Fundamental Parameters and Types of Parabolic Reflector Antenna: A Review

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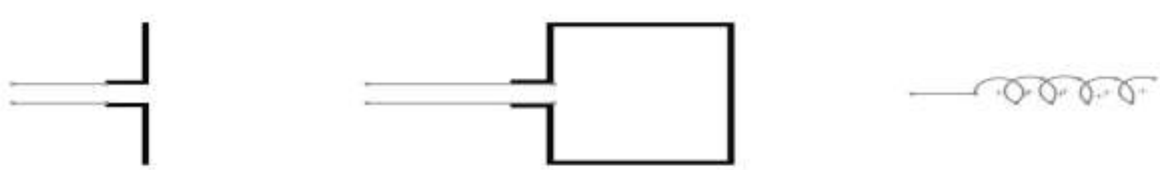
ABSTRACT: An antenna is a metallic object, generally a wire or a group of wires that are designed in a specified manner in order to perform functions like coupling of transmitter output with the free space ,coupling of receiver input with the free space ,capable of radiating or receiving EM waves. Italso performs two way operation of conversion large frequency current ampere readings into their corresponding EM waves at the transmitter and EM waves are then converted to high frequency current by receiving antenna. Antennas are required mainly for wire communication networks like broadcast system, microwave linkage, mobile communication and satellite communication. The main focus of this article is on Parabolic Reflector Antennas which are generally designed to operate at microwave frequencies, so as to achieve desired gain and directivity.In parabolic Reflector antennas, parallel beamis generated when the reflector reflects the signals originating from the source placed at the focus of a parabolic reflector **.**The main aim of parabolic reflector antenna is to transform the curved wave front into the plane wave front originated from the focus of the parabolic reflector.

I) INTRODUCTION

There are many types of structures used for antennas ranging from a simple length of wire suspended above the ground to the certain arrays used for very low or very high frequency broadcasting .Hence on the basis of specified requirements antennas are of different types:

Linear Wire Antenna: They are the oldest, simplest antennas [1] and are available in different shapes as shown in figure:

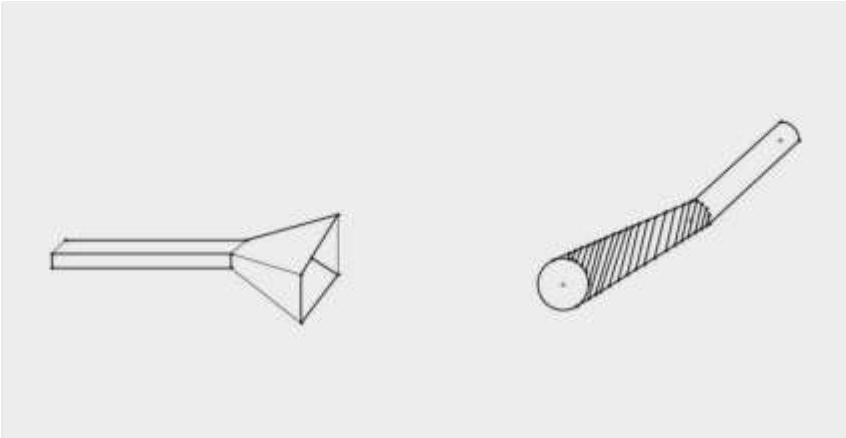


a) Dipole Antenna **b)Rectangular loop Antenna** **c) Helix Antenna**

Fig.1: Linear Wire Antennas

Aperture Antenna:

In order to use antennas at microwave frequencies we make use of aperture antennas [2] which may take the form of elliptical horn, conical horn as shown in figure:



