天线与电波传播
ANTENNAS AND WAVE PROPAGATION

LECTURE 8

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Previous Lecture

- Traveling Wave Antennas
  - Introduction
  - Traveling Wave Antennas: Long Wire, V Antenna, Rhombic Antenna, Yagi-Uda Array
- Broadband Antennas: Helical Antenna
- Frequency Independent Antennas
  - Introduction
  - Theory
  - Frequency Independent Antennas: Equiangular Spiral, Log-Periodic Dipole Array

Outline

- Aperture Antennas
- Reflector Antennas
- Lens Antennas

Aperture Antennas

Classification of Antennas

Wire-Type Antennas	Aperture-Type Antennas
Dipoles	Horn and open waveguide
Monopoles	Reflector antennas
Biconical antennas	Slot antennas
Loop antennas	Microstrip antennas
Helical antennas	

Aperture Antennas

Definition

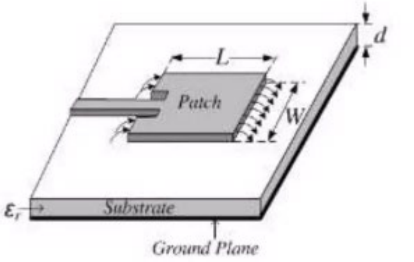
utilizes an opening or aperture in a conductive surface to radiate or receive electromagnetic waves.

Types

slot, patch, horn, reflector

Application

satellite communication, radar systems, and wireless networks



Waveguide and horn Aperture Antennas

High microwave frequencies

- Thin wires and dielectrics cause loss
- Coaxial lines may have 10dB per meter
- Waveguides often used instead

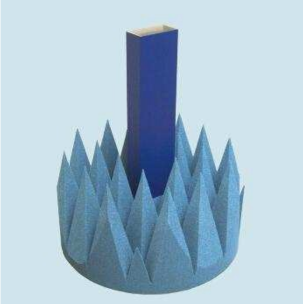
aperture antennas

- Transition from waveguide to free space
- Open end of a waveguide
- Or horn to allow smoother transition

Advantages

- Wideband, low loss
- Can be made directive
- Rigid, flush mounting (aerospace applications), easy integration
- Gain can be very accurately characterized

open waveguide



rectangular horn

circular horn

Aperture Antennas

Paraboloidal antenna

Slot antenna

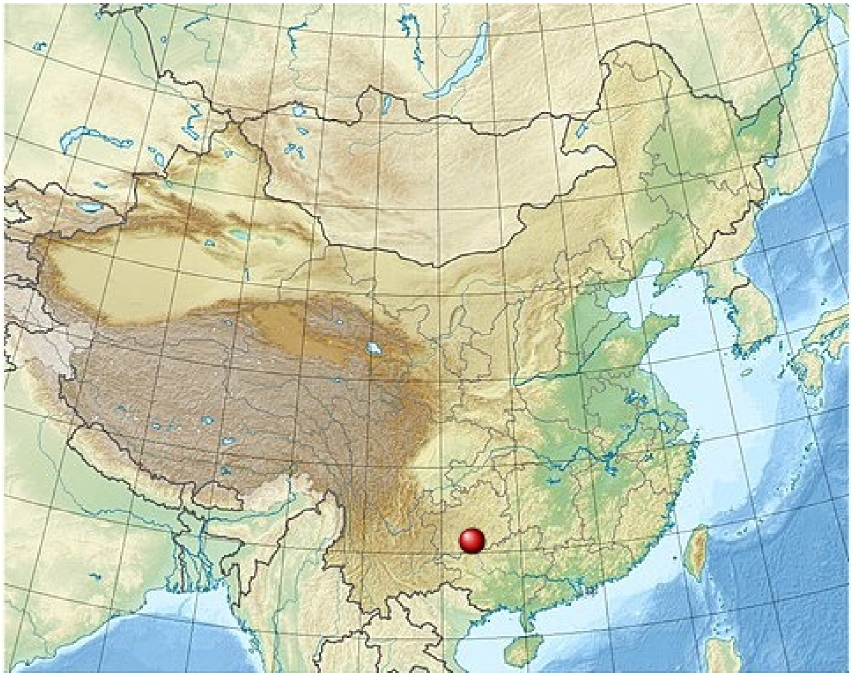
Aperture Antennas

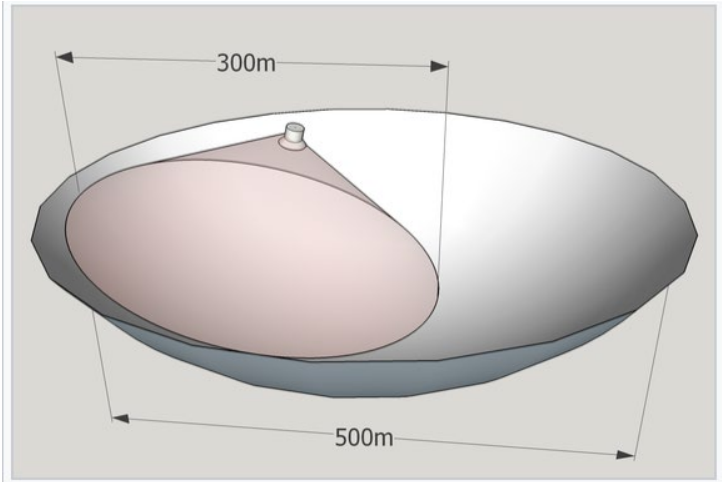
Video 3’08”

With a dish the size of 30 football fields, FAST (Five hundred meter Aperture Spherical Telescope, Guizhou, China) is by far the largest single-aperture telescope in the world (though arrays that link up multiple radio dishes cover more ground). The previous record holder in the field is the 1,000-foot-wide (300 meters) Arecibo Observatory in Puerto Rico (Collapsed on Dec 1, 2020).

Aperture Antennas

Video 3’08”





300 m illuminated aperture within 500 m dish

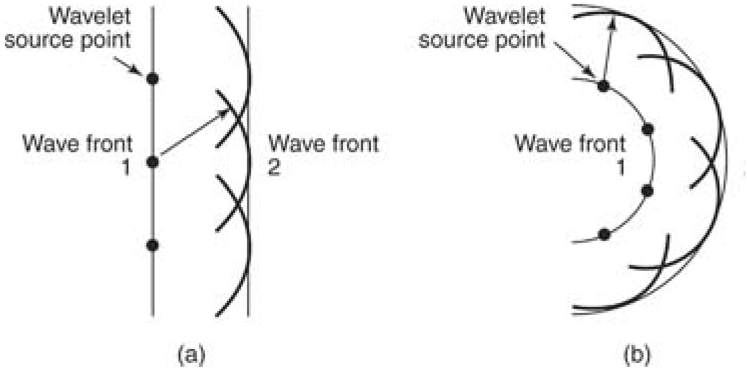
With a dish the size of 30 football fields, FAST (Five hundred meter Aperture Spherical Telescope, Guizhou, China) is by far the largest single-aperture telescope in the world (though arrays that link up multiple radio dishes cover more ground). The previous record holder in the field is the 1,000-foot-wide (300 meters) Arecibo Observatory in Puerto Rico ([Collapsed on Dec 1, 2020]()).

Solve Aperture Antenna Problems

- Huygens principle
- Equivalence principle
- Numerical methods

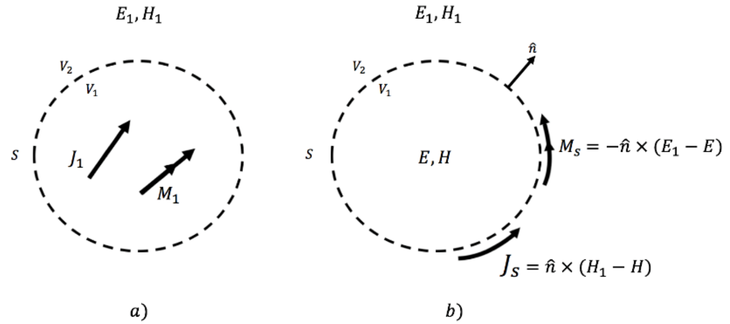
Solve Aperture Antenna Problems

- Huygens principle
  - **Divide** the **aperture into small sections**, each of which can be treated as **a point source**.
  - Calculate the **electric field at each point** in space using the contributions from all of the point sources, taking into account the phase and amplitude of each source.
  - Integrate **the electric field over a large sphere surrounding** the aperture to obtain the far-field radiation pattern of the antenna.
- Equivalence principle
- Numerical methods

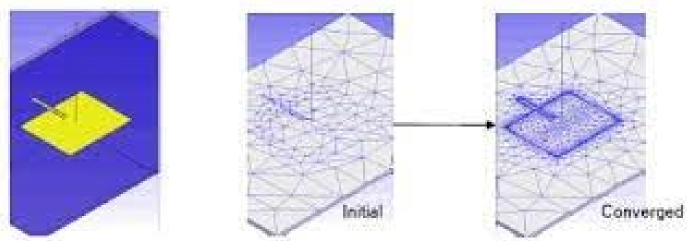


Solve Aperture Antenna Problems

- Huygens principle
- Equivalence principle
  - Model the **aperture as an array of equivalent magnetic current sources**, which are determined **based on the electric field distribution on the aperture**.
  - Calculate the radiation pattern of the equivalent sources using the **magnetic vector potential.**
  - **Transform the radiation pattern of the equivalent sources to the far field** using the Fraunhofer diffraction formula.
- Numerical methods



Solve Aperture Antenna Problems



- Huygens principle
- Equivalence principle
- Numerical methods
  - **Divide the aperture into small elements,** such as triangles or rectangles, and discretize the electromagnetic field equations **using basis functions that represent the electric and magnetic fields**.
  - **Solve the resulting system of linear equations** using a numerical method, such as the finite element method or the method of moments, to **obtain the current distribution on the aperture and the resulting far-field radiation pattern**.
  - **Evaluate the performance of the antenna** by analyzing the radiation pattern and other relevant parameters, and make any necessary design adjustments.

