CHAPTER 3: ANTENNA CLASSIFICATIONS

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LOOP ANTENNA

- AN RF CURRENT CARRYING COIL IS GIVEN A SINGLE TURN INTO A LOOP, CAN BE USED AS AN ANTENNA CALLED AS **LOOP ANTENNA**. THE CURRENTS THROUGH THIS LOOP ANTENNA WILL BE IN PHASE. THE MAGNETIC FIELD WILL BE PERPENDICULAR TO THE WHOLE LOOP CARRYING THE CURRENT.

FREQUENCY RANGE

- THE FREQUENCY RANGE OF OPERATION OF LOOP ANTENNA IS AROUND **300MHZ TO 3GHZ**. THIS ANTENNA WORKS IN **UHF** RANGE.

CONSTRUCTION & WORKING OF LOOP ANTENNAS

- A LOOP ANTENNA IS A COIL CARRYING RADIO FREQUENCY CURRENT. IT MAY BE IN ANY SHAPE SUCH AS CIRCULAR, RECTANGULAR, TRIANGULAR, SQUARE OR HEXAGONAL ACCORDING TO THE DESIGNER'S CONVENIENCE.
- LOOP ANTENNAS ARE OF TWO TYPES.
- LARGE LOOP ANTENNAS
- SMALL LOOP ANTENNAS

LARGE LOOP ANTENNAS

- LARGE LOOP ANTENNAS ARE ALSO CALLED AS **RESONANT ANTENNAS**. THEY HAVE HIGH RADIATION EFFICIENCY. THESE ANTENNAS HAVE LENGTH NEARLY EQUAL TO THE INTENDED WAVELENGTH.

  L=Λ

- WHERE,
- **L** IS THE LENGTH OF THE ANTENNA
- **Λ** IS THE WAVELENGTH
- THE MAIN PARAMETER OF THIS ANTENNA IS ITS PERIMETER LENGTH, WHICH IS ABOUT A WAVELENGTH AND SHOULD BE AN ENCLOSED LOOP. IT IS NOT A GOOD IDEA TO MEANDER THE LOOP SO AS TO REDUCE THE SIZE, AS THAT INCREASES CAPACITIVE EFFECTS AND RESULTS IN LOW EFFICIENCY.

SMALL LOOP ANTENNAS

- SMALL LOOP ANTENNAS ARE ALSO CALLED AS **MAGNETIC LOOP ANTENNAS**. THESE ARE LESS RESONANT. THESE ARE MOSTLY USED AS RECEIVERS.
- THESE ANTENNAS ARE OF THE SIZE OF ONE-TENTH OF THE WAVELENGTH.

$$L = \frac{\lambda}{10}$$

WHERE,

- **L** IS THE LENGTH OF THE ANTENNA
- **Λ** IS THE WAVELENGTH

THE FEATURES OF SMALL LOOP ANTENNAS ARE −

- A SMALL LOOP ANTENNA HAS LOW RADIATION RESISTANCE. IF MULTI-TURN FERRITE CORE CONSTRUCTIONS ARE USED, THEN HIGH RADIATION RESISTANCE CAN BE ACHIEVED.
- IT HAS LOW RADIATION EFFICIENCY DUE TO HIGH LOSSES.
- ITS CONSTRUCTION IS SIMPLE WITH SMALL SIZE AND WEIGHT.
- DUE TO ITS HIGH REACTANCE, ITS IMPEDANCE IS DIFFICULT TO MATCH WITH THE TRANSMITTER. IF LOOP ANTENNA HAS TO ACT AS TRANSMITTING ANTENNA, THEN THIS IMPEDANCE MIS-MATCH WOULD DEFINITELY BE A PROBLEM. HENCE, THESE LOOP ANTENNAS ARE BETTER OPERATED AS **RECEIVER ANTENNAS**.

FREQUENTLY USED LOOPS

- SMALL LOOP ANTENNAS ARE MAINLY OF TWO TYPES −
- CIRCULAR LOOP ANTENNAS
- SQUARE LOOP ANTENNAS
- THESE TWO TYPES OF LOOP ANTENNAS ARE MOSTLY WIDELY USED. OTHER TYPES (RECTANGULAR, DELTA, ELLIPTICAL ETC.) ARE ALSO MADE ACCORDING TO THE DESIGNER SPECIFICATIONS.

Fig 1: Circular loop antenna

Fig 2: Square loop antenna

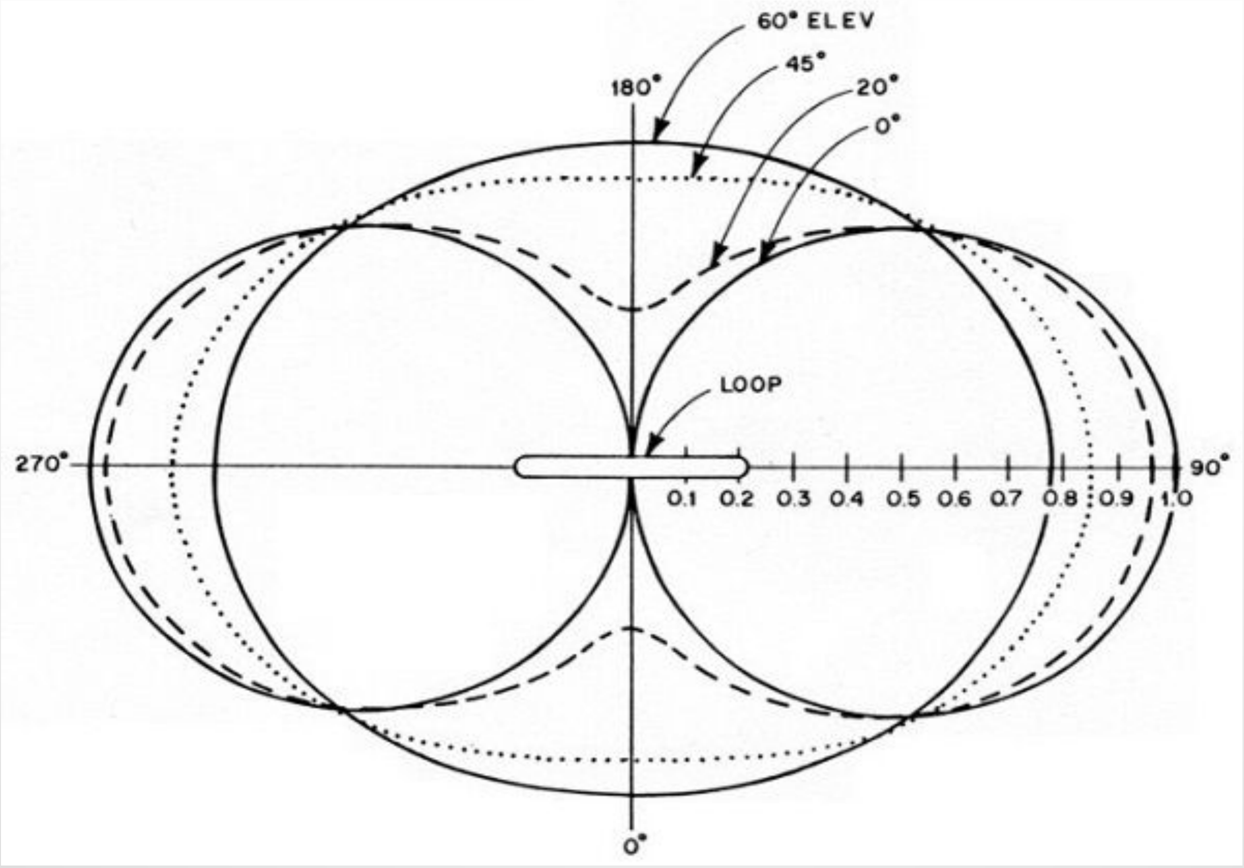
- THE ABOVE IMAGES SHOW **CIRCULAR AND SQUARE LOOP ANTENNAS**. THESE TYPES OF ANTENNAS ARE MOSTLY USED AS AM RECEIVERS BECAUSE OF HIGH SIGNAL-TO-NOISE RATIO. THEY ARE ALSO EASILY TUNABLE AT THE Q-TANK CIRCUIT IN RADIO RECEIVERS.

POLARIZATION OF LOOP

- THE POLARIZATION OF THE LOOP ANTENNA WILL BE VERTICALLY OR HORIZONTALLY POLARIZED DEPENDING UPON THE FEED POSITION. THE VERTICAL POLARIZATION IS GIVEN AT THE CENTER OF THE VERTICAL SIDE WHILE THE HORIZONTAL POLARIZATION IS GIVEN AT THE CENTER OF THE HORIZONTAL SIDE, DEPENDING UPON THE SHAPE OF THE LOOP ANTENNA.
- THE SMALL LOOP ANTENNA IS GENERALLY A **LINEARLY POLARIZED** ONE. WHEN SUCH A SMALL LOOP ANTENNA IS MOUNTED ON TOP OF A PORTABLE RECEIVER, WHOSE OUTPUT IS CONNECTED TO A METER, IT BECOMES A GREAT DIRECTION FINDER.

RADIATION PATTERN

- THE RADIATION PATTERN OF THESE ANTENNAS WILL BE SAME AS THAT OF SHORT HORIZONTAL DIPOLE ANTENNA.



The **radiation pattern** for small, high-efficiency loop antennas is shown in the figure given above. The radiation patterns for different angles of looping are also illustrated clearly in the figure. The tangent line at 0° indicates vertical polarization, whereas the line with 90° indicates horizontal polarization.

ADVANTAGES

THE FOLLOWING ARE THE ADVANTAGES OF LOOP ANTENNA −

- COMPACT IN SIZE
- HIGH DIRECTIVITY

DISADVANTAGES

THE FOLLOWING ARE THE DISADVANTAGES OF LOOP ANTENNA −

- IMPEDANCE MATCHING MAY NOT BE ALWAYS GOOD
- HAS VERY HIGH RESONANCE QUALITY FACTOR

APPLICATIONS

THE FOLLOWING ARE THE APPLICATIONS OF LOOP ANTENNA −

- USED IN RFID DEVICES
- USED IN MF, HF AND SHORT-WAVE RECEIVERS
- USED IN AIRCRAFT RECEIVERS FOR DIRECTION FINDING
- USED IN UHF TRANSMITTERS

HELICAL ANTENNA

- **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.

The image of a helix antenna detailing the antenna parts is shown in figure.

- THE RADIATION OF HELICAL ANTENNA DEPENDS ON THE DIAMETER OF HELIX, THE TURN SPACING AND THE PITCH ANGLE.
- **PITCH ANGLE** IS THE ANGLE BETWEEN A LINE TANGENT TO THE HELIX WIRE AND PLANE NORMAL TO THE HELIX AXIS.

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right)$$

where,

- **D** is the **diameter** of helix.
- **S** is the **turn spacing** (Centre to Centre).
- **α** is the **pitch angle**.

Modes of Operation

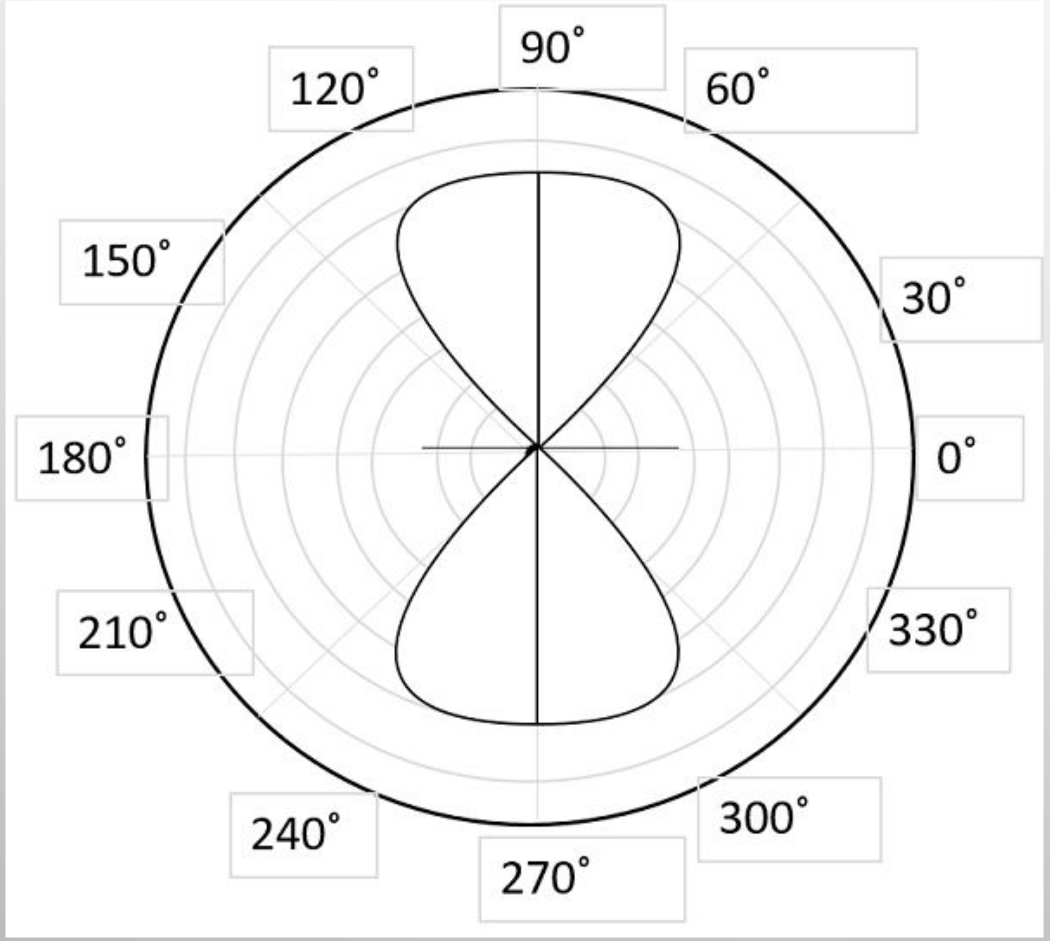
The predominant modes of operation of a helical antenna are −

- **Normal** or perpendicular mode of radiation.
- **Axial** or end-fire or beam mode of radiation.

Let us discuss them in detail.

NORMAL MODE

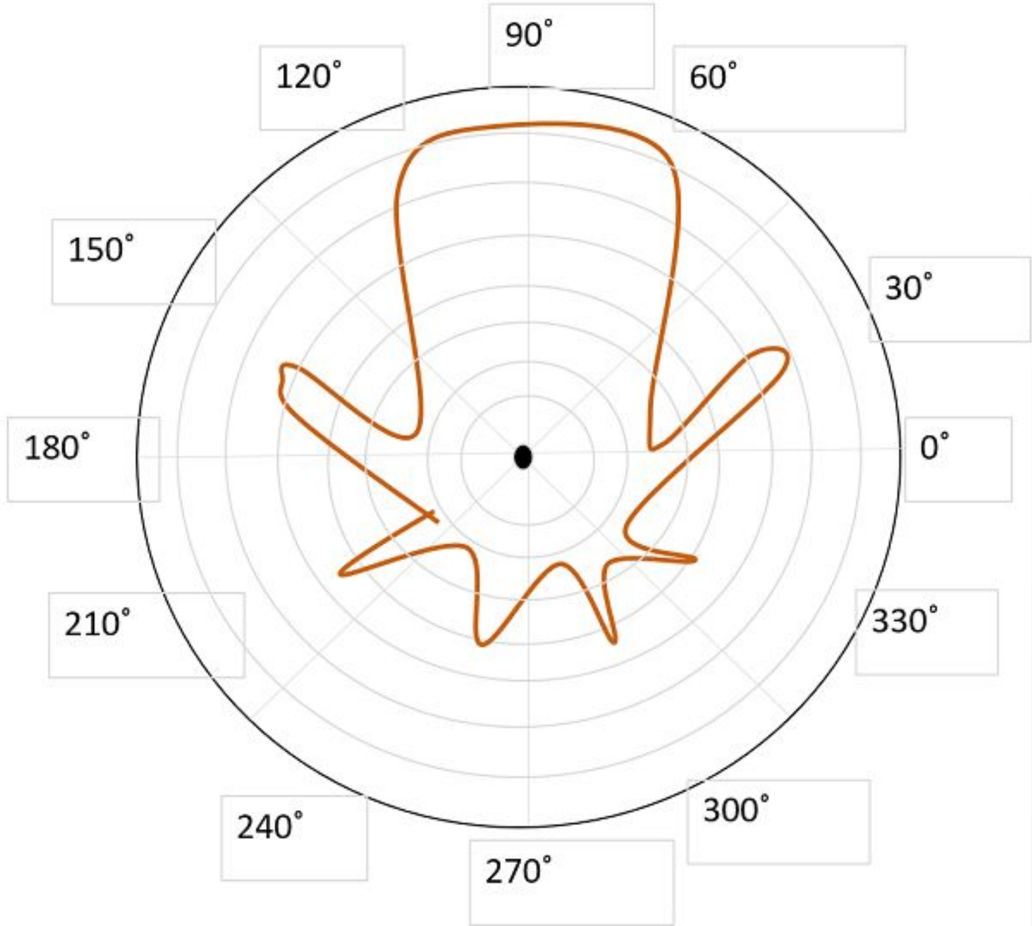
- IN NORMAL MODE OF RADIATION, THE RADIATION FIELD IS NORMAL TO THE HELIX AXIS. THE RADIATED WAVES ARE CIRCULARLY POLARIZED. THIS MODE OF RADIATION IS OBTAINED IF THE DIMENSIONS OF HELIX ARE SMALL COMPARED TO THE WAVELENGTH. THE RADIATION PATTERN OF THIS HELICAL ANTENNA IS A COMBINATION OF SHORT DIPOLE AND LOOP ANTENNA.



- THE ABOVE FIGURE SHOWS THE RADIATION PATTERN FOR NORMAL MODE OF RADIATION IN HELICAL ANTENNA.
- IT DEPENDS UPON THE VALUES OF DIAMETER OF HELIX, **D** AND ITS TURN SPACING, **S**. DRAWBACKS OF THIS MODE OF OPERATION ARE LOW RADIATION EFFICIENCY AND NARROW BANDWIDTH. HENCE, IT IS HARDLY USED.

AXIAL MODE

- IN **AXIAL MODE** OF RADIATION, THE RADIATION IS IN THE END-FIRE DIRECTION ALONG THE HELICAL AXIS AND THE WAVES ARE CIRCULARLY OR NEARLY CIRCULARLY POLARIZED. THIS MODE OF OPERATION IS OBTAINED BY RAISING THE CIRCUMFERENCE TO THE ORDER OF ONE WAVELENGTH **(Λ)** AND SPACING OF APPROXIMATELY **Λ/4**. THE RADIATION PATTERN IS BROAD AND DIRECTIONAL ALONG THE AXIAL BEAM PRODUCING MINOR LOBES AT OBLIQUE ANGLES.



The figure shows the radiation pattern for axial mode of radiation in helical antenna.

If this antenna is designed for right-handed circularly polarized waves, then it will not receive left-handed circularly polarized waves and vice versa. This mode of operation is generated with great ease and is **more practically used**.

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 ballistic missiles and satellites at Earth stations
- Used to establish communications between the moon and the Earth
- Applications in radio astronomy

Aperture antenna

An antenna having an aperture (opening) with a certain geometric shape is referred to as aperture antenna. The aperture may take a form of a wave guide or a horn. A horn is a hollow pipe of different cross section; which has been tapered to a larger opening. The opening may be square, rectangular, circular, and elliptical or any other configuration.