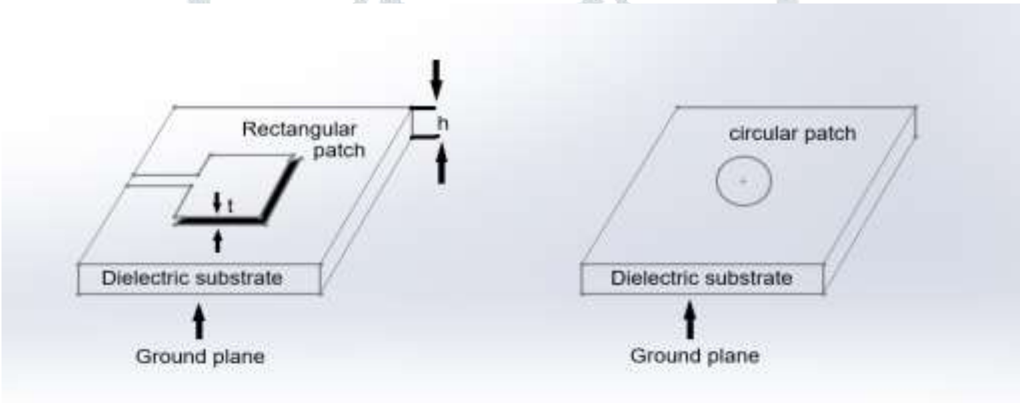
a)Pyramidal Horn Aperture Antenna b)Conical Circular Aperture Antenna

Fig. 2: Aperture Antenna

Micro strip Antenna:

It is one of the most prominent antennas categories which have achieved popularity in the past few decades, primarily used in space applications like satellite, DRDO applications, RADAR systems etc.It is there low profile i.e. small size design which enables them to be used in most of the applications. Such antennas comprises of a module known as patch, on the basis of which these antennas can be classified as shown in figure:

Array

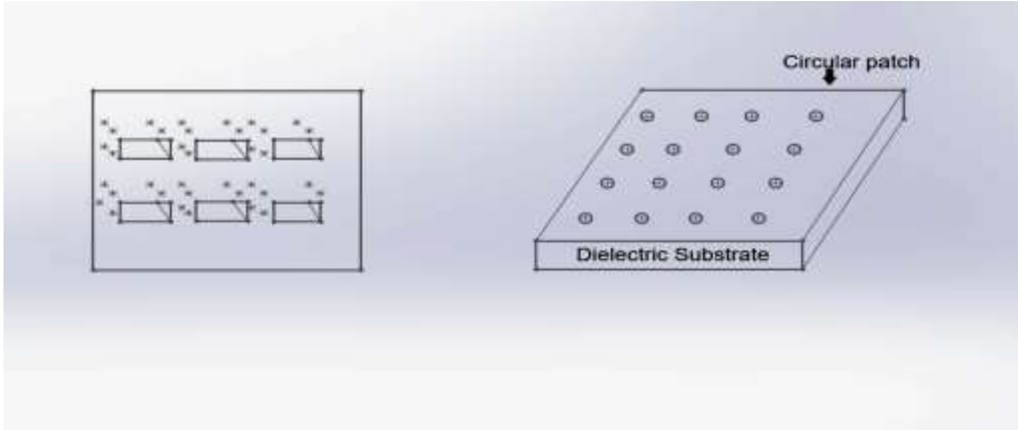


a)Rectangular Patch Antenna b) Circular Patch Antenna

Fig. 3: Micro strip Patch Antenna

Antenna:

These antennas are basically designed to meet the high gain and directivity specifications in order to establish communication at a longer distance [10]. These antennas comprises of multielements in the form of a repetitive arrangement called an array as shown in figure:

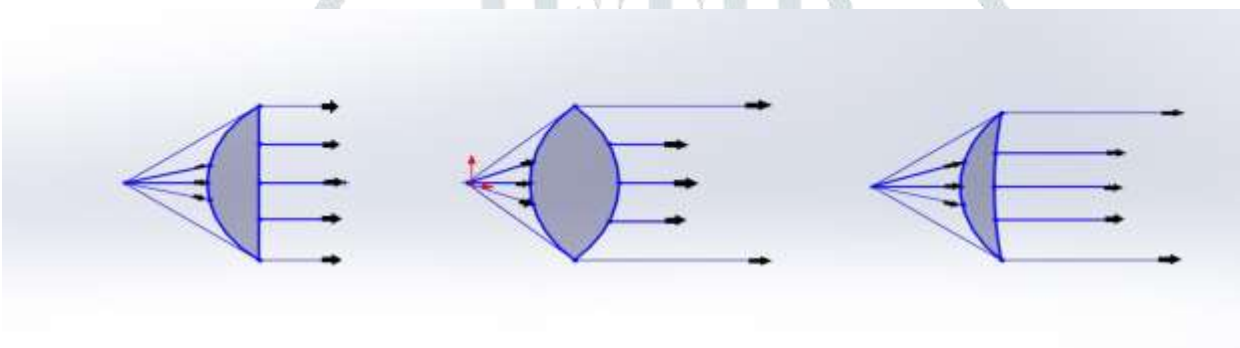


a)Aperture Array Antenna b)Circular Patch Array Antenna

Fig.4:Array Antenna

Lens Antenna:

