Antenna and its parameters : Basics of Antennas, properties and types of antenna. Radiation, resistance, Radiation pattern, Beamwidth, Gain, Directivity, Effective aperture, Beamwidth and Antenna Temperature. Folded dipole, Monodipole, Bi-conical Antenna, Loop Antenna, Helical Antenna.

What is an antenna?

An antenna is basically a transducer. It converts radio frequency (RF) signal into an electromagnetic (EM) wave of the same frequency. It forms a part of transmitter as well as the receiver circuits. Its equivalent circuit is characterized by the presence of resistance, inductance, and capacitance. The current produces a magnetic field and a charge produces an electrostatic field. These two in turn create an induction field. A transducer for converting guided signals in a transmission line or waveguide into electromagnetic radiation in an unbounded medium or vice versa.

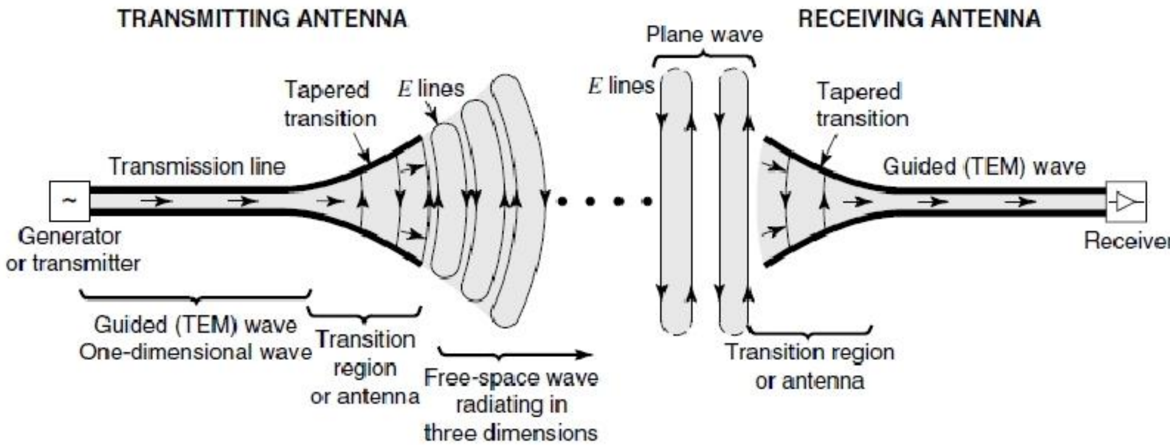
An antenna is define a usually metallic device (as a rod or wire) for radiating or receiving radio waves. The IEEE Standard Definitions of Terms for Antennas defines the antenna or aerial as —

A means for radiating or receiving radio waves. In other words the antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver. In the former case, we have a transmitting antenna and in the latter a receiving antenna

https://www.youtube.com/watch?v=Yo29MI8oieg

Properties

- Conversion should be as efficient as possible
- Match the impedance of the transmission line to that of the unbounded medium
- Prevent unwanted reflections back to the load
- Focus radiation in the direction required
- Needs change in the velocity of charges carried in the antenna for radiation to occur
- Antenna material, shape and size impact the radiation and impedance
- The dimension of an antenna is measured in units of the wavelength λ of the carrier.



Any conductor or dielectric can serve as the transducer. The properties may make it inefficient and thus unsuitable for the application
Needs careful design of the structure of the antenna

a) **As Transmitting Antenna:–**
Here the Transmission Line is connected to source or generator at one end. Along the uniform part of the line energy is guided as Plane TEM wave with little loss. Spacing between line is a small fraction of λ. As the line is opened out and the separation between the two lines becomes comparable to λ, it acts like an antenna and launches a free space wave since currents on the transmission Line flow out on the antenna but fields associated with them keep on going. From the circuit point of view the antenna appears to be a resistance Rr, called Radiation resistance.

b) **Receiving Antenna** –A receiving antenna performs the reverse of the process performed by the transmission antenna. It receives radiofrequency radiation and converts it into electric currents in an electric circuit connected to the antenna.

c) **Reciprocity-**
is the ability to use the same antenna for both transmitting and receiving. The electrical characteristics of an antenna apply equally, regardless of whether you use the antenna for transmitting or receiving. The more efficient an antenna is for transmitting a certain frequency, the more efficient it will be as a receiving antenna for the same frequency. This is illustrated by figure 2-1, view A. When the antenna is used for transmitting, maximum radiation occurs at right angles to its axis. When the same antenna is used for receiving (view B), its best reception is along the same path; that is, at right angles to the axis of the antenna.
An antenna exhibits identical impedance during Transmission or Reception, same directional patterns during Transmission or Reception, same effective height while transmitting or receiving. Transmission and reception antennas can be used interchangeably. Medium must be linear, passive and isotropic (physical properties are the same in different directions.) Antennas are usually optimised for reception or transmission, not both.

