Indian Institute of Information Technology Manipur

ELECTRONICS AND COMMUNICATION ENGINEERING

Frequency Reconfigurable Antenna

Course Code: EC-400 Project

SUPERVISED BY

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ABSTRACT

Frequency Reconfigurable patch antenna for L-Band applications is presented in this paper. L-band applications are GPS, telecommunication and radars . Antenna dimensions are 34.45mm x 45.64mm and antenna had been designed using Ansys HFSS software. It is a microstrip line inset feed patch antenna with square concentric rings as Defected Ground structure(DGS) which is used for size reduction and for improving gain and bandwidth of patch antenna. FR-4 is used as substrate. Two pin diodes have been used on the ground plane to carry out switching mechanism in the frequency domain. The frequency shift operation is done with help of different combinations of two pin diodes. The simulated Return loss values are well below the -10dB value in all four combination

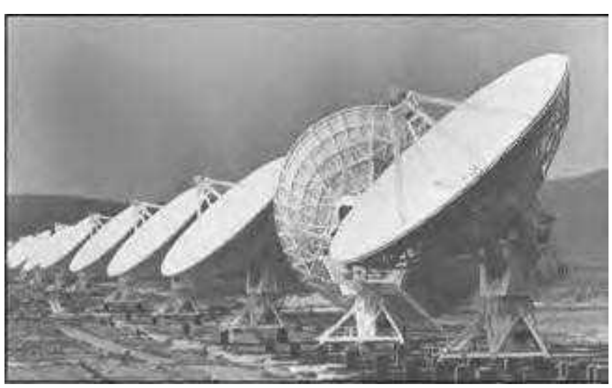
INTRODUCTION TO ANTEENA

An antenna is defined by Webster's Dictionary "**a usually metallic device for radiating or receiving radio waves"**. The IEEE Standard Definitions of Terms for Antennas (IEEE Standard 145- 1983) defines **the antenna or aerial as "a means for radiating or receiving radio waves"**.

In other words, the antenna is a transitional structure between free space & a guiding device It is neither be important that it must be metallic.

• Basic overview of anteena:-

An antenna acts as a **transducer** that converts the electrical power into EM waves. The electric charges are the source of the EM or electromagnetic waves .The transmitting antenna carries the electric current, converts it into the form of radiation, and transmits it into space. The Antenna can be used as a **transmitting antenna** or the **receiving antenna .**The antenna uses voltage and current from the source (transmission line) to launch Electromagnetic waves into the particular medium.



VISUALIZATION OF ANTENNA

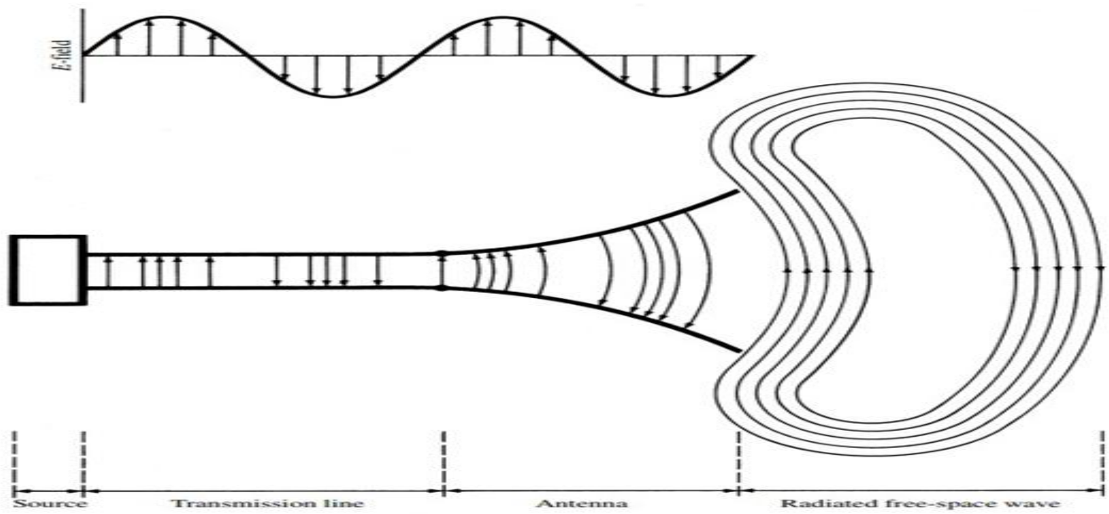


Figure 1.1 Antenna as a transition device.

Explanation :

In the above figure transmission of antenna is shown here we considering electric field or voltage source so what happening as the sinusoidal voltage progresses through transition so as soon as the voltage waveform approaches towards the antenna section some discontinuity is required to create disturbance in acceleration charges acceleration of charges means this voltage disturb that's why shape of the antenna is tapered at the end. The conduction structure of this metallic device some types of electron is vibrating and this oscillation of charged particle create disturbance and this disturbance is nothing, but leakage of radiation in free space, because as we can see that, this is open circuit condition, and we know that open circuit condition. The voltage is or potential is high and current is low. So same alternate scenario for receiving side and at the receiver end we have short circuit condition. In short circuit condition is nothing but voltage is zero. Potential is minimized and current is high. So this is the basic condition or basic requirement for a transmission as well as the receiver antenna.

1.3 THEVENIN EQUIVALENT OF ANTENNA IN TRANSMITTING MODE

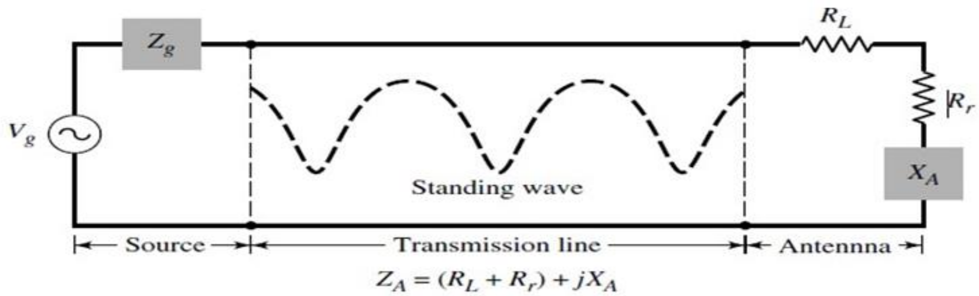


Figure 1.2 Transmission-line Thevenin equivalent of antenna in transmitting mode.

Explanation :-

A transmission-line Thevenin equivalent of the antenna system in the transmitting mode is shown in (Figure1.2) where the source is represented by an ideal generator Vg the transmission line is represented by a line with characteristic impedance Zc The load resistance RL is used to represent the conduction and dielectric losses associated with the antenna structure while Rr referred to as the radiation resistance, is used to represent radiation by the antenna. The reactance XA is used to represent the imaginary part of the impedance associated with radiation by the antenna Zc, and the antenna is represented by a load ZA [ZA = (RL + Rr) + jXA] connected to the transmission line. The reflected waves from the interface create, along with the traveling wavefrom the source toward the antenna, constructive and destructive interference patterns,referred to as standing waves, A typical standing wave pattern is shown dashed in Figure 1.2 An equivalent similar to that of Figure 1.2 is used to represent the antenna system in the receiving mode where the source is replaced by a receiver. All other parts of the transmission-line equivalent remain the same. The radiation resistance Rr is used to represent in the receiving mode the transfer of energy from the free-space wave to the antenna Under ideal conditions, energy generated by the source should be totally transferred to the radiation resistance Rr , which is used to represent radiation by the antenna. However, in a practical system there are conduction-dielectric losses due to the lossy nature of the transmission line and the antenna, as well as those due to reflections (mismatch) losses at the interface between the line and the antenna. Taking into account the internal impedance of the source and neglecting line and reflection (mismatch) losses, maximum power is delivered to the antenna under conjugate matching.

TYPES OF ANTENNAS

1-Wire Antenna :-

Wire Antennas are the type of radio antennas that consists of the long wire suspended over the ground. The wire acts as an antenna by picking up the signals and further radiating them.   There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix .

DIPOLE ANTENNA

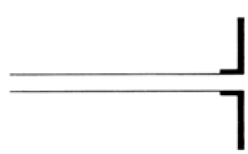
- The Dipole antenna consists of two straight wires that lie along the same axis. It is also called a doublet. It is the most common used class of the antenna. The two wires or conductors of the dipole antenna are connected to the transmitter or receiver

- Other variants of dipole antenna include turnstile antenna, halo antenna, batwing antenna, etc.

- The dipole antennas smaller than one half the wavelength is called as short dipole antennas. It has very low radiation resistance.

Note :-

The dipole antenna is further categorized as **half-wave dipole antenna, monopoleantenna, Quarter-wave monopole antenna,** and **Hertzian dipole**



(a) Dipole

LOOP ANTENNA

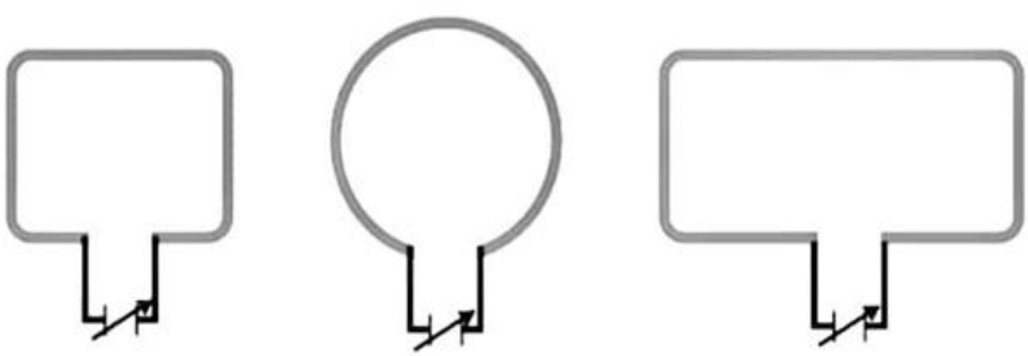
- The loop antenna consists of turns in a wire. The perimeter of the loop can be large or small, depending on the operating frequency.

- The essential requirement of the large loop antennas is the loop's perimeter equal to the 110% of the one-full wavelength.

- Some antennas are shaped in the form of a loop but are not loops due to some breaks in between. For example, Halo Antenna. The Halo Antenna is bent in the form of the loop but has breaks in between. It can be considered as a dipole antenna. The break-in such antennas is analyzed as the air break or air capacitor.

- Small loop antennas are generally lossy. Hence, it is suitable for low-frequency transmissions below 10MHz. Its applications include AM (Amplitude Modulation) broadcast receivers, land mobile radio, etc.

- The loop can be in the shape of a square, rectangle, circle, or any geometrical shape but in the form of a closed loop. It is shown below



Loop Antennas of Different Shapes

HELICAL ANTENNA

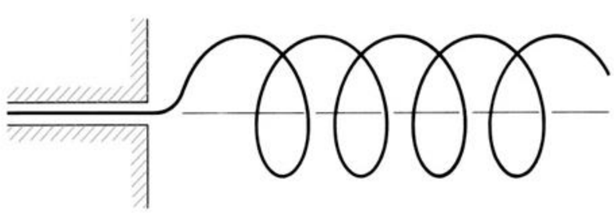
- It consists of a wire in the form of a helix. The helical antennas can be directional or omnidirectional. The directional helical antennas are generally mounted on the ground plane.