Lens antennas are classified on the basis of their convergent and divergent nature as shown in figure:



a)Convex plane lens Antenna b) Convex -Convex lens Antenna c)Convex-Concave lens Antenna

Reflector Antenna:

The main focus of this article is on Reflector Antennas which are generally designed to operate at microwave frequencies, so as to achieve desired gain and directivity [3]. On the basis of directivity and pattern of radiation produced reflector antennas are of different types:

Types of Reflectors

a) Flat Sheet Reflector
b) Corner Reflector
c) Hyperbolic Reflector
d) Circular Reflector
e) Flat Sheet Reflector

a) **Flat Sheet Reflector**: An arrangement of flat sheet reflector is mainly designed so as to reduce the backward radiation from antenna with the motive of large gain and highly directive pattern ,flat sheet reflectors are further classified as large flat sheet and small flat sheet reflector as shown in figure:

a)Large Flat Sheet Reflector b)Small Flat Sheet Reflector

Fig.5: Flat Sheet Reflector with Dipole Feed

b) **Corner Reflector**: In this arrangement of corner reflector directivity is the most prominent factor. In order to make antenna directionally efficient we make the use of corner reflectors. On the basis of conjunction and separation of driven element with corner reflectors two classifications are designed out of which the former one gives the active type design and later one gives the passive type design as shown in figure:

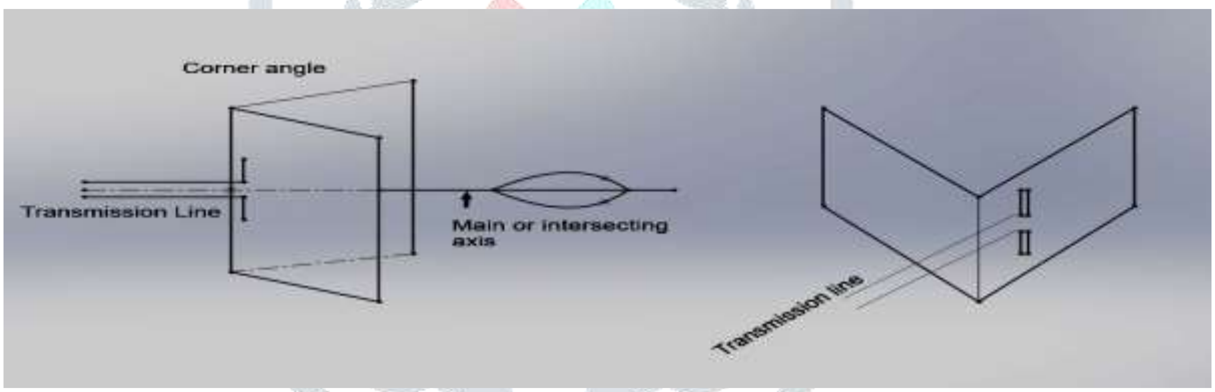
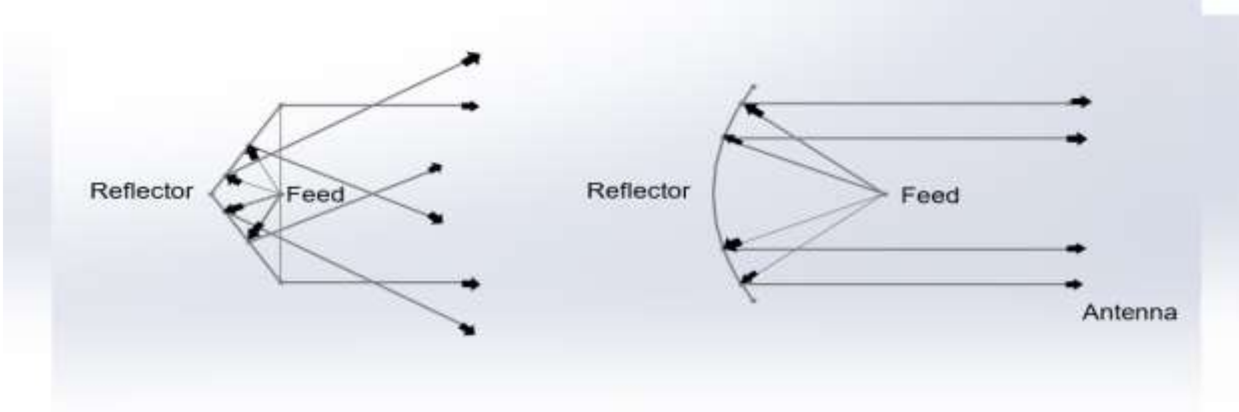