Directivity:

Describes the antenna pattern of a lossless antenna. Indicates how much gain is there due to the directionality.

Directivity of an antenna or array is a measure of the antenna_s ability to focus the energy in one or more specific directions. You can determine an antenna_s directivity by looking at its radiation pattern. In an array propagating a given amount of energy, more radiation takes place in certain directions than in others. The elements in the array can be arranged so they change the pattern and distribute the energy more evenly in all directions. The opposite is also possible. The elements can be arranged so the radiated energy is focused in one direction. The elements can be considered as a group of antennas fed from a common source. It is defined as the ratio of maximum radiation intensity of subject or test antenna to the radiation intensity of an isotropic antenna.

(or)

Directivity is defined as the ratio of maximum radiation intensity to the average radiation intensity. Directivity (D) in terms of total power radiated is,

$$\mathbf{D} = 4\pi \text{ x } \frac{\textit{MAXIMUM RADIATION INTENSITY}}{\textit{TOTAL POWER RADIATED}}$$

From the field point of view, the most important quantitative information on the antenna is the directivity, which is a measure of the concentration of radiated power in a particular direction. It is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total radiated power divided by 4π. If the direction is not specified, the direction of maximum radiation is implied.

Isotropic Antenna

Radiation propagates equally in all directions

"Ideal" – does not exist

Antenna Gain

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will preferentially radiate in a particular direction. Specifically, the antenna gain, or power gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna.

Any physical Antenna has losses associated with it. Depending on structure both ohmic and dielectric losses can be present. Input power Pin is the sum of the Radiated power Prad and losses Ploss

Pin=Prad + Ploss

The Gain G of an Antenna is an actual or realized quantity which is less than Directivity D due to ohmic losses in the antenna. Mismatch in feeding the antenna also reduces gain.

In practice, the total input power to an antenna can be obtained easily, but the total radiated power by an antenna is actually hard to get. The gain of an antenna is introduced to solve this problem. This is defined as the ratio of the radiation intensity in a given direction from the antenna to the total input power accepted by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation is implied. Mathematically, the gain (dimensionless) can be written as

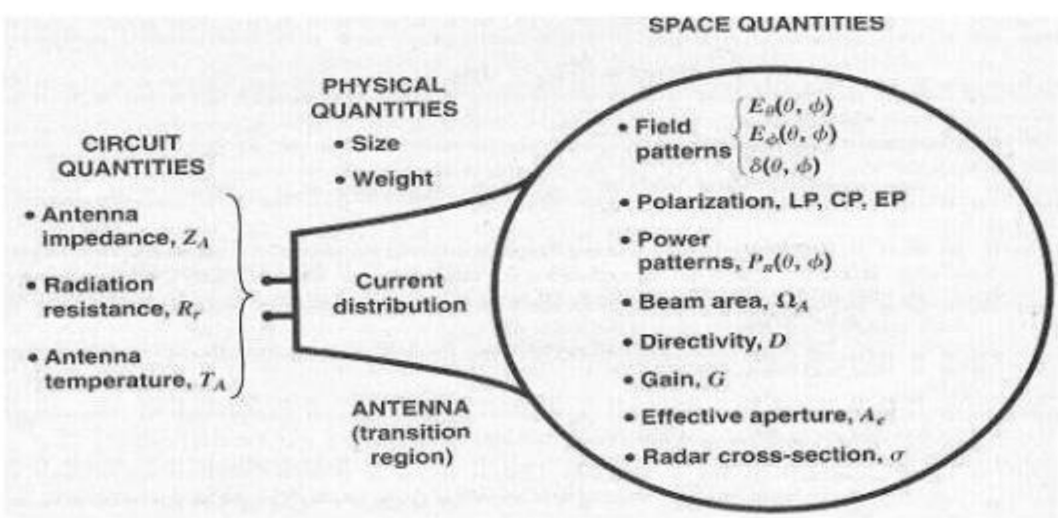
G=4πU/Pin

Directivity and Gain: Directivity and Gain of an antenna represent the ability to focus its beam in a particular direction. Directivity is a parameter dependent only on the shape of radiation pattern while gain takes ohmic and other losses into account.