Reflector Antennas

- Designing reflectors of many various for use in radio astronomy, microwave communication, and satellite tracking
- Development of sophisticated analytical and experimental techniques
- Shaping the reflector surfaces
- Optimizing illumination over their apertures so as to maximize the gain.

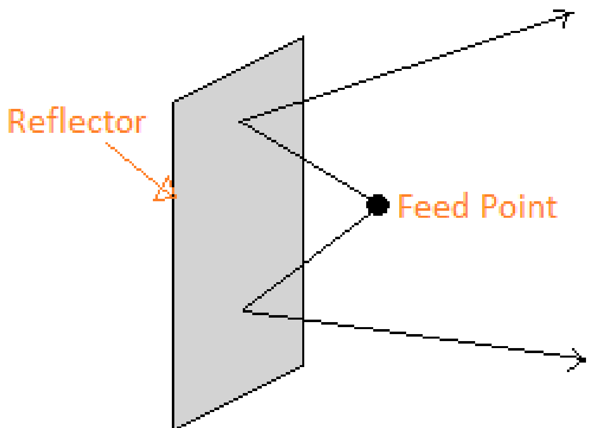
Types of popular reflectors antenna

- **Plane Reflector**
- **Corner Reflector**
- **Parabolic Reflector**
- **Spherical Reflector**

Plane Reflector

- Simplest type of reflector
- Consists of primary antenna and reflecting surface introduced to direct energy in a desired direction
- Position of radiating source and its relation to the reflecting surface used to control the radiating properties (pattern, impedance, directivity) of the overall system
- Increasing directivity and reducing backward radiation (e.g., large flat sheet placed in front of a dipole)
- Image theory used to analyze the radiating characteristics of such a system
- Disadvantage of this type that not possible to **collimate** energy in forward direction.

A collimated beam of light or other electromagnetic radiation has parallel rays, and therefore will spread minimally as it propagates.



Plane Reflector

ARTA's plane passive reflectors

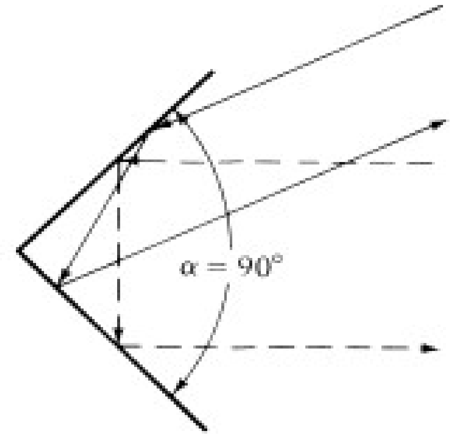
90˚ Corner Reflector

In most practical applications, the included angle formed by the plates is usually 90˚.

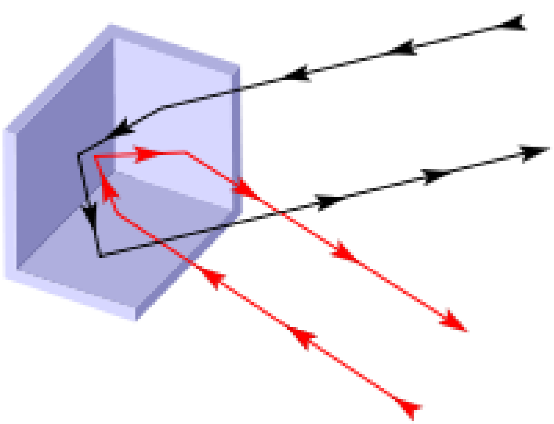
the direction of propagation of the waves reversed

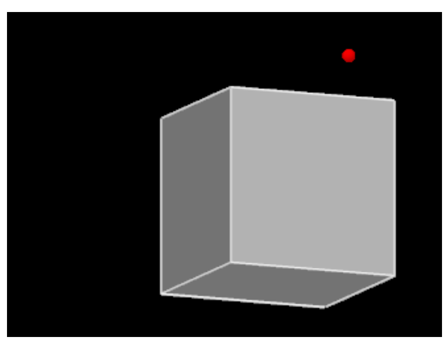
the most popular because of its attractive radiation characteristics

its simplicity in construction allows many unique applications. For example, if the reflector is used as a passive target for radar or communication applications, it will return the signal exactly in the same direction as it received it when its included angle is 90 ˚.



(b) $\alpha = 90°$

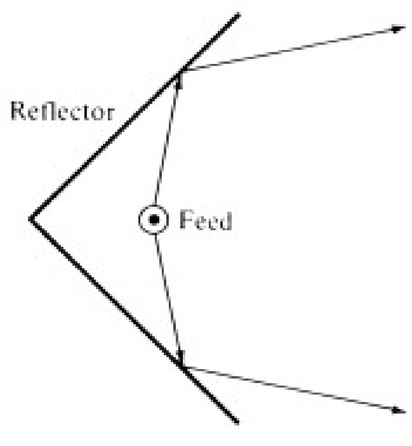




A multireflector at the Nevada Test Site used as radar target for simulated nuclear bombing

Corner Reflector Antenna

- Consists of two plane reflectors joined so as to form a corner
- Allow better collimate the energy in the forward direction
- The feed element almost always a dipole or an array of collinear dipoles placed parallel to the vertex a distance s away
- cylindrical or biconical dipoles instead of thin wires as feed elements for greater bandwidth

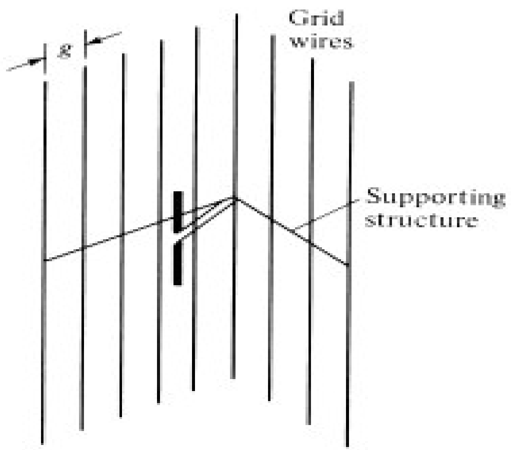


(b) Corner

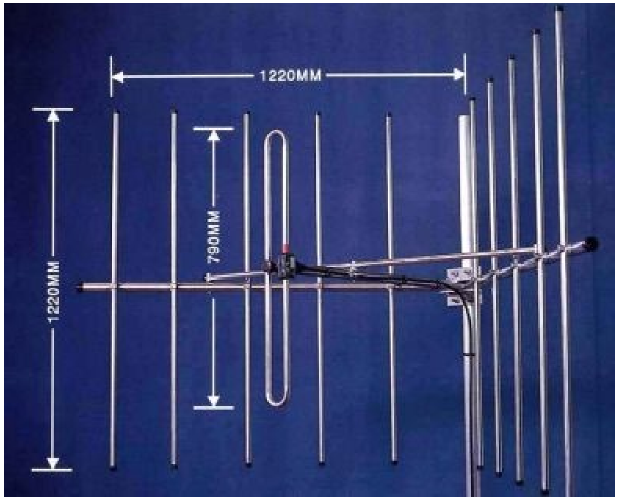
Corner Reflector Antenna

Grid Wires

- When the wavelength is large compared to physical dimensions, grid wires rather than solid sheet metal are used to reduce wind resistance and overall system weight.
- The spacing (g) between wires is made a small fraction of a wavelength (usually $g \leq \lambda/10$).
- For wires that are parallel to the length of the dipole, the reflectivity of the grid-wire surface is as good as that of a solid surface.



(d) Wire-grid arrangement

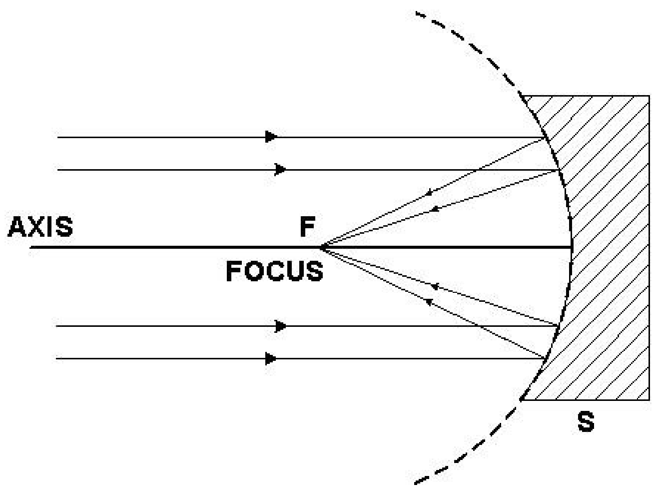


- Gain over 1/2 wave dipole 8dB
- V.S.W.R. Better than 1.3:1 over the operating band
- Maximum input power rating 750 Watts
- Input impedance 50 Ohms
- Band width +/- 3% of the centre frequency
- Polarisation Vertical or Horizontal

http://www.radiostructures.com/antennas/corner-reflectors/vcr-vhf-corner-reflector-frequency-range-130-225mhz/prod_230.html