Fig. 6: Corner Reflector Antenna

c) **Parabolic Reflector Antennas:** In parabolic Reflector antennas, parallelbeam is generated when the reflector reflects the signals originating from the source positioned at the focus of a parabolic reflector [4] **.**The main aim of parabolic reflector antenna is to transform the curved wave into the parallel wave front originated from the focus of the parabolic reflector.



a) Corner Reflector Antenna b)Parabolic Reflector Antenna

Fig.7: Reflector Antennas

II) GENERATION OF CONCENTRATED BEAM OF RADIATION:

As shown in figure a parabola is constructed which has following design parameters:

XF=Focal Length, F=Focus, X=Vertex, XX'=Axis of Parabola

From the definition of parabola:

FP+PP'=FQ+QQ'=FR+RR'=K=constant (see fig.)

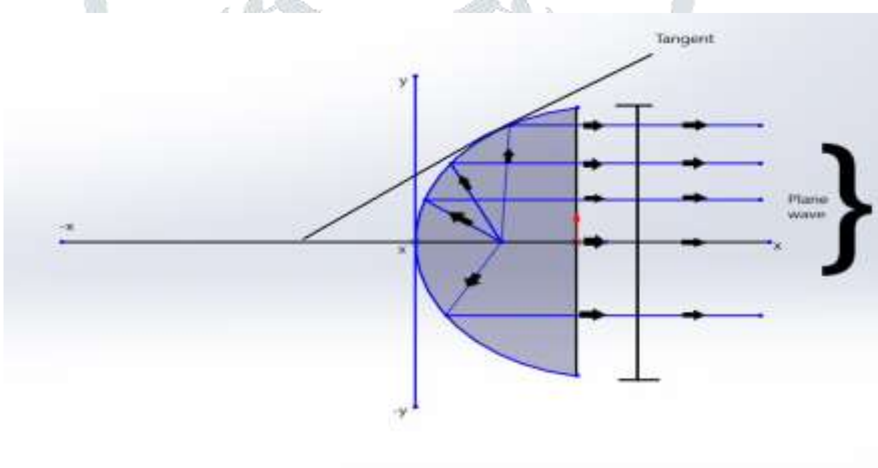


Fig.8: Geometery Of Parabolic Reflector

In order to generate the waves which are in phase, a source is to be placed at the focus of the parabolic axis. Hence a wave front which is also known as surface of constant plane is generated in the plane of parabolic aperture since all the waves are in phase therefore a directional beam of radiation is generated along the parabolic axis, moreover with the aid of parabolic reflector plane wave fronts are generated by the reflection of spherical wavefronts from the parabolic reflector as shown in figure:

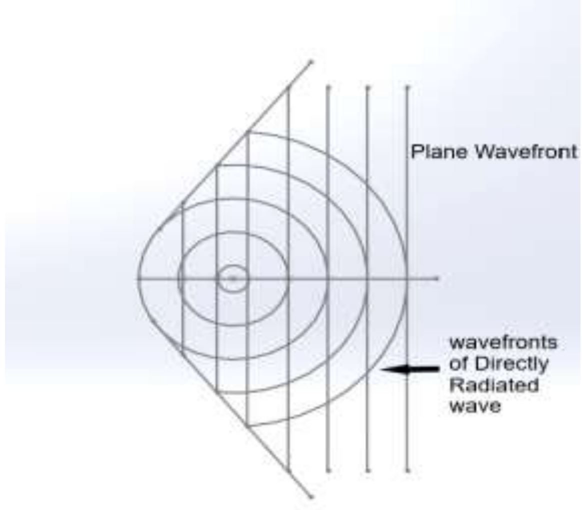


Fig.9: Plane Wavefront Generation using Parabolic Reflector

Some of the spherical waves which are generated by the source placed at focus do not strike the parabolic curve, hence such waves directly leads to the wastage of power which can be minimized by using a partial shielding nearby the focus as shown in figure which can lead to the minimization of wastage of power [9].