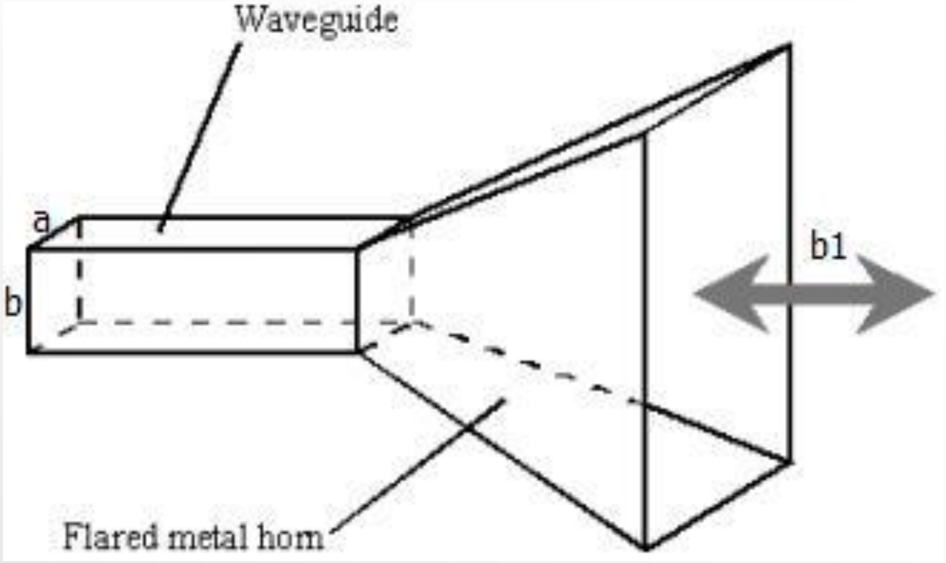
Figure 1. Types of horn antennas: (a) pyramidal, (b) rectangular, (c) conical, (d) hor n with parabolic generatrix; (1) wave guide, (2) horn

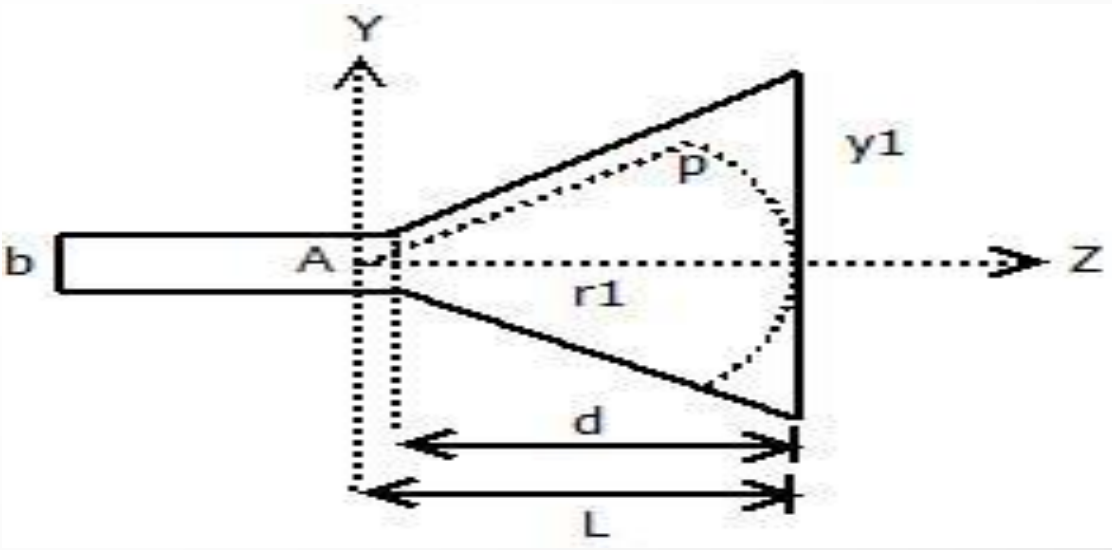
The formation of the horn is to produce a uniform phase front with a larger opening than that of the wave guide and greater directivity.

When the aperture of a horn takes the form of rectangle then such type of horn is called rectangular horn. So the names of the horns are taken from the aperture they have.

If the opening of such antenna is flared in the direction of E (electric) field then such horn is called E plane horn.

In E plane horn path difference P = $\frac{1}{2}(\frac{y1^2}{r1})$

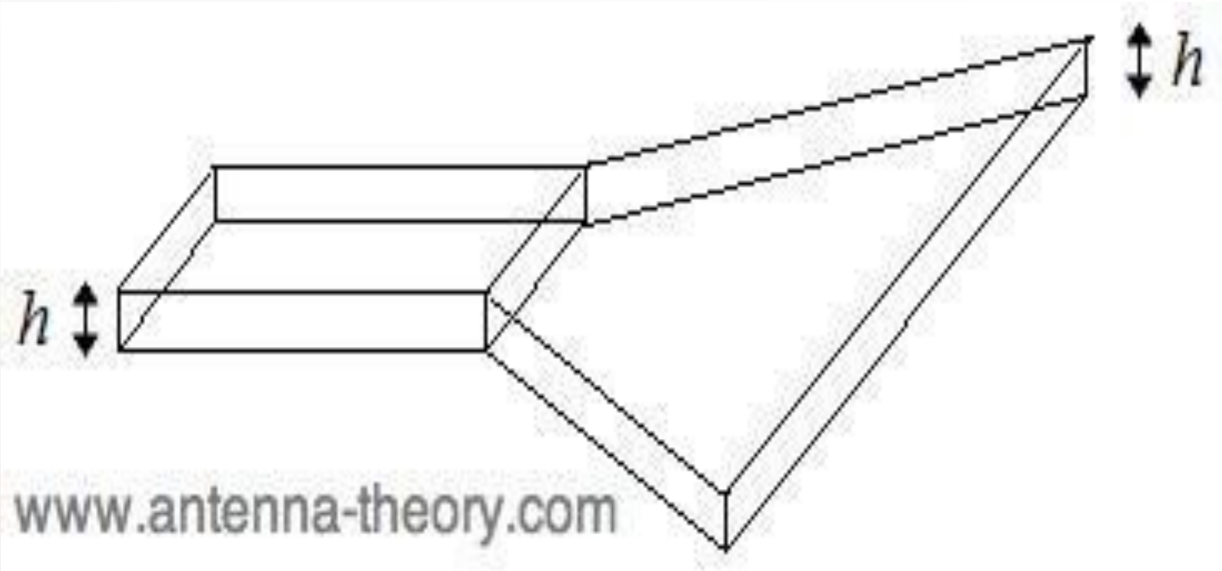




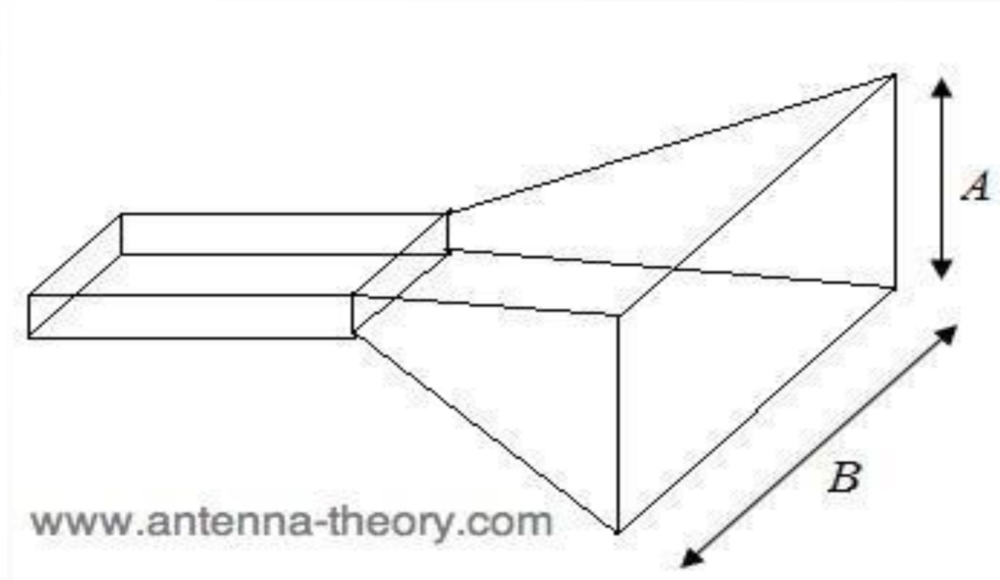
E-plane horn antenna

Multiplying path difference with phase constant β phase difference is obtained. Radiation pattern is the function of θ and ϕ and it is more complicated. So for easier $\phi=\frac{\pi}{2}$ and θ=0 are considered for plotting radiation pattern. The directivity $b1 = \sqrt{2\lambda r1}$;where r1 is expressed in terms of λ.

Similarly in H plane horn opening is flared in the direction of H(magnetic) field. In H plane all features are similar to E plane horn and flare angle is different. Optimum directivity $a1 = \sqrt{3\lambda r2}$ where r1=r2.



H plane horn



pyramidal horn

In pyramidal horn the directivity $Dp = \frac{\pi\lambda^2}{32ab} DE * DH$

Where DE and DH are directivities in electric and magnetic field.

Waveguide Antenna

A **Waveguide** is capable of radiating energy when excited at one end and opened at the other end. The radiation in wave guide is greater than a two-wire transmission line.

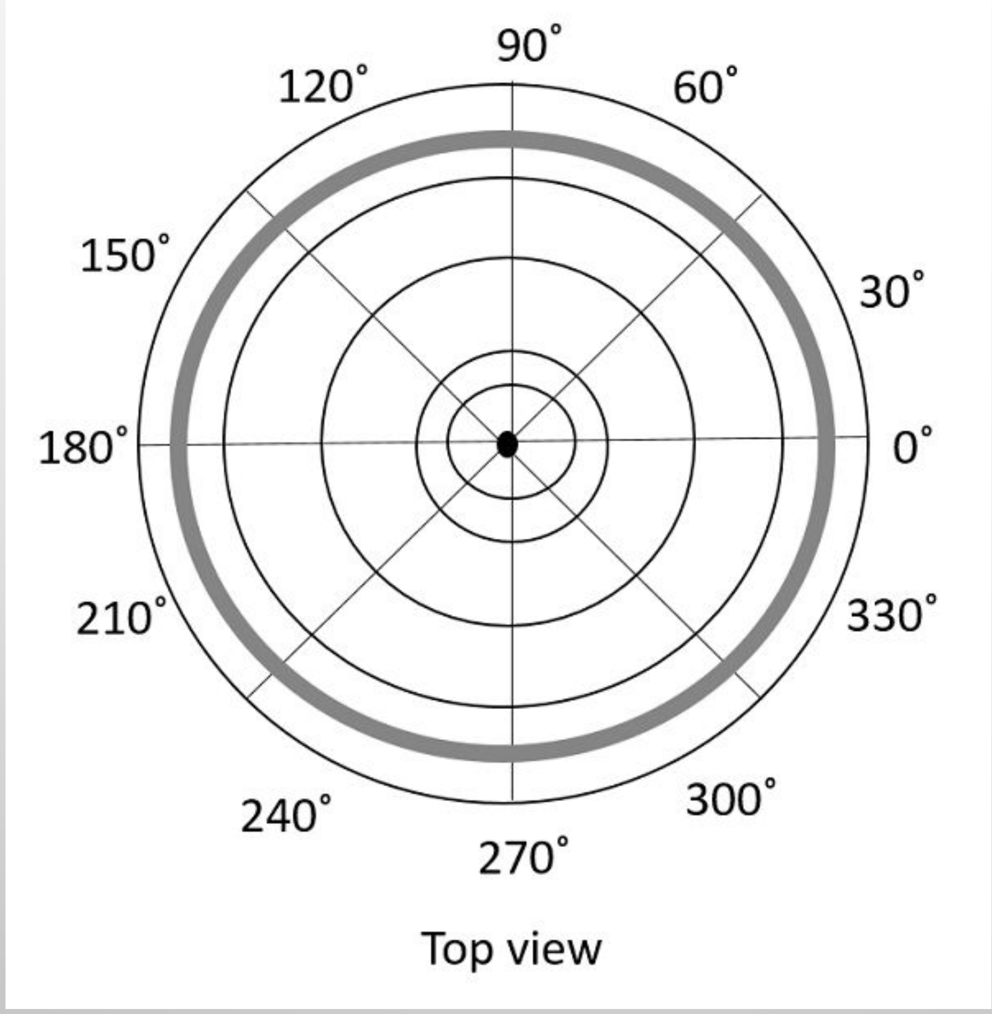
FREQUENCY RANGE

- THE OPERATIONAL FREQUENCY RANGE OF A WAVE GUIDE IS AROUND **300MHZ TO 300GHZ**. THIS ANTENNA WORKS IN **UHF** AND **EHF** FREQUENCY RANGES. THE FOLLOWING IMAGE SHOWS A WAVEGUIDE.

This waveguide with terminated end, acts as an antenna. But only a small portion of the energy is radiated while a large portion of it gets reflected back in the open circuit. It means **VSWR** (voltage standing wave ratio, discussed in basic parameters chapter) value increases. The diffraction around the waveguide provides poor radiation and non-directive radiation pattern.

RADIATION PATTERN

- THE RADIATION OF WAVEGUIDE ANTENNA IS POOR AND THE PATTERN IS NON-DIRECTIVE, WHICH MEANS OMNI-DIRECTIONAL.
  AN **OMNI-DIRECTIONAL** PATTERN IS THE ONE WHICH HAS NO CERTAIN DIRECTIVITY BUT RADIATES IN ALL DIRECTIONS, HENCE IT IS CALLED AS **NON-DIRECTIVE RADIATION PATTERN**.



- THE ABOVE FIGURE SHOWS A TOP SECTION VIEW OF AN OMNI-DIRECTIONAL PATTERN, WHICH IS ALSO CALLED AS **NON-DIRECTIONAL PATTERN**. THE TWO-DIMENSIONAL VIEW IS A FIGURE-OF-EIGHT PATTERN, AS WE ALREADY KNOW.

ADVANTAGES

- THE FOLLOWING ARE THE ADVANTAGES OF APERTURE ANTENNA −
- RADIATION IS GREATER THAN TWO-WIRE TRANSMISSION LINE
- RADIATION IS OMNI-DIRECTIONAL

DISADVANTAGES

- THE FOLLOWING ARE THE DISADVANTAGES OF APERTURE ANTENNA −
- VSWR INCREASES
- POOR RADIATION

APPLICATIONS

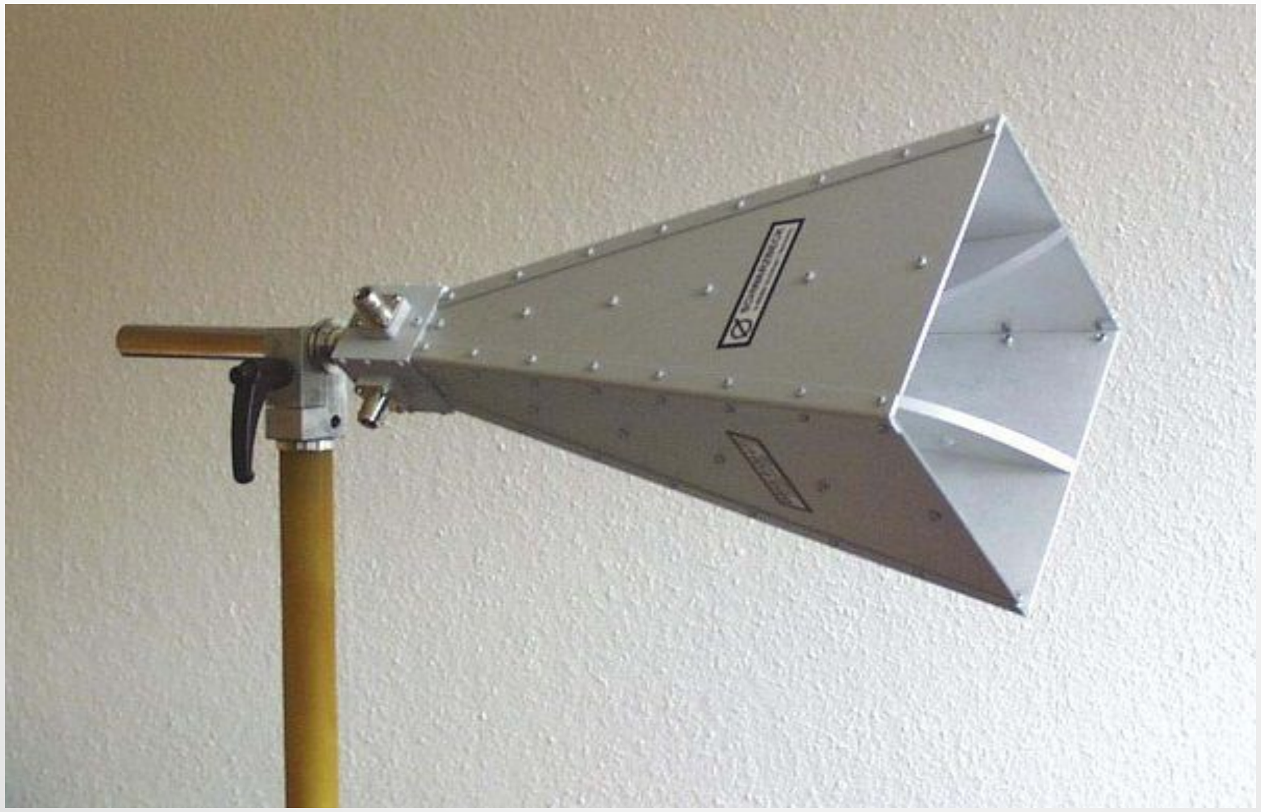
THE FOLLOWING ARE THE APPLICATIONS OF APERTURE ANTENNA −

- MICRO WAVE APPLICATIONS
- SURFACE SEARCH RADAR APPLICATIONS
- EXTENSIVELY USED IN MICROWAVE RANGE(ABOVE 1 GHZ)
- CAN BE EASILY FLUSHED MOUNTED TO THE SURFACE OF THE AIR CRAFT.
- SUITABLE AS A FEEDING SYSTEM IN REFLECTOR ANTENNA.

THE WAVEGUIDE ANTENNA HAS TO BE FURTHER MODIFIED TO ACHIEVE BETTER PERFORMANCE, WHICH RESULTS IN THE FORMATION OF **HORN ANTENNA**.

HORN ANTENNA

- TO IMPROVE THE RADIATION EFFICIENCY AND DIRECTIVITY OF THE BEAM, THE WAVE GUIDE SHOULD BE PROVIDED WITH AN EXTENDED APERTURE TO MAKE THE ABRUPT DISCONTINUITY OF THE WAVE INTO A GRADUAL TRANSFORMATION. SO THAT ALL THE ENERGY IN THE FORWARD DIRECTION GETS RADIATED. THIS CAN BE TERMED AS **FLARING**. NOW, THIS CAN BE DONE USING A HORN ANTENNA.
- **FREQUENCY RANGE**
- THE OPERATIONAL FREQUENCY RANGE OF A HORN ANTENNA IS AROUND **300MHZ TO 30GHZ**. THIS ANTENNA WORKS IN **UHF** AND **SHF** FREQUENCY RANGES.
- **CONSTRUCTION & WORKING OF HORN ANTENNA**
- THE ENERGY OF THE BEAM WHEN SLOWLY TRANSFORM INTO RADIATION, THE LOSSES ARE REDUCED AND THE FOCUSING OF THE BEAM IMPROVES. A **HORN ANTENNA** MAY BE CONSIDERED AS A **FLARED-OUT WAVE GUIDE**, BY WHICH THE DIRECTIVITY IS IMPROVED AND THE DIFFRACTION IS REDUCED.



The above image shows the model of a horn antenna. The flaring of the horn is clearly shown. There are several horn configurations out of which, three configurations are most commonly used.

Sectoral horn

This type of horn antenna, flares out in only one direction. Flaring in the direction of Electric vector produces the **sectorial E-plane horn**. Similarly, flaring in the direction of Magnetic vector, produces the **sectorial H-plane horn**.