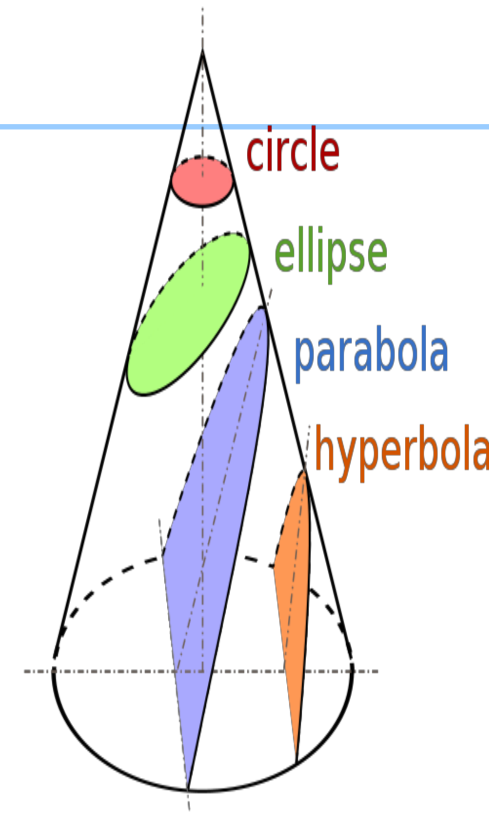
Reflector Antennas

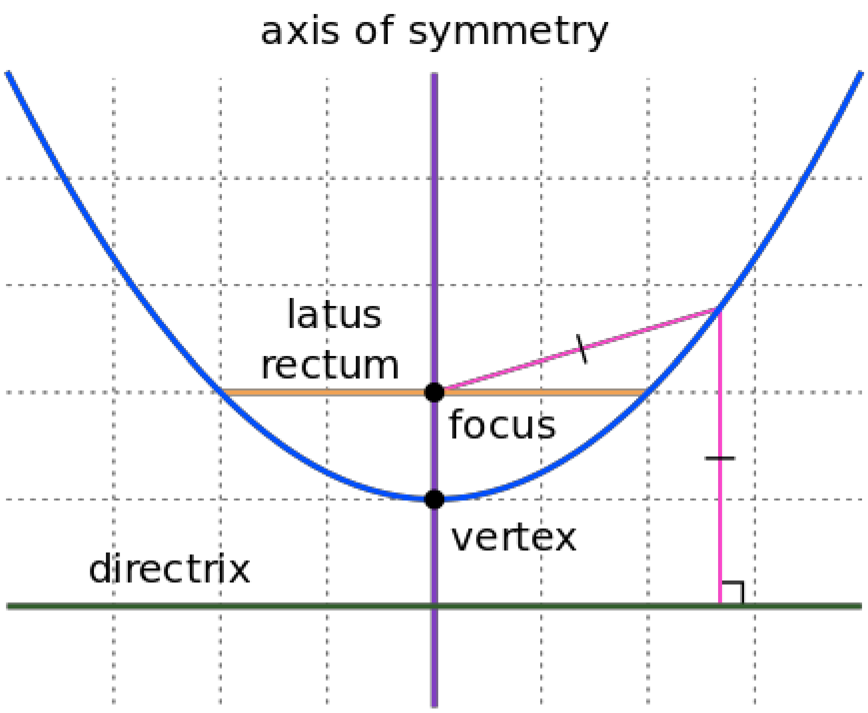
- the easiest way to get high directivities (> 30 dB).
- consists of **a feeder** (low directivity antenna) illuminating a metallic surface (**a reflector**) where electric and magnetic currents are induced, which are responsible of the radiated fields.

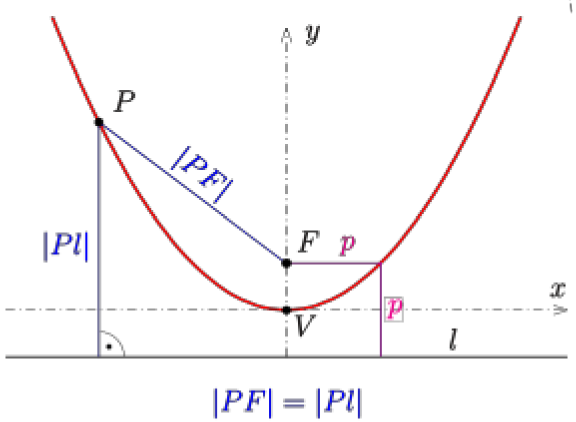


Parabolic Reflector

- This type of reflector has shape of paraboloid and hence it has properties of a parabola
- Part of a parabola (**blue**), with various features (other colours). The complete parabola has no endpoints. In this orientation, it extends infinitely to the left, right, and upward.