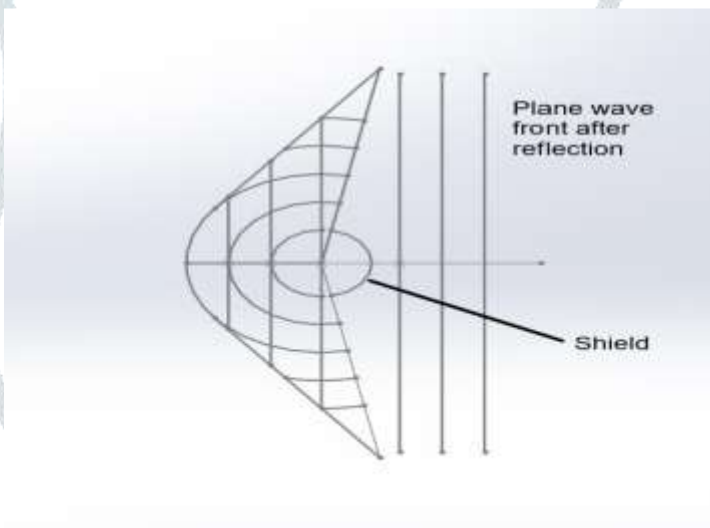


Fig. 10: Partial Shielding to reduce wastage of power

III)FUNDAMENTAL PARAMETERS OF PARABOLIC REFLECTOR ANTENNA:

Primary radiator is also known as the source radiator which is placed at the focal point of a parabolic reflector whereas secondary radiator works as a reflector in order to direct the waves coming from the focus in the forward direction.

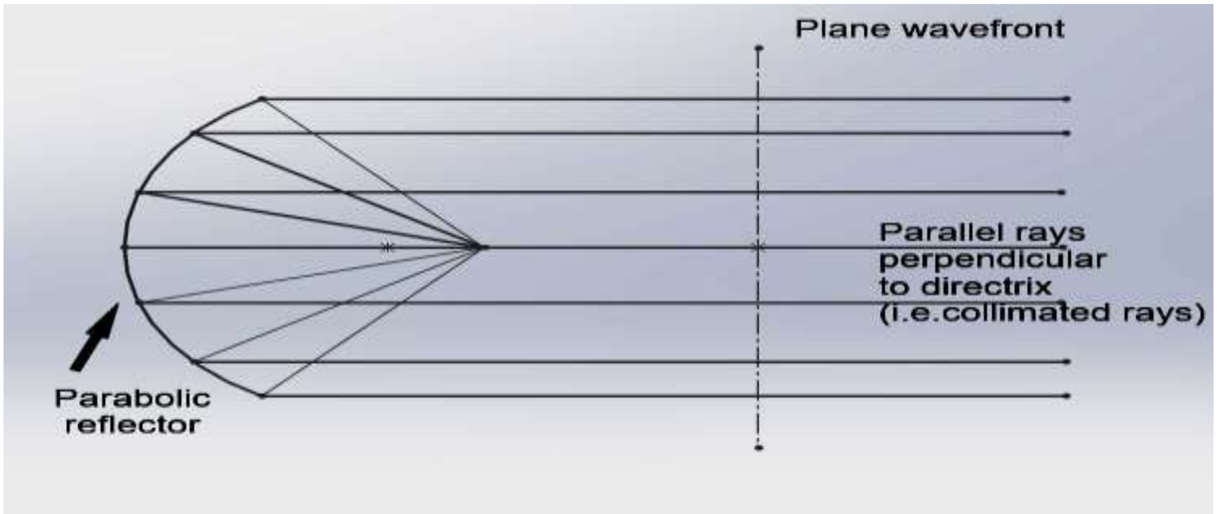


Fig.11: Paraboloid Used for Reception

BEAM WIDTH OF FIRST NULL (BWFN):BWFN is the separation of the first null pattern from the main lobe in terms of an angle, which can be calculated by the given formula:

BWFN=$\frac{140\lambda}{d}$; Whereλ=free space wavelength in meters, d=diameters of aperture in meters