BASIC PRINCIPLE OF RADIATION:-

Under time varying conditions, Maxwells equations predict the radiation of EM energy from current source (or accelerated charge). This happens at all frequencies, but is insignificant as long as the size of the source region is not comparable to the wavelength. While transmission lines are designed to minimize this radiation loss, radiation into free space becomes main purpose in case of Antennas. For steady state harmonic variation, usually we focus on time changing current For transients or pulses ,we focus on accelerated charge The radiation is perpendicular to the acceleration.
The radiated power is proportional to the square of I L or Q V
Where I = Time changing current in Amps/sec
L = Length of the current element in meters
Q= Charge in Coulombs
V= Time changing velocity

Antenna Parameters:



Radiation Pattern:

https://www.youtube.com/watch?v=-5AcIZYxdw8

The relative distribution of radiated power as a function of direction in space is called the radiation pattern of the antenna. Instead of 3D surface, it is common practice to show planar cross section radiation pattern. E-plane and H-plane patterns give two most important views. The E-plane pattern is a view obtained from a section containing maximum value of the radiated field and electric field lies in the plane of the section. Similarly when such a section is taken such that the plane of the section contains H field and the direction of maximum radiation. A typical radiation patter plot is shown in figure. The main lobe contains the direction of maximum radiation. However in some antennas, more than one major lobe may exist. Lobe other than major lobe are called minor lobes. Minor lobes can be further represent radiation in the considered direction and require to be minimized.

HPBW or half power beam width refers to the angular width between the points at which the radiated power per unit area is one half of the maximum or 3dB down from maximum power.

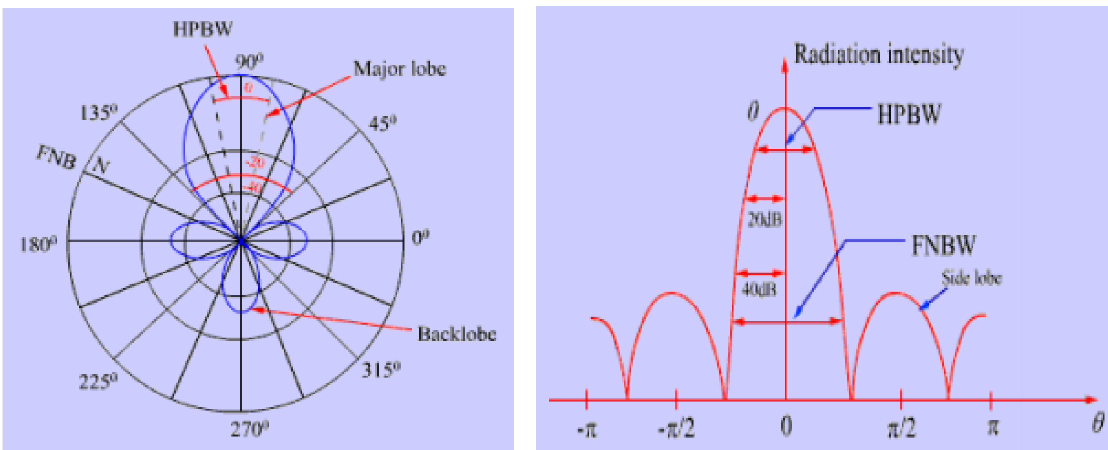


Figure Radiation Pattern

Similarly **FNBW** (First null beam width) refers to the angular width between the first two nulls as shown in Figure. By the term beam width we usually refer to 3 dB beam width or HPBW.