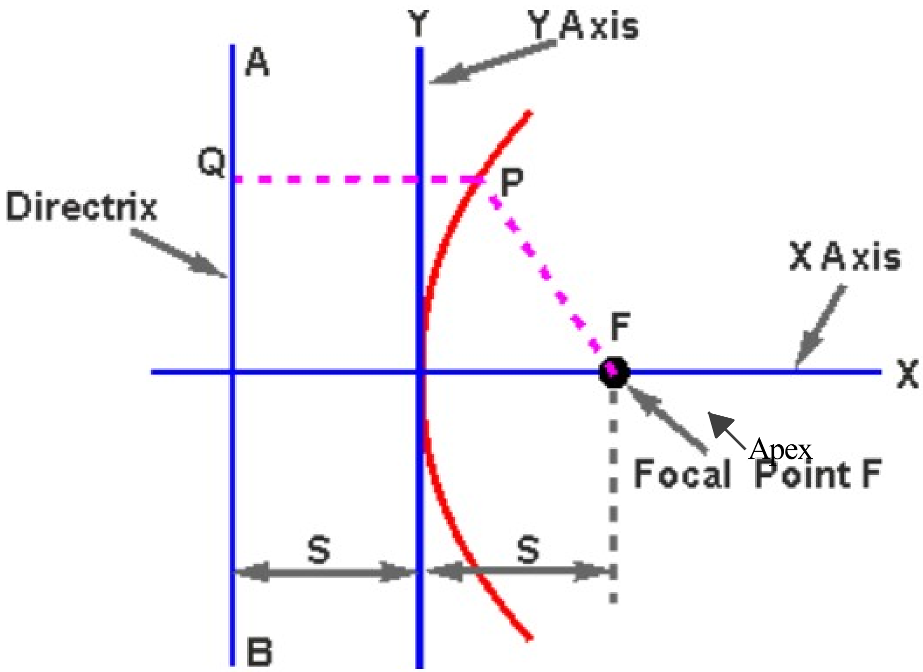




Parabolic Reflector Antennas

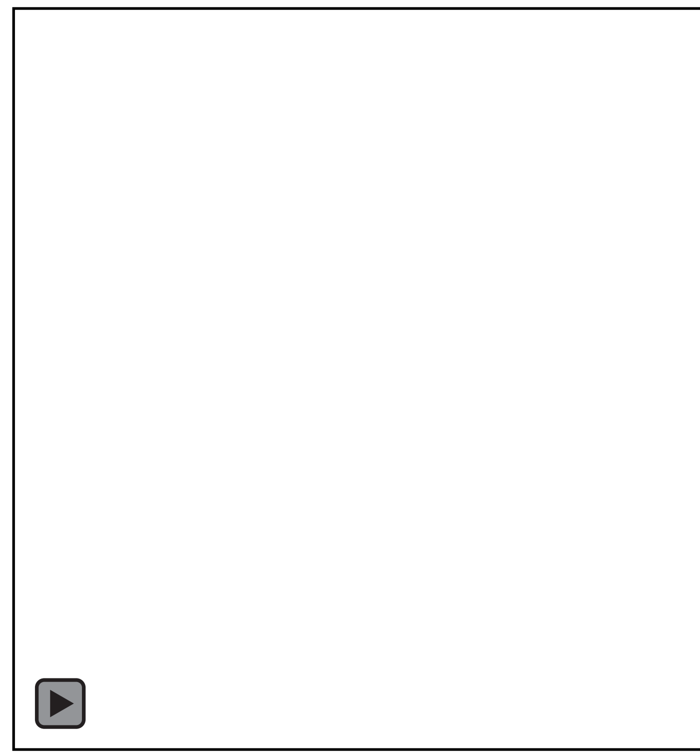
Parabola Curve

$$Y^2 = 4\ S\ X$$



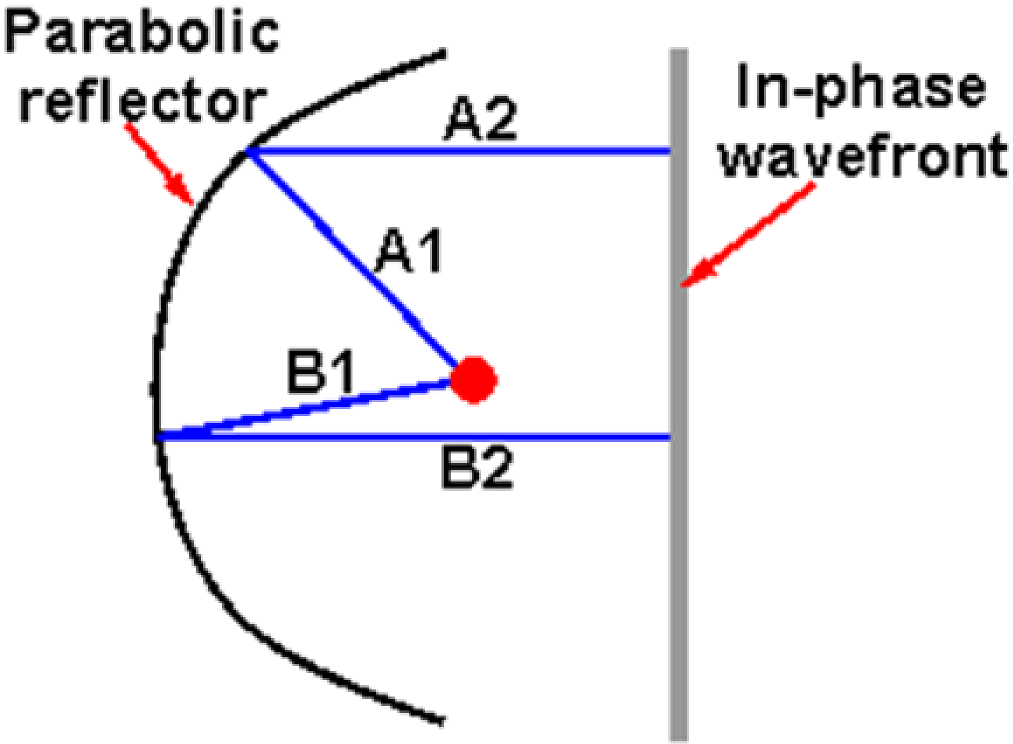
The parabolic curve and its details

FP = PQ

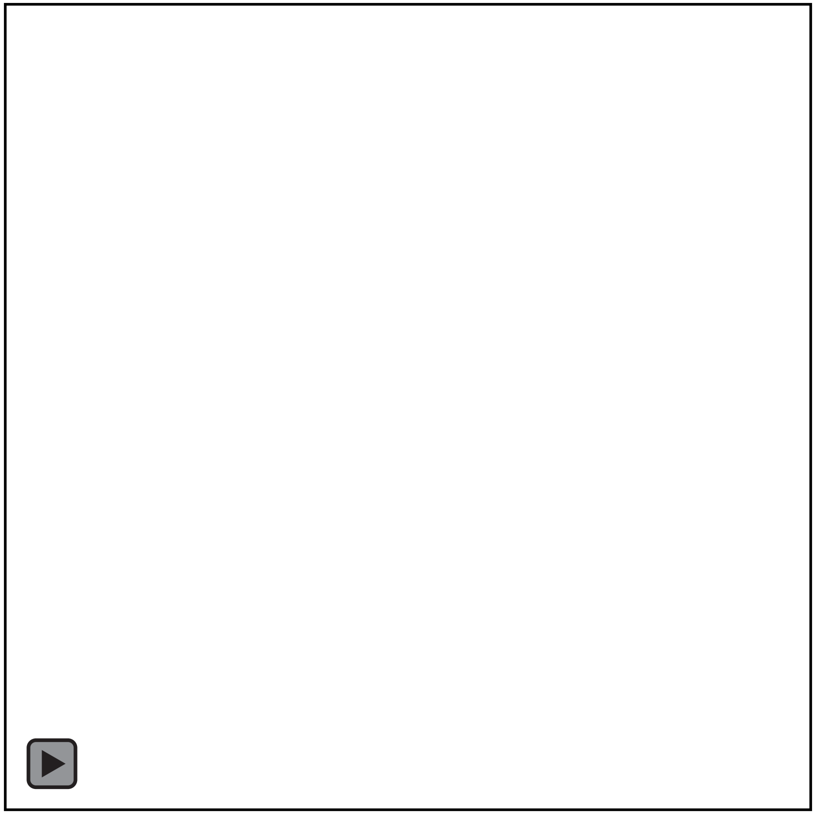


animation

Reflector Antennas



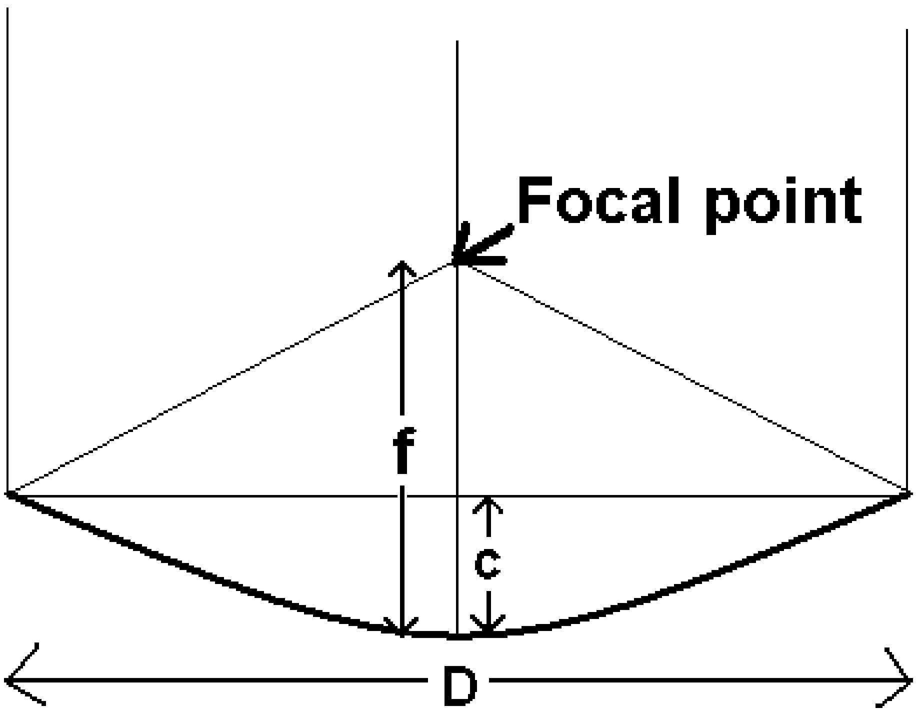
$$A1 + A2 = B1 + B2$$



animation

A paraboloid enables the wavefronts to combine and not be out of phase

Parabolic Reflector Antennas



Focal length $f = \dfrac{D^2}{16\,c}$

Where:

f is the focal length

D is the diameter of the reflector

c is the depth of the reflector

Parabolic Reflector Antennas

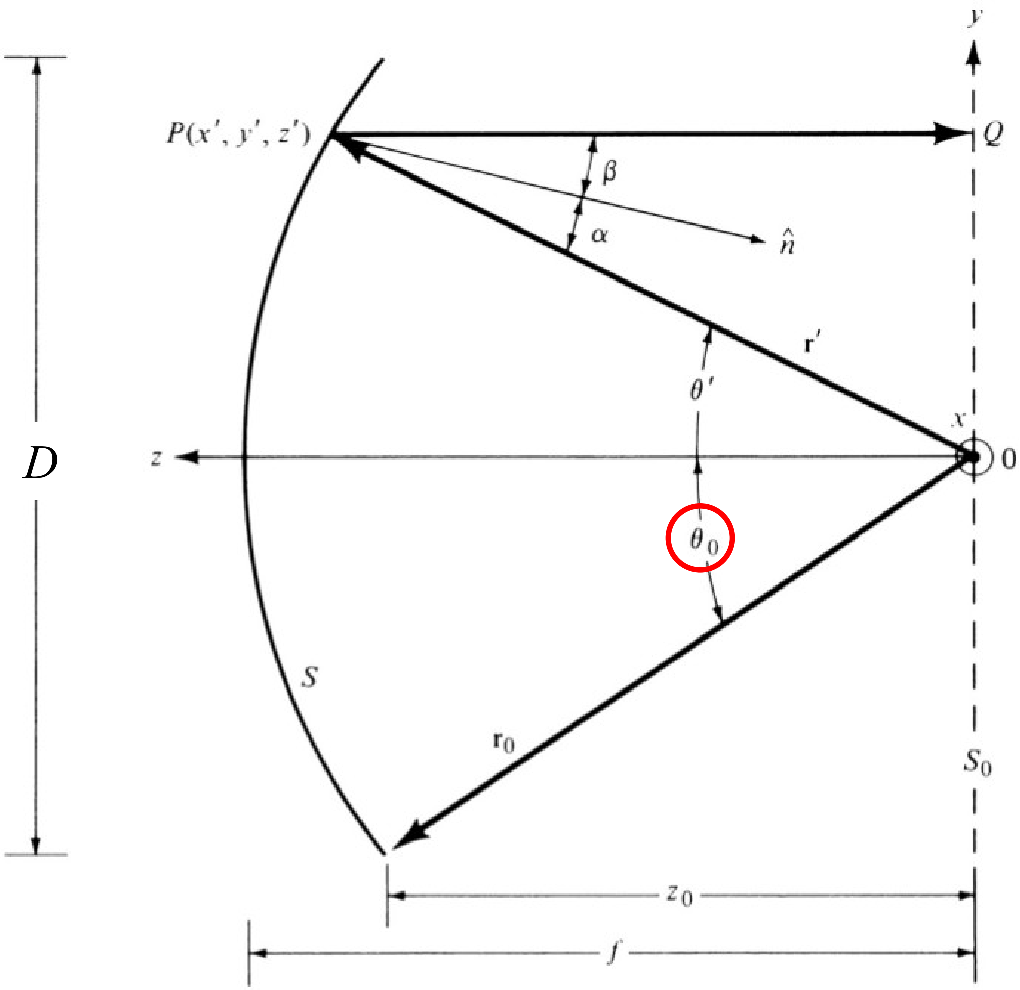


Figure 15.10 Two-dimensional configuration of a paraboloidal reflector.