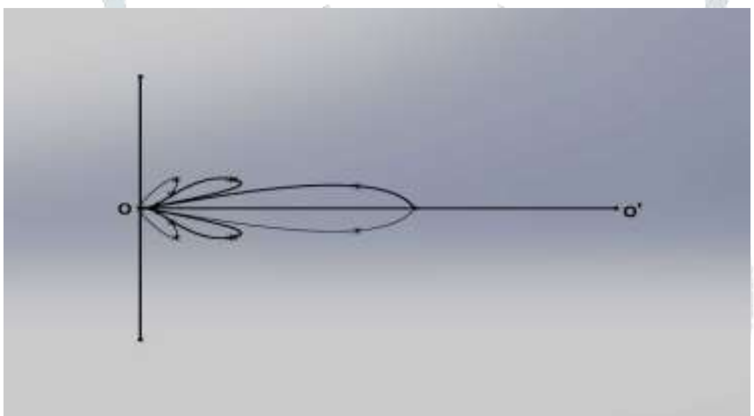


Fig.12:Radiation Pattern of a parabolic reflector

HALF POWER BEAM WIDTH (HPBW): HPBWis defined as the angle between the half power points of the main lobe:

$$HPBW=\frac{58\lambda}{d}$$

DIRECTIVITY (D):

It is the measurement of the degree to which the radiated beam is concentrated in single direction.

$$D=\frac{4\pi A}{\lambda^2}$$

Where $A = \pi d^2/4$

Hence $$D=\left(\frac{4\pi}{\lambda^2}\right)(\pi d^2/4) = \pi^2 (d/\lambda)^2$$

$$D=9.87(d/\lambda)^2$$

POWER GAIN OF PARABOLOID REFLECTOR:

$$G_p=\frac{4\pi\tilde{A}}{\lambda^2}=\frac{4\pi KA}{\lambda^2}$$

Where A= Actual Area of aperture

Ã=KA=capture area of aperture, K value depends upon the type of antenna used its value is typically 0.65 if dipole feed antenna is used at the primary feed focus point [6].

Hence consider a case of dipole feed:

$$G_p=\frac{4\pi\tilde{A}}{\lambda^2}=\frac{4\pi KA}{\lambda^2}$$

Put k=0.65 in above equation

$$G_p=\frac{4\pi\tilde{A}}{\lambda^2}=\frac{4\pi(0.65)}{\lambda^2}\left(\frac{\pi d^2}{4}\right)$$

$$Gp= (0.65)\pi^2(d/\lambda)^2$$

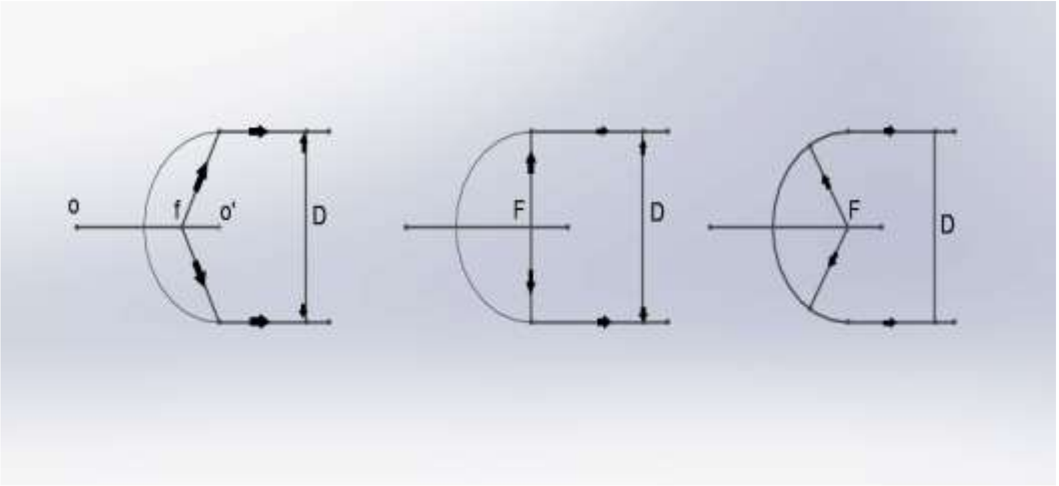
$$Gp= (0.65)(9.87)(d/\lambda)^2$$

***Reason why Parabolic Reflectors are not used at Low Frequencies:**

It is experimentally observed that the mouth aperture size of parabolic reflector must be minimum of 10λ meter i.e. for low frequencies waves which are having very large wavelength λ, for such waves aperture size will become ten times which in turn increasing the size of reflector and will make it bulky.