Ideal antenna

Gain = 1 over a certain angle

Gain = 0 over the rest of the directions

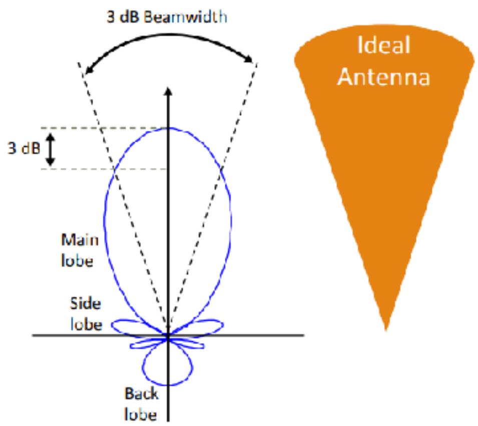
Real antenna

Radiates power in unwanted directions

Has one or more main lobes and many side lobes

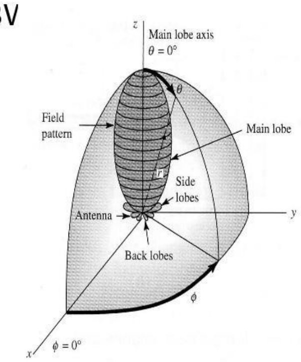
Specified “beamwidth”

Radiation lobes



Radiation Pattern Characteristics

- 3 dB beamwidth (HPBV
- Sidelobes
- Nulls
- Front-to-back ratio
- Gain (approximate)
- Maximum signal position



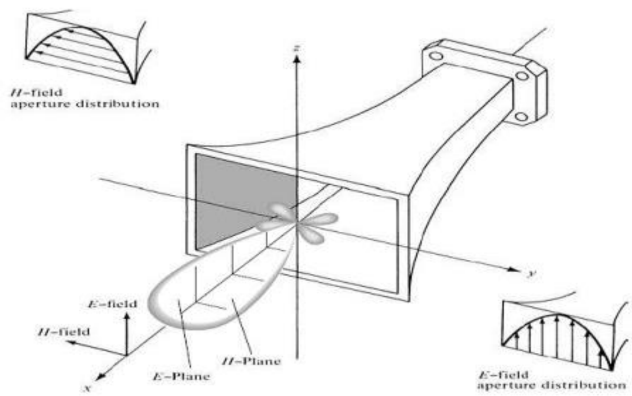


Fig. Principal E- and H-plane patterns for a pyramidal horn antenna

ANTENNA TEMPERATURE

https://www.youtube.com/watch?v=CQFpp1c7UQw

Antenna Temperature (Ta) is a parameter that describes how much noise an antenna produces in a given environment. This temperature is not the physical temperature of the antenna. Moreover, an antenna does not have an intrinsic "antenna temperature" associated with it; rather the temperature depends on its gain pattern and the thermal environment that it is placed in. Antenna temperature is also sometimes referred to as Antenna Noise Temperature. To define the environment, we'll introduce a temperature distribution - this is the temperature in every direction away from the antenna in spherical coordinates. For instance, the night sky is roughly 4 Kelvin; the value of the temperature pattern in the direction of the Earth's ground is the physical temperature of the Earth's ground. This temperature distribution will be written as

T(θ,Ø).

Hence, an antenna's temperature will vary depending on whether it is directional and pointed into space or staring into the sun.

Antenna Impedance, Radiation Resistance

It is a part of antennas feed point resistance that is caused by the radiation of electromagnetic waves from the antenna. Physically it is not available so it is virtual resistance represented as Rr. So the radiation resistance of an antenna is a good indicator of the strength of the electromagnetic field radiated by a transmitting antenna or being received by a receiving antenna.

The antenna shows impedance at its input terminals consisting of a resistive and a reactive part. The real part is responsible for radiation and power loss.

Z = R + jX

The antenna dissipates the power fed to it. If the radiated power and the dissipated power are respectively represented by Wr and Wl , then the total power Wt consumed by the antenna can be expressed as:

Wt = Wr +Wl

If I is the current flowing through the antenna at its terminals then we may express the total power Wt consumed by the antenna is given as:

Wt= I^2 (Rr + Rl)

Here, Rr is a fictitious resistance that would consume the amount of power lost as radiation. It is known as radiation resistance. Rl is a resistance that would consume the amount of power lost as heat. It is called the loss resistance. For an ideal antenna, Rl = 0

Effective Aperture Area of an Antenna

https://www.youtube.com/watch?v=Q9l0YS5tYLU

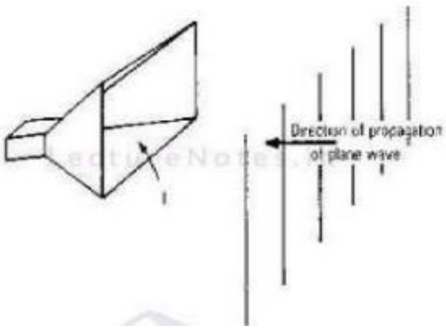
The concept of effective aperture area has been developed based on a receiving antenna. Let us assume we have a device which converts the electromagnetic energy into electrical power at its terminals. The **amount of electromagnetic energy collected is proportional to the collecting area**. This arises from the fact that electromagnetic energy is measured as a flow of energy per unit time per unit area across a frequency bandwidth. In other words, it is flux density. Thus more the collecting area (more aperture area) the more is the received power.