- The helix antennas can use operators in either normal mode or axial mode. The antenna's diameter and pitch in the case of the normal mode are smaller than the wavelength. It acts as a monopole antenna in such a case. The helix antenna operating in the normal mode is also called a broadside helical antenna.

- The antenna's diameter and pitch in the case of the axial mode are comparable to the wavelength. The antenna behaves as a directional antenna in the axial mode. The helix antenna operating in the axial mode is also called an end-fire helical antenna.

- The helix antenna can comprise of one, two, three, or four wires. A helix antenna with two wires is called a bifilar Similarly, a helix antenna with four wires is called a quadrifilar.

- The helix antenna behaves like an inductively loaded monopole due to the added inductance. The inductance is due to its helical shape. The monopole antennas can be used as the electrically short monopoles (antenna shorter than the signal wavelength).



(c) Helix

APERTURE ANTENNA

- It is shaped like a horn that directs the radio waves in the form of beam.

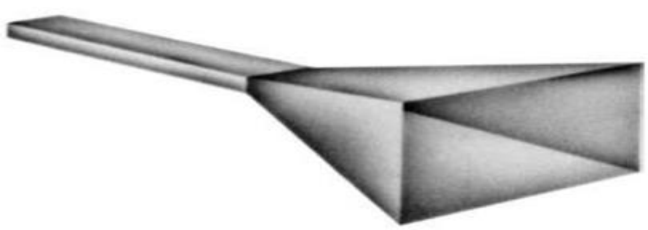
- The horn antennas are used at microwave and Ultra High Frequencies. The frequency range generally lies above 300MHz. The working of a horn antenna is similar to that of a musical instrument trumpet.

- The horn antenna allows the radiation of the wave energy with minimum reflection. The other types of horn antenna are ridged horn, exponential horn, conical horn, etc.

- The wavefronts of the horn antenna are spherical. The phase due to the spherical wavefronts increases smoothly from the edges towards the center.

- The increase in the size of the horn increases phase error. It further provides the horn antenna a wider radiation pattern.

- When the horn antenna is combined with the parabolic reflector, the antenna thus formed is called horn-reflector antenna.

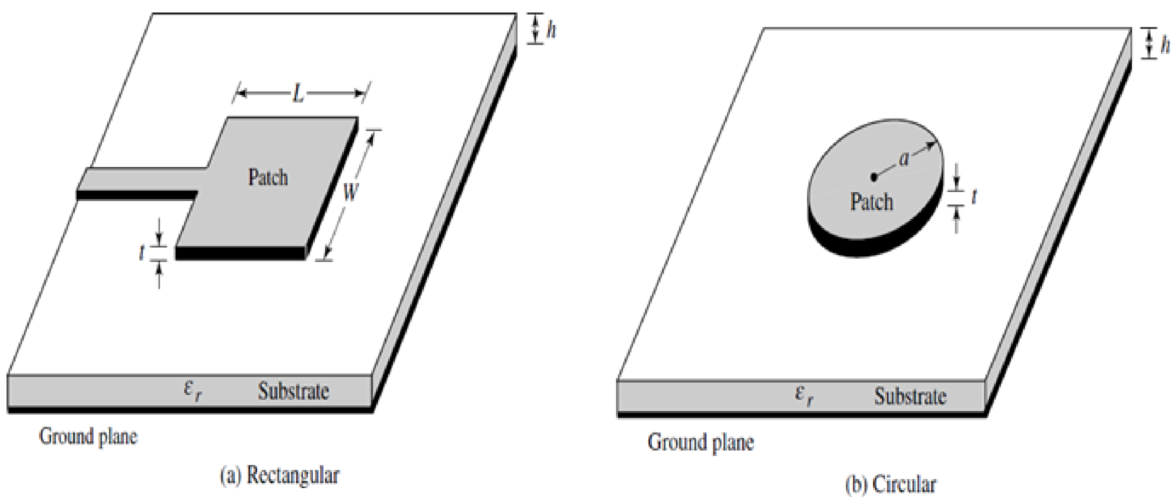


(a) Pyramidal horn

MICROSTRIP ANTENNAS

Micro strip antennas are low-profile antennas. A metal patch mounted at a ground level with a di-electric material in-between constitutes a Micro strip or Patch Antenna. These are very low size antennas having low radiation. The patch antennas are popular for low profile applications at frequencies above 100MHz.

Micro strip antenna consists of a very thin metallic strip placed on a ground plane with a di-electric material in-between. The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the patch or micro-strip is choosen to be square, circular or rectangular in shape for the ease of analysis and fabrication. The following image shows a micro-strip or patch antenna .

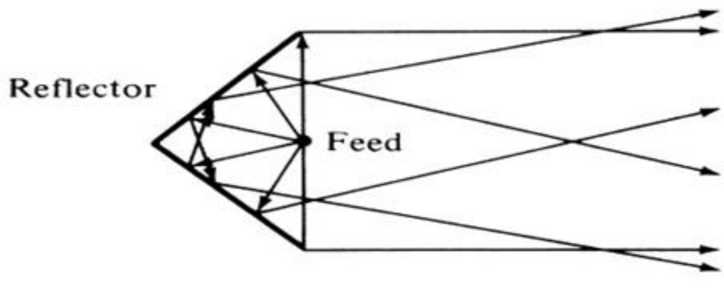


ARRAY ANTENNAS

An antenna array is a radiating system, which consists of individual radiators and elements. Each of this radiator, while functioning has its own induction field. The elements are placed so closely that each one lies in the neighbouring one's induction field. The spacing between the elements and the length of the elements according to the wavelength are also to be kept in mind while designing these antennas In array, the radiation of all the elements sum up, to form the radiation beam, which has high gain, high directivity and better performance, with minimum losses.

REFLECTOR ANTENNAS

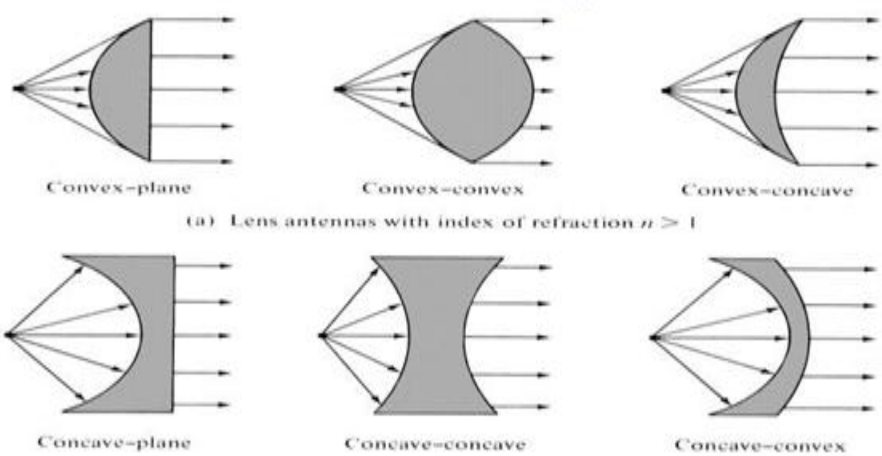
An antenna consisting of one or more reflecting surfaces and a feed system for transmitting and/or receiving electromagnetic waves. Such type of antenna is used to communicate over great distances that is in order to transmit and receive signals that had to travel millions of miles Antennas of this type have been built with diameters as large as 305 m. Such large dimensions are needed to achieve the high gain required to transmit or receive signals after millions of miles of travel.



(c) Corner reflector

LENS ANTENNAS

A lens antenna is a microwave antenna that uses a shaped piece of microwave-transparent material to bend and focus the radio waves by refraction, as an optical lens does for light



(a) Lens antennas with index of refraction $n > 1$

(b) Lens antennas with index of refraction $n < 1$

SUMMARY FOR ALL THE ANTENNA

SUMMARY

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

RADIATION MECHANISM OF ANTENNA

Radiation Mechanism principle depend upon Two laws (from Maxwell Equation) :-

- A Moving Electric Field Creates a Magnetic (H) field A Moving Magnetic Field Creates an Electric (E) field.

- All radiation is caused by accelerating charges which produces time-varying E-field.

And from above two laws, changing E-field give rise to time-varying Magnetic (H) field and Vice-Versa.

- Radiating transmission line is technically an antenna
- Good transmission line= poor antenna

Explanation:-

All radiation is caused by accelerating charges, which produces time varying electric field. And as per law of Maxwell time varying electric field will give rise to the time varying magnetic field. So this way the concept of generation of electromagnetic wave happening .Hence there must be time, varying current if there is a constant DC there is no radiation. There must be some time varying current or time varying voltage and second part acceleration or deceleration of charge. A uniform flow will not result into radiation. There must be some disturbance in velocity of charge, so that they will change their acceleration.

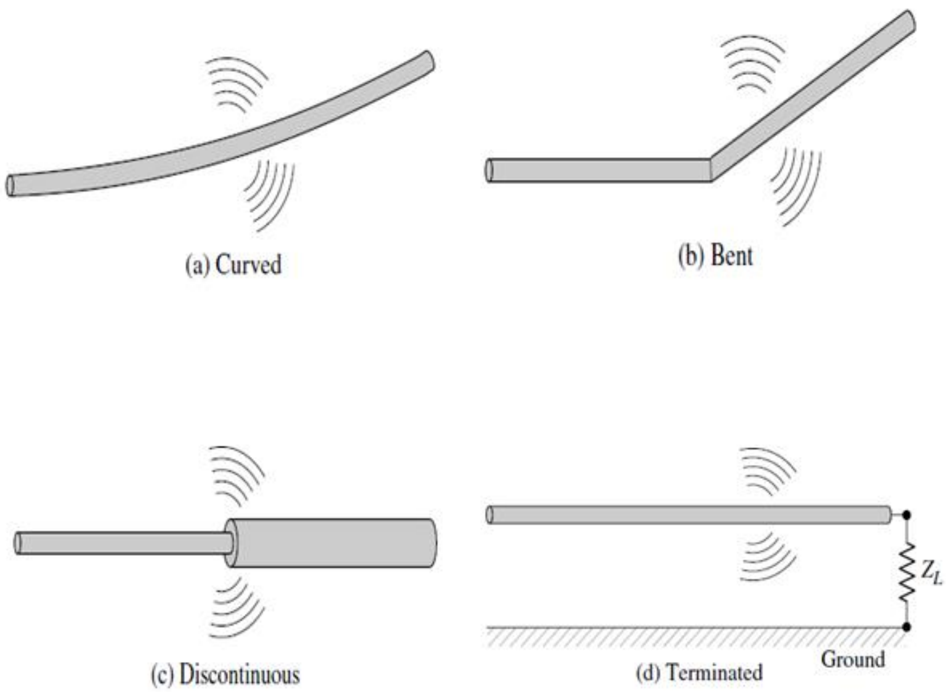
Hence we can conclude that if there is Uniform velocity No radiation. If charge is not moving, no radiation. If charge is oscillating in free space, or in a bounded media, there must be radiation.