PYRAMIDAL HORN

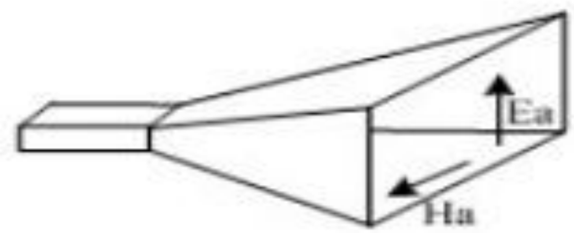
- THIS TYPE OF HORN ANTENNA HAS FLARING ON BOTH SIDES. IF FLARING IS DONE ON BOTH THE E & H WALLS OF A RECTANGULAR WAVEGUIDE, THEN **PYRAMIDAL HORN ANTENNA** IS PRODUCED. THIS ANTENNA HAS THE SHAPE OF A TRUNCATED PYRAMID.

CONICAL HORN

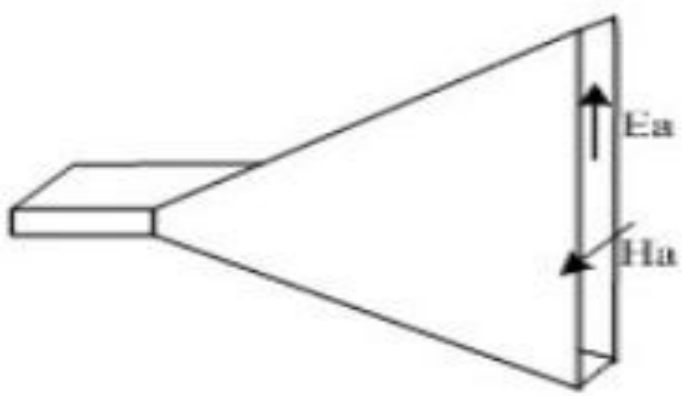
- WHEN THE WALLS OF A CIRCULAR WAVE GUIDE ARE FLARED, IT IS KNOWN AS A **CONICAL HORN**. THIS IS A LOGICAL TERMINATION OF A CIRCULAR WAVE GUIDE.

DIFFERENT TYPES OF HORN ANTENNA

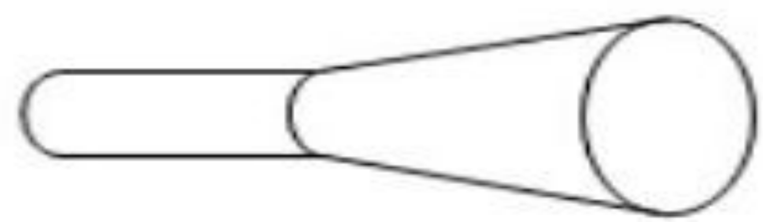
H-plane sectoral horn



Pyramidal horn



E-plane sectoral horn



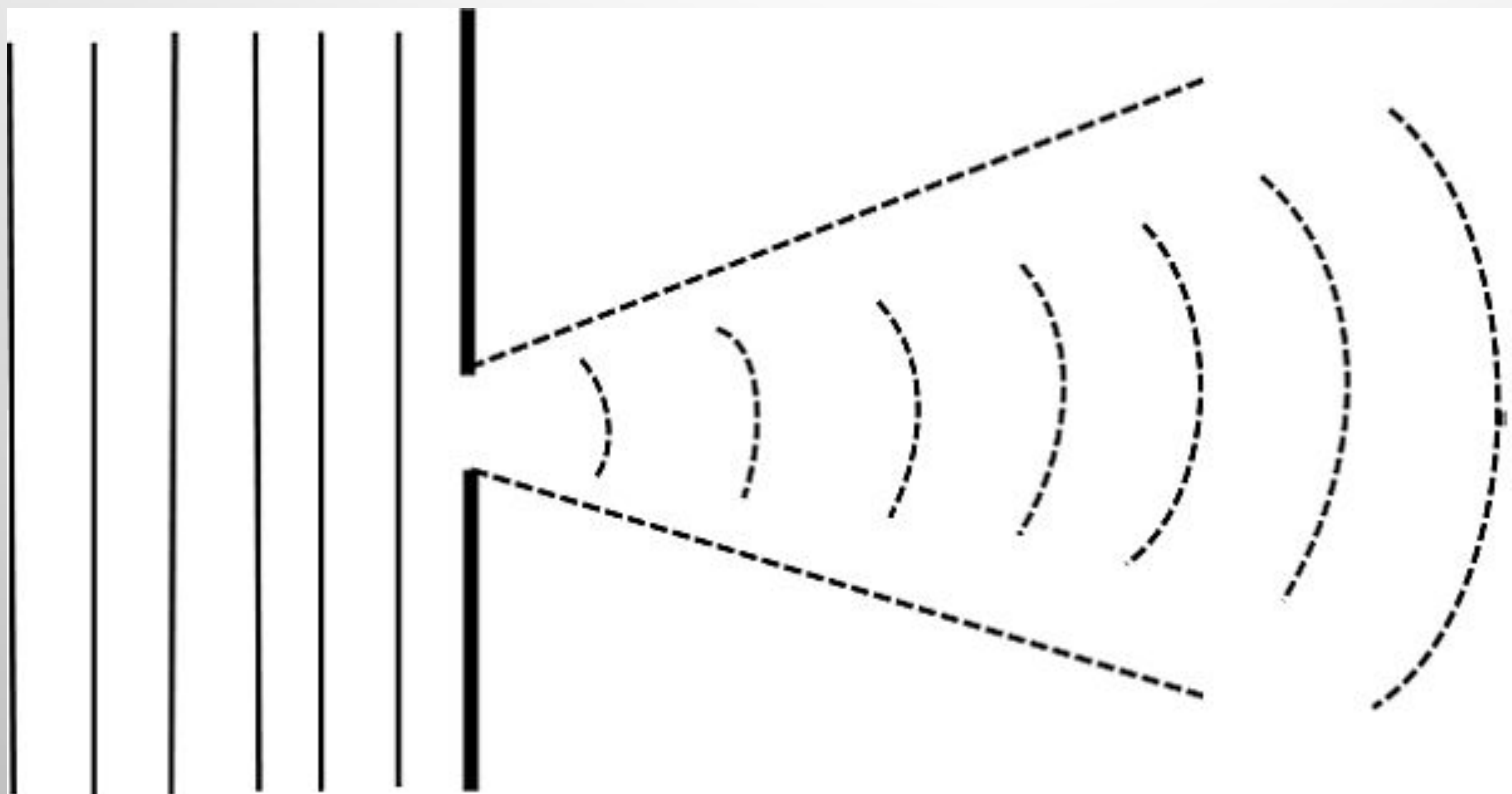
Conical Horn Antenna

COMBINATIONS

- HORN ANTENNAS, MAY ALSO BE COMBINED WITH PARABOLIC REFLECTOR ANTENNAS TO FORM SPECIAL TYPE OF HORN ANTENNAS. THESE ARE −
- CASS-HORN ANTENNA
- HOG-HORN OR TRIPLY FOLDED HORN REFLECTOR
- IN **CASS-HORN ANTENNA**, RADIO WAVES ARE COLLECTED BY THE LARGE BOTTOM SURFACE, WHICH IS PARABOLICALLY CURVED AND REFLECTED UPWARD AT 45° ANGLE. AFTER HITTING TOP SURFACE, THEY ARE REFLECTED TO THE FOCAL POINT. THE GAIN AND BEAM WIDTH OF THESE ARE JUST LIKE PARABOLIC REFLECTORS.
- IN **HOG-HORN** ANTENNA, A PARABOLIC CYLINDER IS JOINED TO PYRAMIDAL HORN, WHERE THE BEAM REACHES APEX OF THE HORN. IT FORMS A LOW-NOISE MICROWAVE ANTENNA. THE MAIN ADVANTAGE OF HOG-HORN ANTENNA IS THAT ITS RECEIVING POINT DOES NOT MOVE, THOUGH THE ANTENNA IS ROTATED ABOUT ITS AXIS.

RADIATION PATTERN

- THE RADIATION PATTERN OF A HORN ANTENNA IS A SPHERICAL WAVE FRONT. THE FOLLOWING FIGURE SHOWS THE **RADIATION PATTERN** OF HORN ANTENNA. THE WAVE RADIATES FROM THE APERTURE, MINIMIZING THE DIFFRACTION OF WAVES. THE FLARING KEEPS THE BEAM FOCUSSED. THE RADIATED BEAM HAS HIGH DIRECTIVITY.



ADVANTAGES

- THE FOLLOWING ARE THE ADVANTAGES OF HORN ANTENNA −
- SMALL MINOR LOBES ARE FORMED
- IMPEDANCE MATCHING IS GOOD
- GREATER DIRECTIVITY
- NARROWER BEAM WIDTH
- STANDING WAVES ARE AVOIDED

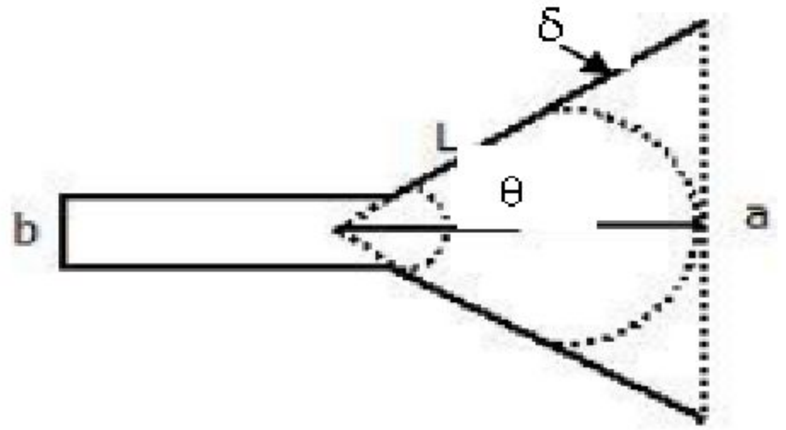
DISADVANTAGES

- THE FOLLOWING ARE THE DISADVANTAGES OF HORN ANTENNA −
- DESIGNING OF FLARE ANGLE, DECIDES THE DIRECTIVITY
- FLARE ANGLE AND LENGTH OF THE FLARE SHOULD NOT BE VERY SMALL

APPLICATIONS

- THE FOLLOWING ARE THE APPLICATIONS OF HORN ANTENNA −
- USED FOR ASTRONOMICAL STUDIES
- USED IN MICROWAVE APPLICATIONS

DERIVATION OF FLARE ANGLE AND DIMENSION OF HORN ANTENNA



From the above figure $cos\frac{\theta}{2} = \frac{L}{L+\delta}$ and $sin\frac{\theta}{2} = \frac{a}{2(L+\delta)}$

$\therefore tan\frac{\theta}{2} = \frac{a}{2L}$

Where, θ is a flare angle and it is represented by θE for electric plane and θH for magnetic plane.

a= aperture, L=length of horn

In geometry we take $L = \frac{a^2}{8\delta}$ $where\ \delta \ll L$

$\therefore \theta = 2\tan^{-1}\frac{a}{2L} = 2\cos^{-1}\frac{L}{L+\delta}$

TO OBTAIN UNIFORM APERTURE DISTRIBUTION VERY LONG HORN WITH A SMALL FLARE ANGLE IS REQUIRED. WHEN δ DOES NOT EXCEEDS A CERTAIN VALUE $\delta 0$ THEN SUCH $\delta 0$ IS CALLED LARGEST FLARE ANGLE. THUS THE OPTIMUM HORN DIMENSION CAN BE REDUCED BY

$$\delta 0 = \frac{L}{COS\frac{\theta}{2}} - L$$

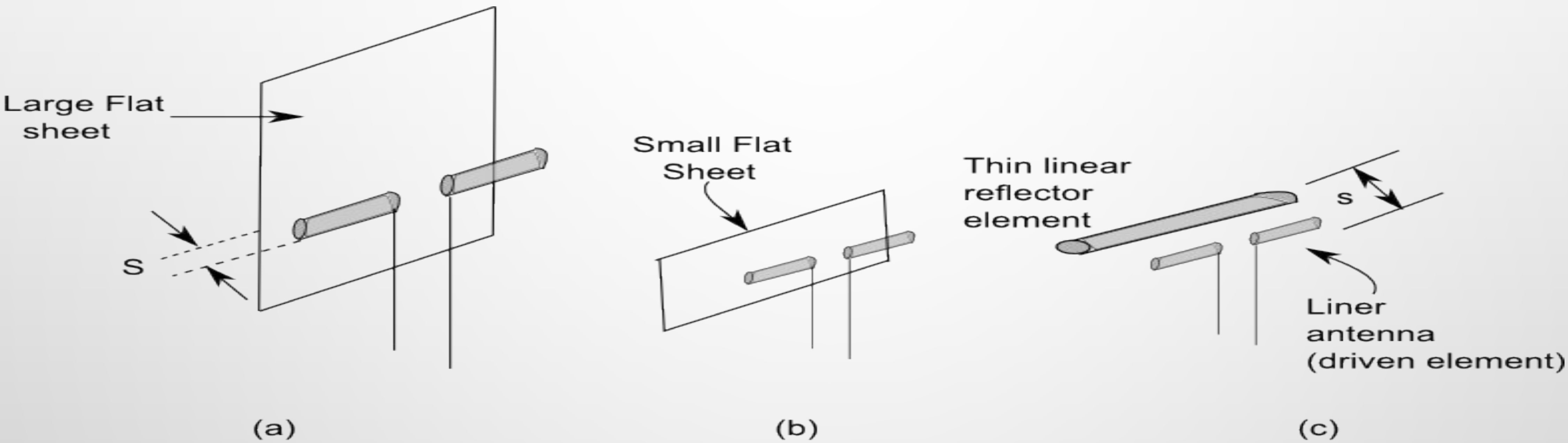
$\therefore L = \frac{\delta 0 COS\frac{\theta}{2}}{1-COS\frac{\theta}{2}}$ WHERE $\delta 0$ =0.1 – 0.4 FOR FREE SPACE.

Reflector antenna:

Reflector antennas are typically used when very high gain (e.g. satellite transmission or reception) or a very narrow main beam (e.g. secure communication) is required. Gain is improved and the main beam narrowed with increase in the reflector size. It is a sophisticated form of antenna for communication over greater distances about geostationary distance.

Types of reflector antenna:

Plane sheet reflector:

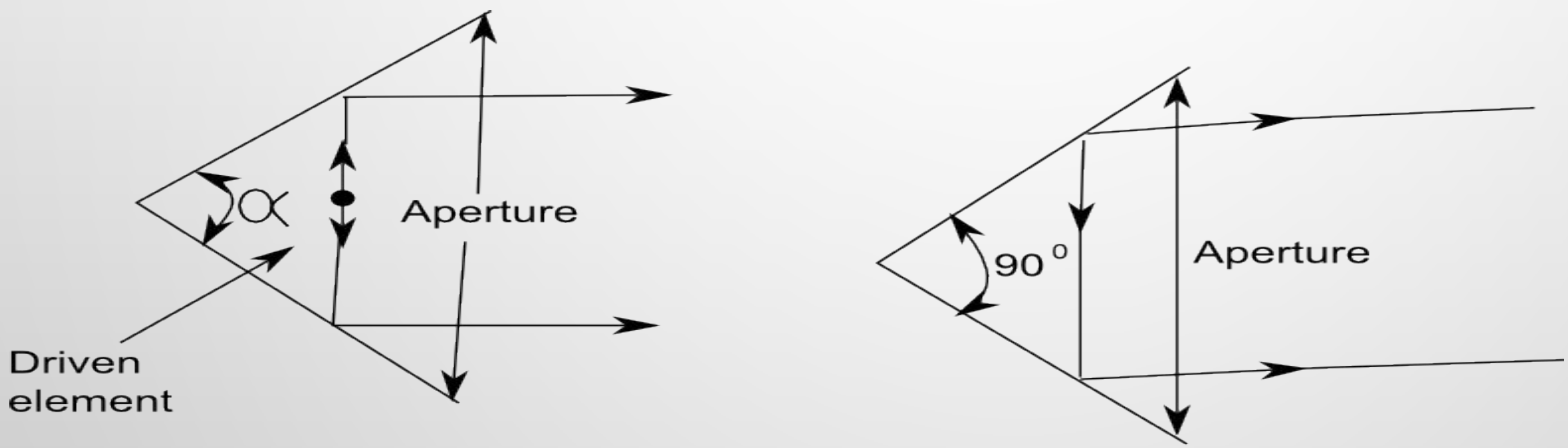


(a) Ideal reflector ; (b and c) Reflector with reduced size

Fig.(a) shows a ideal plane reflector. This is large, flat sheet reflector near a linear dipole antenna (an example) to reduce the backward radiation. With small spacing between the antenna and sheet is arrangement also result in increase in gain in the forward direction.

It can be shown that the polarization of the radiating source and its position relative to the reflecting surface can be used to control the radiation properties (pattern, impedance, directivity) of the overall system.

Corner Reflector:



(a) Active corner reflector (b) Passive corner or retroreflector

Corner reflector

Corner reflector consist of two flat sheets intersecting at an angle $\propto$ (<180°).

In fig. (a), when the angle $\propto$ is made equal to 180°, the corner reflector will take a form of plane reflector. The corner reflector is used in one of the two forms.

1. Active Corner Reflector:

A sharper radiation pattern than from a flat sheet reflector ($\propto$=180°) can be obtained. This arrangement is called as ''active corner reflector'', shows in Fig. (a). In practice aperture of 1 or 2λ are of convenient size.

2. Passive Reflectors:

A corner reflector without an exciting antenna can be used as a passive reflector or target for radar waves. In this application the aperture may be many wavelengths and the corner angle is always 90°. Reflector with $\propto$=90° have the property that an incident wave is reflected back toward its source as shown in Fig.(b), the corner acting as retro reflector.

Applications:

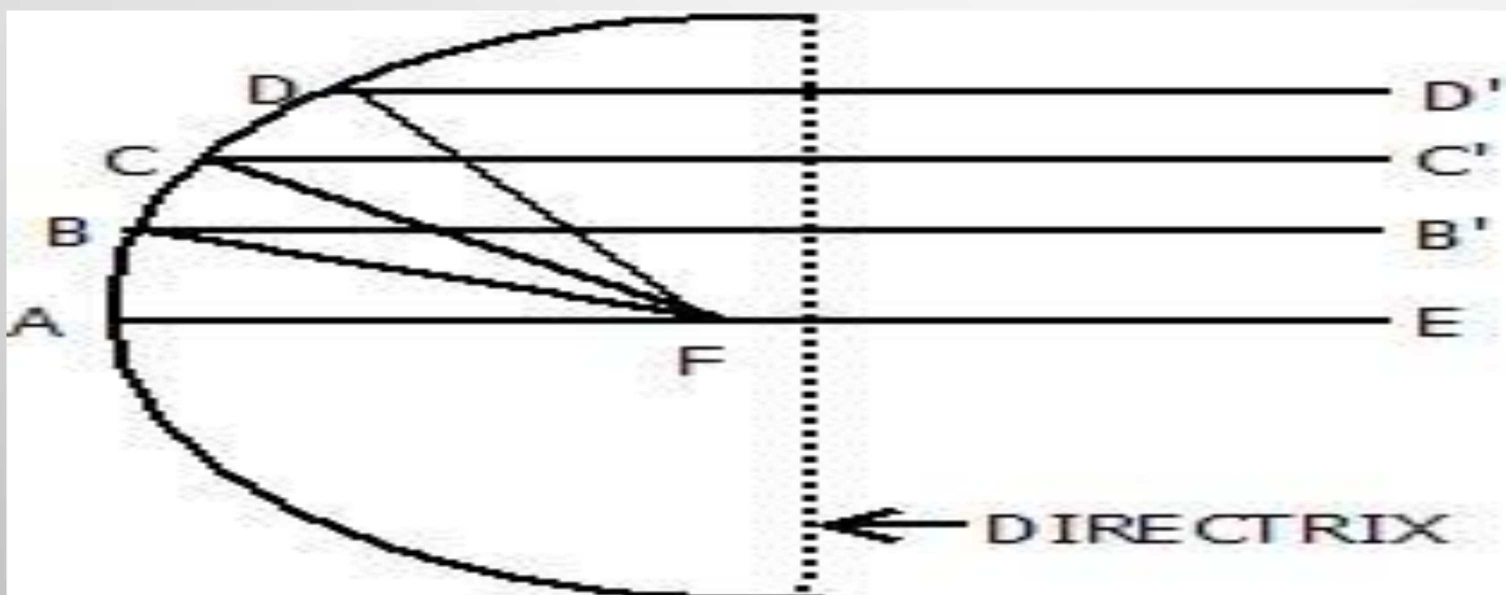
It is used in many applications like radio astronomy, microwave communication, satellite tracking, and deep space communication such as in the space program.