The amount of power P_{ant} received by an antenna is the product of a fictitious area called the effective aperture area A_e with the flux density of the electromagnetic waves S falling perpendicular over this area. This is shown below:

$$P_{ant} = S\ A_e$$

Aperture of an Antenna is the area through which the power is radiated or received. Concept of Apertures is most simply introduced by considering a Receiving Antenna. Let receiving antenna be a rectangular Horn immersed in the field of uniform plane wave

Let the Pointing vector or power density of the plane wave be S watts/sq –m and let the area or physical aperture be Ap sq-m. But the Field response of Horn is not uniform across Ap because E at sidewalls must equal zero. Thus effective Aperture Ae of the Horn is less than Ap.



Aperture Efficiency is as follows: ε_{ap}=Ae/Ap

The effective antenna aperture is the ratio of the available power at the terminals of the antenna to the power flux density of a plane wave incident upon the antenna, which is matched to the antenna in terms of polarization.

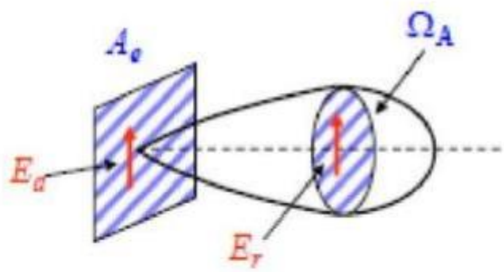


Fig.7 Effective Aperture

The effective aperture area is specific for different type of antennas. For example, the effective aperture area of a dish antenna could be equal to the physical cross sectional area of the dish if the antenna is lossless, whereas for a dipole antenna, this area is generally more than its physical area.

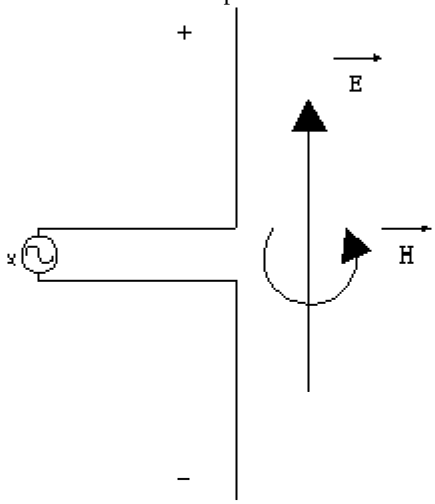
Antennas

Antennas couple the current flowing in wires or waveguides into electromagnetic waves in the air. The most basic form of the antenna is the dipole antenna.

The Dipole Antenna

https://www.youtube.com/watch?v=ZaXm6wau-jc

This is nothing more than a straight piece of wire. When voltage is applied to the wire, current flows and the electrical charges pile up in either end. A balanced set of positive and negative charges separated by some distance is called a dipole.



When an alternating voltage is applied the antenna, dipole moment oscillates up and down on the antenna, corresponding to the current. The oscillating current creates oscillating electric (E) and magnetic (H) fields which in turn generate more electric and magnetic fields. Thus a outward propagating electromagnetic wave is created. The electric field is oriented along the axis of the antenna and the magnetic field is perpendicular to both the electric field and the direction of propagation. The orientation of the fields is called the polarization.

If the signal is coming from a direction perpendicular to the line connecting them, there will be equal path lengths and therefore complete constructive interference. They will be more sensitive along the directions perpendicular to the line connecting them. Therefore, the two-dipole antenna array is directional in the horizontal plane. As it turns out, the three-dipole antenna linear array is even more directional. There is no reception from the directions along the axis, and a more narrow region perpendicular to the array from which they receive strongly. The width of good reception is called the **beamwidth.** For a many-dipole linear array, the beamwidth gets smaller proportionally.