RADIATION MECHANISM NECESSARY CONDITION

1. If a charge is not moving, current is not created and there is no radiation.

2. If charge is moving with a uniform velocity:
a. There is no radiation if the wire is straight, and infinite in extent.
b. There is radiation if the wire is curved, bent, discontinuous, terminated, or truncated, as shown in Figure 1.10

3. If charge is oscillating in a time-motion, it radiates even if the wire is straight.



ANTEENA PARAMETERS

- RADIATION PATTERN :-

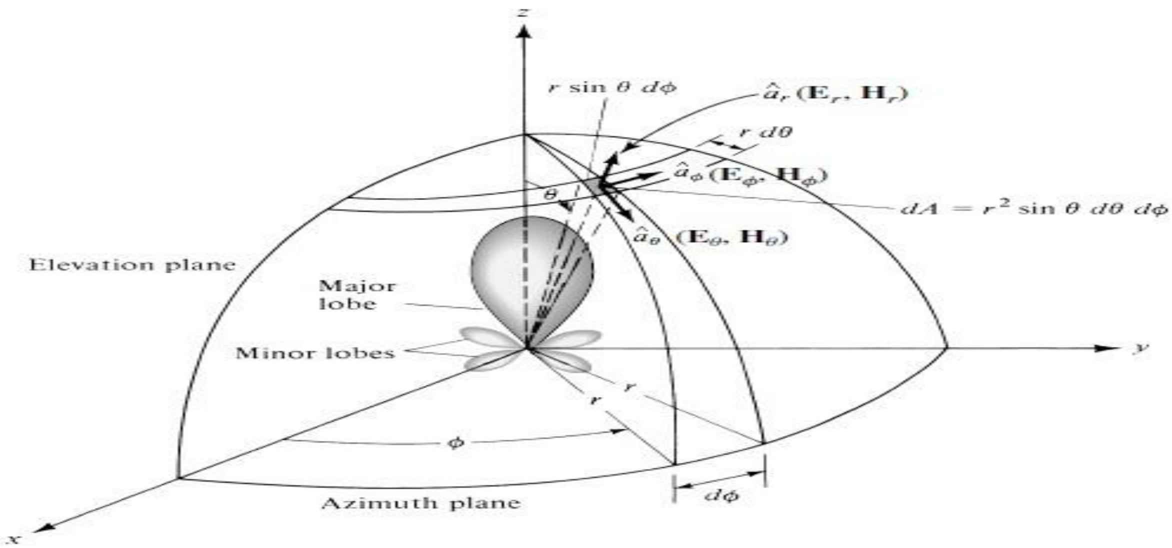


Figure 2.1 Coordinate system for antenna analysis.

A mathematical or graphical representation of the radiation properties of an antenna, such as amplitude, phase, polarization etc. as a function of the angular space coordinates θ, Φ Or in other words it is a variation of the field intensity of an antenna as an angular function with respect to the axis.
The radiation pattern is also called as the antenna pattern. It is the three-dimensional plot of the radiations from the antenna at the far field. It means that the radiation pattern of an antenna is also known as a far-field pattern.

COMMON TYPES OF ANTENNA PATTERN

- **Power Pattern -** normalized power vs spherical coordinate position.

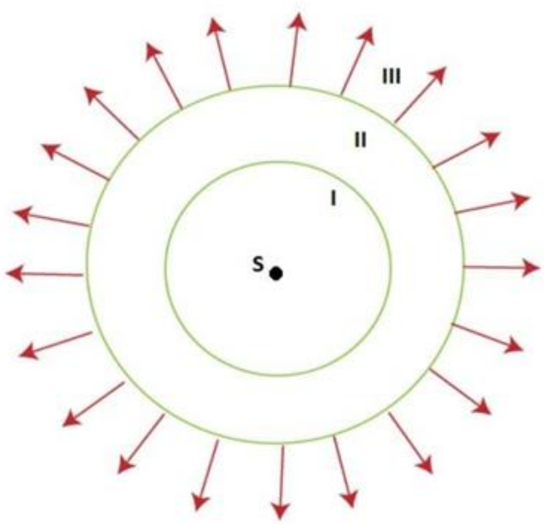
- **Field Pattern -** normalized |E| or |H| vs spherical coordinate position.

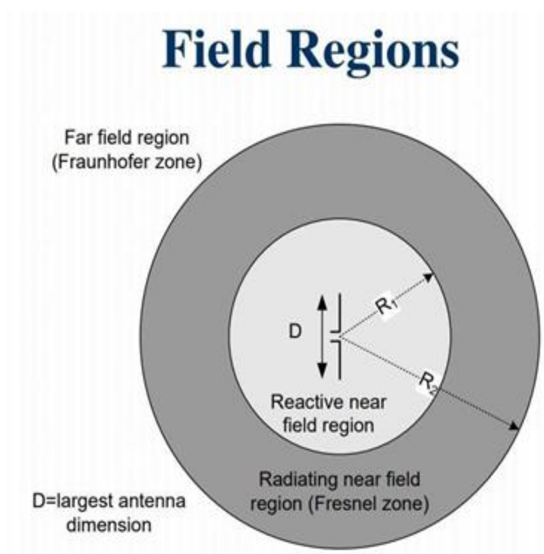
ANTENNA FIELD TYPES

- **Reactive field -** the portion of the antenna field characterized by standing (stationary) waves which represent stored energy.

- **Radiation field -** the portion of the antenna field characterized by radiating (propagating) waves which represent transmitted energy.

REGIONS OF AN ANTENNA





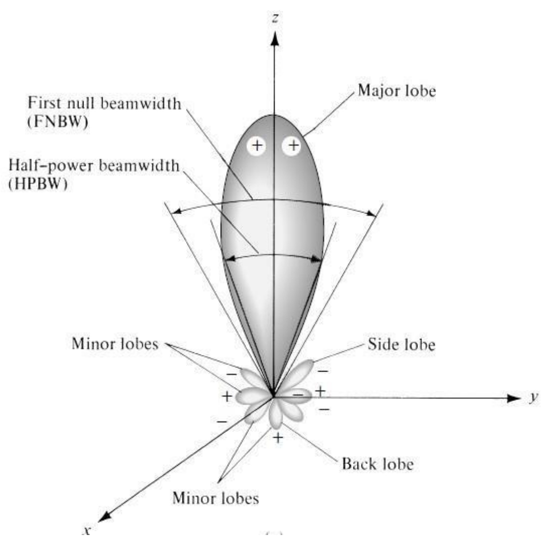
three regions are numbered I. II. and III

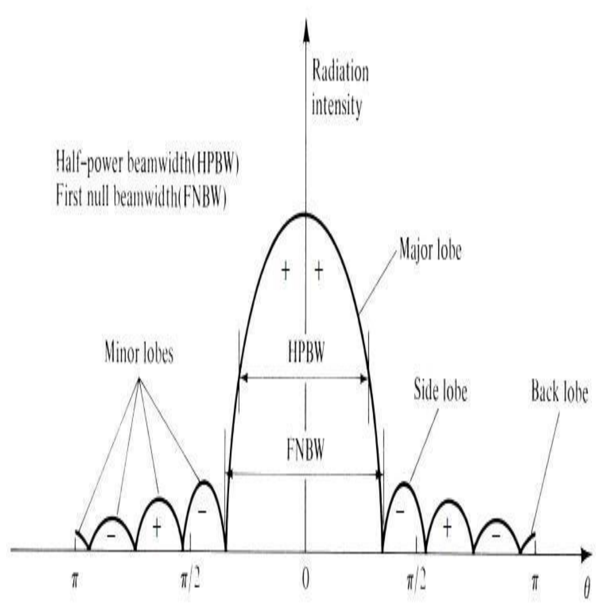
- Region I:-The region immediately surrounding the antenna where the reactive field (stored energy - standing waves) is dominant. It is called the oscillatory field region. It is generally close to the source (marked as S). It is the region within the 1/r^3.

- Region II:-The region between the reactive near field and the far-field where the radiation fields are dominant and the field distribution is dependent on the distance from the antenna It is called the near field region. It range lies between the 1/r^3 and 1/r^2.

- Region III:-The region farthest away from the antenna where the field distribution is essentially independent of the distance from the antenna It is called the far field region and it is the Region where angular field distribution is essentially independent of the distance from antenna.

RADIATION PATTERN LOBES





- Radiation Lobe - a clear peak in the radiation intensity surrounded by regions of weaker radiation intensity.

- Main Lobe :- (major lobe, main beam) - radiation lobe in the direction of maximum radiation.

- Minor Lobe :- any radiation lobe other than the main lobe.

- Side Lobe - a radiation lobe in any direction other than the direction(s) of intended radiation.

- Back Lobe - the radiation lobe opposite to the main lobe.

- Half-Power Beamwidth (HPBW) - the angular width of the main beam at the half-power points.

- First Null Beamwidth (FNBW) - angular width between the first nulls on either side of the main beam.

As the radiation pattern corresponds to the field distribution in space thus it has various parts known as lobes. These are classified as main lobe and side lobe. The main lobe is also called as major lobe while the side lobe includes minor lobe and back lobe.
These are classified according to the amount of their radiation intensity : -

1. The major lobes have more radiation intensity than the side lobes .The major lobe corresponds to the direction of maximum radiation of the antenna.
2. All the lobes which are present except the major lobe are known as the minor lobe.
3. These are of two types :-

a. A side lobe is a minor lobe present adjacent to the main lobe. A back lobe is another minor lobe present on the opposite side of the main lobe.

b. Minor lobes are the radiation of the antenna in an undesired direction and should be reduced to an extent as much as possible.

NORMALIZED FIELD PATTERN

It is obtained by dividing a field component by its maximum value. The normalized field pattern is a dimensionless number with maximum value of unity.

$$E\theta(\theta,\phi)n = \frac{E\theta(\theta,\phi)}{E\theta(\theta,\phi)max}$$

NORMALIZED POWER PATTERN

Pattern expressed in terms of power per unit area is called power pattern. Normalizing the power with respect to maximum value yields normalized power patterns as a function of angle which is dimensionless and maximum value is unity

$$Pn(\theta,\phi)n = \frac{S(\theta,\phi)}{S(\theta,\phi)max}$$

TYPES OF PATTERNS

1.Isotropic Pattern

2.Directional Pattern

3.Omnidirectional Pattern

1.Isotropic Pattern

It is the radiation from a point source, radiating uniformly in all directions, with same intensity regardless of the direction of measurement.
Examples:

Sun, Bulb antenna

2.Directional Pattern

Radiates more in a particular direction and less in other direction.

- **Major lobe | main lobe :** The radiation lobe containing the direction of maximum radiation
- **Minor lobe | side lobe :** Any lobe except major lobe.

Examples:

Dipole antenna, Folded dipole antenna.

3. Omnidirectional Pattern :-

The antenna which radiates power only in one direction is called omni directional antenna.
Examples :-

Horn antenna , Yagi-oda antenna.

