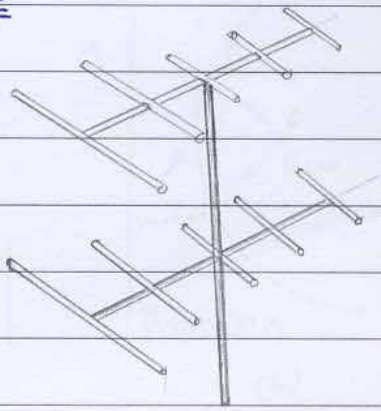
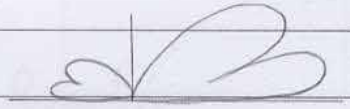
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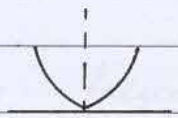
# Stacked Yagis



* The Yagis are mounted one above the other & fed in-phase is a pair of Stacked Yagis.
* This combination give better directivity than a single Yagi and gain will be 3dB > than for a single Yagi of same type.
* It is also possible to combine large no. of Yagis & similar arrays can be constructed from other types of ata, such a Log-Periodic or Helical atas.



# Parabola

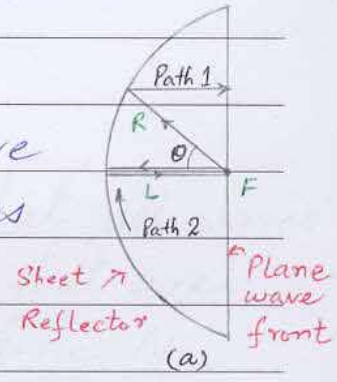


* Suppose that we have a point source & that we wish to produce a plane-wave front over a large aperture by means of sheet reflector. Refer fig (a) it is then required that distance from source to plane-wave front via path 1 & 2 be equal or

$$2L = R(1+\cos\theta)$$

and

$$R = \frac{2L}{1+\cos\theta}$$



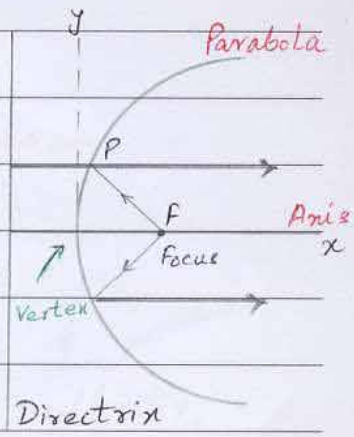

↳ This is the required surface contour. It is eqn of Parabola with focus at 'F'.

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* According fig (b) parabolic curve may be defined as; The distance from any point P' on a parabolic curve to a fixed line called "Directrix".

Thus from fig (b)

$$PF = PQ.$$




(b)

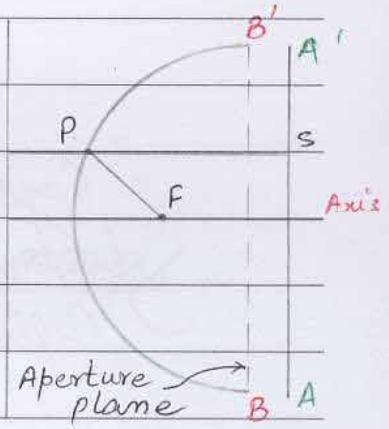
* Now referring fig (c):

Let AA' be a line normal to axis at an arbitary distance QS from directrix. (Since normal to axis at an arbitary distance QS from directrix) Since

$$PS = QS - PQ$$

and $$PF = PQ$$

it follows that distance from focus to 'S' is




(c)

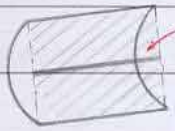
$$PF + PS = PF + QS - QP = QS.$$

Conclusions :-

* A property of Parabolic reflector is that all waves from an isotropic source at focus that are reflected from parabola arrive at line AA' with equal phase.
* The "image" of focus is directrix & reflected field along line AA' appears as through it originated at directrix as a plane-wave.
* The plane BB' at wh reflector is cut-off is called the "Aperture Plane".

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## Dish Antennas:




↳ Cylindrical

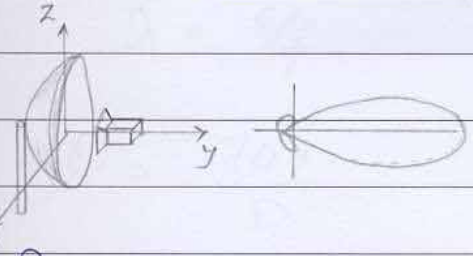
* Line Source & cylindrical parabolic reflector.