IV) ROLE OF APERTURE NUMBER IN REDUCING THE BACKLOBE AND SPILLOVER EFFECT:

Aperture number is the ratio of focal length of reflector to the diameter of aperture i.e. f/d .This article describes the role of f/d ratio in order to get maximum efficient directive pattern and minimum Backlobe radiation and spill over [6].



a) f< d/4 b) f=d/4 c) f>d/4

Fig.13:Different cases of Aperture Number

Figure a: When focus lies well inside the aperture mouth than it is difficult to achieve wide angle illumination

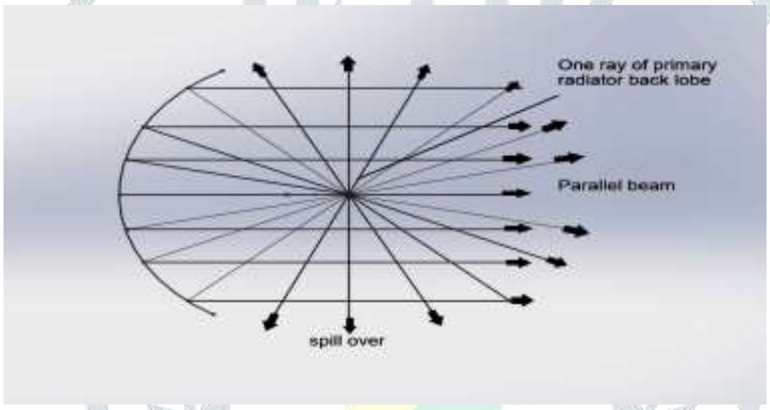


Fig.14:Spill over and Backlobe effect

Figure c: When focus lies outside the mouth aperture than most of the radiations are not reflected and leads to wastage of power or spill over /backlobes

Figure b: This arrangement shows a compromise between the above two cases when focus lies on the plane of aperture mouth than wide illumination along with minimum backlobes spill over waves fronts are achieved

To Summarize:

When **f> d/4**:In this case spill over increases, aperture efficiency decreases **, f< d/4 :**In this case non uniform illumination is achieved ,aperture efficiency decreasesand when **f=d/4**:In this case the reflector will focus all the parallel waves on to the focal point.

V) FEED MECHANISM: There are two types of feed mechanism available in practice

- Cassegrain Feed
- Gregorian Feed

CASSEGRAIN FEED: It is one of the most popular feeding mechanisms which make the use of hyperboloid secondary reflector and primary feed radiator in the form of horn antenna .In addition to the above parameters the main aim of Cassegrain feed mechanism is to reduce minor lobes and Backlobe radiations along with spill over[12].

CASSEGRAIN FEED ARRANGEMENT

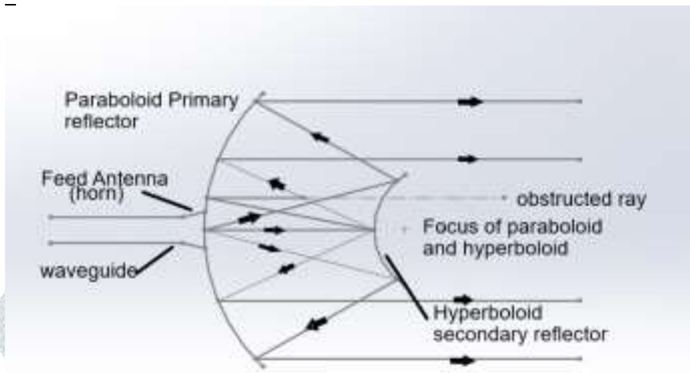


Fig.15: Cassegrain Feed Arrangement

***Points to be noted while feeding a parabolic reflector using Cassegrain Mechanism:**

1) Chiefsupply radiator is to be placed in the region of opening close to the vertex of Paraboloid instead of focus
2) Foci of Paraboloid reflector should coincide with the foci of primary reflector.
3) Chief supply radiator should aim at the hyperboloid

GREGORIAN FEED: It makes the use of main reflector and sub reflector surfaces. In the Gregorian feed mechanism the incident beam of parallel rays initially strikes theParaboloid and then allowed to be reflected by the sub reflector and refocused at the feed [12].