Curved Reflector

Curved reflectors are categorized in parabolic reflector, elliptical reflector, circular reflector and hyperbolic reflector.

Parabolic reflector

A parabola is very suitable reflector for light rays or microwaves. Distance travelled by each wave parallel to axis up to directrix is same so all waves are in same phase.



Where focus is F and axis is AE. Mathematically from the definition of parabola;

FB+BB' =FC+CC'

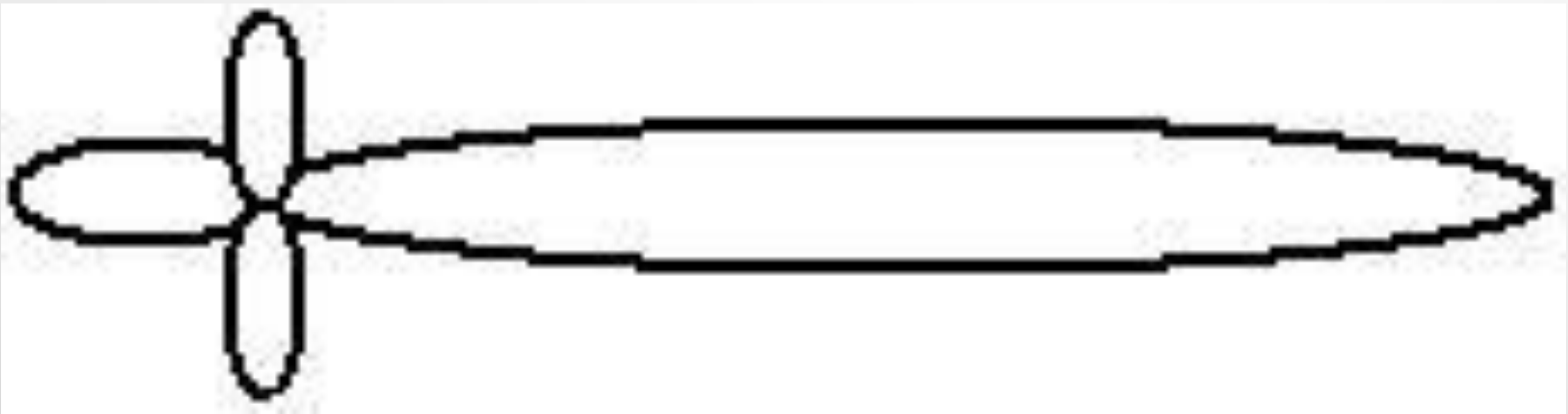
=FD+DD'

=K (constant)........ (i)

Constant K is changed if the shape of the parabola changed. In the figure focal length is AF then the aperture of parabola$= \frac{\boldsymbol{focal\ length}}{\boldsymbol{mouth\ diameter}}$. Equation (i) implies that if a source of radiation placed at the focus all waves coming from it and reflected by the parabola will have travelled the same distance. By the time to reach the directrix they will be then in phase. Thus the radiation is very strong and concentrated along the axis but cancellation will take place in any other direction because of path length differences and this leads to concentrated beam of radiation. It is high gain and more directional. The radiation pattern has a very sharp main lobe and surrounded by the main lobe are the minor lobes, which are very small in size compared to the main lobe.

Gain of antenna = $\frac{\boldsymbol{power\ measured\ at\ the\ particular\ distance(\ in\ main\ lobe\ )of\ directional\ antenna}}{\boldsymbol{power\ measured\ in\ the\ same\ distance\ in\ an\ isotropic\ antenna}}$ keeping the transmitting power constant.

Radiation pattern:



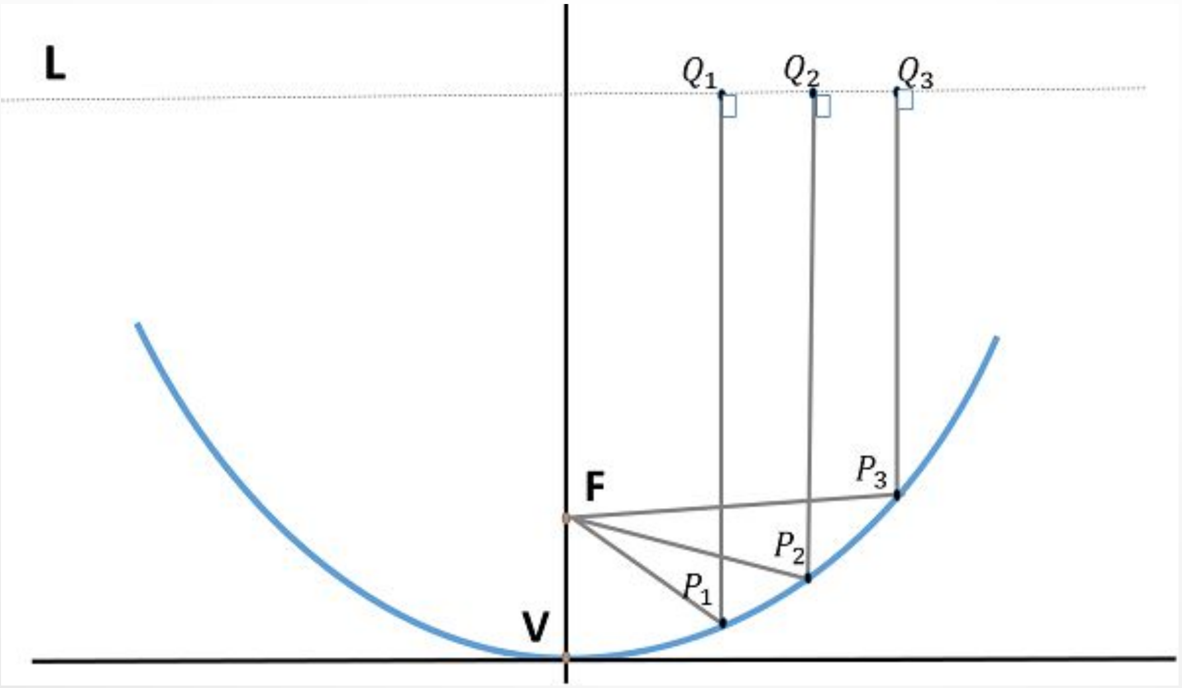
Gain in dB =$\mathbf{10}\boldsymbol{log}\frac{\boldsymbol{pd}}{\boldsymbol{pi}}$ where $\boldsymbol{pd}$ =power of directional antenna and $\boldsymbol{pi}$ =power of isotropic antenna.

If the driven element is non directional then beam width ϕ=$\frac{\mathbf{70\lambda}}{\boldsymbol{D}}$ and bandwidth between two nulls ϕ0=2 ϕ. Where D is mouth diameter of the reflector and ϕ is half power beam width (HPBW).

If D increase ϕ decreases and beam will be sharp. The maximum gain of an antenna using a uniformly illuminated parabolid reflector Ap= $\mathbf{6}\frac{\boldsymbol{D}}{\boldsymbol{\lambda}}$. Where Ap is power gain of an antenna. If the intensity of illumination at the reflector falls off at the edges then power gain will be Ap'= $\mathbf{4.2}(\frac{\boldsymbol{D}}{\boldsymbol{\lambda}})$^$\mathbf{2}$.

PARABOLIC REFLECTOR 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 colllimated 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.

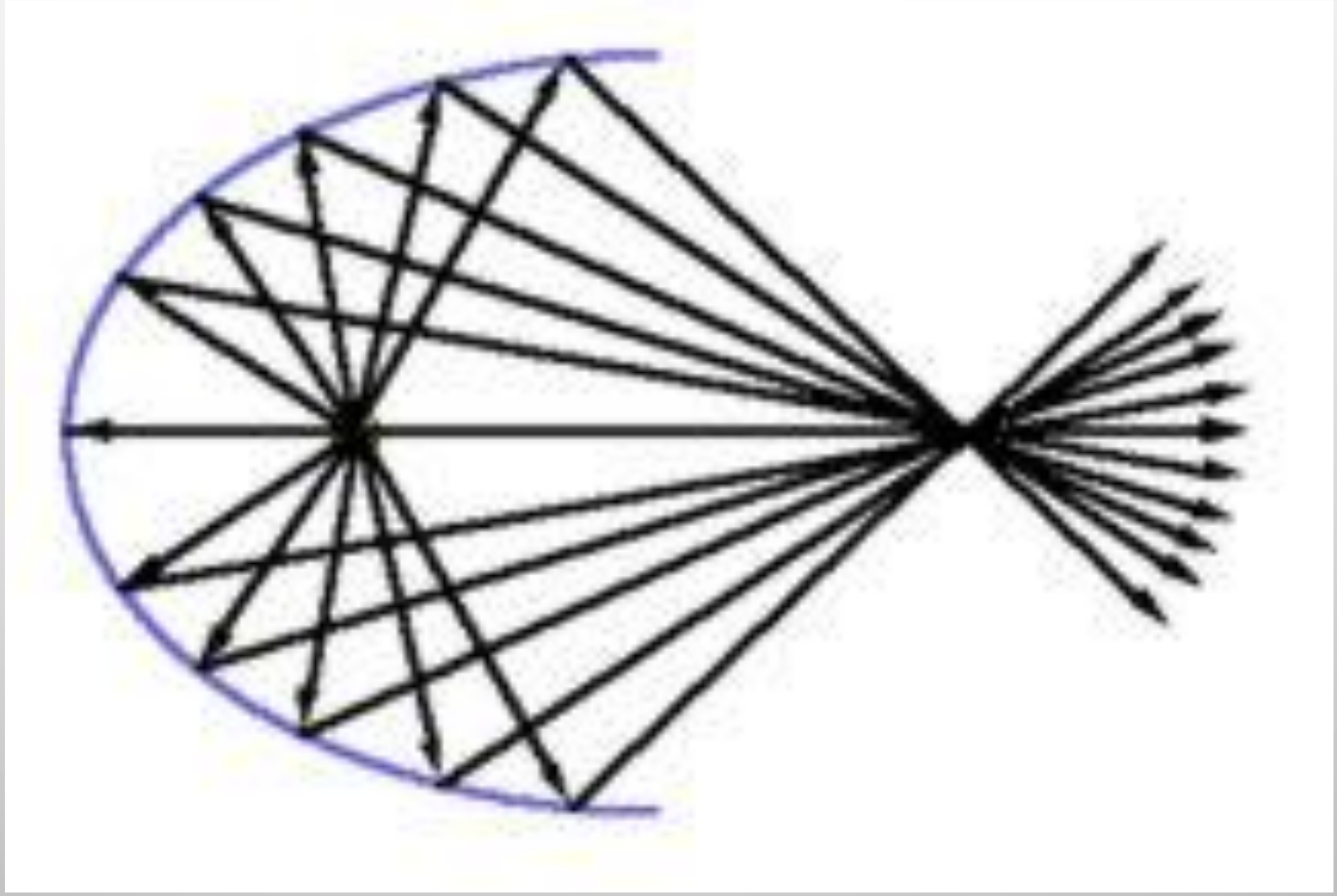
CONSTRUCTION & WORKING OF A PARABOLIC REFLECTOR

- 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.

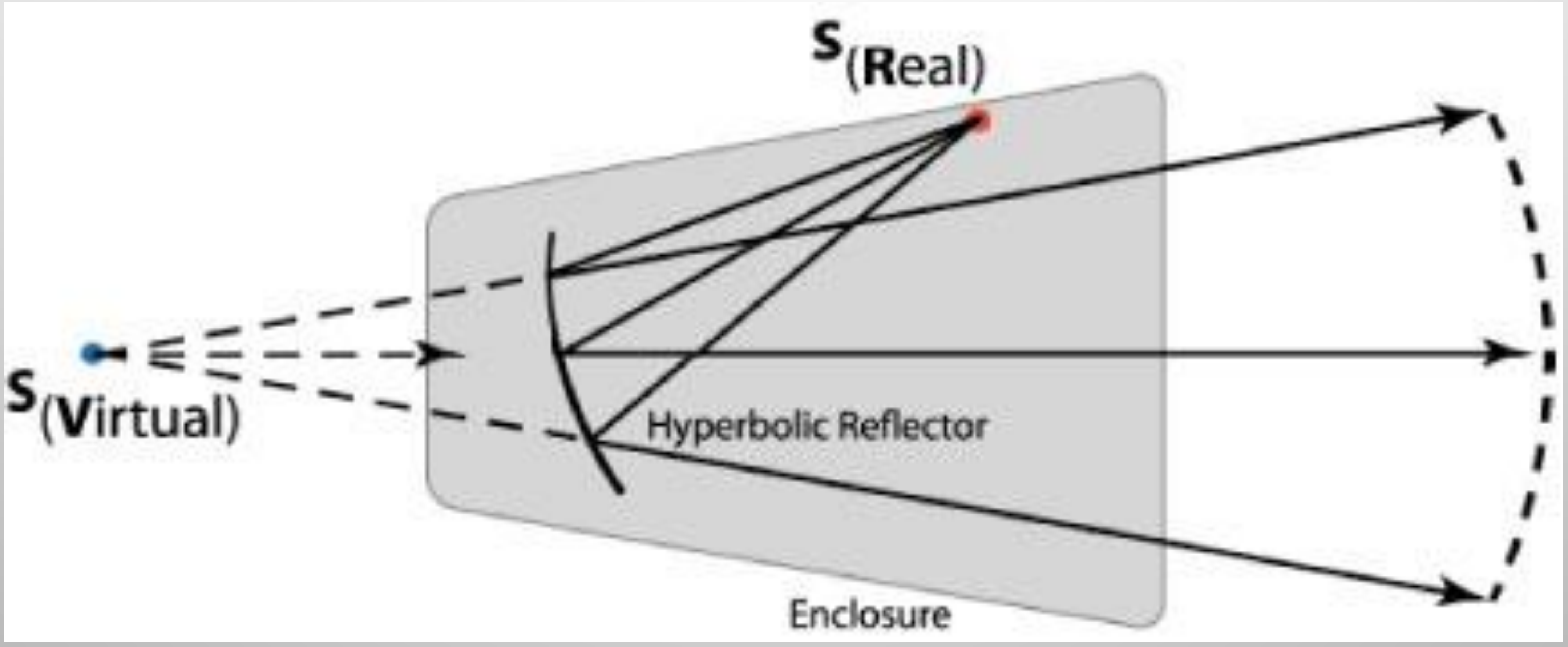
Usually a wave guide horn antenna is used as a feed radiator for the paraboloid reflector antenna. Along with this technique, we have another type of feed given to the paraboloid reflector antenna, called as Cassegrain feed.

ELLIPTICAL REFLECTOR

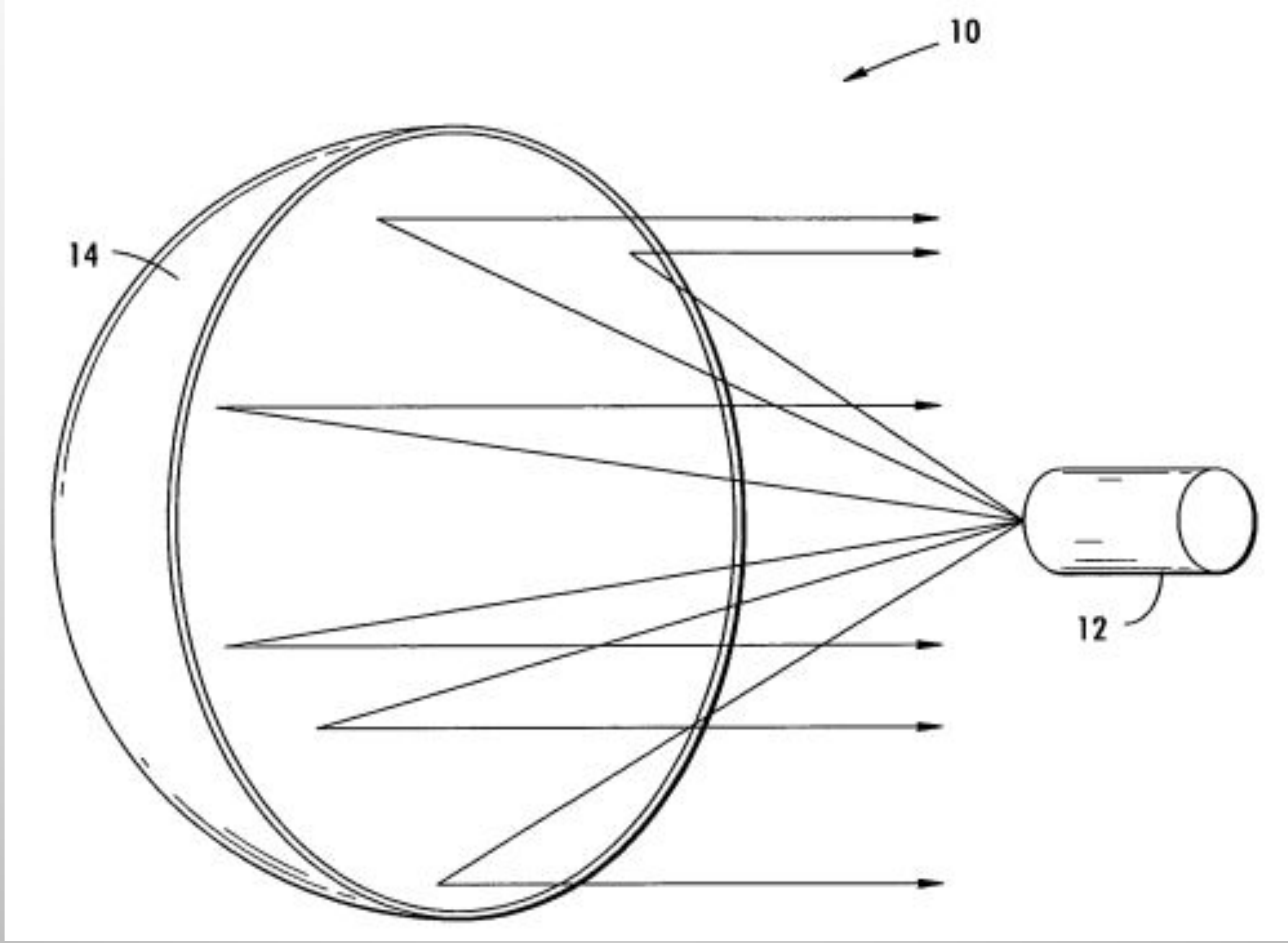


The elliptical reflector is more efficient than either the spherical (circular) or parabolic. By mathematical definition an Ellipsoid has two focal points. When a reflector is placed at the focal point at that end, all rays of the light that strike the reflector will be diverted through the second focal point. The result is that an enormous percentage of the light from the source is directed in a manner that makes it easily usable.