ANTENNA BASIC PARAMETERS

RADIATION POWER DENSITY:-

POYNTING VECTOR :-

Poynting vector = Power density

The magnitude of the Poynting vector gives the instantaneous or average Power Density of the electromagnetic wave. Its direction gives the direction of the power flow at that particular point.

and it is defined as:-

$$W = E \times H$$

- W = instantaneous Poynting vector (W/m2)
- E= instantaneous electric-field intensity (V/m)
- H= instantaneous magnetic-field intensity (A/m)

RADIATION INTENSITY

The power radiated from an antenna per unit solid angle.

$$U = r^2 Wrad$$

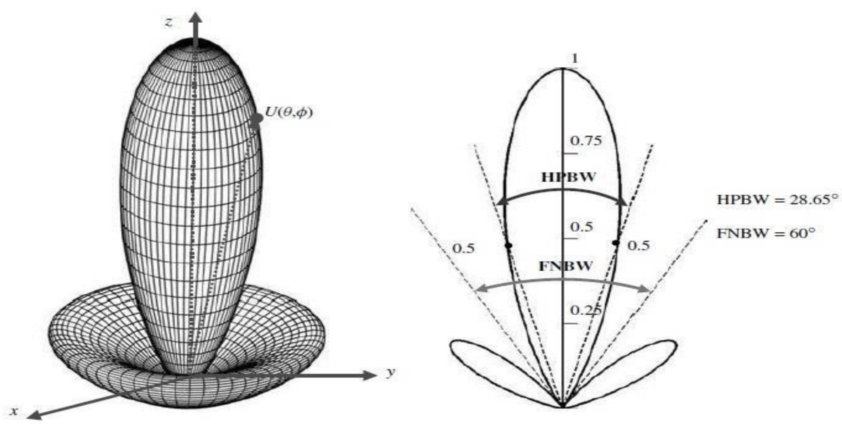
U: Radiation intensity [W/unit solid angle]
Wrad: Radiation density [W/m]

AVERAGE RADIATION INTENSITY

The average radiation intensity for a given antenna represents the radiation intensity of a point source producing the same amount of radiated power as the antenna

$$U_{avg} = \frac{\int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\, d\Omega}{4\pi} = \frac{P_{rad}}{4\pi}$$

BEAMWIDTH



(a) Three dimensional (b) Two-dimensional

Beamwidth is the angular separation between two identical points on opposite site of the pattern maximum.

- **Half-power beamwidth (HPBW) :**

In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is onehalf value of the beam.

- **First-Null beamwidth (FNBW) :**

Angular separation between the first nulls of the pattern

DIRECTIVITY

The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions

$$D(\theta,\phi) = \frac{U(\theta,\phi)}{U_{avg}} = \frac{4\pi U(\theta,\phi)}{P_{rad}}$$

The directivity of a non isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source.

$$\boxed{D = \frac{U}{U_0} = \frac{4\pi U}{P_{\text{rad}}}}$$

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as-

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

where

- D = directivity (dimensionless)
- D0 = maximum di
- U = radiation intensity (W/unit solid angle)
- Umax = maximum radiation intensity (W/unit solid angle)
- U0 = radiation intensity of isotropic source
- (W/unit solid angle)
- Prad = total radiated power

NOTE:-

- The directivity of an isotropic radiator is $D(\theta, \Phi) = 1$
- The maximum directivity is defined as $[D(\theta, \Phi)]max = Do$
- The directivity range for any antenna is $0 <= D(\theta, \Phi) <= D0$

1.2 FR4 SUBSTRATE

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

If the material has to be flame or fire retardant, there are certain requirements to be fulfilled for the material to be certified, as FR. When an equipment using FR4 grade PCB and if there is some kind of overvoltage or short circuit in the equipment, then the PCB made of organic material can catch fire but it should have the ability to retard the fire by itself; that means, it should have a self-extinguishing property.

The FR4 substrate is manufactured by compressing an epoxy resin at high pressure and a glass fiber mat (or mats) is embedded within the structure. The glass fiber gives the strength to substrate and increases the dielectric constant of the composite material. The weave is usually more densely packed in the one direction, and so the material is inherently anisotropic, with a small variation in the dielectric constant in different planes. Furthermore, the manufacturing technique employed introduces inconsistency in board thickness, which can cause variation in microstrip circuit parameters. Typical FR4 board characterization is generally carried out by the manufacturers at 1MHz. At microwave frequencies, the bulk dielectric constant value is typically similar to the value at 1 MHZ, decreasing slightly at the frequencies above a few GHz.

FR4 epoxy glass substrates are the material of choice for most PCB applications. The material is of low cost and has excellent mechanical properties, making it ideal for a wide range of electronic equipments. As more and more microwave systems are developed for consumer market, there is a considerable interest in minimizing the cost of these systems.

Commercial substrate materials are promptly available for the use at RF and microwave frequencies for the design of microstrip and printed antennas. The substrate can be preferred based on the desired material characteristics for optimal performance over the specific frequency range. Dielectric constant, thickness and loss tangent are the commonly used parameters. Normally the dielectric constant ranges from 2.2 to 12 for the operations at frequencies ranging from 1 to 100 GHz.

The microstrip patch antenna design depends upon the substrate thickness. The thick substrates with low dielectric constants are the desired ones to obtain the larger bandwidth and higher efficiency due to loosely bound fringing fields. While thin substrates with large dielectric constants reduce the overall size of the antenna, however due to high loss tangents thin substrates are less efficient that results with narrow bandwidth. Therefore substrate selection is an important matter which has to be done in the beginning to get the desirable. features for a given application.

1.2 FR4 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 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 are given below:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to hostsur face.
- 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).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas. Some of their major disadvantages are given below:

- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

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 scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by use of photonic bandgap structures as discussed by Qian et al [11]. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

1.3 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).

1.4.1 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 3.3. The conducting strip 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.

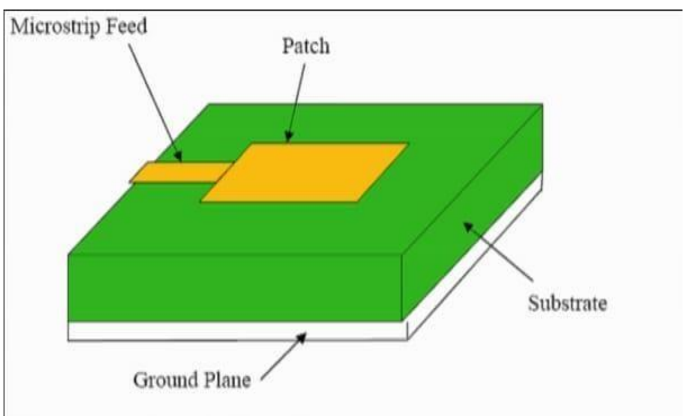


Figure 1.3 Microstrip Feed Line

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 being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna [5]. The feed radiation also leads to undesired cross polarized radiation.

1.4.2 COAXIAL FEED

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 3.4, 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.

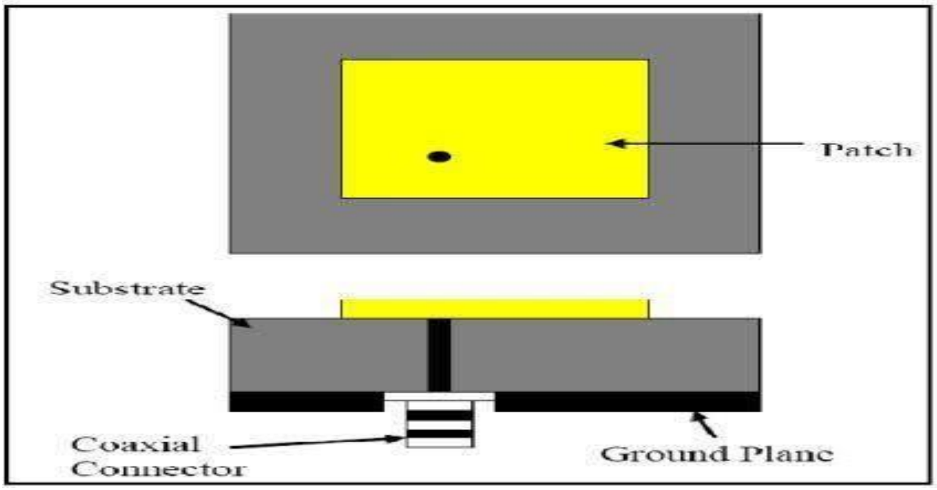


Figure 1.4 Probe feed Rectangular Microstrip Patch Antenna

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 . Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems . It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problems.

1.4.3 METHODS OF ANALYSIS

There are many methods of analysis for microstrip antennas .The most popular models are the transmission model and cavity model and full wave (which include primarily integrations/methods).The transmission line model is the easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling. Compared to transmission line model, the cavity model is more accurate at the same time more complex. However it gives also physical insight and is rather difficult to model coupling, although it has been used successfully. In general, when applied properly, the full wave models are accurate, very versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and coupling. However they are the most complex models and usually give less physical insight. In this section we will cover the transmission-line model only.

1.4.3.1 Rectangular Patch Antenna

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

Transmission Line Model

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

a .Fringing Field:

The fringing field in rectangular microstrip antenna as shown in fig.1.7, arises from the radiating edges shown in the figure below. Fringing field are mainly depends on the dielectric constant and length L to height h ratio. Since in most of the cases the L/h ratio is <<1 therefore the fringing fields are less.

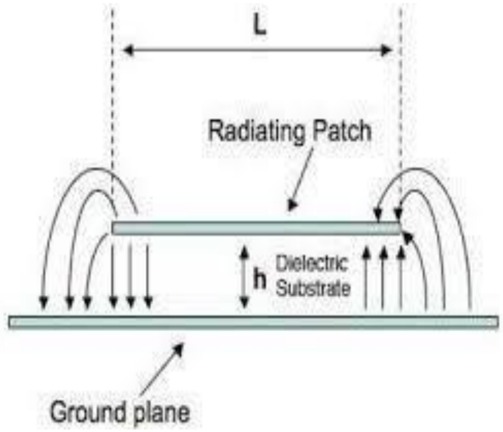


Fig.1.7: Fringing Field Effect

Higher dielectric constant substrate leads to bounded electric fields more enclosed in the substrate as used in the microstrip lines. While the lower dielectric constants substrates results in loosely bounded electric fields means they will go more further from the patch. Lesser the dielectric constant material used in substrate more bowed the fringing fields .We know that the fringing fields are responsible for the radiations from microstrip antenna. Therefore lower dielectric constants more the fringing fields and more the radiation leads to better efficiency and better antenna performance. From figure it can be seen that fringing field lines are not only enclosed in substrate but also further out in the air. As the field lines travel in substrate and air also we have to calculate an Effective Dielectric constant by taking the air also in account as shown in Fig 1.8

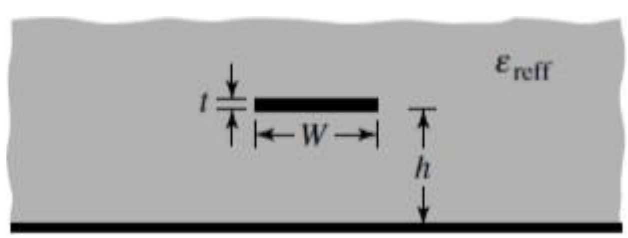


Fig.1.8.Effective dielectric constant

The effective dielectric constant is a dielectric constant of the material for which the antenna characteristics are same as for the real one. The range of effective dielectric constant varies from 1>Ereff<Er. In most cases the Ereff value is close Er. If the air is used as a substrate then the effective dielectric constant is equal to dielectric constant Ereff=Er. The Ereff is also depends on frequency. As the operating frequency increases the value of effective dielectric constant reaches to the real value of dielectric material used. Fig. 1.9 below showing the variation of effective dielectric constant with the frequency below.