The dipole antenna is cut and bent for effective radiation. The length of the total wire, which is being used as a dipole, equals half of the wavelength (i.e., **l = λ/2).** Such an antenna is called as **half-wave dipole antenna**. This is the most widely used antenna because of its advantages. It is also known as **Hertz antenna**.

The Folded Dipole Antenna

https://www.youtube.com/watch?v=GbKp1yQQqGU

A **folded dipole** is a dipole antenna with the ends folded back around and connected to each other, forming a loop as shown in Figure. A folded dipole is an antenna, with two conductors connected on both sides, and folded to form a cylindrical closed shape, to which feed is given at the center. The length of the dipole is half of the wavelength. Hence, it is called as half wave folded dipole antenna. The directivity of Folded dipole Antenna is bi-directional. The input impedance is higher. Folded Dipole Antenna Frequency range The range of frequency in which half wave folded dipole operates is around **3KHz to 300GHz**. This is mostly used in television receivers.

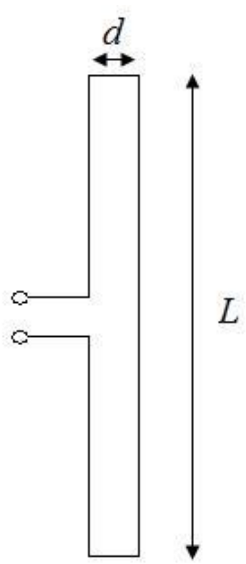


Figure. A Folded Dipole Antenna of length *L*.

Typically, the width *d* of the folded dipole antenna is much smaller than the length *L*.

Because the folded dipole forms a closed loop, one might expect the input impedance to depend on the input impedance of a short-circuited transmission line of length *L*. However, you can imagine the folded dipole antenna as two parallel short-circuited transmission lines of length *L*/2 (separated at the midpoint by the feed in Figure 1). It turns out the impedance of the folded dipole antenna will be a function of the impedance of a transmission line of length *L*/2.

Yagi-uda Antenna

Yagi-Uda antenna is the most commonly used type of antenna for TV reception over the last few decades. It is the most popular and easy-to-use type of antenna with better performance, which is famous for its high gain and directivity.

Frequency range

The frequency range in which the Yagi-Uda antennas operate is around **30 MHz to 3GHz** which belong to the **VHF** and **UHF** bands.

Construction of Yagi-Uda Antenna

A Yagi-Uda antenna was seen on top of almost every house during the past decades. The parasitic elements and the dipole together form this Yagi-Uda antenna.

The figure shows a **Yagi-Uda antenna**. It is seen that there are many directors placed to increase the directivity of the antenna. The feeder is the folded dipole. The reflector is the lengthy element, which is at the end of the structure.

The figure depicts a clear form of the Yagi-Uda antenna. The center rod like structure on which the elements are mounted is called as **boom**. The element to which a thick black head is connected is the **driven element** to which the transmission line is connected internally, through that black stud. The single element present at the back of the driven element is the **reflector**, which reflects all the energy towards the direction of the radiation pattern. The other elements, before the driven element, are the **directors**, which direct the beam towards the desired angle

Advantages

The following are the advantages of Yagi-Uda antennas −

- High gain is achieved.
- High directivity is achieved.
- Ease of handling and maintenance.
- Less amount of power is wasted.
- Broader coverage of frequencies.

Applications

The following are the applications of Yagi-Uda antennas −

- Mostly used for TV reception.
- Used where a single-frequency application is needed.

PARABOLIC ANTENNA

Parabolic Reflectors are Microwave antennas. For better understanding of these antennas, the concept of parabolic reflector has to be discussed.