↳ Paraboloid

* Point source & paraboloidal reflector.

# Parabolic Dish Antenna




* Parabolic reflector produces a collimated* beam when any ray that originates at a point called focus and strikes reflecting surface which is reflected back parallel to axis of Parabola.
* The Parabolic 'Dish' ata consists of a small ata (normally LNB or LNA) at focus of a large parabolic reflector w/c focuses (radiated) radiation entering the dish along to it.
* The beamwidth of ata can be expressed with $$\Theta = \frac{70\lambda}{D}$$

where:

$\Theta$ := Beamwidth is in degrees at 3dB Point.

$\lambda$ := Free Space wavelength, D := Diameter of dish.

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* The Gain is reduced by uneven illumination of ata, losses and any radiation spilling off at edges, thus gain can be calculated through:

$$G = \eta \frac{\pi^2 D^2}{\lambda^2}$$

Q: A parabolic ata has a diameter of 3m an efficiency of 60% and operates at a frequency of 4GHz, Calculate its gain & beam width?

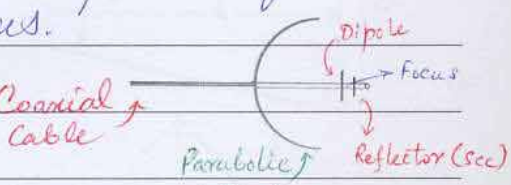
Sol: $\lambda = c/f \Rightarrow \frac{3\times10^8}{4\times10^9} \Rightarrow \lambda = 0.075m$

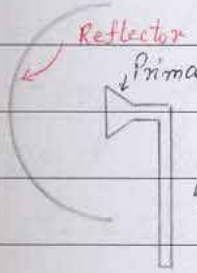
$$\theta = \frac{70\lambda}{D} \Rightarrow 1.75^\circ$$

$$G = \eta \frac{\pi^2 D^2}{\lambda^2} \Rightarrow \frac{(0.6)\pi^2(3)^2}{(0.075)^2} \Rightarrow G = 39.8 dB_i$$

# Feeding Methods

* One way to feed the ℓ wave dish is that dish is being fed with a simple dipole-reflector combination at paraboloid focus.

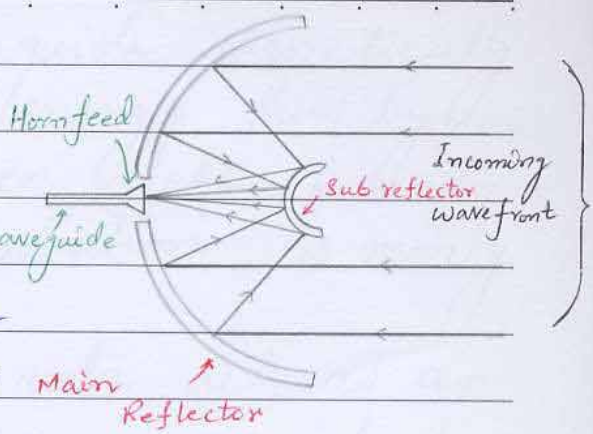



A Horn-fed version in w/c open-ended sections of waveguides can be used as radiators of electromagnetic ℓ energy -

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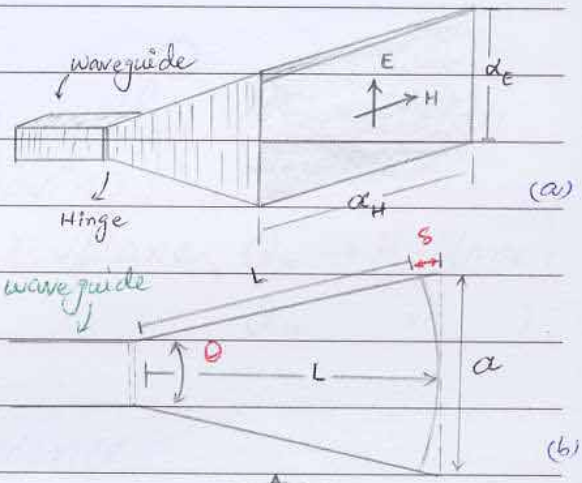
* Cassegrain feed is another type of feeding method w/c is used to shorten length of feed-machanism in highly critical applications. It uses a hyperboloid secondary reflector (sub-reflector) whose foci coincide with that of the parabola.