Focal length

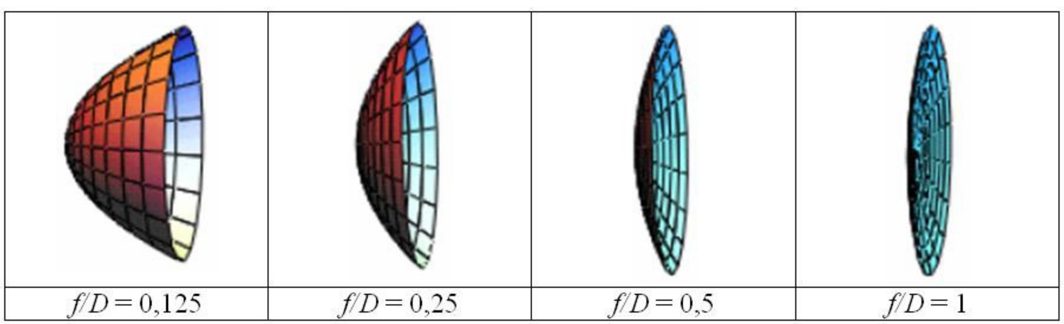
$$f = \left(\frac{D}{4}\right)\cot\left(\frac{\theta_0}{2}\right)$$

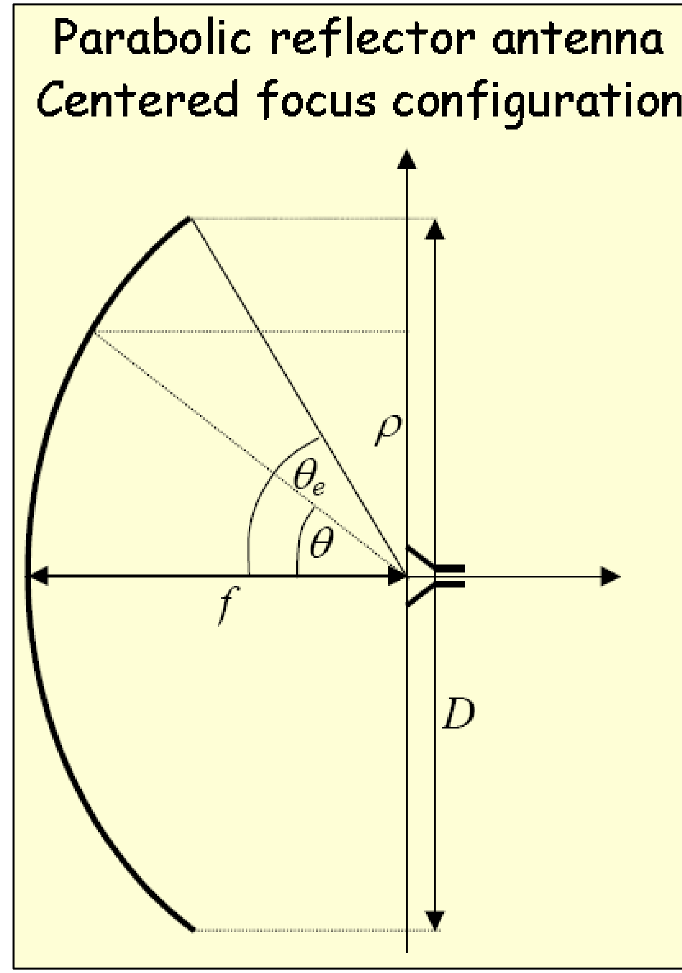
Rim angle

$$\theta_0 = 2\arctan\left[\frac{f}{4(F/D)}\right]$$

Parabolic Reflector Antennas

- In a **parabolic reflector** antenna, the parameter f/D determines the antenna appearance as well as some of its electromagnetic features
- As f/D parameter increases the parabolic surface is more flat

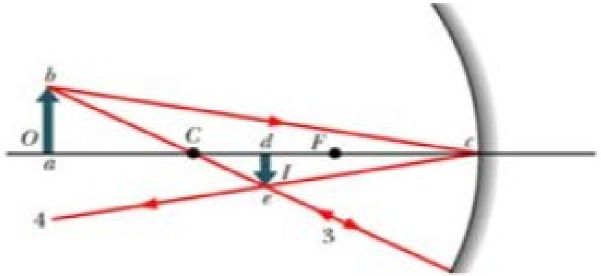




Reflector Antenna Analysis (GO/PO)

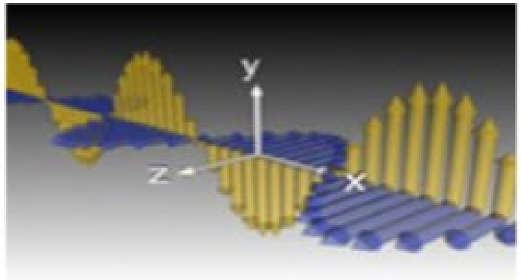
• "Geometrical" optics: light rays ("particles") that travel in straight lines.

GO



• "Physical" optics: electromagnetic waves which have amplitude and phase that can change.

PO

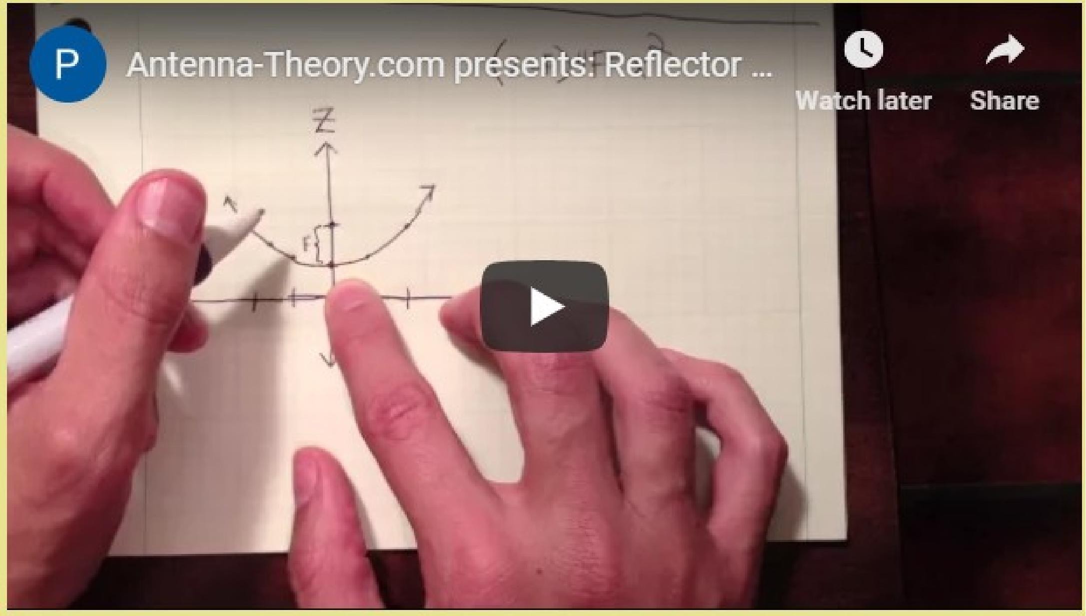


• far fields of reflector antennas obtained from **GO aperture field integration** and **PO aperture current integration**

Reflector Antenna Analysis (GO/PO)

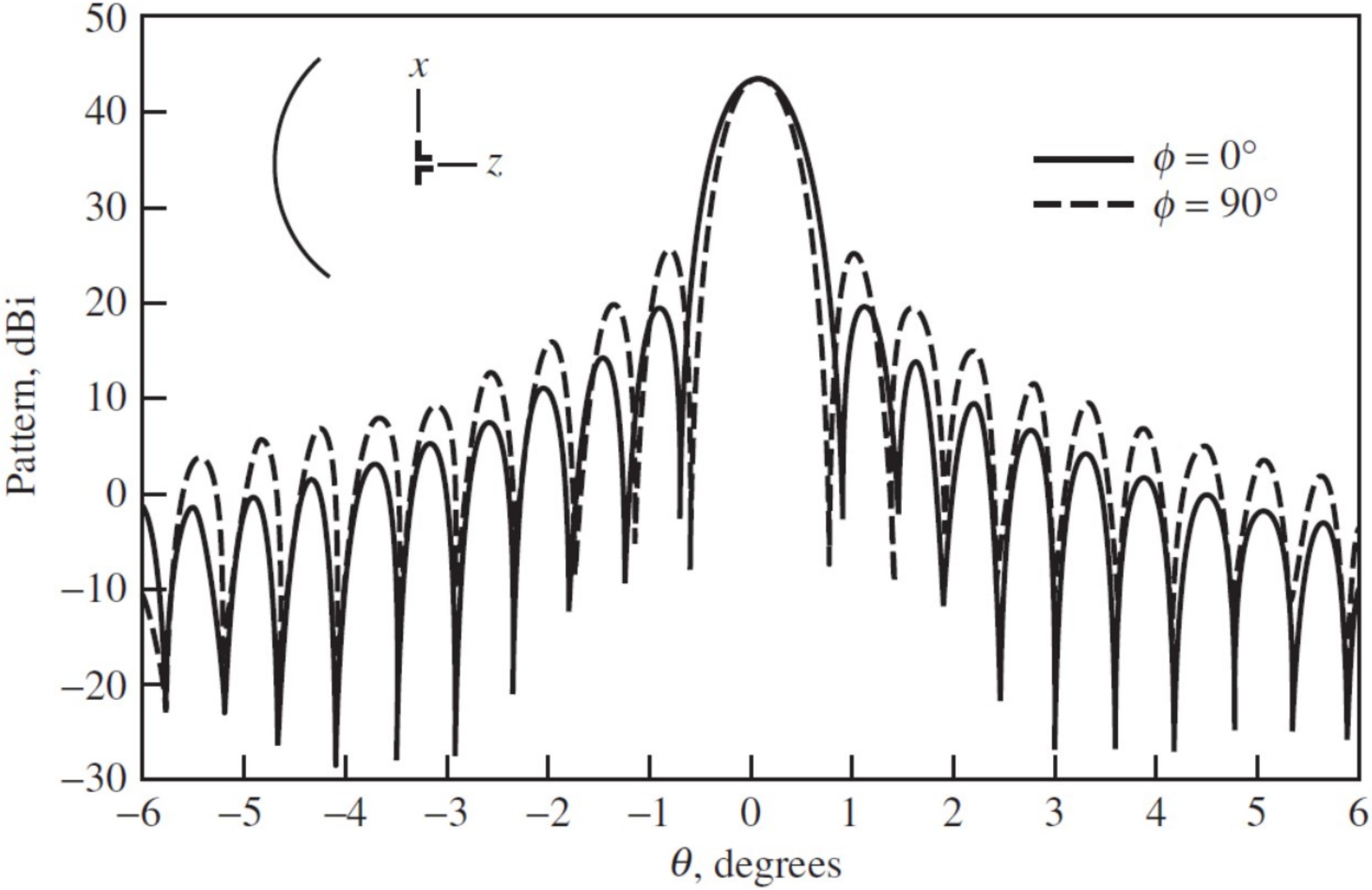
Feature	Geometrical Optics	Physical Optics
Wave behavior	Assumes rays propagate in straight lines	Accounts for diffraction and interference effects
Applicability	Reflector surface much larger than wavelength	Reflector surface similar in size to wavelength
Design and Optimization	Used to optimize reflector shape and predict reflection and refraction	Used to analyze radiation patterns and polarization properties, and predict effects of surface imperfections
Limitations	GO cannot account for diffraction and interference effects	PO assumes ideal reflector surface and cannot predict all effects of surface imperfections
Combination of Approaches	GO used for initial design and optimization, PO used to refine design and predict detailed performance.	