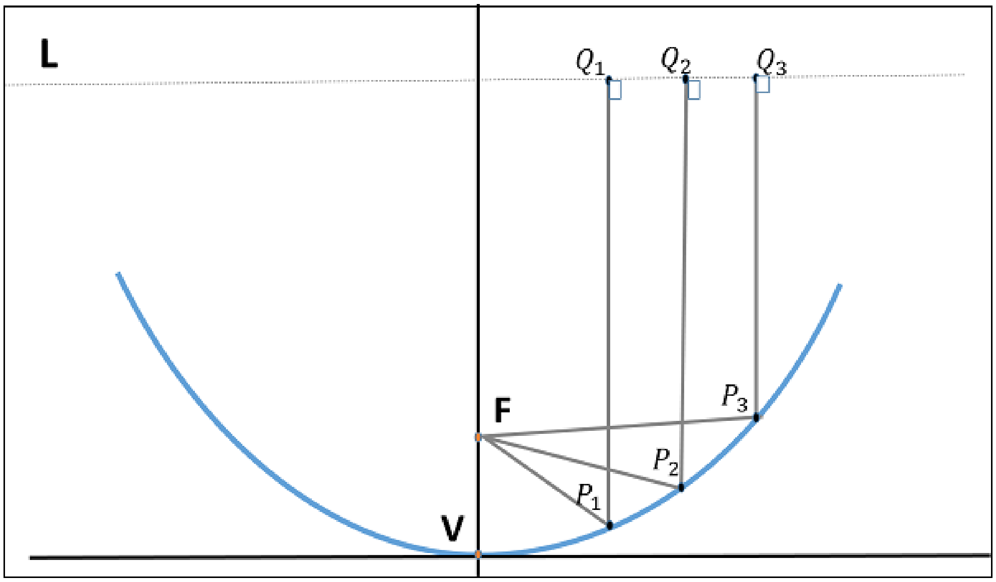
Frequency Range

The frequency range used for the application of Parabolic reflector antennas is **above 1MHz**. These antennas are widely used for radio and wireless applications.

Principle of Operation

The standard definition of a parabola is - Locus of a point, which moves in such a way that its distance from the fixed point (called **focus**) plus its distance from a straight line (called **directrix**) is constant.

The following figure shows the geometry of parabolic reflector. The point **F** is the focus (feed is given) and **V** is the vertex. The line joining F and V is the axis of symmetry. PQ are the reflected rays where **L** represents the line directrix on which the reflected points lie (to say that they are being collinear). Hence, as per the above definition, the distance between F and L lie constant with respect to the waves being focused.



The reflected wave forms a collimated wave front, out of the parabolic shape. The ratio of focal length to aperture size (ie., f/D) known as **"f over D ratio"** is an important parameter of parabolic reflector. Its value varies from **0.25 to 0.50**.

The law of reflection states that the angle of incidence and the angle of reflection are equal. This law when used along with a parabola, helps the beam focus. The shape of the parabola when used for the purpose of reflection of waves, exhibits some properties of the parabola, which are helpful for building an antenna, using the waves reflected.

Properties of Parabola

- All the waves originating from focus, reflects back to the parabolic axis. Hence, all the waves reaching the aperture are in phase.
- As the waves are in phase, the beam of radiation along the parabolic axis will be strong and concentrated.

Following these points, the parabolic reflectors help in producing high directivity with narrower beam width.

Construction & Working of a Parabolic Reflector

If a Parabolic Reflector antenna is used for transmitting a signal, the signal from the feed, comes out of a dipole or a horn antenna, to focus the wave on to the parabola. It means that, the waves come out of the focal point and strike the Paraboloidal reflector. This wave now gets reflected as **collimated wave front**, as discussed previously, to get transmitted.

The same antenna is used as a receiver. When the electromagnetic wave hits the shape of the parabola, the wave gets reflected onto the feed point. The dipole or the horn antenna, which acts as the receiver antenna at its feed, receives this signal, to convert it into electric signal and forwards it to the receiver circuitry.

The following image shows a Parabolic Reflector Antenna.

The gain of the paraboloid is a function of aperture ratio **(D/λ)**. The Effective Radiated Power **(ERP)** of an antenna is the multiplication of the input power fed to the antenna and its power gain.

Beam Width = 70 * Wavelength/Diameter of Antenna

Usually a wave guide horn antenna is used as a feed radiator for the paraboloid reflector antenna. Along with this technique, we have another type of feed given to the paraboloid reflector antenna, called as Cassegrain feed.

Advantages

The following are the advantages of Parabolic reflector antenna −

- Reduction of minor lobes
- Wastage of power is reduced
- Equivalent focal length is achieved
- Feed can be placed in any location, according to our convenience
- Adjustment of beam (narrowing or widening) is done by adjusting the reflecting surfaces

Disadvantage

The following is the disadvantage of a Parabolic reflector antenna −

- Some of the power that gets reflected from the parabolic reflector is obstructed. This becomes a problem with small dimension paraboloid.