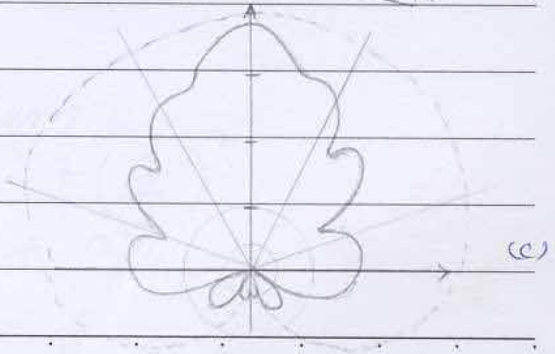



* Often these ata have a low-loss dielectric material as a Cover known as "Radome" whose purpose is to maintain internal pressure & to provide protection from environment.

# Horn Antenna

* A wave ata produced by flaring-out (or opened out) the end of a circular or rectangular waveguide into shape of a horn for radiating a uniform phase front of radio waves with a larger aperture than that of waveguide and hence greater directivity.



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* A plain open circuited waveguide theoretically reflects 100% of incident energy thus by gradually flaring out open ckt of waveguide, the goal of total radiation is nearly attained.
* The flared end of horn anta acts as an impedance transformer b/w waveguide & free space. For a proper transformation ratio, linear dimension of each side must be at least a half-'λ'.
* The standard waveguide ata operates from [0.75 to 40 GHz] in contiguous waveguide bands. The voltage SWR is less than 1.5 : 1.
* All horns have removeable waveguide to coaxial adapters & can be mounted for both vertical & horizontal polarity.

* W.r.t fig (b) on Previous Page:
↳ Consider a cross-section with dimension of Pyramidal horn ata having;
  - θ: Flare angle ($\theta_E \rightarrow$ E-plane, $\theta_H \rightarrow$ H-plane)
  - a: Aperture ($a_E$ " , $a_H$ " )
  - L: Horn Length
  - δ: Path length difference.

* Using Pythagorous Theorem:

$$(L+\delta)^2 = L^2 + \left(\frac{a}{2}\right)^2$$

$$L^2 + 2L\delta + \delta^2 = L^2 + a^2/4$$

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$$\delta^2 + 2L\delta = \frac{a^2}{4}$$

$\because \quad \delta << L$ Neglecting higher powers.

$$2L\delta = \frac{a^2}{4}$$

$$\hookrightarrow \quad L = \frac{a^2}{8\delta}$$

$\delta$ for flare angle using trigonometric ratios;

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

$$\frac{\theta}{2} = \tan^{-1}\left(\frac{a/2}{L}\right)$$

or

$$\hookrightarrow \quad \theta = 2\tan^{-1}\left(\frac{a/2}{L}\right)$$

↳ can be $\theta_e$ or $\theta_h$ depends.

Also using Cosine function:

$$\hookrightarrow \quad \theta = 2\cos^{-1}\left[\frac{L}{L+\delta}\right]$$

## Gain of Horn Antenna:

* The directivity (or gain assuming no loss) of a horn antenna can be enpressed in terms of effective aperture; thus,

$$D = G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \epsilon_{ap} A_p}{\lambda^2} \quad (A_e = A_p \epsilon_{ap})$$

where; $A_e$: effective aperture ($m^2$). $\epsilon_{ap}$: Aperture efficiency. $\left(\frac{A_e}{A_p}\right)$

$A_p$: Physical aperture. $\lambda$: wavelength (m).

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Typical value of $e_{ap} \simeq 0.6$ ; therefore,

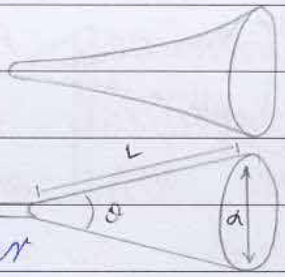
$$D \simeq G_1 \simeq \frac{7.5 A_p}{\lambda^2}$$

or

$$D_{dB} \simeq G_{dB} \simeq 10 \log\left(\frac{7.5 A_p}{\lambda^2}\right) dB_i$$

# Types of Horn Antenna

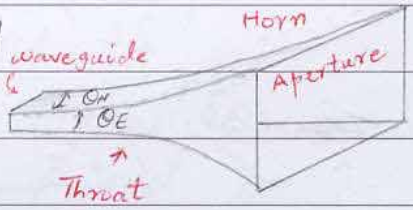
## (i) Circular Horn:



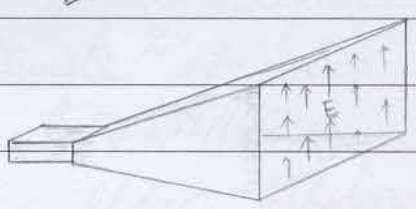

* The circular horn provides efficient radiation from a circular waveguide.
* The flare angle 'θ' & 'L' are important to amount of gain it can provide. Generally, the greater diameter 'd', the greater is gain optimum flare angle is 50° w/c provides max. gain.

$$A_p = \pi r^2 = \frac{\pi D^2}{4}$$

## (ii) Pyramidal Horn:




* This type has two flare angles; one with horizontal $\theta_H$ while another is along vertical $\theta_E$.
* Wider horizontal patterns are obtained by increasing $\theta_H$ (magnetic field), while vetical pattern can be obtained by varying $\theta_E$.