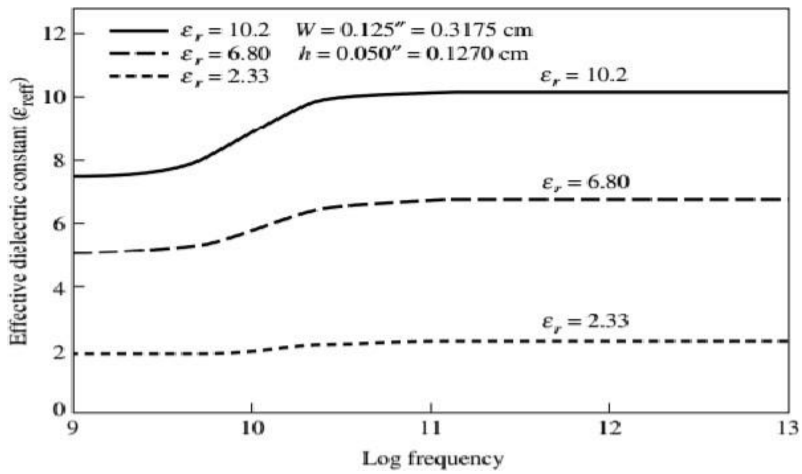


Fig.1.9.Effective dielectric constant Vs Frequency

For the lower frequency the effective dielectric constant does not varies but as the frequency increases the effective dielectric constant approaches towards the actual dielectric constant of substrate material.

The Ereff for W/h>1 can be given by equation 1.1

$$\varepsilon eff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}[1 + 12\frac{h}{w}]^{-\frac{1}{2}}$$

b. EFFECTIVE LENGTH, RESONANT FREQUENCY, AND EFFECTIVE WIDTH:

Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical dimensions. Where the dimensions of the patch along its length have been extended on each end by a distance delta L which is a function of the effective dielectric constant Ereff and the width-to-height ratio (W/h). A very popular and practical approximate relation for the normalized extension of the length is given by equation

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

Since the length of the patch has been extended by AL on each side, the effective length of the patch as shown in Fig. 1.10.

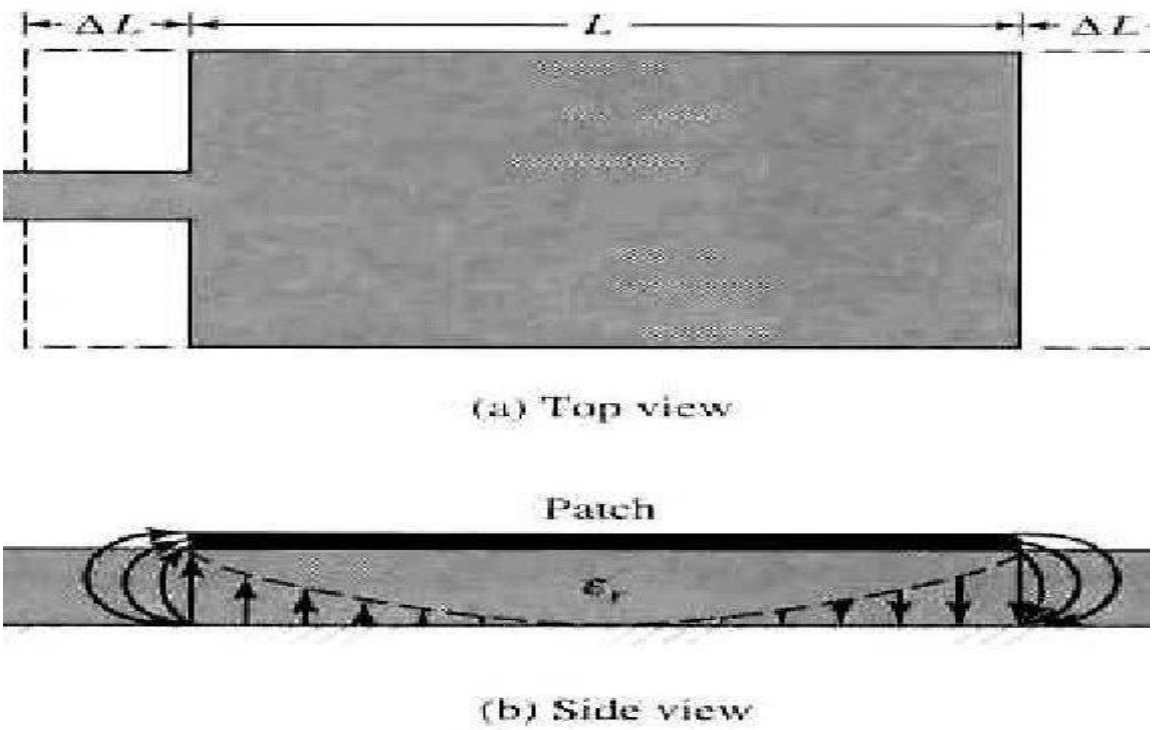


Fig.1.10.Length Extension

This delta L value mainly depends on the effective dielectric constant and the width to height ratio. Due to this length extension length of patch is about 0.48lambda rather than 0.5lambda. Therefore to get the actual physical length of the patch equal to lambda/2. we have consider the extension on both the ends and that is, the length of the patch is given by equation

$$L = Leff - 2\Delta L$$

As we know for dominant mode the length of patch is equal to lambda/2 therefore the Left is given by equation

$$Leff = \frac{c}{2f_{0\sqrt{\varepsilon eff}}}$$

Where Co is the velocity of light in free space and f, is the resonance frequency for which antenna is to be design.

For the dominant mode TM010 there is no fringing fields along the width therefore there is no need to consider the effective dielectric constant. Width of the patch can be calculated by this formula is given by equation

$$w = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

For the dominant mode TM010 the antenna resonates (without taking fringing into account) at the frequency given by the equation

$$f_{10} = \frac{c}{\sqrt{\varepsilon_r}}(\frac{1}{2L})$$

And when considering the effective length and effective dielectric constant the antenna will radiate at the frequency.

CHAPTER 2

RECONFIGURABLE ANTENNA

RECONFIGURABLE ANTENNA

2.1 INTRODUCTION

Antennas are necessary and critical components of communication and radar systems. Arguably, nine different types of antennas have proliferated during the past 50 years in both wireless communication and radar systems. These nine varieties include dipoles, monopoles. loop antennas, slot/horn antennas, reflector antennas. Microstrip antennas, log periodic antennas, helical antennas, dielectric/lens antennas and frequency-independent antennas. Each category possesses inherent benefits and detriments that make them more or less suitable for particular applications. When faced with new system design guidelines as starting points to develop new structures that often produce acceptable results.

Nevertheless, the choice of antenna from the families mentioned above also imposes restrictions on the overall system performance that arises because the antenna characteristics are fixed Making antennas reconfigurable so that their behavior can adapt with changing system requirement or environmental conditions can ameliorate or eliminate these restrictions and provide additional levels of functionality for any system. The reconfigurable antennas have a capacity to change an individual radiator's fundamental operating characteristics through electrical, mechanical or other means.

2.2 NECESSITY OF RECONFIGURABILITY

Let us consider two general application areas, single-element scenarios and array scenarios, In single- element scenarios an antenna used in portable wireless devices, such as a cellular telephone, a personal digital assistant, or a laptop computer. Single antennas typically used in these devices are monopole or microstrip antenna based and may or may not have multiple-frequency capabilities. Some packages may use two or three antennas for diversity reception on small devices to increase the probability of receiving a usable signal, but usually only one of the antennas is used for transmission. The transmission from the portable device to a base station or other access point is the weakest part of the bidirectional communication link because of the power, size, and cost restrictions imposed by portability. Moreover, the portable device is often used in unpredictable and/or harsh electromagnetic conditions, resulting in antenna performance that is certainly less than optimal. Antenna reconfigurability in such a situation could provide numerous advantages. For instance, the ability to tune the antenna's operating frequency could be utilized to change operating bands, filter out interfering signals, or tune the antenna to account for a new environment. If the antenna's radiation pattern could be changed, it could be redirected toward the access point and use less power for transmission, resulting in a significant savings in battery power. The antennas are mostly used in array configuration, feed structures with power dividers/combiners and phase shifters. For instance, current planar phased array radar technology is typically limited in both scan angle and frequency bandwidth as a result of the limitations of the individual array elements and the restrictions on antenna element spacing. This restriction comes from mutual coupling effect on one hand, appearance on grating lobe on other hand. Many of these established applications assume that the antenna

element pattern is fixed, all of the elements are identical, and the elements lie on a periodic grid. The addition of reconfigurability to antenna arrays can provide additional degrees of freedom that may result in wider instantaneous frequency bandwidths, more extensive scan volumes, and radiation patterns with control on side lobe distributions.

There are several antenna structures that are suitable for implementation of reconfigurable antennas, Among them microstrip patch antennas are very attractive structures for various types of reconfigurable antennas, all such antennas are usually equipped with switches that are controlled by DC bias signals. Upon toggling the switch between on and off states, the antenna can be reconfigured. The following section describes the design procedure of microstrip patch antenna types presented and different feed types used in this dissertation.

2.1 HISTORY

Reconfigurable antennas have been implemented in various ways over past 40 years. The concept of antenna reconfigurability appears very early in the context of radio communications which dates back to 1893-1901 with the first wireless Transmissions disputed by Tesla and Marconi. On the early years of radio broadcasting the main motivation for antenna reconfigurability was the requirement of antennas that could cover a large frequency range without degrading its performance. This was the very first form of frequency reconfigurability. One illustrative example of the initial works towards frequency reconfiguration corresponds to a patent by A.N.Goldsmith in 1926 where an antenna is tuned by using a variable inductive loading. A second example of a frequency tunable antenna is found in a patent by E. Werndl in 1942 where it is proposed to adjust the length of dipole antenna by using a liquid metal. After some years the first frequency tunable antennas are designed and the first designs of antennas with steerable radiation pattern are also designed. The development of antennas with radiation pattern agility took place in 1950s and then feed reflector and phased array techniques to achieve pattern reconfigurability are proposed. Laser polarization reconfigurable antenna concepts are defined.

The concept of antenna reconfigurability is traced back in the first half of the twentieth century and it has been applicable to all the electronic equipments which are using more than one antenna.

2.4CHALLENGES

The development of the reconfigurable antennas poses significant challenges to both antennas and system designers. These challenges lie not only in obtaining the desired levels of antennas functionality but also in integrating this functionality into complete systems to arrive at efficient and cost-effective solutions. As in many cases of technology development, most of the system cost will come from the antenna but the surrounding technologies that enable reconfigurability.

The reconfiguration of one property, say, frequency response will have an impact on radiation characteristics. Likewise, reconfiguration that results in radiation pattern changes will also alter the antenna's frequency response. This linkage is one of the latest challenges faced by the reconfigurable antenna developers who would usually prefer the characteristics to be separable.

2.2 TYPES OF RECONFIGURABLE ANTENNA

Reconfigurable antenna has an ability to change any one of the antenna parameter (operating frequency, radiation pattern and polarization) without effecting the remaining parameters. Based on the antenna parameter that is dynamically adjusted, the reconfigurable antennas are classified into four types. They are

2.2.1 FREQUENCY RECONFIGURABLE ANTENNA:

Frequency reconfigurable antennas can adjust their frequency of operation dynamically. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by physical or electrical modifications to the antenna dimensions using RF- switches, impedance loading or tunable materials.

These antennas can be developed by two mechanisms, electrical or mechanical. The electrical mechanism employs discrete tuning and continuous tuning methods. Discrete tuning can be achieved by radio frequency (RF) switches and continuous tuning can be achieved by varactor diodes. The mechanical mechanism employs the impedance loading tunable materials such as liquid crystalsto achieve the frequency reconfiguration.