Applications

The following are the applications of Parabolic reflector antenna −

- The cassegrain feed parabolic reflector is mainly used in satellite communications.
- Also used in wireless telecommunication systems.

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HELICAL ANTENNA

https://www.youtube.com/watch?v=NVyYRdhGaEg

Helical antenna is an example of wire antenna and itself forms the shape of a helix. This is a broadband VHF and UHF antenna.

Frequency Range

The frequency range of operation of helical antenna is around **30MHz to 3GHz**. This antenna works in **VHF** and **UHF** ranges.

Construction & Working of Helical Antenna

Helical antenna or helix antenna is the antenna in which the conducting wire is wound in helical shape and connected to the ground plate with a feeder line. It is the simplest antenna, which provides **circularly polarized waves**. It is used in extra-terrestrial communications in which satellite relays etc., are involved.

The above image shows a helical antenna system, which is used for satellite communications. These antennas require wider outdoor space.

It consists of a helix of thick copper wire or tubing wound in the shape of a screw thread used as an antenna in conjunction with a flat metal plate called a ground plate. One end of the helix is connected to the center conductor of the cable and the outer conductor is connected to the ground plate.

Advantages

The following are the advantages of Helical antenna −

- Simple design
- Highest directivity

- Wider bandwidth
- Can achieve circular polarization
- Can be used at HF & VHF bands also

Disadvantages

The following are the disadvantages of Helical antenna −

- Antenna is larger and requires more space
- Efficiency decreases with number of turns

Applications

The following are the applications of Helical antenna −

- A single helical antenna or its array is used to transmit and receive VHF signals
- Frequently used for satellite and space probe communications
- Used for telemetry links with ballastic missiles and satellites at Earth stations
- Used to establish communications between the moon and the Earth
- Applications in radio astronomy

Frequencies used for Met Data communication

Sno	Frequency Range	Name	Antennas Used	Where used in Meteorology
1	3 to 30MHZ	High Frequency	Wire Antenna, rhombic antenna, Log periodic antenna	Synoptic/ Pilot data communication through Radio as communication is Long distance several KM. effected by Ionosphere above earth.
2	30MHZ to 300MHZ	VHF	Quarter wave whip antenna, Yagi antenna	Amateur Radio communications
3	300MHZ to 3 GHZ	UHF	Omni Directional-Short whips, Planar Inverted F antenna. Directional- Yagi, Reflective array antenna, Helical Antenna	AWS data communication to INSAT, For communication of Runway site data to MBR & ATC.
4	3GHZ to 30GHZ	Microwave	Parabolic, Horn Antenna, Plasma antenna	For X, C and S Band Radars.

1. Define Antenna.
2. Define Directivity of Antenna.
3. What is Half Power Beam width?
4. Write any four type of antennas commonly used.
5. Write a Short note on parabolic antenna.
6. Which antenna is used for S- Band radar?
7. ---------- is also called 3-Db beam width.
8. Half-power Beamwidth is given by ____

✓ a) $70\lambda/D$
b) $70D/\lambda$
c) $35\lambda/D$
d) $35D/\lambda$

9. If the antenna dimension is two times the wavelength of the signal then the half power beam width will be _____

✓ a) 35

b) 140

c) 70

d) 280

10. The directivity of Yagi-Uda antenna is increased by adding ______

✓ a) reflectors

b) driven element

c) directors

d) boom

11. Directors are used to increase ______ of the Yagi-Uda antenna.

a) Directivity

✓ b) Gain

c) Back lobe

d) Reflection away from the radiation

12. An ideal antenna in which the power is radiated equally in all directions is called as ________ antenna.

13. What is the ratio of focal length to diameter (f/D) for practical applications in a parabolic reflector?

14. If beam width of the antenna increases, then directivity _________

✓a) Decreases

b) Increases

c) Remains unchanged

d) Depends on type of antenna

15. The radiation lobe containing the direction of maximum radiation is called as ______

✓a) Major lobe

b) Minor lobe

c) Side lobe

d) Back lobe

16. The ratio of maximum power density in the desired direction to the average power radiated from the antenna is called as ________

✓a) directivity

b) directive gain

c) power gain

d) partial directivity

17. Which one of the following antennas is mostly used in TV Dish?

✓a) Parabolic reflector

b) Lens antenna

c) Log periodic

d) Rhombus antenna

18. -----------antenna can achieve circular polarization.