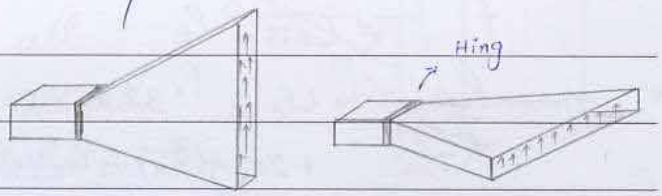
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- When ratio of $a_H$ and $a_E$ is 1.35 a symmetrical radiation pattern is realized, Also radiation pattern depends on area of the aperture i.e,

$$A_p = a_H a_E$$

* Due to symmetrical radiation pattern Pyramidal horn can be used as a txr or rxr of both vertical & horizontal pattern.

## (iii) Sectorial Horn:




* Sectoral horn is a type of horn ata with top & bottom walls at a 0° flare angle.
* The side walls are sometimes hinged to provide adjustment in flare angle.
* Max radiation occurs for angle b/w 40° & 60°. The gain is directly proportional to length.

### Advantages

* The horns just described, provide maximum gain on order of 20dB compared to $\frac{\lambda}{2}$ dipole.
* While they do not provide amount of gain of subsequently described μwave ata, their simplicity and low cost make them popular for non critical applications.

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Q. Determine length and flare angle of a Pyramidal horn ata for which the E plane aperture $10\lambda$ and let $\delta_E = 0.2\lambda$, for H-plane $\delta_H = 0.375\lambda$. Also calculate directivity.

$L = ?$ , $\theta_E = ?$ , $\theta_H = ?$ $D = ?$

Given:

$$a_E = 10\lambda; \quad \delta_E = 0.2\lambda \quad ; \quad \delta_H = 0.375\lambda$$

Calculation:

$$L = \frac{a_E^2}{8\delta_E} = \frac{(10\lambda)^2}{8(\frac{\lambda}{5})} = 62.5\lambda$$

$$\theta_E = 2\tan^{-1}\left(\frac{a_E}{2L}\right) \Rightarrow 2\tan^{-1}\left(\frac{10\lambda}{2\times 62.5\lambda}\right) = 9.1^\circ$$

$$\theta_H = 2\cos^{-1}\frac{L}{L+\delta_H} \Rightarrow 2\cos^{-1}\frac{62.5\lambda}{62.5\lambda+0.375\lambda} = 12.52^\circ$$

$$a_H = 2L\tan\frac{\theta_H}{2} = 13.7\lambda$$

$$A_p = a_E a_H$$

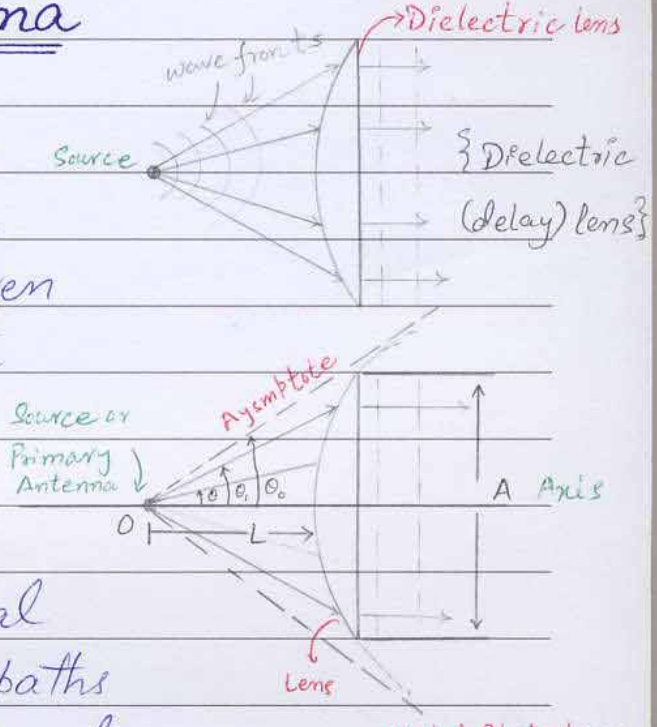
$$D \simeq 10\log\left(\frac{7.5 A_p}{\lambda^2}\right) = 10\log\left(\frac{7.5\, a_E a_H}{\lambda^2}\right)$$