Hyperbolic reflector



Circular reflector



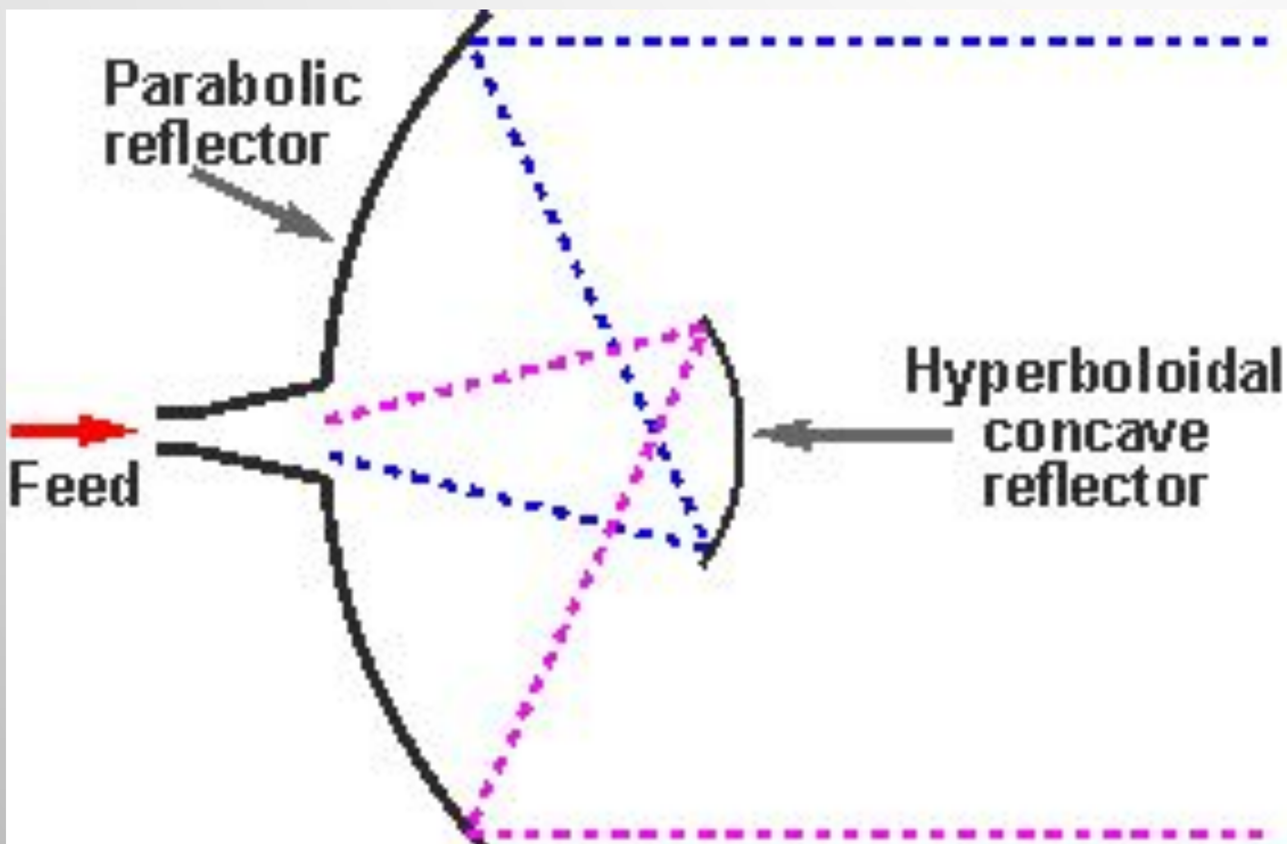
FEED SYSTEM:

- THERE ARE SEVERAL DIFFERENT TYPES OF PARABOLIC REFLECTOR FEED SYSTEMS THAT CAN BE USED. EACH HAS ITS OWN CHARACTERISTICS THAT CAN BE MATCHED TO THE REQUIREMENTS OF THE APPLICATION.

- CASSEGRAIN FEED SYSTEM
- FOCAL FEED - OFTEN ALSO KNOWN AS AXIAL OR FRONT FEED SYSTEM
- GREGORIAN FEED SYSTEM
- OFF AXIS OR OFFSET FEED

CASSEGRAIN FEED

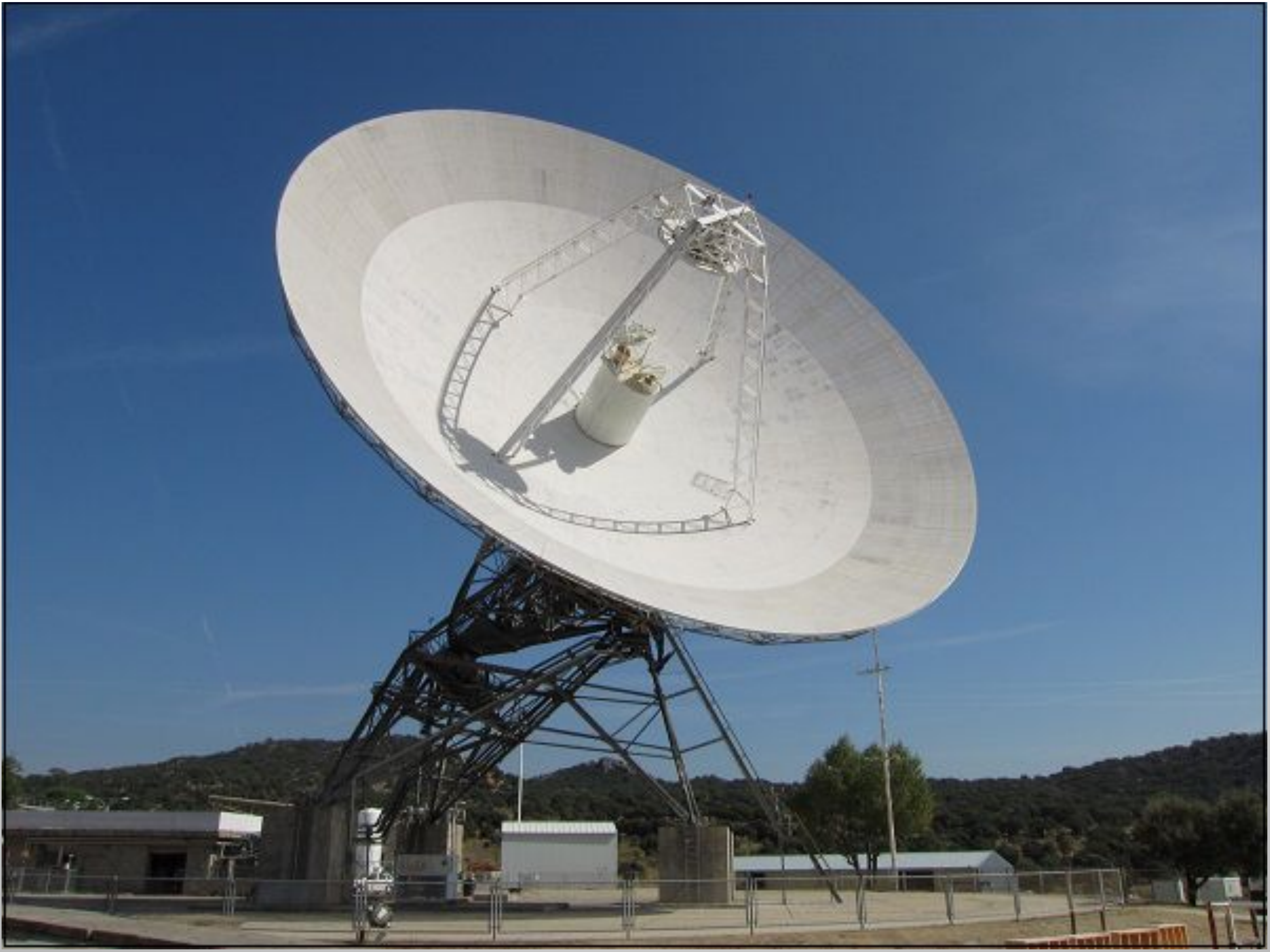
- CASSE GRAIN IS ANOTHER TYPE OF FEED GIVEN TO THE REFLECTOR ANTENNA. IN THIS TYPE, THE FEED IS LOCATED AT THE VERTEX OF THE PARABOLOID, UNLIKE IN THE PARABOLIC REFLECTOR. A CONVEX SHAPED REFLECTOR, WHICH ACTS AS A HYPERBOLOID IS PLACED OPPOSITE TO THE FEED OF THE ANTENNA. IT IS ALSO KNOWN AS **SECONDARY HYPERBOLOID REFLECTOR** OR **SUB-REFLECTOR**. IT IS PLACED SUCH THAT ITS ONE OF THE FOCI COINCIDES WITH THE FOCUS OF THE PARABOLOID. THUS, THE WAVE GETS REFLECTED TWICE.



The above figure shows the working model of cassegrain feed.

WORKING OF A CASSEGRAIN ANTENNA

- WHEN THE ANTENNA ACTS AS A TRANSMITTING ANTENNA, THE ENERGY FROM THE FEED RADIATES THROUGH A HORN ANTENNA ONTO THE HYPERBOLOID CONCAVE REFLECTOR, WHICH AGAIN REFLECTS BACK ON TO THE PARABOLIC REFLECTOR. THE SIGNAL GETS REFLECTED INTO THE SPACE FROM THERE. HENCE, WASTAGE OF POWER IS CONTROLLED AND THE DIRECTIVITY GETS IMPROVED.
- WHEN THE SAME ANTENNA IS USED FOR RECEPTION, THE ELECTROMAGNETIC WAVES STRIKE THE REFLECTOR, GETS REFLECTED ON TO THE CONCAVE HYPERBOLOID AND FROM THERE, IT REACHES TO THE FEED. A WAVE GUIDE HORN ANTENNA PRESENTS THERE TO RECEIVE THIS SIGNAL AND SENDS TO THE RECEIVER CIRCUITRY FOR AMPLIFICATION.
- TAKE A LOOK AT THE FOLLOWING IMAGE. IT SHOWS A PARABOLOID REFLECTOR WITH 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.

Focal or axial or front feed system

The parabolic reflector or dish antenna consists of a radiating element which may be a simple dipole or a waveguide horn antenna. This is placed at the focal point of the parabolic reflecting surface. The energy from the radiating element is arranged so that it illuminates the reflecting surface. Once the energy is reflected it leaves the antenna system in a narrow beam. As a result considerable levels of gain can be achieved.

Achieving this is not always easy because it is dependent upon the radiator that is used. For lower frequencies a dipole element is often employed whereas at higher frequencies a circular waveguide may be used. In fact the circular waveguide provides one of the optimum sources of illumination.

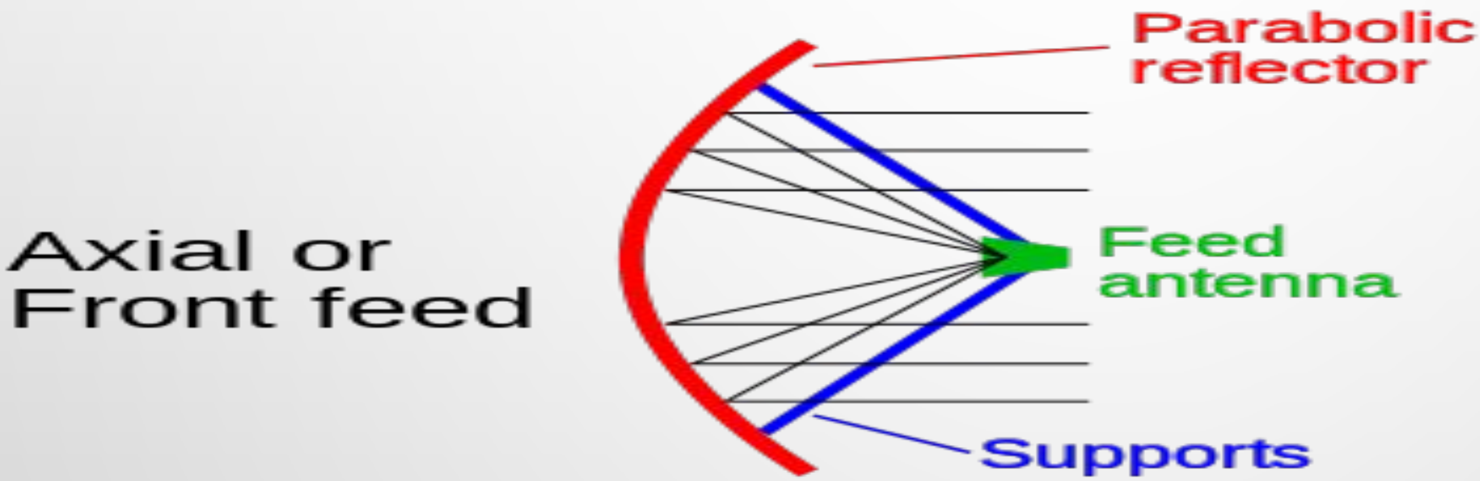


Figure: Diagram of a focal feed parabolic reflector antenna

The focal feed system is one of the most widely used feed systems for larger parabolic reflector antennas as it is straightforward. The major disadvantage is that the feed and its supports block some of the beam, and this typically limits the aperture efficiency to only about 55 to 60%.

Gregorian parabolic reflector feed

The Gregorian parabolic reflector feed technique is very similar to the Cassegrain design. The major difference is that except that the secondary reflector is concave or more correctly ellipsoidal in shape.

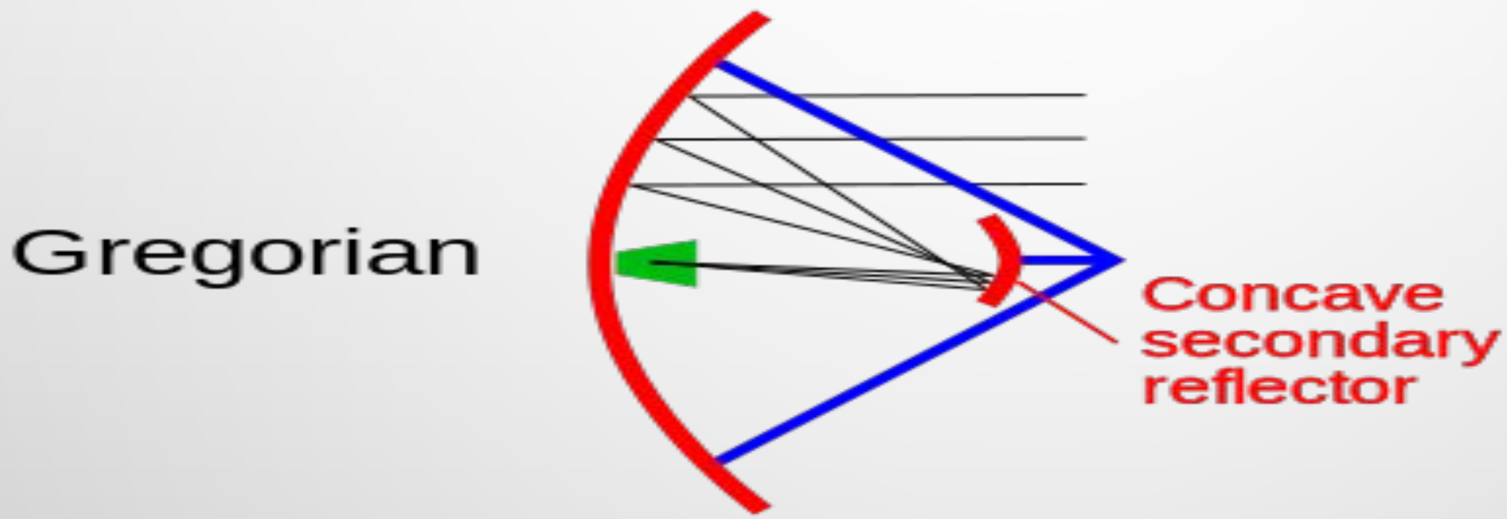


Figure: Diagram of a Gregorian feed parabolic reflector or dish antenna

Typical aperture efficiency levels of over 70% can be achieved because the system is able to provide a better illumination of all of the reflector surface.

Off axis or offset parabolic reflector antenna feed

As the name indicates this form of parabolic reflector antenna feed is offset from the centre of the actual antenna dish used.

The reflector used in this type of feed system is an asymmetrical segment of the parabolic shape normally used. In this way the focus and the feed antenna are located to one side of the reflector surface.

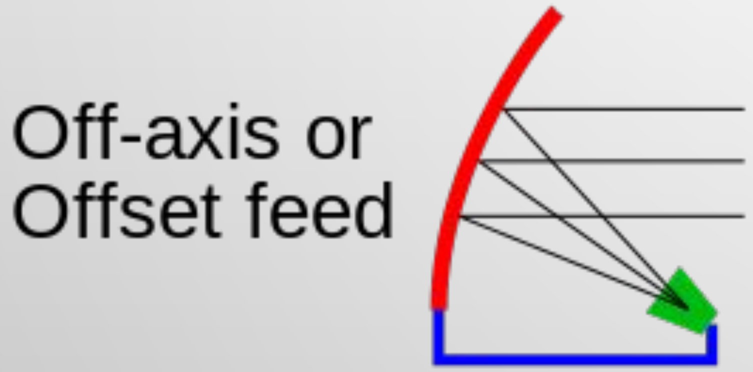
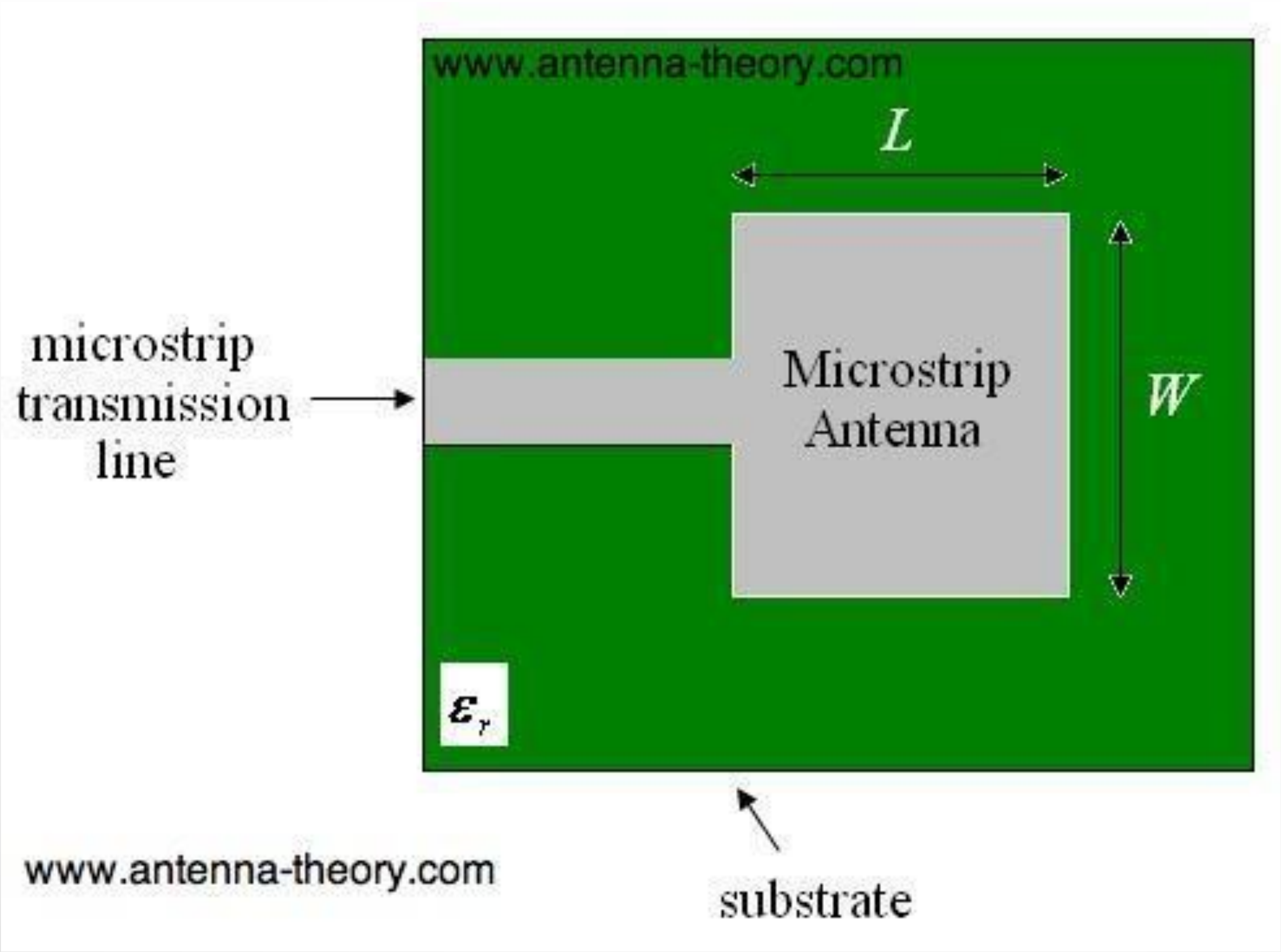


