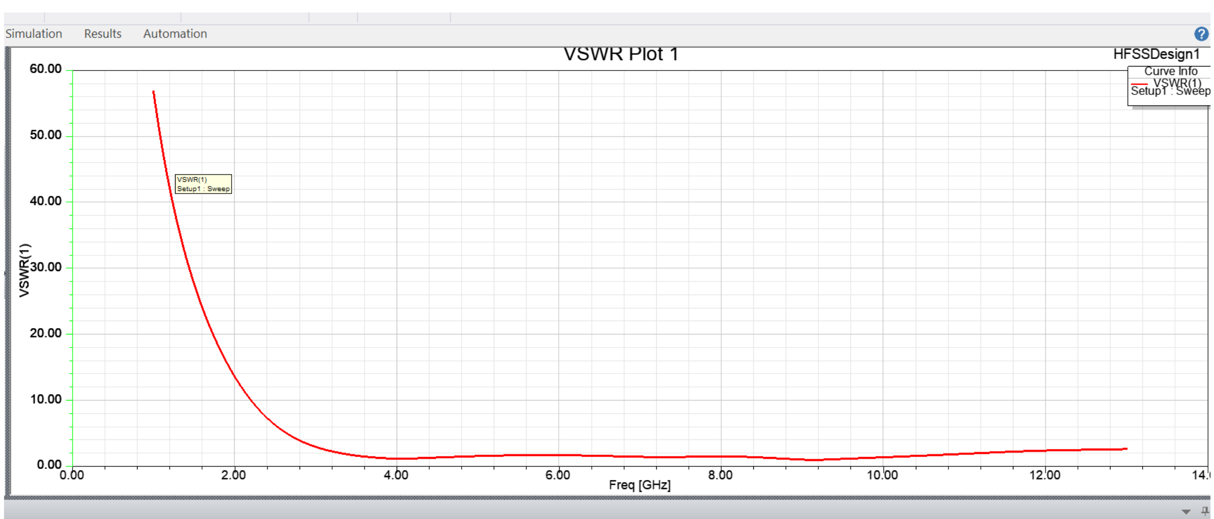
# Chapter-6

# RESULTS

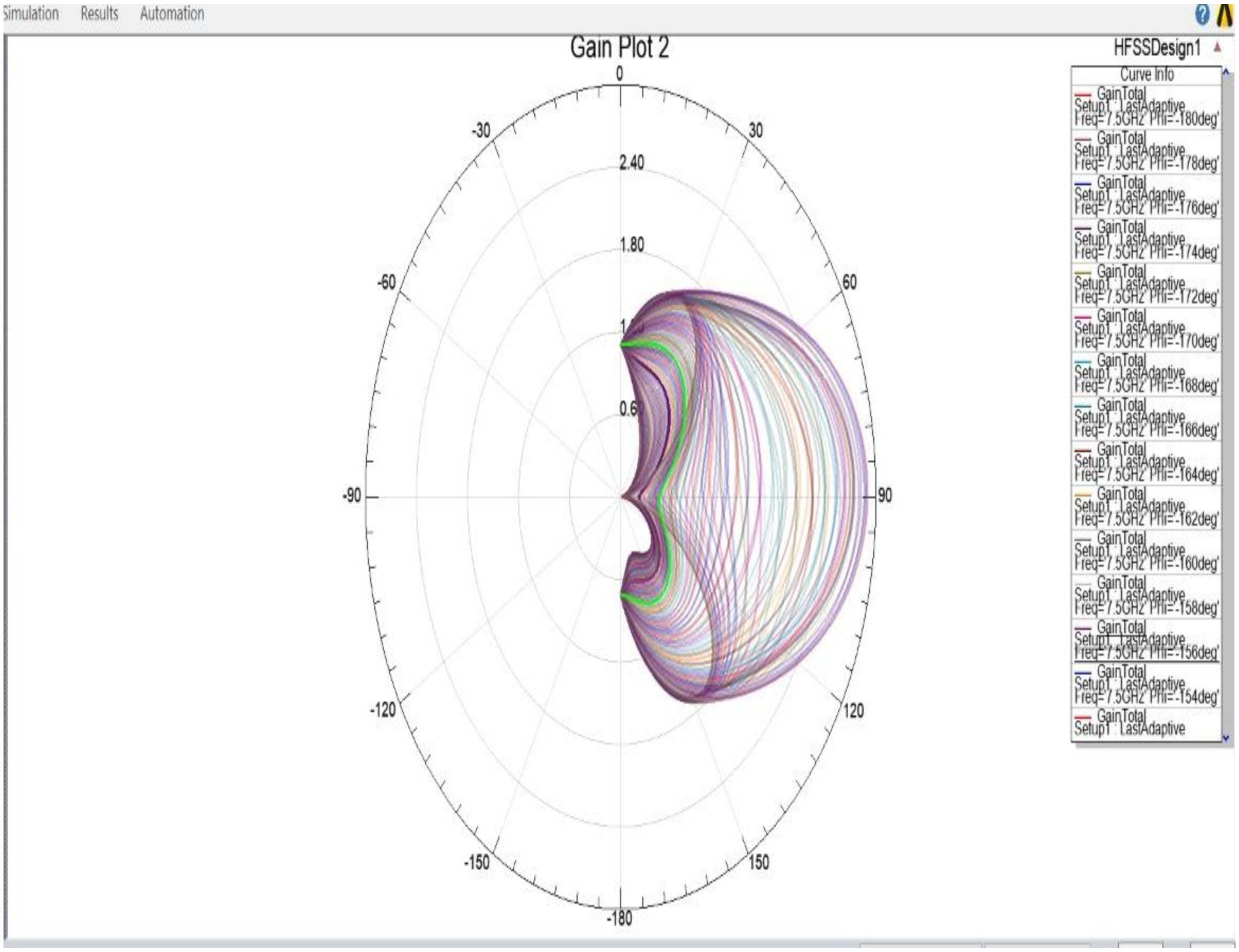
## 6.1 S-PARAMETER GRAPH:




## 6.2 VSWR GRAPH:



## 6.3 RADIATION PATTERN:



# CONCLUSION

The proposed UWB antenna using Defected Ground Structure is designed for Ultra wide band applications. The proposed antenna having multiband response resonating at 4.0 GHz and 8.9GHz with a return loss of -20dB and -43dB and bandwidth of 3.3 to 10.8GHz, VSWR is less than 2.The proposed antenna is designed by using HFSS software. The future scope of this project is by changing the structural modifications using different DGS techniques, slots and meta surfaces to achieve more gain and resonate at various applications.

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