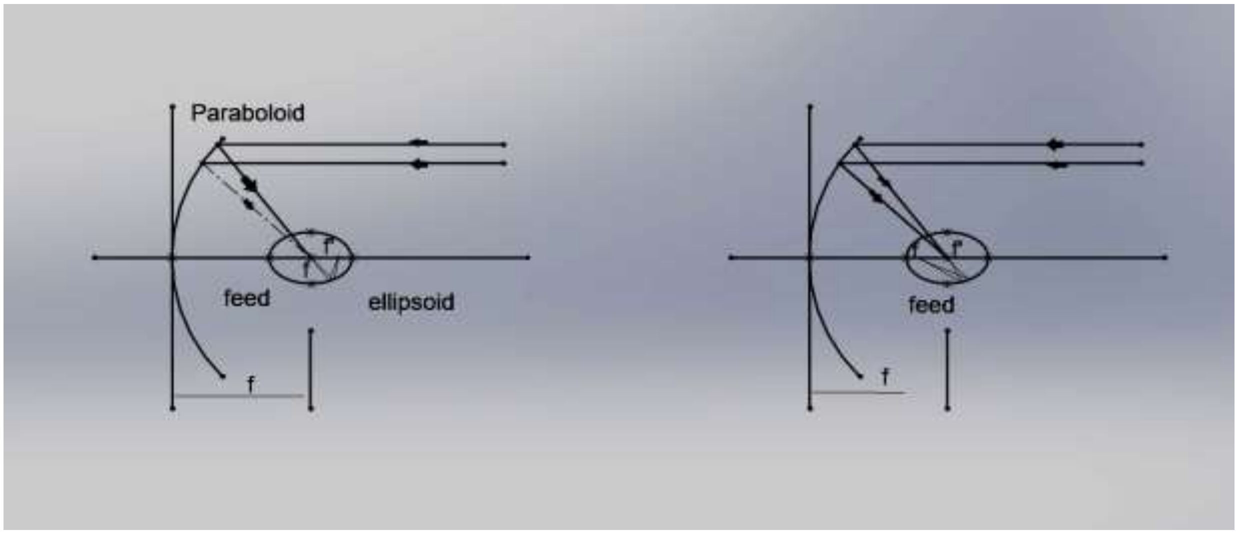


Fig. 16 Gregorian dual Reflector antenna system using ellipsoidal sub reflector

***Points to be noted while feeding a parabolic reflector using Gregorian Mechanism:**

1) One of the focal points of the ellipsoid must coincide with that of the Paraboloid
2) Feed System requires line source instead of point source.

VI) HIGH GAIN DIRECTIONAL APERTURE ANTENNA: Parabolic reflector antennas can be used in the high gain directional aperture antenna applications, which requires a typical gain of 20dBi and maximum EIRP of 33 dBw along with equivalent gain to noise temperature ration of about 4dBk.There are two basic types of High Gaindirectional parabolic antennas available which are Parabolic Dish and Parabolic Umbrella antennas. Such high gain directional pattern antennas can also be designed using parabolic reflectors with the properties of strong tracking system, in -built multiplexer unit, accurate beam pointing and high speed tracking mechanism

a)Parabolic Dish Antenna b)Parabolic Umbrella Antenna

Fig.17: High Gain Directional Aperture Antenna

VII) CONCLUSION:

Reflectors may be primary or secondary are applied in conjunction with antennas in various wireless communicationrequirements such as radar and space applications. In addition to the same the working of reflector is to focus a beam signal into single track for superior antenna gain and to get better signal strength. In this article main focus is given on parabolic reflector antennas along with their different type. Geometry of parabolic reflector antenna is also discussed in order to locate the feed antenna at a particular location so as to increase antenna gain and directivity. Major application areas of parabolic reflector antennas are in beam steering antennas, wide-band antennas with preferred radiation pattern and antennas with superior suppression of spill over and side lobes. Different antenna parameters such as gain, cross polarization, and efficiency are discussed for Paraboloid, having different focal-length-to-diameter ratios.Various feed mechanism are also described on the basis of different location of the feed radiator Special antenna parameters such as polarization , efficiency and gain are also described for Paraboloid, with different focal lengths to aperture - diameter ratio.

VIII) REFERENCES:

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