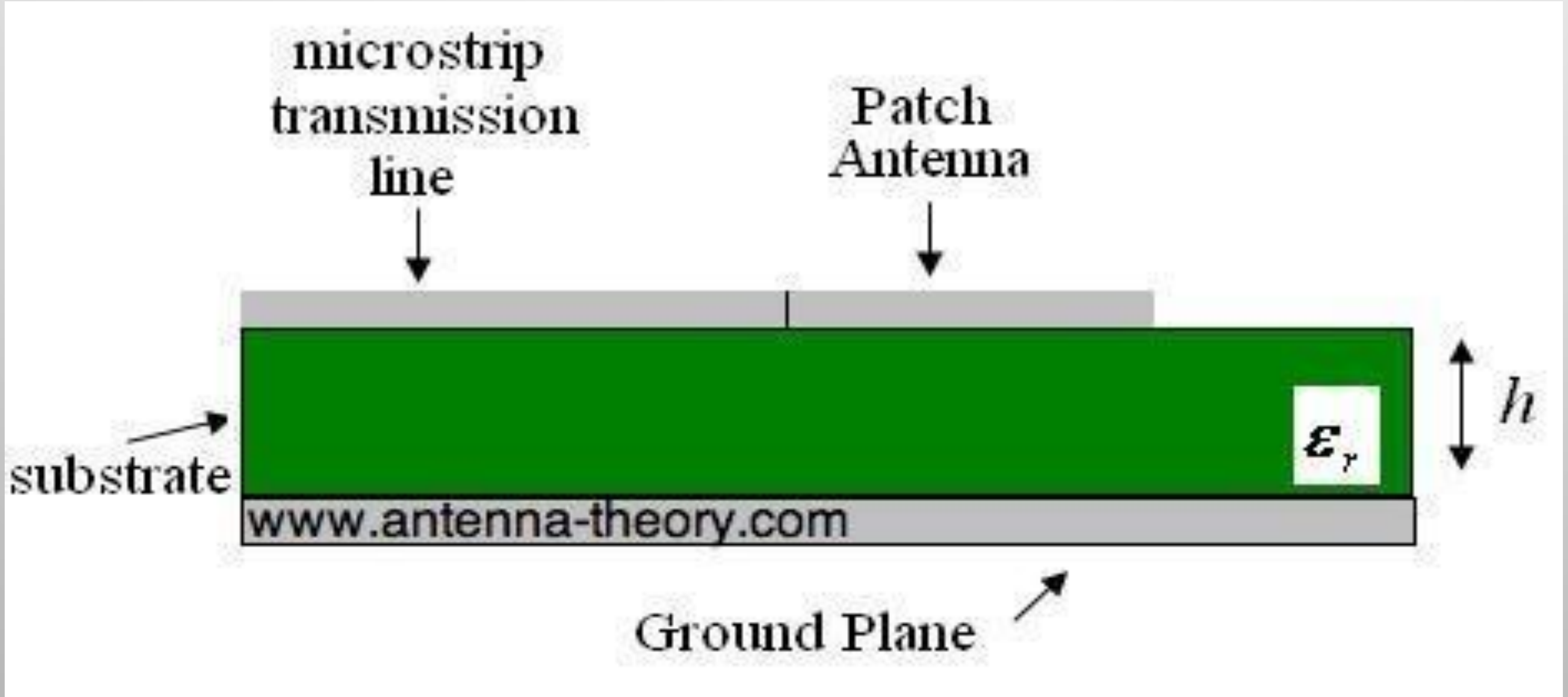
Figure: Diagram of an Offset feed parabolic reflector or dish antenna

The advantage of using this approach to the parabolic reflector feed system is to move the feed structure out of the beam path. In this way it does not block the beam. The offset feed is also used in multiple reflector designs such as the Cassegrain and Gregorian because the small reflector would also suffer the same issues.

MICRO STRIP ANTENNA

MICRO STRIP ANTENNA

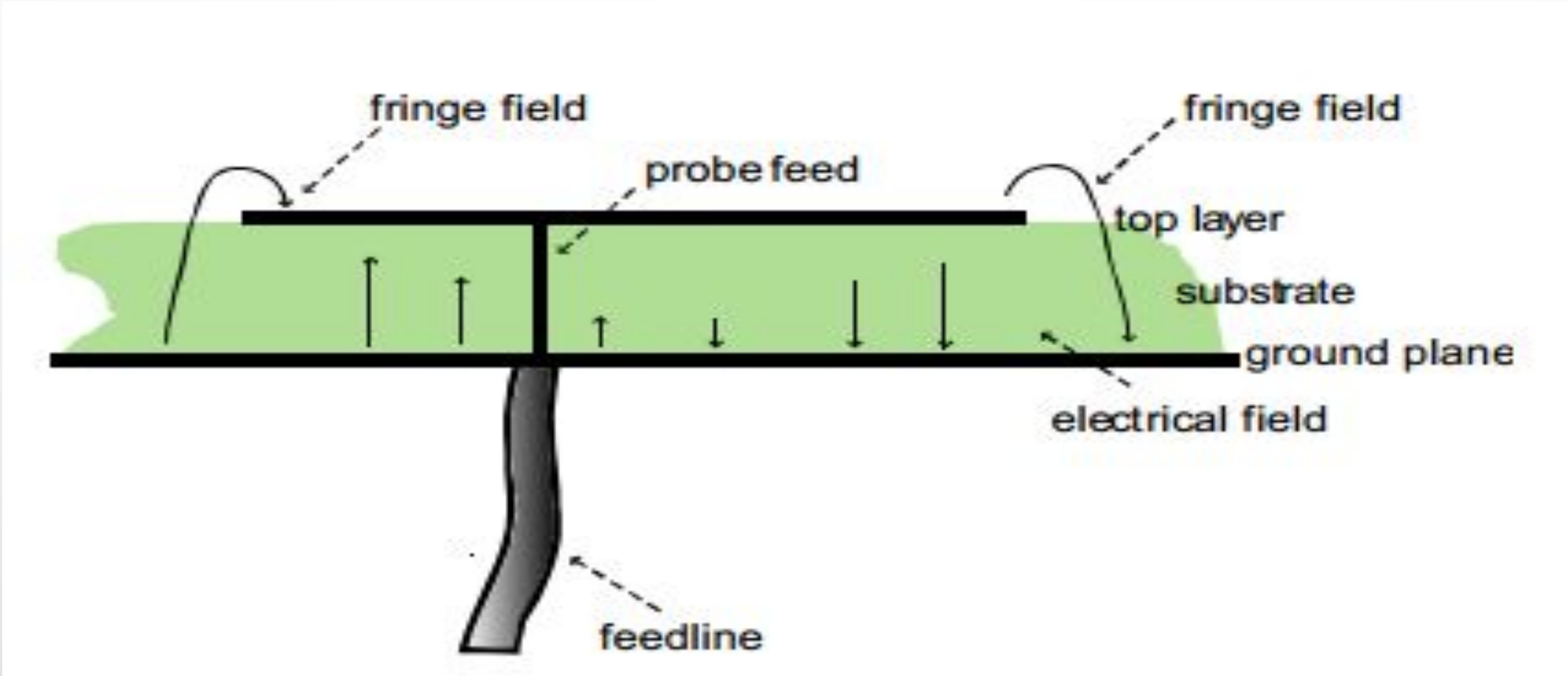




MICRO STRIP ANTENNA

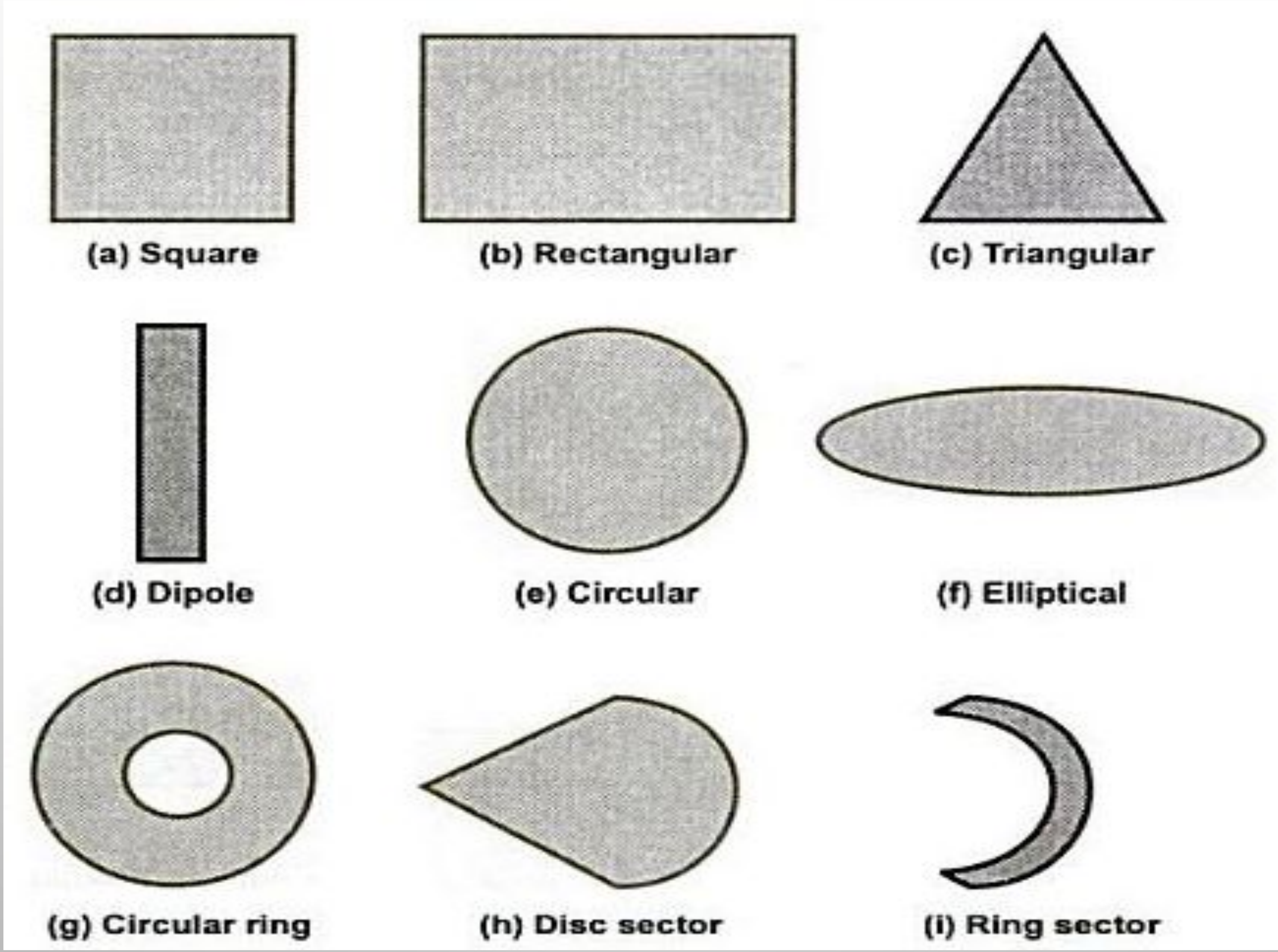
- MICROSTRIP OR PATCH ANTENNA IS A LOWPROFILE ANTENNA THAT HAS A NUMBER OF ADVANTAGES OVER OTHER ANTENNAS IT IS **LIGHTWEIGHT, INEXPENSIVE, AND EASY TO INTEGRATE WITH ACCOMPANYING ELECTRONICS**.
- WHILE THE ANTENNA CAN BE 3D IN STRUCTURE (WRAPPED AROUND AN OBJECT, FOR EXAMPLE), THE ELEMENTS ARE USUALLY FLAT; HENCE THEIR OTHER NAME, PLANAR ANTENNAS.
- **APPLICATIONS:** SPACE CRAFTS, AIRCRAFTS, MOBILE COMMUNICATIONS, SATELLITE COMMUNICATION, WIRELESS COMMUNICATIONS.

MICRO STRIP ANTENNA

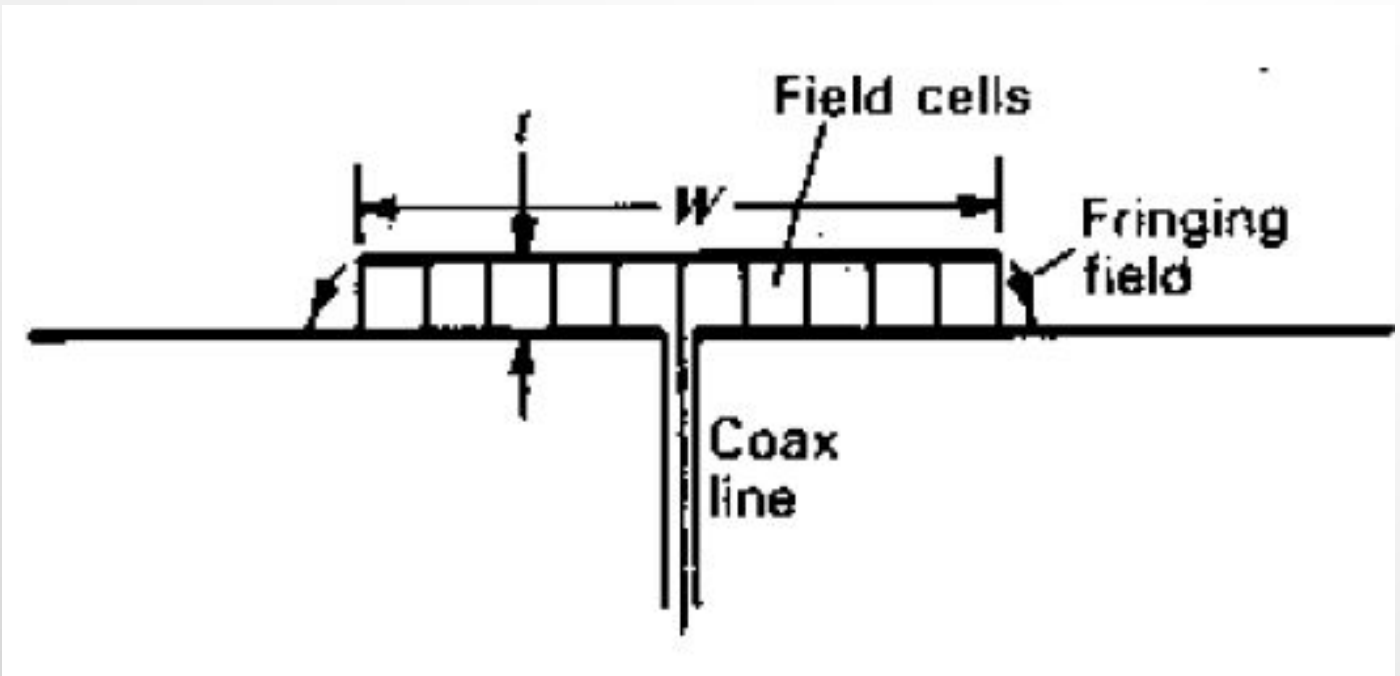


- THE ELECTRIC FIELD IS ZERO AT THE CENTRE OF THE PATCH, MAXIMUM (POSITIVE) AT ONE SIDE, AND MINIMUM (NEGATIVE) ON THE OPPOSITE SIDE.
- IT SHOULD BE MENTIONED THAT THE MINIMUM AND MAXIMUM CONTINUOUSLY CHANGE SIDE ACCORDING TO THE INSTANTANEOUS PHASE OF THE APPLIED SIGNAL.
- THE ELECTRIC FIELD DOES NOT STOP ABRUPTLY AT THE PATCH'S PERIPHERY AS IN A CAVITY; RATHER, THE FIELDS EXTEND THE OUTER PERIPHERY TO SOME DEGREE. THESE FIELD EXTENSIONS ARE K NOWN AS FRINGING FIELDS AND CAUSE THE PATCH TO RADIATE.

TYPES OF PATCH IN MICRO STRIP ANTENNA



TYPES OF PATCH IN MICRO STRIP ANTENNA

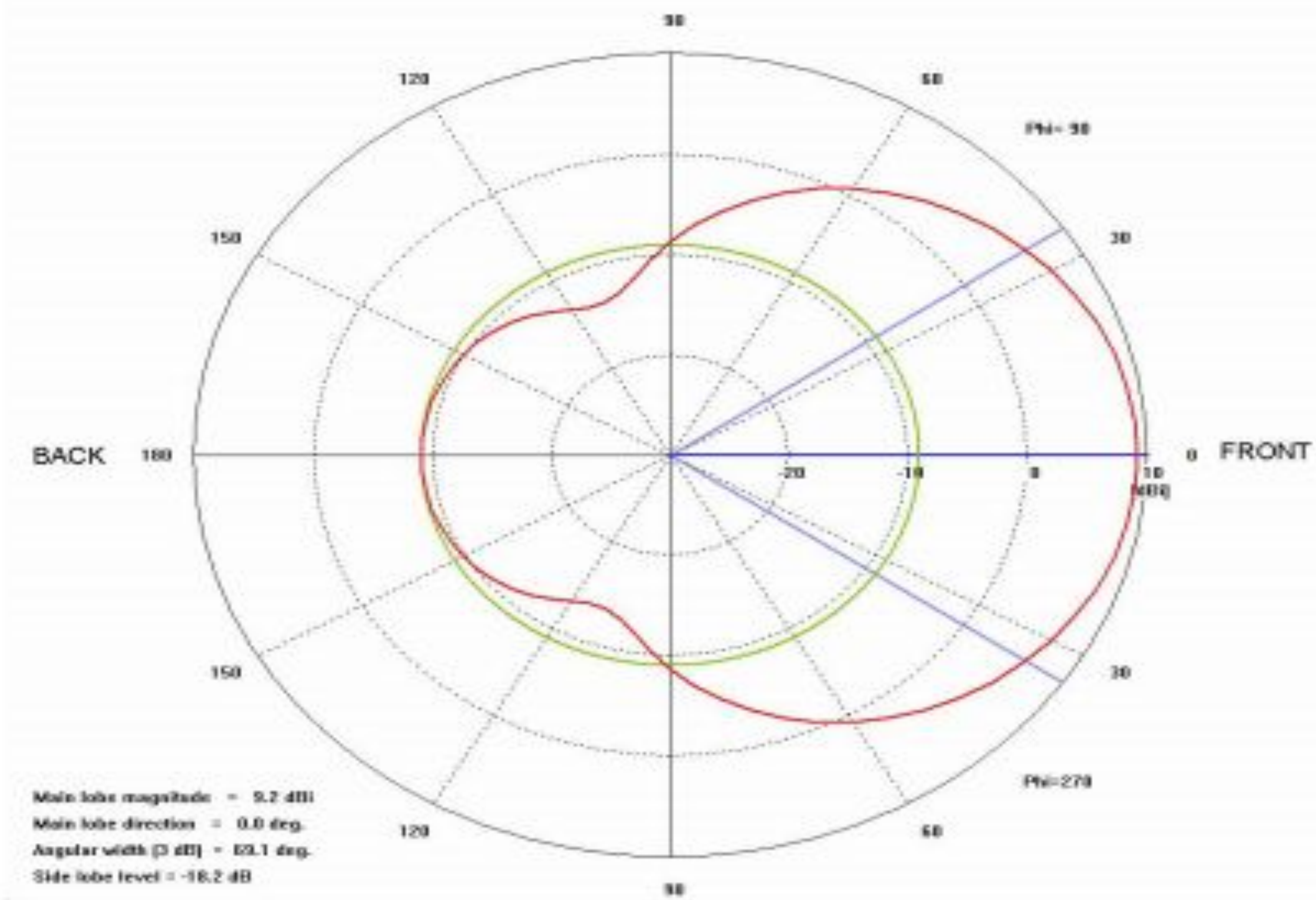


$$Z_i = \sqrt{\frac{\mu}{\varepsilon}} = Z_0\sqrt{\frac{\mu_r}{\varepsilon_r}}$$

- WHERE Z0=120 Π

$$Z_c = \frac{Z_0}{n\sqrt{\varepsilon_r}} = \frac{377}{10\sqrt{2}} = 26.7\ \Omega$$