2.2.2 RADIATION-PATTERN RECONFIGURABLE ANTENNA

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of the radiation pattern. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or switchable and reactively-loaded parasitic elements.

2.2.3 POLARIZATION RECONFIGURABLE ANTENNA

These antennas use switching between different polarizations, i.e. from linear polarization to left hand circular polarization (LHCP) and righthand circular polarization (RHCP), using multi modes structures. To reduce the polarization mismatch, losses in portable devices, switching between horizontal, vertical and circular polarizations are needed.

2.2.4 COMPOUND RECONFIGURABLE ANTENNAS

These antennas use simultaneous tuning of several antenna parameters, e.g. frequency and radiation pattern, for independent reconfiguration of operating frequency, radiation pattern and polarization. The most common application of compound reconfiguration is the combination of frequency agility and beam-scanning to provide improved spectral efficiencies. Compound reconfigurability is achieved by combining in the same structure different single-parameter reconfiguration techniques or by reshaping dynamically a pixel surface.

2.3 SWITCHABLE DEVICES USED FOR RECONFIGURATION

In order to demonstrate the reconfigurable antennas, various effective implementation techniques have been proposed to be used in different wireless systems such as satellite, multiple-input multiple-output (MIMO) and cognitive ratio communications, which are classified as below:

• Electrical reconfiguration

• Optical reconfiguration

• Physical reconfiguration

• Reconfigurable antennas with smart materials.

The most common technique is electrical reconfiguration, which uses active elements such as positive- intrinsic-negative (PIN) diodes, varactors and radiofrequency micro-electromechanical system (RFMEMS) switches. Compared to RFMEMS switches, PIN diodes have acceptable performance and a low price. Another technique is called optical reconfiguration, which relies on photoconductive switching elements. The antenna reconfigurable characteristic can also be implemented by altering the structure of the antenna this is called the mechanical reconfiguration method. The antenna can be also reconfigured using smart materials in the antenna configuration.

2.3.1 ELECTRICAL RECONFIGURATION

In this type of reconfiguration method, the antenna characteristics are changed using electronic switching components such as PIN diodes, varactors or MEMS. Using these switches, the antenna structure can be reconfigured, which causes the redistribution of the surface current and alters the antenna’s fundamental characteristics in terms of frequency, radiation pattern and polarization. The implementation of such a reconfigurable antenna with switching elements is easy and has received lots of attention in research. Next, different methods along with some examples of electrically reconfigurable antennas to obtain the corresponding reconfigurability function with their own advantages and disadvantages using PIN diodes, varactors or MEMS switches are described.

2.3.2 PIN DIODES

A PIN diode is a diode with a wide, undoped intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region. The wide intrinsic region makes the PIN diode as an fast switch, photo detectors, and high voltage power electronics applications. PIN diodes are widely used as the switching components in different wireless systems .The PIN diode needs a high tuning speed, a high bias current in the ON-state and a high power-handling capacity it is very reliable and extremely low-cost which makes it a good choice for the reconfiguration technique

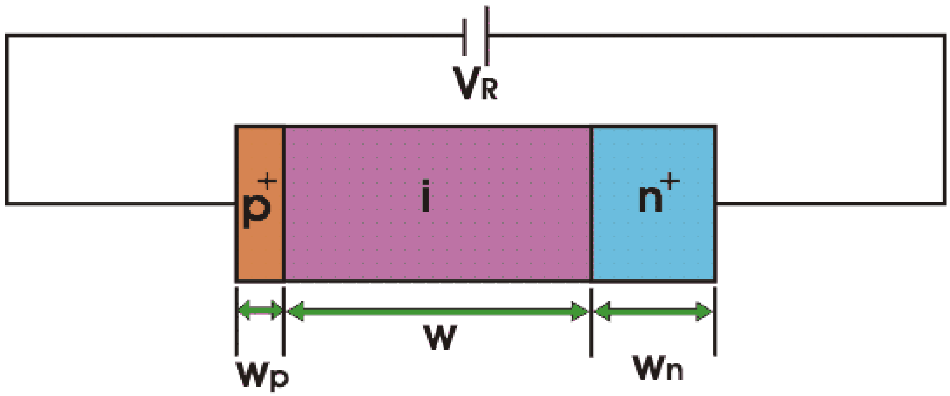


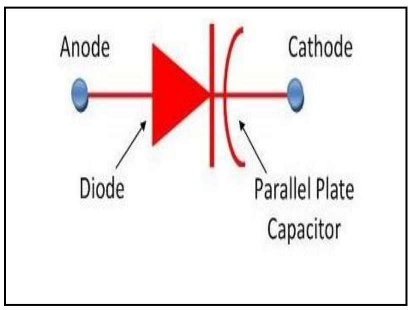
Fig.2.1 PIN Diode

2.6.3. TUNABLE VARACTORS

Varactors are used as voltage-controlled capacitors. By changing the voltage levels of the varactor, its capacitance changes, which leads to tune the antenna performance. Usage of varactors in reconfigurable designs helps to achieve the frequency tuning function. The varactor is nonlinear with a low dynamic range. It also requires a complex bias circuitry. When compared with other active elements such as a PIN diode or MEMS, it has a small current flow and continuous tuning characteristics. Voltage-controlled oscillators have many applications such as Phase-locked loops are used for the frequency synthesizers that tune many radios, television sets, and cellular telephones

The equation for capacitance is:

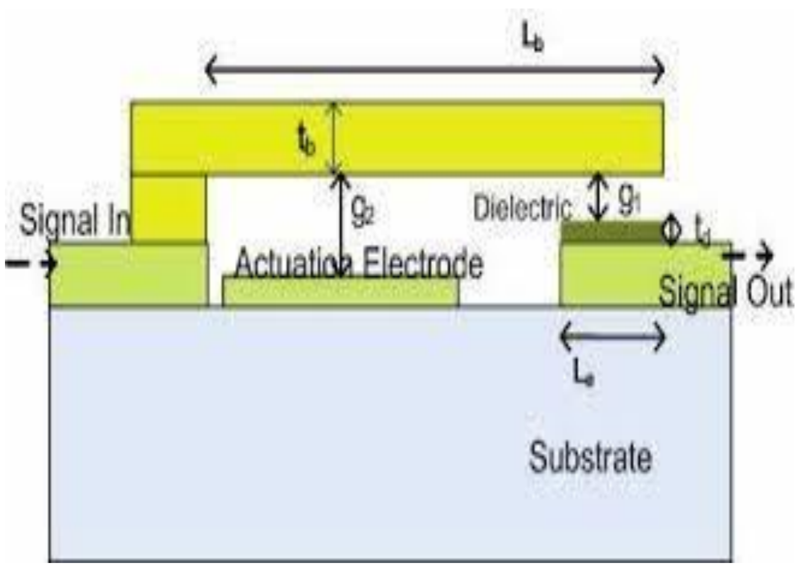
$$C = (\varepsilon_r \varepsilon_0) A/d$$



C is the capacitance in Farads
A is the area of each plate measured in square meters Er is the relative permittivity of the insulator
Eo is the permittivity of free space
d is the separation between the plates in meters.

2.6.4 MEMS

Reconfigurable antennas with MEMS switches are more interested for research. MEMS switches are devices which operate by the use of mechanical movement to achieve a short or open circuit in RF circuits. MEMS switches can be designed in different configurations based on signal path, the required force for mechanical movement can be obtained by different mechanisms for actuation such as electrostatic and magnetostatic. RFMEMS switches that are able to handle up to 20 W. These have applications in radar system, network analyser , satellite communication systems and base stations. An RFMEMS shunt switch is a type of MEMS switch, It is a series switch, which consists of a suspended movable thin metal bridge over the centre conductor. MEMS switches for RF applications operate through short and open circuits to transmit signals.



g.2.2 Varactor Diode

F
i

2.6.5 OPTICAL RECONFIGURATION

This is based on the use of photoconductive switches, made of a semiconductor material In optical reconfiguration, the photoconductive switches need for metallic wires, and bias lines are used which provide less interference and high isolation compared to electrical switches. In addition, they exhibit extremely fast switching speeds, switching in nanoseconds. Using photoconductive switches allows one to optically control an antenna’s operational bandwidths and radiation pattern. In an optically reconfigurable antenna is proposed for cognitive radio applications.

2.6.6. MECHANICAL RECONFIGURATION

In mechanical reconfiguration, the main radiator of the antenna can be reconfigured mechanically to provide different characteristics. In contrast to other reconfiguration techniques with the switches, this type of reconfigurable antenna does need active element integration, biasing systems. The performance flexibility of this type of antenna is limited, and it is difficult to provide multi-function reconfigurable characteristics. In a reconfigurable antenna is proposed that uses a liquid metal to mechanically reconfigure its performance. By changing the size of channel filling, the operation frequency and impedance bandwidth of the proposed mechanically reconfigurable antenna can be easily tuned for different frequencies. The performance flexibility of this type of antenna is limited, and it is difficult to provide multi-function reconfigurable characteristics. In a reconfigurable antenna is proposed that uses a liquid metal to mechanically reconfigure its performance.

2.6.7. RECONFIGURABLE ANTENNAS WITH SMART MATERIALS

Reconfigurable antennas with smart materials are new area of research, In this type of reconfiguration technique, the characteristics of the antennas can be reconfigured by pumping fluid into a hollow placed behind the antenna to change the characteristics of the substrate in terms of relative electric permittivity or magnetic permeability. In a broadband polarization reconfigurable antenna is proposed. The antenna utilizes two water arms and is mounted above a large ground plane for unidirectional radiation. Two water channels are mounted above the ground plane to generate different polarizations. By controlling the water flow along the water channels, the polarization of the antenna can be switched between right-hand and left-hand circular polarizations. The antenna operation band covers a frequency range of 1.2–1.84 Another design of the reconfigurable antenna with smart materials is introduced. It uses a low-loss transformer oil at high frequency to tune the operation frequency of a coaxial-fed patch antenna. As shown in Figure 10a, a two-layer substrate is employed between the radiation patch and ground plane of the proposed antenna. By changing the height of the oil layer, the volume ratio of air to liquid is varied, which leads to tuning the effective permittivity of the entire substrate of the patch radiators to generate the frequency reconfiguration. Figure 10b shows the fabricated prototype of the design. An aluminium plate is used as the ground plane. As can be observed from Fig for different heights of the transformer oil (0~9 mm), the operation frequency of the patch antenna can be tuned in a wide range from 1.42 to 1.96 GHz**.**

2.4 ADVANTAGES

Reconfigurable antennas have several advantages when compared to multi-band/wideband antennas or multiple antennas. Some of them are

1. Ability to support more than one wireless standard

a) Minimizes cost

b) Minimizes space requirement

c) Allows easier integration.

d) Good isolation between different wireless standards.

2. Lower front-end complexity

a) No need for front-end filtering

b) Good out-of-band rejection

3. Multifunctional capabilities

a) Act as a single element or as an array

b) Provide narrow band or wideband operation

c) Provide narrow band or wideband operation

4. Best candidate for software defined radio

a) Capability to adapt and learn

b) Automated via a microcontroller or a field programmable gate array (FPGA).