Reflector Antenna Pattern



9’57”

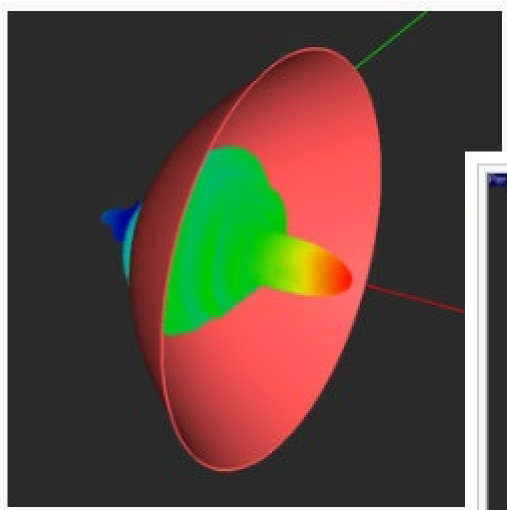
Reflector Antenna Pattern



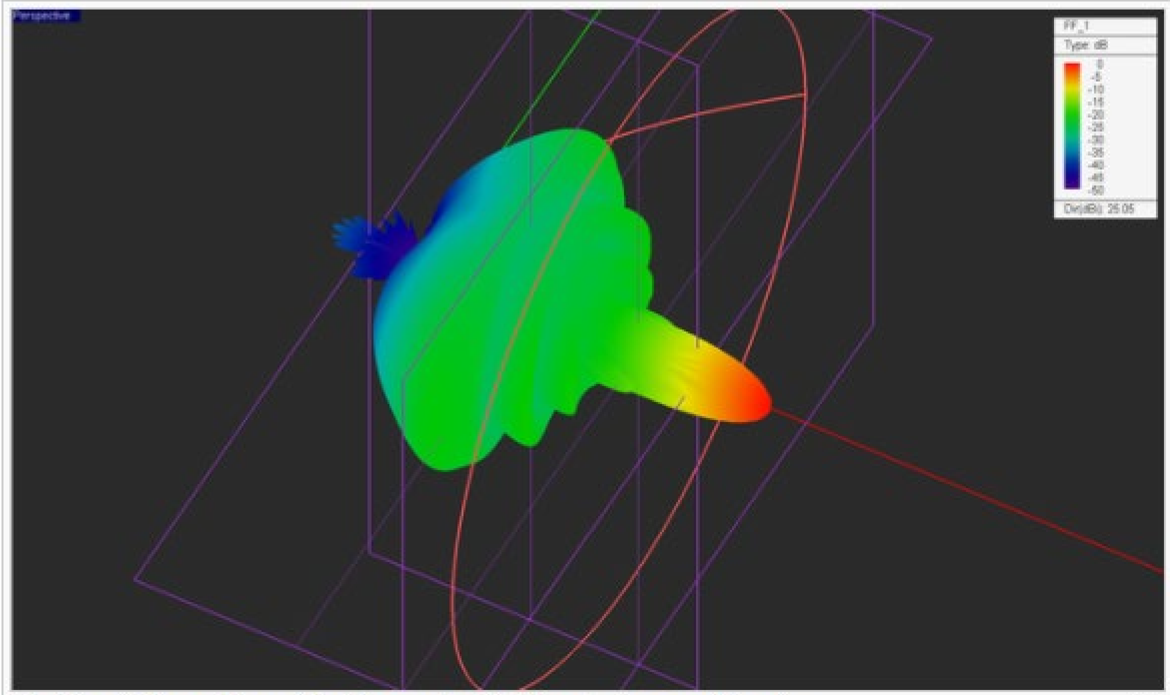
(a) Principal plane patterns.

An example is presented in <u>W.L. Stutzman, G. Thiele, ***Antenna Theory and Design***</u>, of an axisymmetric parabolic reflector with diameter $D = 100\lambda$ and $F / D = 0.5$, fed by a half-wavelength dipole located at the focus.

Reflector Antenna Pattern



Objective: In this project, you will build a parabolic dish reflector excited by a short dipole radiator and compute its near-field distributions and far-field radiation patterns.

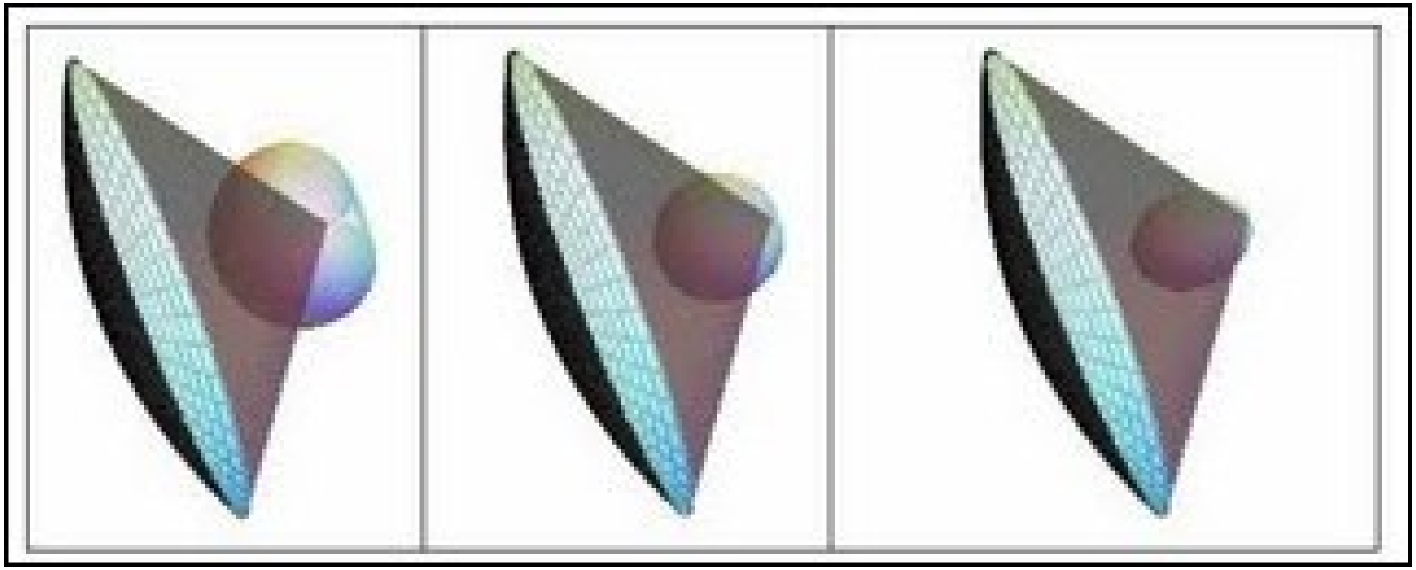


The 3D radiation pattern plot of the parabolic dish reflector on a dB scale.

http://www.emagtech.com/wiki/index.php/EM.Illumina_Tutorial_Lesson_3:_Computing_The_Radiation_Pattern_Of_Parabolic_Dish_Reflectors

Feed Pattern

- The radiation pattern of the feed antenna has to be tailored to the shape of the dish, because it has a strong influence on the aperture efficiency, which determines the antenna gain



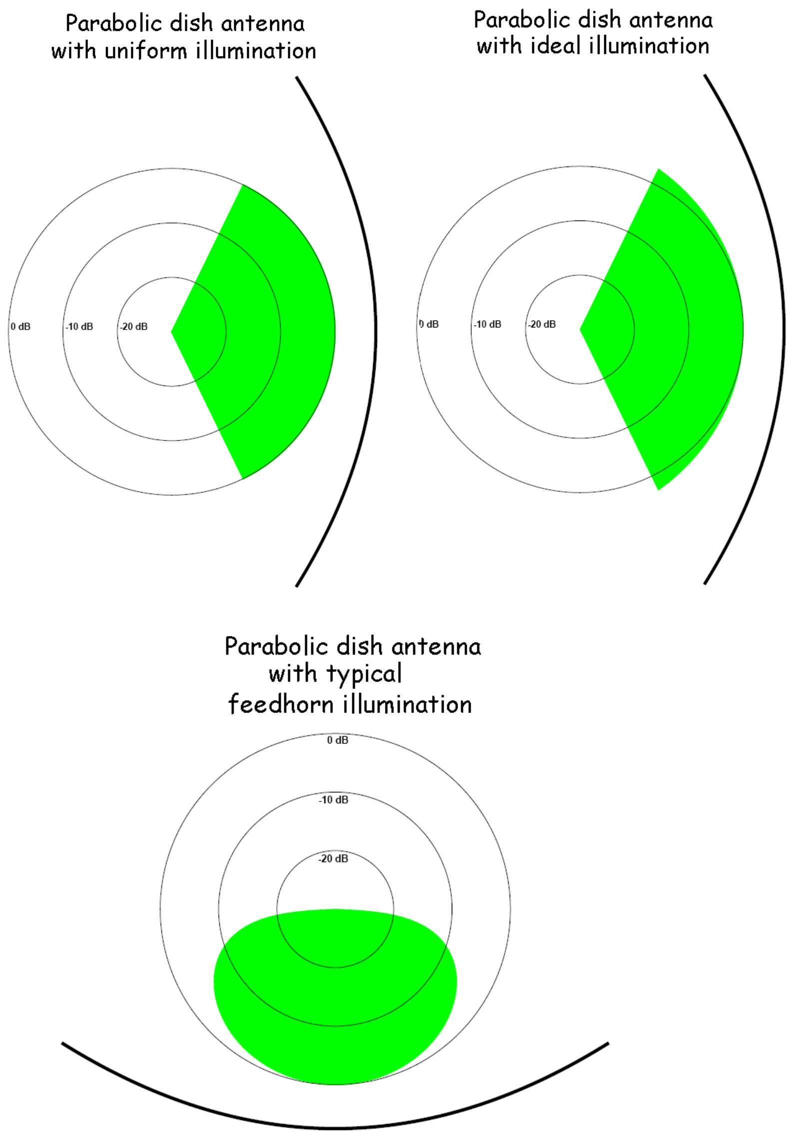
Effect of the feed antenna radiation pattern (small pumpkin-shaped surface) on spillover.
Left: With a low gain feed antenna, significant parts of its radiation fall outside the dish.
Right: With a higher gain feed, almost all its radiation is emitted within the angle of the dish.