TYPICAL RADIATION PATTERN FOR SQUARE MICRO STRIP ANTENNA

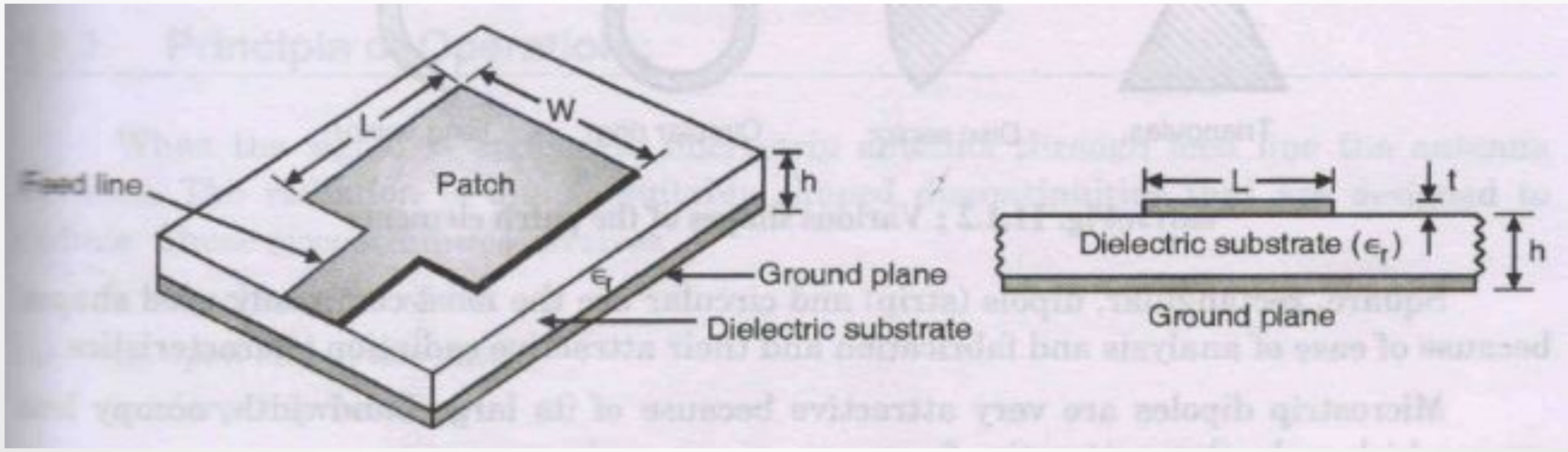


Typical radiation pattern of a simple square patch.

DISADVANTAGES: MICRO STRIP ANTENNA

- EFFICIENCY AND POWER IS GENERALLY LOW.
- POOR POLARIZATION.
- BANDWIDTH IS VERY LOW.
- LOW PROFILE ANTENNA WHICH IS AFFECTED BY SPURIOUS FEED RADIATIONS.
- VALUE OF DIRECTIVITY WILL BE 6.021 DB

PATCH ANTENNA



(a) Micro strip antenna (b) Side view

Typical values of parameters:

$t \ll \lambda$

$h \ll \lambda$

$2.2 \leq \epsilon_r \leq 12$

- The micro strip patch is designed so that its pattern is normal to the patch. This is done by properly choosing the excitation method .
- It is processed by photo etching on the dielectric substrate similar to printed circuit board.

FEEDING METHODS

- **DIRECT CONTACTING FEEDS**: FEED LINE IS IN DIRECT CONTACT WITH THE PATCH

(1) MICRO STRIP LINE FEED

(2) COAXIAL FEED

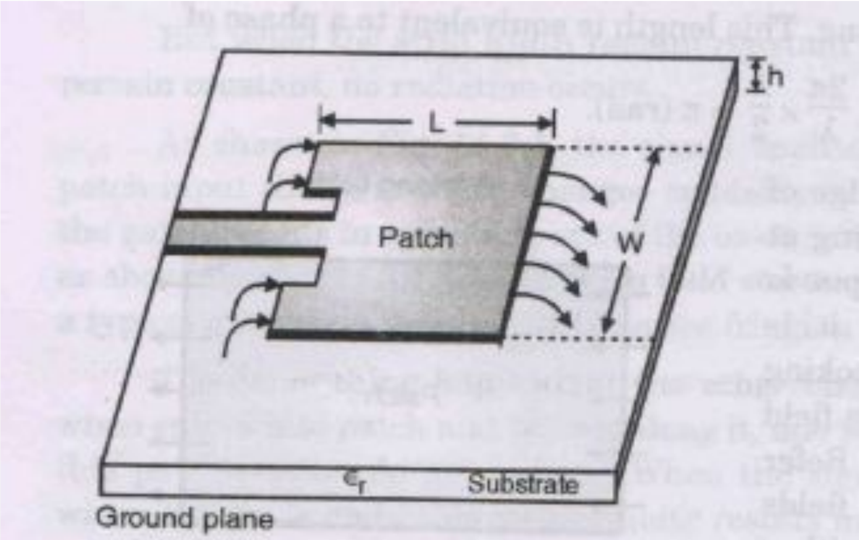
- **NON CONTACTING FEEDS**: FEED LINE IS NOT IN DIRECT CONTACT WITH THE PATCH

(1) PROXIMITY FEED

(2) APERTURE COUPLED FEED

DIRECT CONTACTING FEEDS CREATE HIGHER ORDER MODES WHICH PRODUCES CROSS POLARIZED RADIATION.

MICRO STRIP LINE FEED



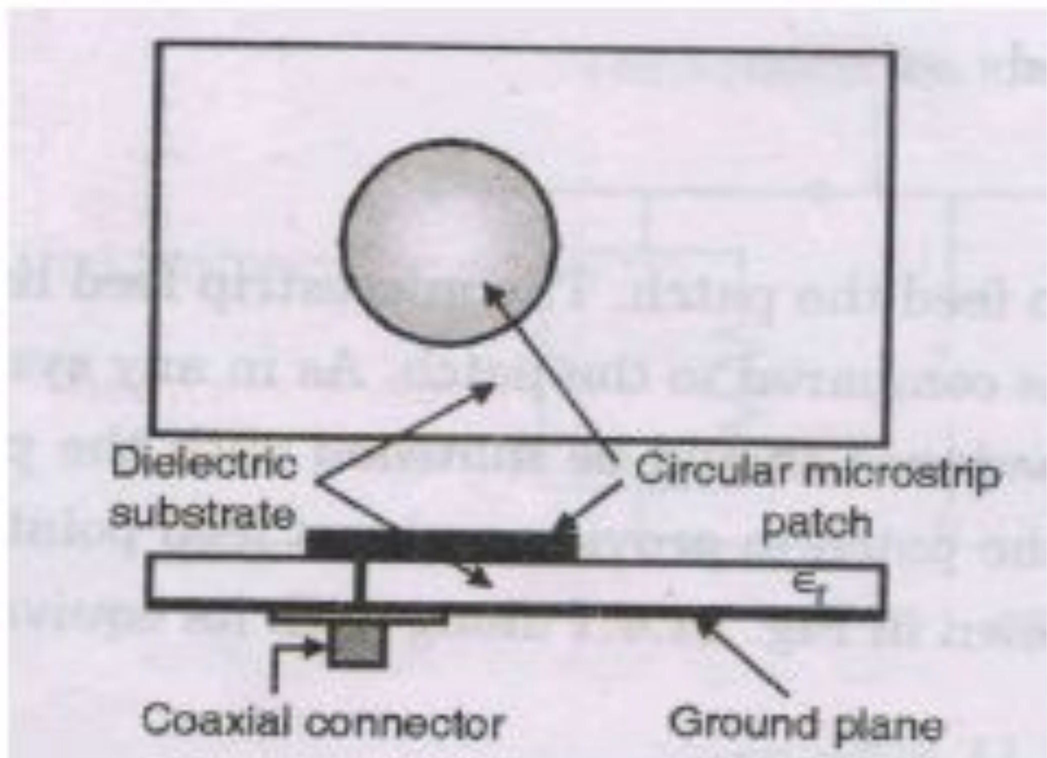
(a) Microstrip line feed

- As in any system, for maximum power Transfer the feed line impedance should be matched with the patch impedance. The matching is done by notching the patch.

<u>Advantages:</u> Easy to fabricate, simple to match by controlling the inset position

<u>Disadvantages</u>: as the substrate thickness increases, surface waves and spurious feed radiation increases, which limits the bandwidth.

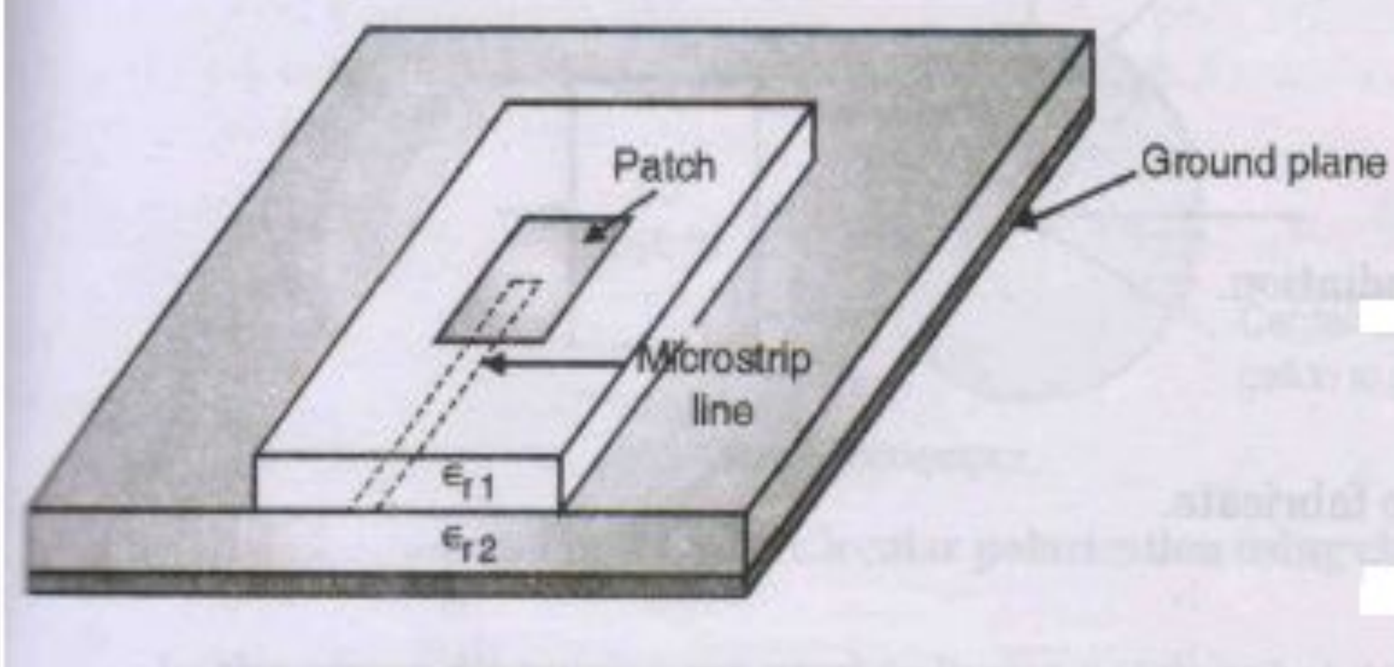
COAXIAL FEED



(a) Probe feed

- WHEN THE SIGNAL FROM THE TRANSMITTER IS AVAILABLE VIA COAXIAL LINE WE GO FOR THIS METHOD. IN THIS METHOD THE INNER CONDUCTOR OF COAXIAL LINE IS ATTACHED TO THE PATCH WHILE THE OUTER CONDUCTOR IS ATTACHED TO THE GROUND PLANE. THIS METHOD IS WIDELY USED.
- <u>ADVANTAGES</u>: EASY TO FABRICATE, LOW SPURIOUS RADIATION
- <u>DISADVANTAGES</u>: MORE DIFFICULT TO MODEL FOR THICKNESS OF SUBSTRATE $H<0.02\Lambda$, NARROW BANDWIDTH, GENERATES HIGHER ORDER MODES WHICH PRODUCES CROSS POLARIZED RADIATION.

PROXIMITY COUPLED



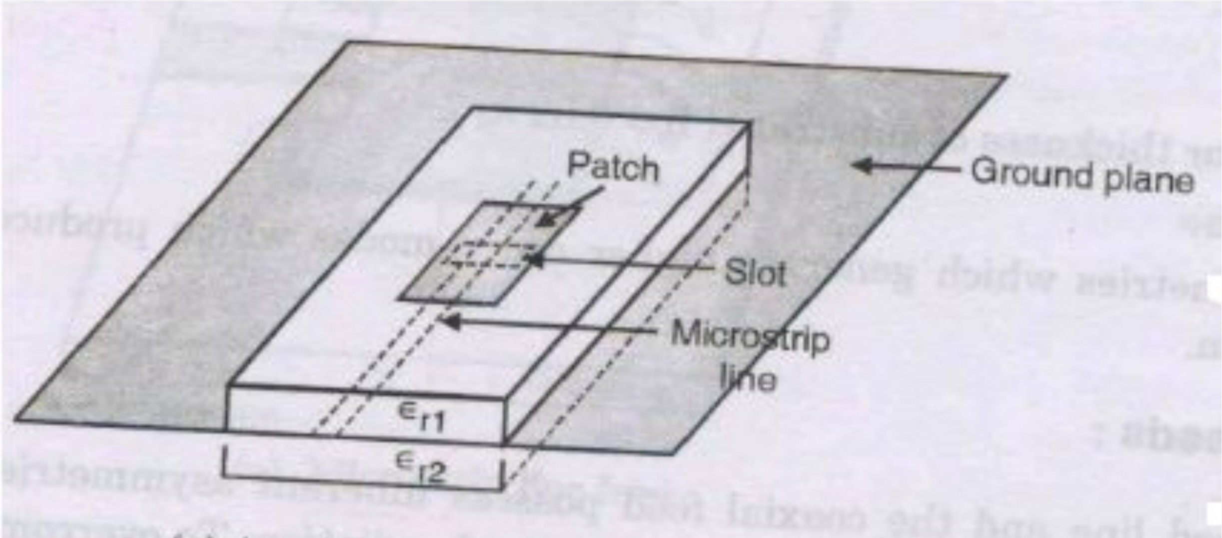
(a) Proximity - coupled feed

Two layer substrate is used with patch on upper substrate and feeding micro strip on the lower Substrate.

Advantages: largest bandwidth, easy to model, low spurious radiation

Disadvantages: fabrication is difficult.

APERTURE COUPLED



(a) Aperture-coupled feed

Two substrates are separated by ground plane. The patch and slot are
on second substrate.
Energy is coupled to the patch through a slot.
Advantages: easier to model, moderate spurious radiation
Disadvantages: narrow bandwidth, most difficult to fabricate.

DESIGN STEPS

Input

f_0, ε_r and h

$$W = \frac{\lambda_0}{2}\left(\frac{\varepsilon_r + 1}{2}\right)^{-\frac{1}{2}}$$

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}}\,\sqrt{\mu_0 \varepsilon_0}} - 2\Delta L$$

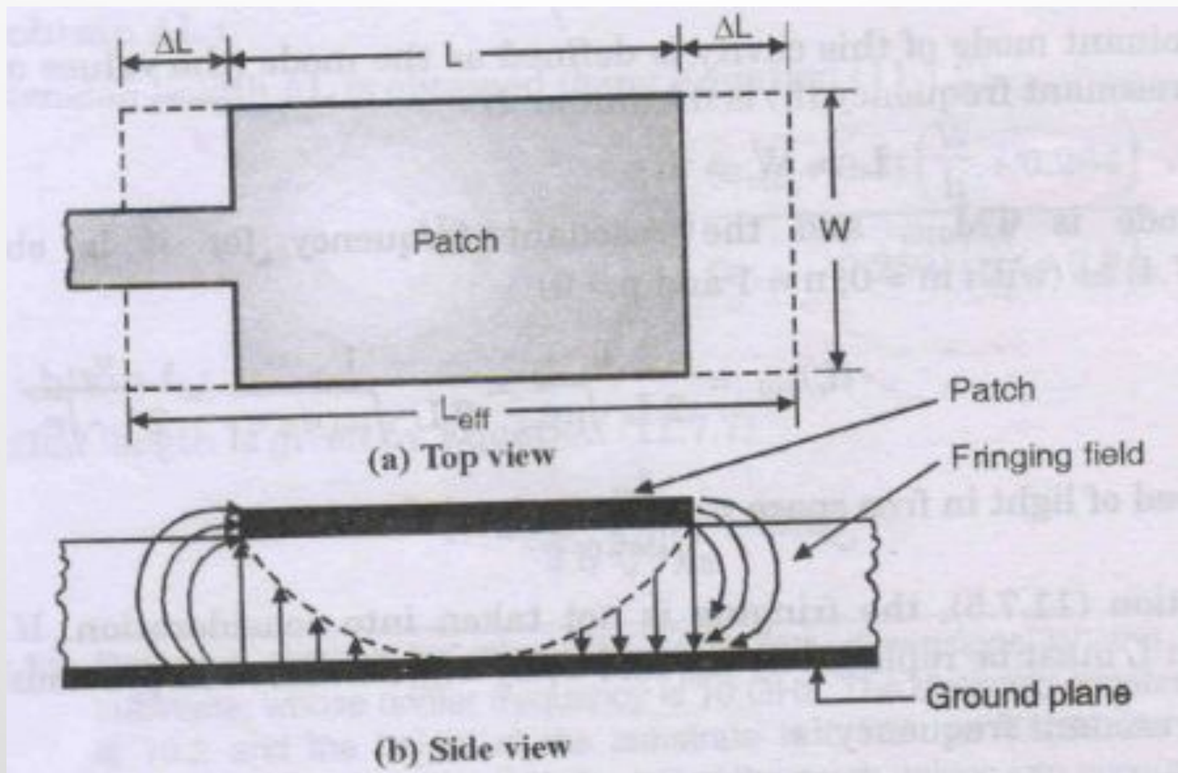
Where:

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

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} \quad \frac{(\varepsilon_r - 1)}{2} \quad \frac{1}{\left(1 + 12\frac{h}{w}\right)^{\frac{1}{2}}}$$