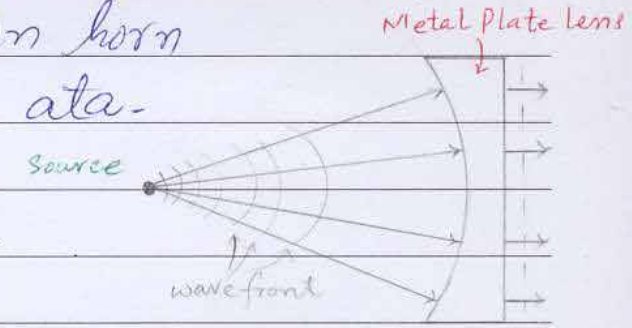
$$D = 30.1 \text{ dBi}$$

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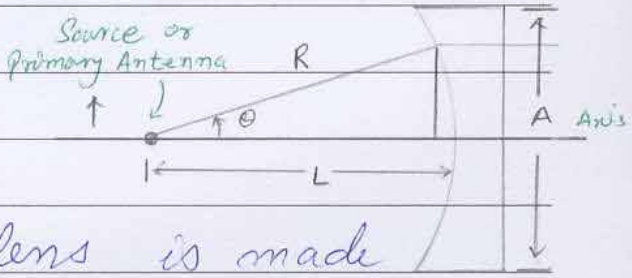
# Lens Antenna

* Lens ata can convert spherically radiated μwave energy into a plane wave in a field given direction by using a point source (open end of waveguide) with a collinating lens.
* A collinating lens forces all radiated segments of spherical wavefront into parallel paths where point sources are often horn radiator or a simple dipole ata.
* The same effect can be obtained with much less bulk using principle of Zoning (A fabrication process that allows a dielectric to change a spherical wavefront into a plane wave).
* The inside section of lens is made thick at the center & thinner towards edge in order to permit (energy) the lagging portion of spherical wave to catch up with the faster portions at centre of wavefront & vice versa.




{ Metal Plate (fast) Lens }



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# Formulae

* $\lambda = \frac{c}{f}$

* $L = \frac{142.5}{f}$

* $\eta = \frac{R_r}{R_T}$

* $G_t(dBd) = G_{dBi} - 2.14dB$

* $G_t = D\eta$

* $EIRP = P_t G_t$

* $ERP = EIRP - 2.15dB$

* $G_t = \frac{15NS(\pi D)}{\lambda^3}$

* $\theta = \frac{52\lambda}{\pi D}\sqrt{\frac{\lambda}{NS}}$

Helical Antenna

* $\tau = \frac{L_1}{L_2} = \frac{L_2}{L_3} \cdots$

* $\tau = \frac{D_1}{D_2} = \frac{D_2}{D_3} \cdots$

* $\frac{L_1}{2D_1} = \tan\frac{\alpha}{2}$

Log-Periodic antenna

$P_t = P_{rl} = \frac{E^2}{Z} = \frac{E^2}{120\pi \text{ or } 377}$

$E = \frac{5.477}{r}\sqrt{P_t}$

* $Loss = \frac{P_t}{P_r}$

↳ $LF_c = 32.44 + 20\log(f_{in}) + 20\log(r_{in}) - G_T d_{Bi} - G_r d_{Bi}$

Friis Eqn:

* $\frac{P_r}{P_t} = G_t G_r \left(\frac{c}{f 4\pi r}\right)^2$

* $\theta = \frac{70\lambda}{D}$

* $G_t = \frac{\eta \pi^2 D^2}{\lambda^2}$

Parabolic Antenna

* $BW_{narrow} = \frac{f_{max} - f_c}{f_c}$

-"- $= \left|\frac{f_{min} - f_c}{f_c}\right|$

* $BW_{wide} = \frac{f_{max}}{f_{min}}$

Horn Antenna:

* $L = \frac{a^2}{8\delta}$

* $\theta = 2\tan^{-1}\left(\frac{a}{2L}\right)$

* $\theta = 2\cos^{-1}\left(\frac{L}{L+\delta}\right)$

* $D = G_t = \frac{4\pi \epsilon_{ap} A_p}{\lambda^2} \simeq \frac{7.5 A_p}{\lambda^2}$

-"- $= 10\log\left(\frac{7.5 A_p}{\lambda^2}\right) dB_i$

* Power Density: $\wp = \frac{P_{in} G_t}{4\pi r^2}$

* $\wp = \frac{P_{in}}{4\pi r^2}$ (Isotropic Ata)

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