Reflector Analysis

- The gain of a reflector antenna is given by:

$$G = 4 \cdot \pi \cdot \frac{S}{\lambda^2} \cdot \eta_t$$

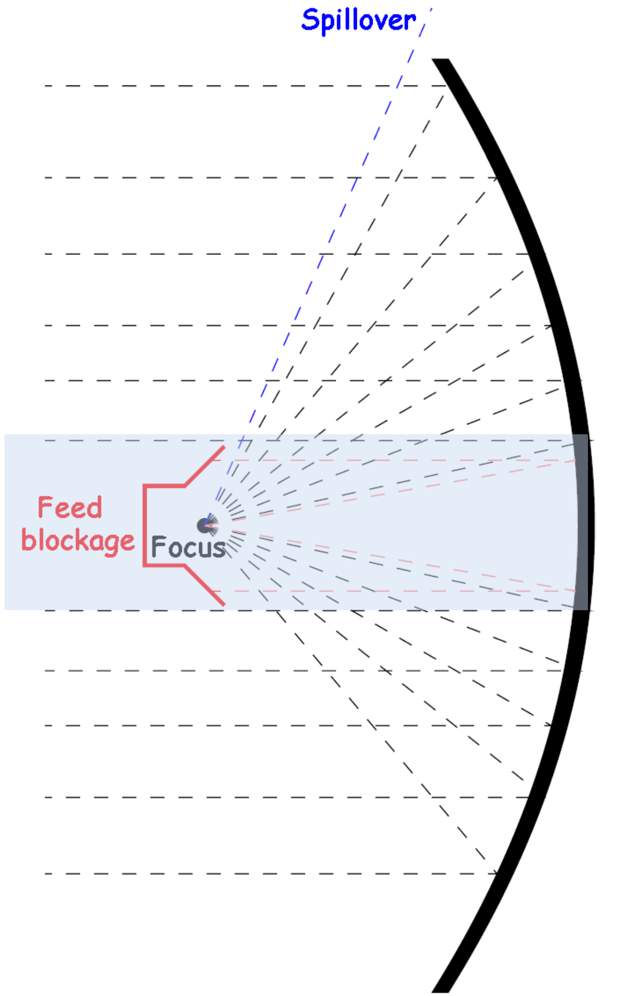
where S is the reflector surface and η_t is the total illumination efficiency of the antenna.



Reflector Analysis

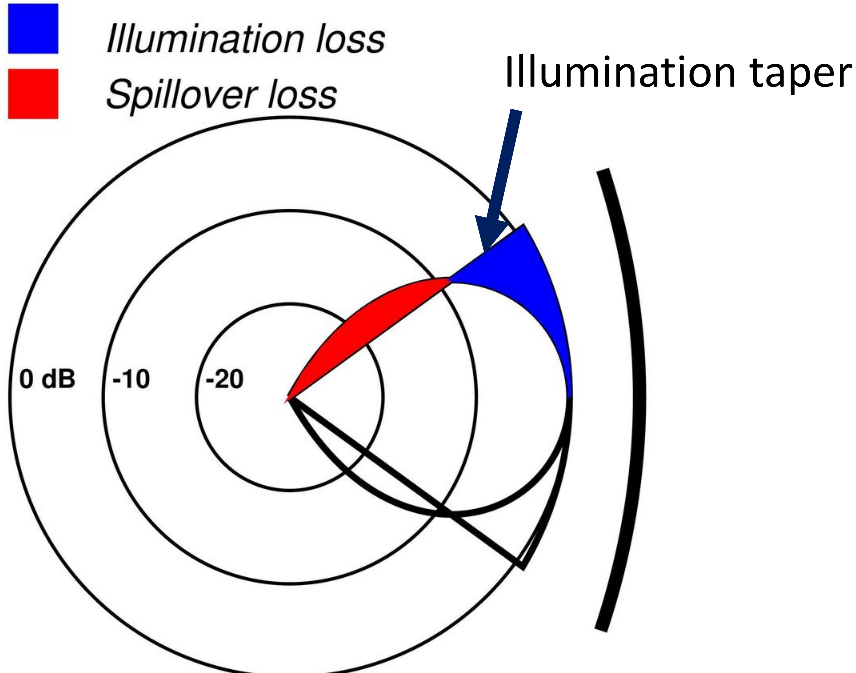
- The reflector efficiency is a combination of several loss factors:
  - Uniformity of the illumination, η_i
  - Spillover, η_s
  - Phase uniformity, η_p
  - Polarization uniformity, η_x
  - Blockage efficiency, η_b
  - Random error efficiency, η_r, over the reflector surface

$$\eta_t = \eta_i \cdot \eta_s \cdot \eta_p \cdot \eta_x \cdot \eta_b \cdot \eta_r$$



Illumination Taper

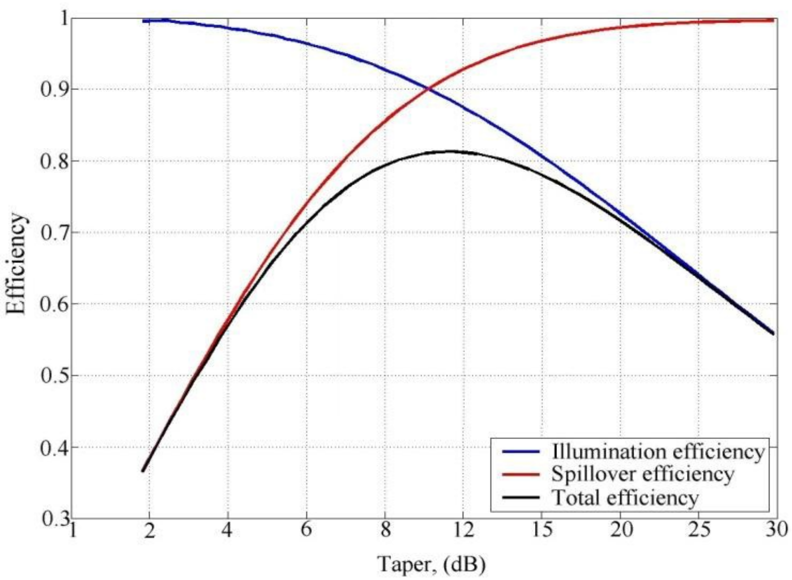
- The aperture illumination or **illumination taper** is the **variation in amplitude across the aperture**.
- Tapered illumination **occurs naturally** in reflector antennas due to the **feed radiation pattern** and the **variation in distance** from the feed to different portions of the reflector.