2.5 APPLICATIONS:

The reconfigurable antennas are applicable in situations where the operating requirements of a communication system change over time. Major applications of the reconfigurable antenna are

1. WIRELESS EQUIPMENT'S

In wireless equipment's where several communication systems will converge and integration of multiple antennas are used. Instead of using multiple single-function antennas, a single frequency reconfigurable antennas can accommodate the multiple requirements. This is a very attractive approach for actual wireless equipment which integrate multiple communication systems, as depicted in Fig 2.1, and would lead to significant size reductions, which is of utmost importance in portable and compact devices.

2. COGNITIVE RADIO

Frequency reconfigurable antennas play a key role is cognitive radio (CR). Cognitive radio transceivers sense the spectrum usage and the channel characteristics to dynamically select the operating frequency band according to specific performance metrics as illustrated in Fig. 2.2. Cognitive radio can benefit from frequency reconfigurable antennas because of the capability to tune the operating frequency over the required frequency range.

3. SAR LEVEL REDUCTION

Pattern reconfigurable antenna is used to reduce the specific absorption rate (SAR) in the personal wireless devices as shown in Fig 2.3. When the radiation from the wireless devices are travelling into the user's body, in that situation the pattern reconfigurable antenna changes its pattern to other direction rather than in the direction of the body and it reduce the power dissipation in the user's body.

4. PORTABLE DEVICES

Due to the variable orientations in the portable devices, the polarization of the transmitter and the receiver are not in align which in turn degrades the performance of the device. In this situation, the polarization reconfigurable antenna is useful in order to improve the performance of the portable devices

Some other interesting applications of reconfigurable antennas are

- In line of sight condition when mobile devices are moving
- To mitigate in-hand and out-band interference
- Adaptive MIMO systems
- Space applications
- Beam scanning

2.6 DESIGN EQUATIONS

The three important parameters while designing the antenna are

1. Operating frequency (f)

2. Dielectric constant

3. Substrate thickness (h)

By using above three parameters, the dimensions of an antenna can be determined

Chapter 4

Reconfigurable Antenna Literature Survey

INTRODUCTION

In this paper, a multi-functional and reconfiugurable antenna is realized using the design concept presented in [9] and [24]. A pair of SRRs and PIN diode loaded in the CPW feed line constitute a dual state filter section, exhibiting frequency notched/ narrow band-pass response depending on the status (ON/OFF) of the PIN diode. This filter section can be integrated in the feed-section of any CPW fed antenna. The present antenna, due to this integrated dual state filter section, exhibits a unique frequency reconfiguration capability that transforms a frequency notched wideband antenna into a narrowband antenna where the narrowband frequency complements the notch frequency. A single printed monopole antenna loaded with SRRs and PIN diodes on the feed section provides the dual functionality. Here, unlike in [9], the SRRs used are square shaped and no additional PIN/varactors diodes are connected between them. The frequency notch in the wideband printed monopole antenna is caused by the SRRs which are magnetically coupled with feeding CPW line and inhibit signal propagation around the SRRs' resonance frequency [24][26].With the loading of PIN diodes on CPW and appropriate biasing, the frequency notched wideband antenna can be reconfigured into a narrowband antenna operating at the SRR's resonance. The design is realized using a printed circular monopole antenna having a wide bandwidth. The printed monopole is fed by a CPW transmission line loaded with a pair of SRRs and PIN diodes.

It is further demonstrated that the notch frequency and the narrowband frequency can be tuned by changing the physical dimension of the SRR geometry as well as shape of the SRRs without perturbing the radiator dimension. The various shapes of SRRs that can be utilized are circular, square, hexagonal and triangular. Moreover, the inclusion of the SRRs and the PIN diodes on the feed section of the antenna do not have any adverse impact on the radiation performance of the antenna. Physical insight of the dual functionality is explained using the simulated contour Poynting vector plots. Potent application of such reconfigurable antennas are, i) MIMO systems used for high-data rate applications, ii) cognitive radio (CR) systems of Software Defined Radio (SDR) which demand wideband and narrowband antennas [27], iii) multiservice/multiband/multi-standard radio (MSR). The paper is organized as follows: Sec. II describes the realization of the dual state filter. Section III deals with the design and development of the proposed dual complimentary response based CPW fed monopole antenna. Antenna configurations and corresponding simulated and measured results are reported in section IV. This section also presents some physically insightful plots obtained from [28] which sheds more light on the principle of operation of the proposed antenna and are in confirmation with the measured results.

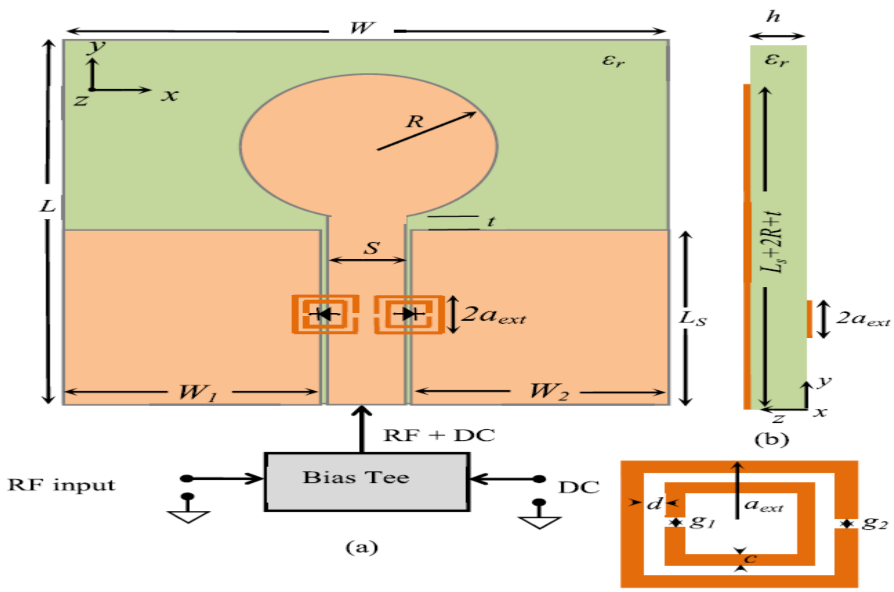
ANTENNA CONFIGURATION

A circular monopole having radius R is fed by a CPW line consisting of ground planes having width W1 and W2, length Ls and a signal line of width S and length Ls + t. The signal line and the ground planes are separated by a symmetric pair of slot gaps, sg. The antenna is printed on a substrate having thickness h and dielectric constant "r" . Two square shaped split ring resonators having dimension, aext , which is half the dimension of the side-length of the SRR, conductor thickness c, separation between rings d and split gaps g1 and g2 as shown in Fig. 6(c), are printed on the other side of the substrate with their centers coinciding with the slot lines of the CPW feed. A pair of PIN diodes are placed on the slots of the CPW with their positions coinciding with the axes passing through the center of the SRRs. In the proposed configuration, the CPW is inductively coupled to a pair of SRRs, having narrow split gaps g1 and g2, which are symmetrically placed on the backside of the substrate. The propagating electric field vector is polarized along the plane of the SRRs and the magnetic field vector is polarized along the SRRs' axes. The propagating signal excites the SRR, which prohibits transmission around its resonance frequency determined by the SRRs' dimensions and the constitutive parameters of the host substrate yielding in frequency notch [26]. The symmetric position of the SRRs to optimize efficient magnetic coupling has been shown to yield notch in the antenna impedance and radiation characteristic [26], [29], [30].The CPW transmission line also being loaded with PIN diodes which on different biasing conditions (reverse and forward) would effectively open and short the signal line with the ground planes. This, in turn provides frequency notched response and its complementary narrow band response.

DIMENSIONS OF FREQUENCY RECONFIGURABLE *ANTENNA*

The prototype was fabricated on Taconic substrate having εr=2.33, tanδ=0.0009 and thickness h=1.575mm. The circular monopole having radius R =12.5mm and fed with a CPW having ground plane length Ls = 22:5 mm, width W =50mm, signal line width S = 6mm, slot gap Sg=0.3mm and feed gap t = 0.2mm was etched on one side of the substrate. The slot gaps and the signal line width were optimized to yield a line impedance close to 50Ω. A pair of SRRs having dimensions aext =2.5mm, c = 0.35 mm, d =0.6 mm and split gaps g1 =g2 =0.5 mm, were printed on the other side of the substrate with their axes coinciding with the slot line in the CPW A pair of silicon PIN diodes (SMP 1145) were placed on the slots between the ground planes and the signal line and aligned to the position of SRRs axes required DC bias to the diodes are provided using a Mini circuits 15542 bias tee.

ANTENNA DESIGN



MEASUREMENTS AND RESULTS

The proposed SRR and PIN diode loaded active antenna is simulated using a commercial electromagnetic simulator [28]. In this simulation two different configuration of the active antenna for ON and OFF state of the diodes are considered by replacing the diodes with the corresponding equivalent circuits as shown in Fig. 8. The lumped circuit parameters, obtained from the manufacturer's data sheet, in diode ON condition assigned in the simulation were Ls= 0.45nH and Rs =2Ω and in diode OFF condition were Ls = 0.45nH and Rp= 5MΩ and CT=0.14fF. The resultant HFSS model with lumped circuit parameters for both the cases are simulated. Figure 9 shows the simulated and measured S11 plots of the proposed active antenna for OFF status of the diode. The plot indicates wideband characteristic from 2.5 GHz to 11 GHz with a sharp notch at 6.1 GHz and 6.01 GHz for simulated and measured data, respectively. This notch corresponds to the resonance frequency of the SRR and can be varied by scaling the physical dimension of the SRRs [26]. The variation between simulation and measurement post-resonance is due to the ohmic loss arising from the finite impedance of the PIN diodes in their OFF state Figure 10 shows the simulated and measured S11 of the prototype active antenna with the diode in ON condition. As revealed in the plot, with the diode in ON condition, the antenna yields a narrowband response centered at 6.12 GHz and 6.02 GHz for simulated and measured data and effectively complements the impedance behavior of the antenna in diode OFF condition. Figures 9 and 10 reveal the complementary nature of the antenna under diode OFF and ON conditions. The active antenna with diode ON condition provides a narrow band response due to the narrow band pass filter formed with the combination of SRRs and PIN diodes on the slots of the CPW. On the other hand, with diode in OFF condition, the band notch filtering of the SRRs contribute to frequency notched UWB response of the antenna gain plotted against the frequency of the prototype active antenna in diode OFF and ON conditions. In diode OFF condition, the gain drops sharply at the notch frequency of 6.01 GHz prohibiting radiation whereas for the rest of the frequencies the gain remains above 0 dBi. A complementary gain profile is yielded when the diode is switched ON and the gain rises sharply at 6.02 GHz and drops off at either side of the radiating frequency. The measured gain value in diode ON condition at the narrowband frequency 6.02 GHz was obtained as 3.59 dBi .