END

EFFECTIVE LENGTH



(a) Top view

(b) Side view

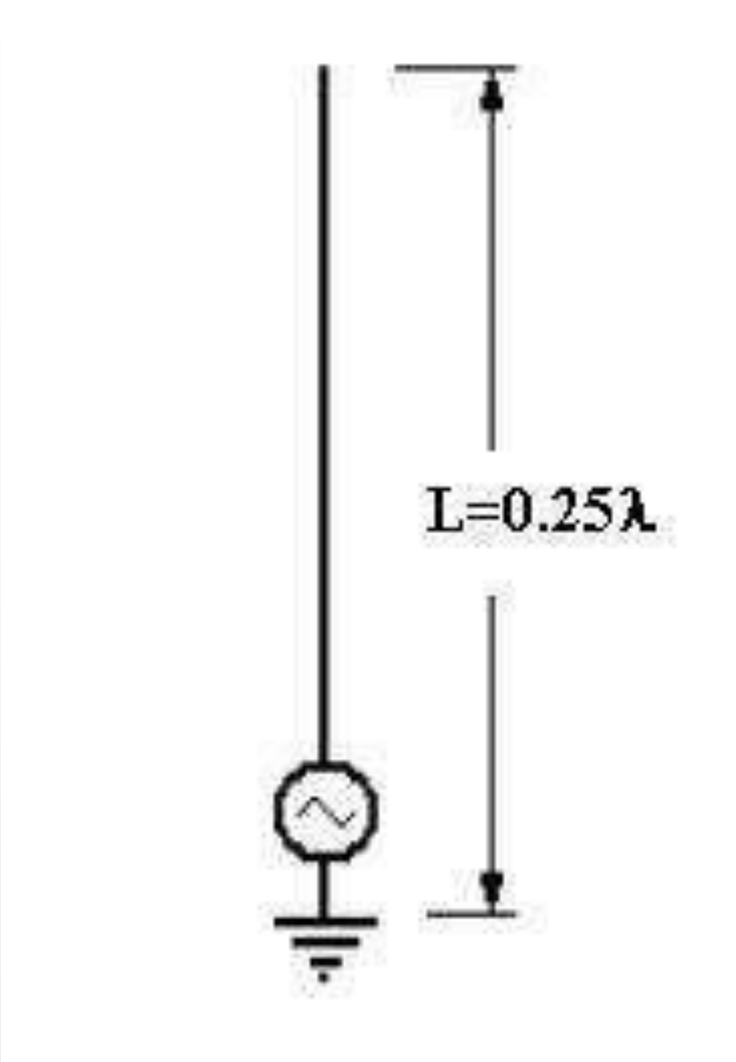
MARCONI (VERTICAL)ANTENNA

A vertical antenna is used to launch a vertically polarized RF wave. Vertical antennas are most often used in two areas:

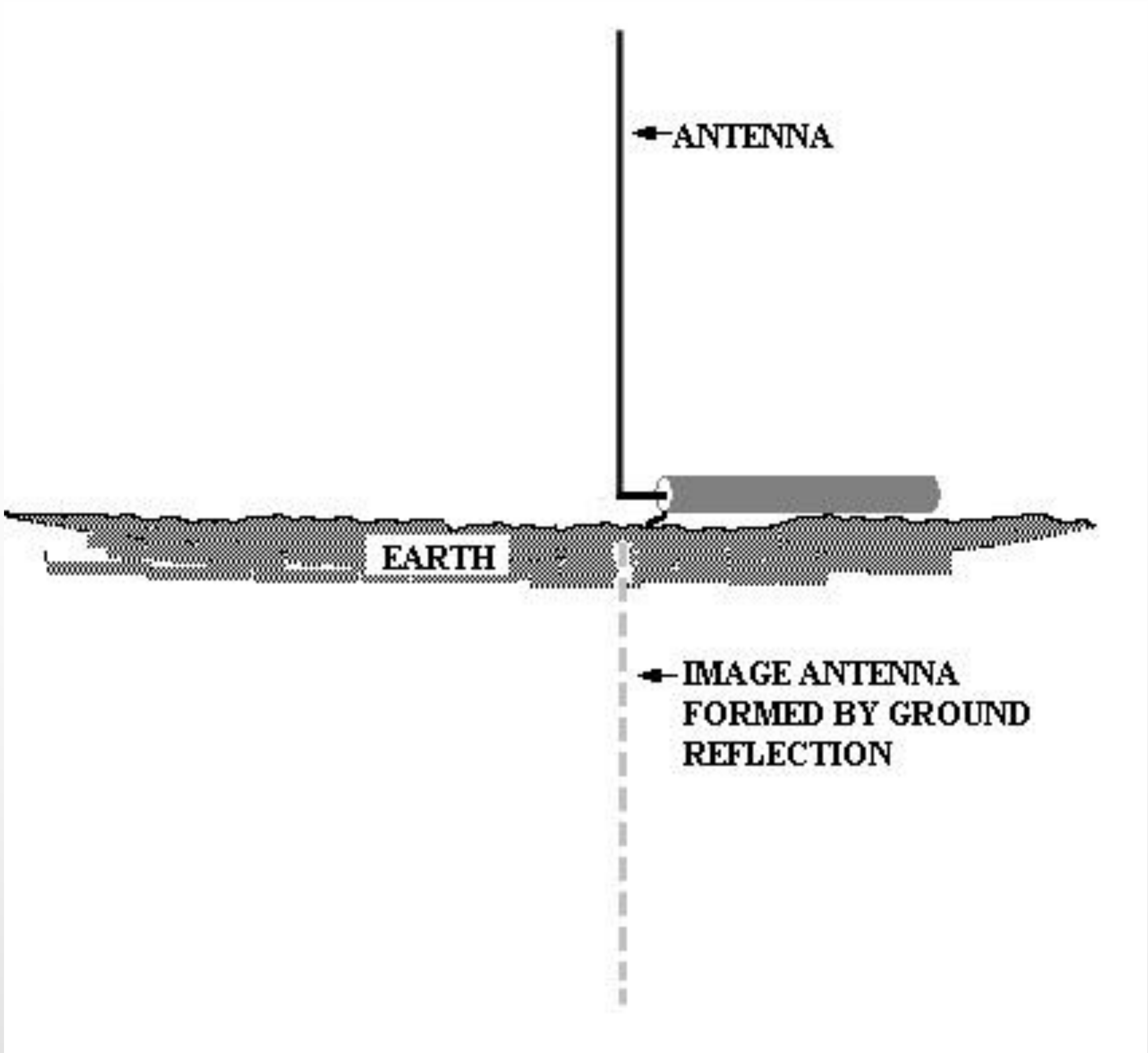
1. Low frequency communications – at frequencies below 2 MHz, it is difficult to use dipole antennas because of their length and the requirement that they be mounted at least a half wavelength above ground. For example: a 2 MHz dipole antenna is approximately 234 ft long and needs to be approximately 234 feet above ground. Also, most communications at frequencies below 2 MHz is via ground wave, which requires vertical polarization.

1. Mobile communications – it is difficult to mount a horizontally polarized dipole on a vehicle. A vertical antenna only has one mounting point and less wind resistance.

The most common vertical antenna is the Marconi antenna. It is a vertical conductor $\lambda/4$ high, fed at the end near ground. It is essentially a vertical dipole, in which one side of the dipole is the RF image of the antenna in the ground. This may sound strange, but remember that ground reflects RF as a mirror reflects light



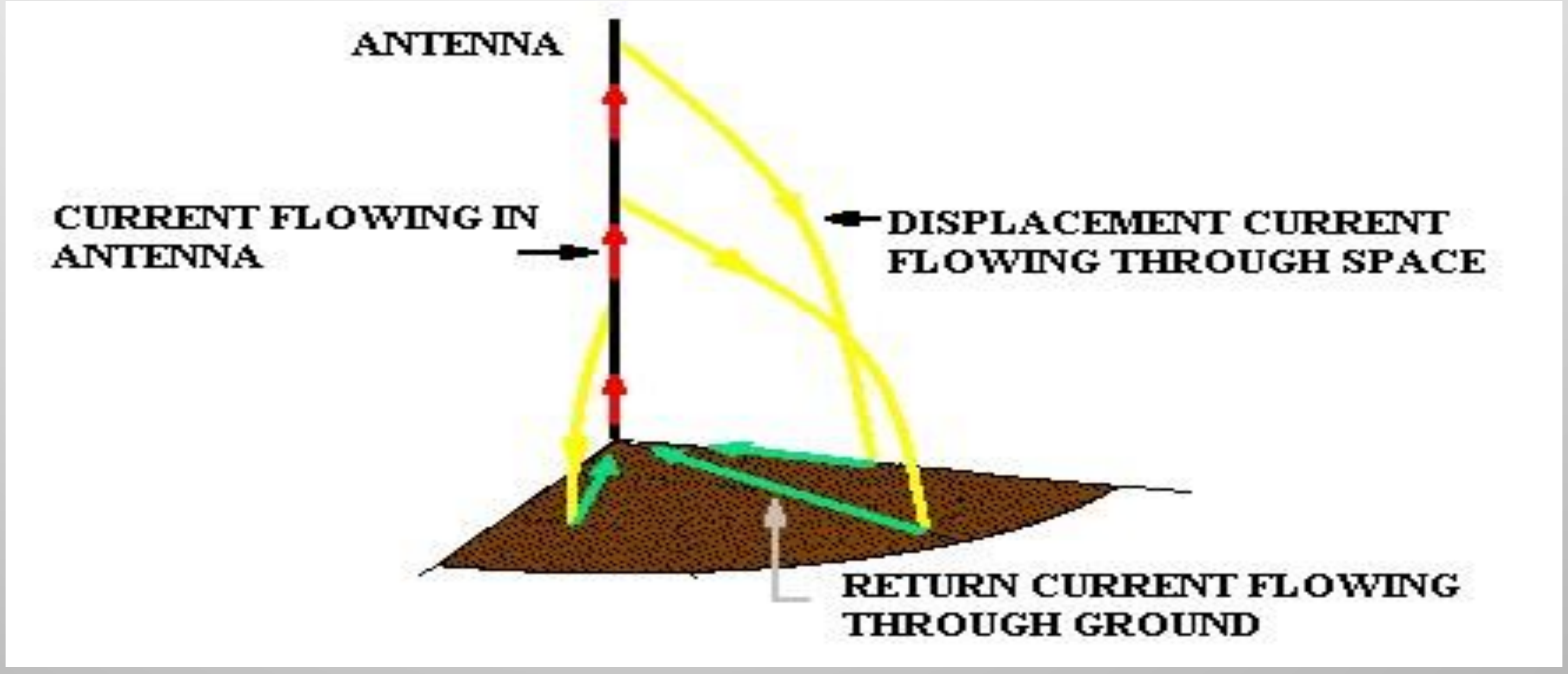
Simple Marconi Antenna



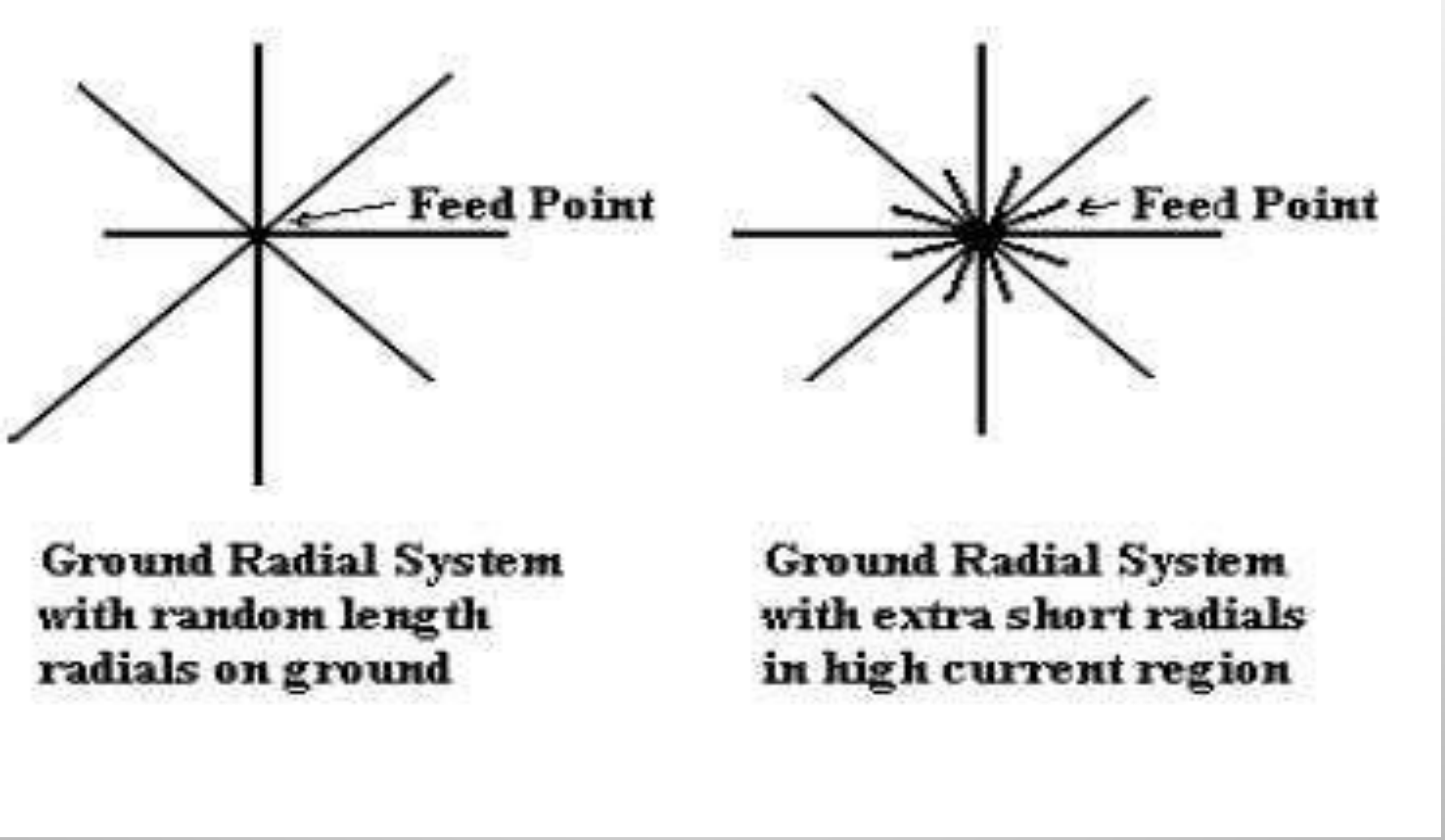
The image antenna formed in the ground under a Marconi antenna. This type of antenna, unlike the dipole, is an unbalanced antenna, and should be fed directly with coaxial cable. The shield of the coax is connected to the ground at the base of the antenna and the center lead of the coax is connected to the vertical radiator.

Because the ground under a vertical antenna is actually part of the antenna, it is necessary that ground losses be minimized. To minimize the losses, the electrical conductivity of the ground must be made as high as possible, or an artificial low loss ground must be provided.

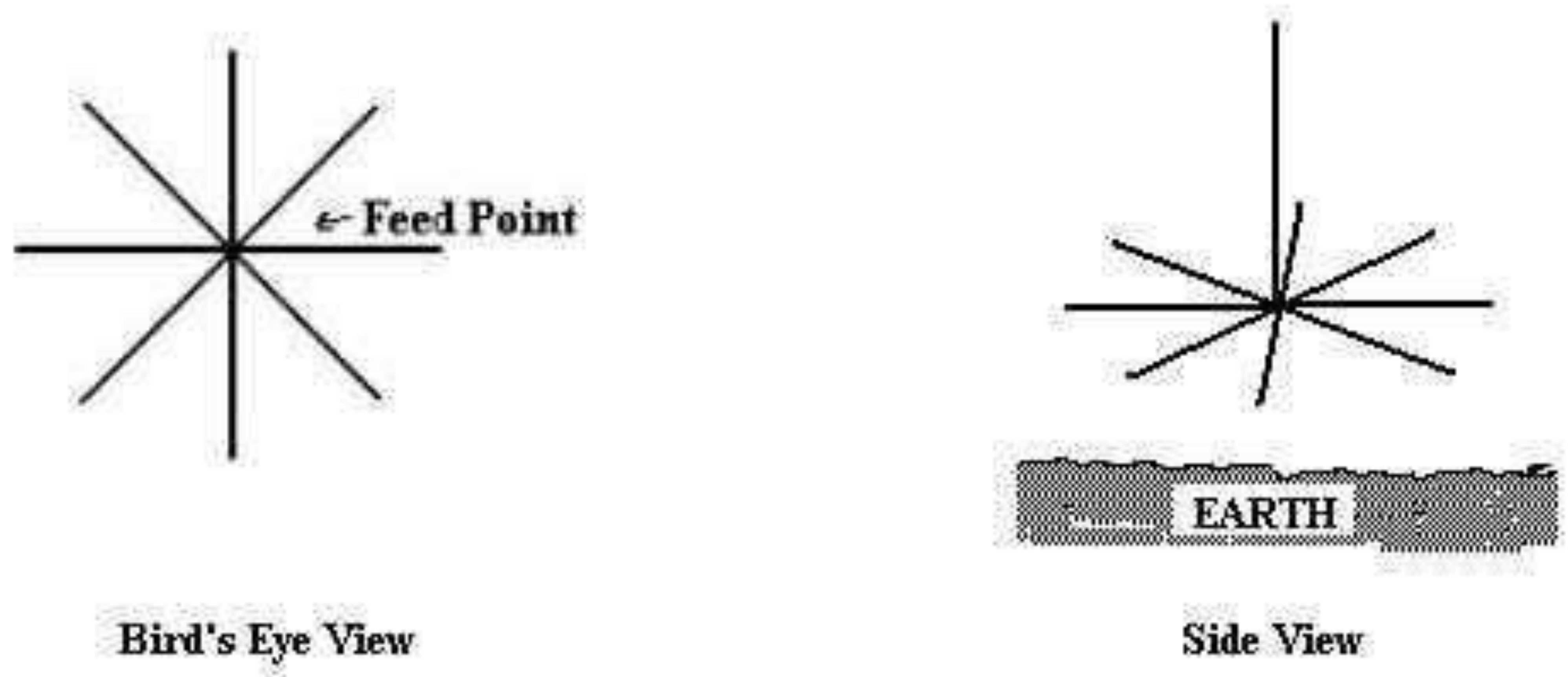
Ground conductivity can be improved by using ground radial wires. These are wires buried just under the earth's surface or laid on the surface that provide a low resistance path for RF currents flowing in the ground. The ground currents are greatest in the vicinity of the feed point of a Marconi antenna, so the radials run out from the feed point, up to a distance of λ/4 from the antenna, if possible. The ground radials do not have to be any specific length and the general rule is that a large number of short radials is preferable to a few long radials. The diagram below shows how current flows through the ground to the feed point of the Marconi antenna.



The radials should be laid out in a pattern that follows the ground current, that is running radially out from the feed point of the antenna. The diagram below is a bird's eye view of typical ground radial layouts. Note that the radials do not all have to be the same length and that losses may be decreased by adding extra radials near the feed point. These extra radials can be as short as λ/40 and still be effective.



When a Marconi antenna cannot be mounted on the ground, an artificial ground system, called a counterpoise, is used. The counterpoise consists of $\lambda/4$ wires emanating radially from the antenna feed point as shown below. The shield of the coax is connected to the counterpoise at the feed point. The counterpoise is not connected to ground.



Elevated Counterpoise
using $\lambda/4$ radials

Ground losses affect the feed point impedance and antenna efficiency. A Marconi antenna mounted on a perfectly conducting ground would have an input impedance that is ½ the impedance of a dipole, or approximately 36 ohms. When mounted on a real ground, the input impedance can range from 38 ohms for a well designed AM broadcast antenna mounted over a specially prepared ground, to over 100 ohms for a Marconi mounted above poor, unprepared ground that has no radials.

Ground loss reduces the antenna's efficiency, because part of the power being delivered to the antenna is being dissipated in the ground rather than being radiated. The efficiency can be computed from the measured value of input resistance by using the following formula:

$$Efficiency = \eta = \frac{36}{R_{INPUT}}$$

The radiation pattern of the Marconi antenna is a half doughnut as shown in the figure below. There is no radiation straight up in the direction of the wire. The bulk of the radiation occurs at a low elevation angle, which is what is needed to launch a ground wave.

THANK YOU