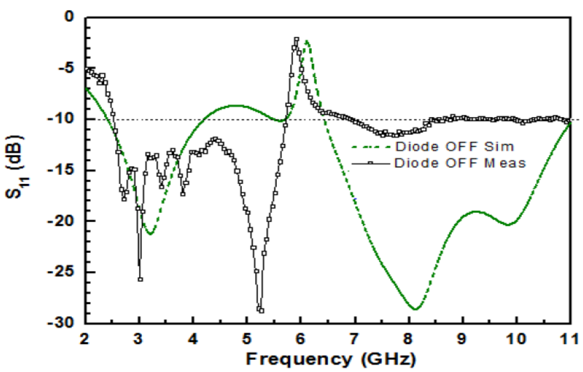


FIGURE 9. Measured and simulated S_{11} response of the SRR coupled PIN diode loaded CPW fed printed circular monopole active antenna with diodes in OFF conditions. $\varepsilon_r = 2.33$, thickness $h = 1.575$mm, $R = 12.5$mm, $L_s = 22.5$ mm, $W = 50$mm, $S = 6$mm, $S_g = 0.3$mm, $t = 0.2$mm; SRR parameters: $a_{ext} = 2.5$ mm, $c = 0.35$ mm, $d = 0.6$ mm and split gaps, $g_1 = g_2 = 0.5$ mm.

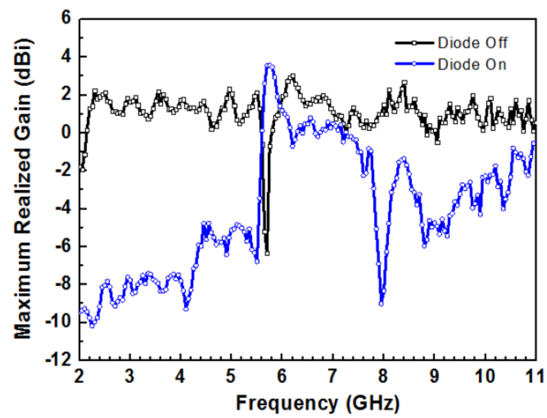


FIGURE 11. Measured realized peak gain of the SRR coupled PIN diode loaded CPW fed printed circular monopole active antenna with diodes OFF and ON conditions. Parameters as in Fig. 9.

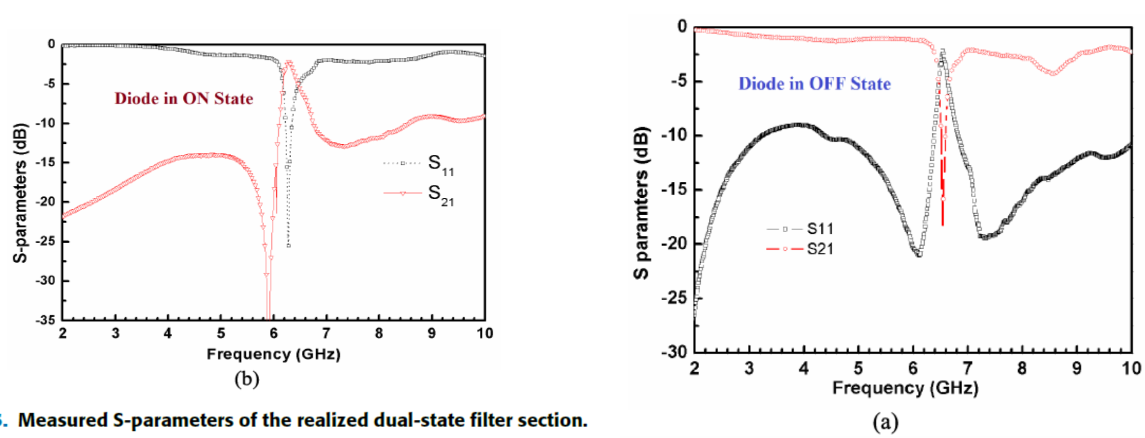


FIGURE 5. Measured S-parameters of the realized dual-state filter section.

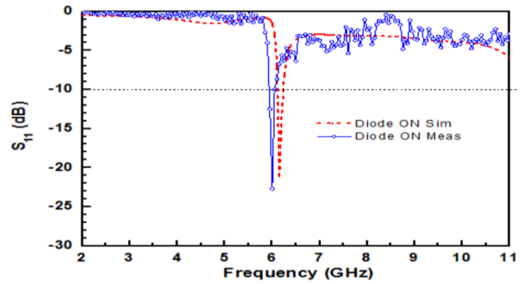


FIGURE 10. Measured and simulated S_{11} response of the SRR coupled PIN diode loaded CPW fed printed circular monopole active antenna with diodes in ON conditions. Parameters as in Fig. 9.

OVERALL LITERATURE SURVEY CONCLUSION

In this survey we have observe that for three different aext dimensions of 2.3mm, 2.5mm and 2.7mm yielded notch frequencies in diode OFF condition at 5.45 GHz, 6.1 GHz and 6.65 GHz while with diode in ON condition narrowband response centered at 5.5 GHz, 6.15 GHz and 6.7GHz is obtained. Figure 14 has an inset which shows the zoomed view of the notch and narrowband frequencies from 5GHz to 7GHz to increase the legibility. The wide variation of the notch and narrowband frequency using the proposed concept by changing the SRR parameter and without altering the basic radiator dimension is evident from the figure. Similar variation can also be achieved by changing the other parameters of the SRRs like c, d and g. The corresponding simulated maximum realized gain as a function of frequency of SRRs with varying aext is shown in Fig. 15. The dip and peak in gain parameters in diode OFF and ON conditions are evident from the plots

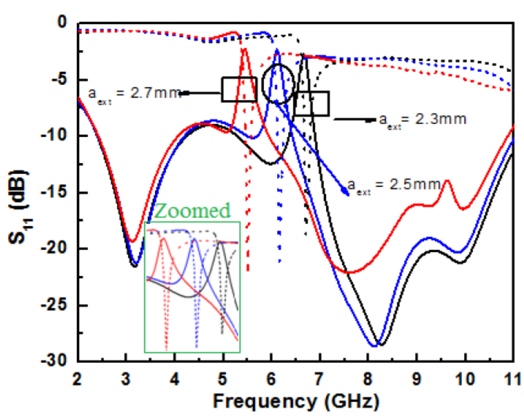


FIGURE 14. Simulated S_{11} of the SRR coupled PIN diode loaded CPW fed printed circular monopole active antenna with diodes OFF and ON conditions for various a_{ext} values. Solid curves are for diode OFF case and dotted curves are for diode ON case.

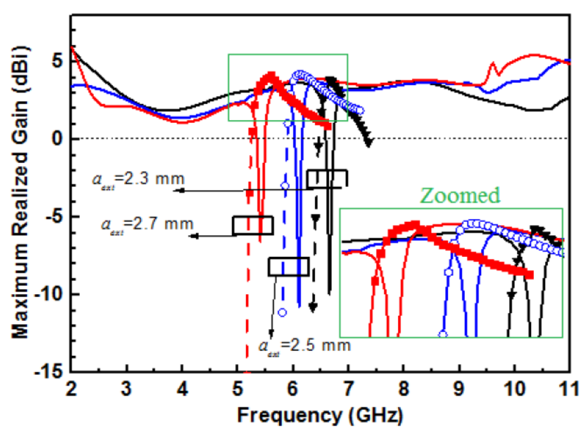


FIGURE 15. Simulated realized peak gain of the SRR coupled PIN diode loaded CPW fed printed circular monopole active antenna with diodes OFF and ON conditions for various a_{ext} values. Solid curves are for diode OFF case and dotted curves are for diode ON case conditions.

MODIFICATION IDEA FOR EXISTING ANTENNA

After doing the literature survey we found that in the existing antenna diode has been used for achieving the reconfigurability and we know that The wide intrinsic region makes the PIN diode as an fast switch, photo detectors, and high voltage power electronics applications. PIN diodes are widely used as the switching components in different wireless systems .But problem of using the PIN diode is that it needs a high tuning speed, a high bias current in the ON-state and a high power-handling capacity.Our idea is that if we used Varactor diode instead of using the pin diode because Varactors are used as voltage-controlled capacitors. By changing the voltage levels of the varactor, its capacitance changes, which leads to tune the antenna performance. Usage of varactors in reconfigurable designs helps to achieve the frequency tuning function When compared with other active elements such as a PIN diode or MEMS, it has a small current flow and continuous tuning characteristics.

KEY CONCEPT

When the voltage is increased capacitance is reduced since capacitance of varactor diode is inversely proportional to the voltage applied. When capacitance is reduced frequency is increased as capacitance of varactor diode is inversely proportional to the frequency. As a result, there is right shift of resonance frequency and in this way we will be able to use the same antenna for different frequency.

TABLE 1. Comprehensive survey of the existing reconfigurable antennas.

Ref.	Antenna Functionality	Means of Reconfiguration	No of switching/tuning elements used	Antenna Type	Antenna Size (mm×mm)	Frequency Range GHz
[8]	Tuning the operating frequency	Varactor	One varactor	Dual sided vivaldi	59.8 × 30	6.1-6.5
[10]	Dual band selected through PIN diode and tuned with varactor	Varactor and PIN diode	1 varactor and 1 PIN	Meandered and U-shaped monopole	11.5 × 8.4	2.39-3.0
[11]	UWB for sensing and narrow band for communicating	Photoconductive silicon switches	4 Switches	U-shaped monopole and open annulus	40 × 38.5	3.1-10.6 and 5.8-6.8, 6.7-7.3, 7.0-8.4, 7.9-9.2
[12]	Wideband or four different narrowband operations	PIN diode	2 PIN diode	CPW fed monopole	80 × 60	1.3-6, 2.55, 2.6, 2.8, 3.2GHz
[13]	Wideband and narrowband	Reconfigurable Filter section in the feed-line	1 PIN and 2 varactor	Circular disc monopole	60×30	3.8-6, 3.9-4.82
[14]	Wideband and tunable narrowband	Varactor and PIN diode	2 varactor and 1 PIN	Funnel shaped monopole	50 × 30	2.4-5, NB tuned between 3.0-4.4GHz
[15]	Wideband and two narrow bands	PIN diode	5 PIN diodes	Elliptical shaped monopole	45 × 40	2.2-11, 2.4-2.6, 5-6.2GHz
[16]	One wideband and four narrow-bands	PIN diode	4 PIN diodes	Folded bow-tie dipole, thin dipole and loop	3D antenna	0.83-2.16 and 0.9, 1.15, 1.5 and 1.85
[17]	Two wide-bands (extending the BW of 1st band)	PIN diode	2 PIN diodes	Slot antenna	24.6 × 8.6	5.2, 5.5
[18]	Two different antenna (one employs varactor and other PIN diode)	Varactor and PIN diode	2 varactor and 6 PIN diodes	Printed folded dipoles	NA	Ant1: 6-6.6 Ant 2:5.3-6.6 and 6.4-8
[19]	Five narrow-bands	Motorized rotation of substrate	Motor	Printed monopole and multiple patches	70 × 50	3.4-5.56, 6.3-10, 2.1-3, 5.4-6.2, 3-3.4
[20]	Converting wideband antenna to 4 different narrowband antennas	GaAs FET switch	Two SPDT switched	Circular monopole	50 × 50	2-11, 2.1-2.6, 3.6-4.6, 2.8-3.4 and 4.9-5.8
[21]	Tuning the operating frequency	Varactor and motion actuation	One varactor	Dual sided vivaldi	59.8 × 30	6.6-7.2
[22]	Converting wideband antenna to four different narrowband antennas	PIN diodes	12 PIN diodes	Inverted U-shaped patch	68×51	2.5-3.75
[23]	Reconfigurable MIMO	Varactors and PIN diodes	4 PIN and 2 Varactor	UWB monopole and meandered line monopole	65 × 120	0.72-3.44

CHAPTER 7

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