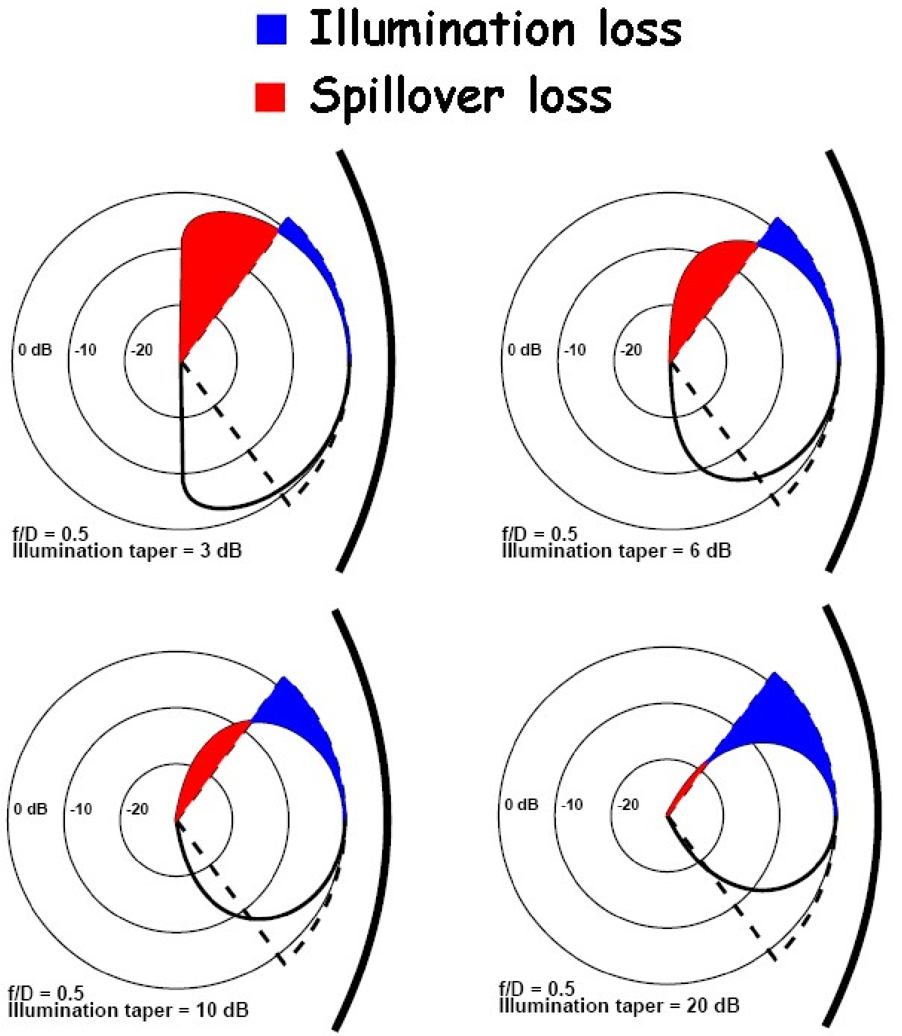


Illumination taper = 10 dB
Figure 11-4b: Dish Illumination f/D = 0.75

Illumination Taper/Spillover Loss

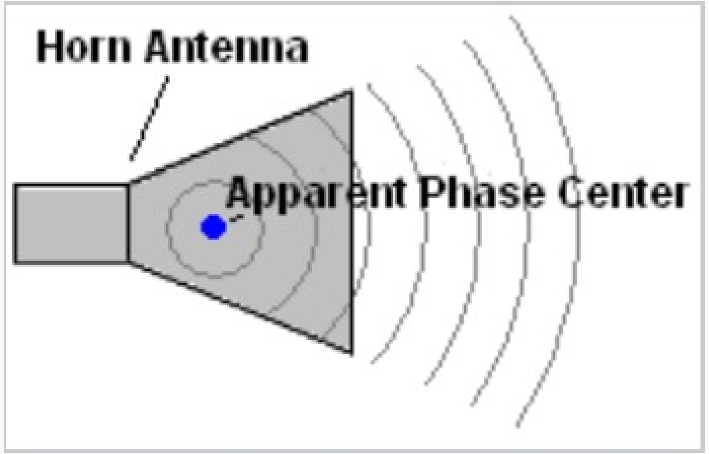
- The reflector efficiency is mainly derived from illumination and spillover efficiencies product.
- It's maximum lies for 9 to 13 dB illumination taper.





Phase Center

- Point where electromagnetic wave appears to originate from antenna
- Position depends on antenna geometry, signal frequency, and feed location
- Important for analyzing antenna performance
- Important for precise pointing and tracking applications
- Determined experimentally by measuring radiation pattern and phase distribution
- Stability of phase center crucial for accurate pointing and tracking
- Environmental factors can affect phase center position.

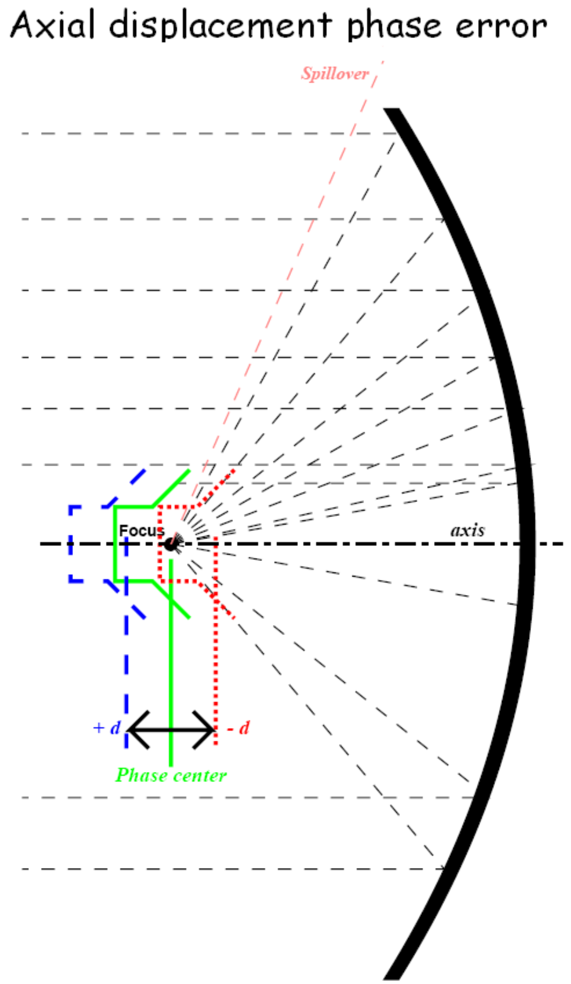


In horn and other directional antennas, the **apparent phase center** is used since radiation is only emitted at certain angles .

Apparent phase center is used to describe the phase center in a limited section of the radiation pattern.

Phase Error

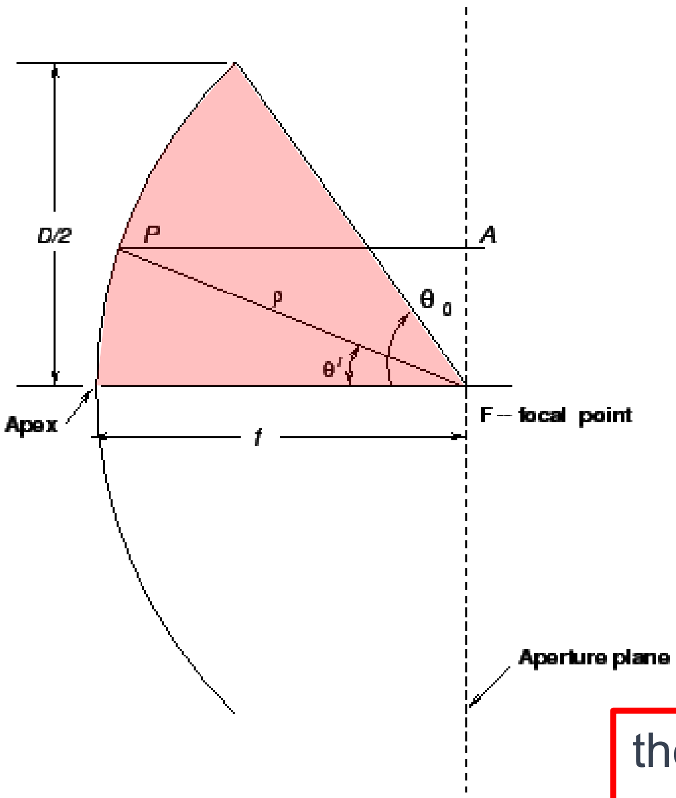
- In a parabolic reflector, the position of the feed **phase centre** exactly at the focus of the reflector is very important.
- important losses because of **axial defocusing**.
- affected by f/D parameter of the reflector.
- The best feed-horns must present **the same phase center position for E and H planes** and as stable as possible in its usable band.



Aperture Efficiency

aperture efficiency defined as

$$\epsilon_{ap} = \frac{A_e}{A_p}$$



A_e is the effective aperture and A_p is the physical aperture.

$$\varepsilon_{ap} = \cot^2\left(\frac{\theta_0}{2}\right)\left|\int_0^{\theta_0}\sqrt{G_f(\theta')}\tan\left(\frac{\theta'}{2}\right)\,d\theta'\right|^2$$

$G_f(\theta)$ is a feed pattern

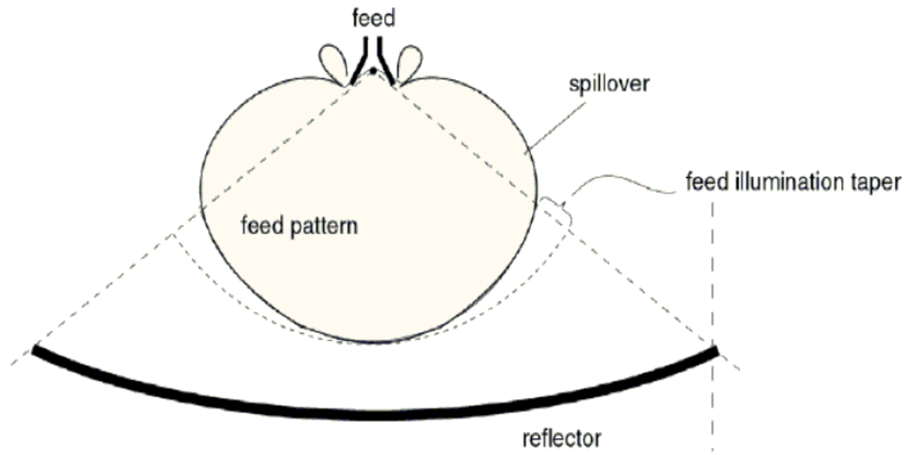
the **ratio** of the **power radiated by an antenna** to the power that would be radiated if the **entire aperture area** of the antenna were radiating with **the same power per** unit area as the **maximum value**.

Feed Pattern

assume a feed pattern

$$G_f(\theta') = \begin{cases} {G_0}^{(n)} \cos^n(\theta') & 0 \le \theta' \le \pi/2 \\ 0 & \pi/2 < \theta' \le \pi \end{cases}$$

where ${G_0}^{(n)}$ is a constant for a given value of n. Although idealistic, these patterns were chosen because (1) closed form solutions can be obtained, and (2) they often are used to represent a major part of the main lobe of many practical antennas. The intensity in the back region ($\pi/2 < \theta' \le \pi$) was assumed to be zero in order to avoid interference between the direct radiation from the feed and scattered radiation from the reflector.



Aperture Efficiency

efficiency is calucated as follows

$$\varepsilon_{ap}(n=2) = 24\left\{\sin^2\left(\frac{\theta_0}{2}\right) + \ln\left[\cos\left(\frac{\theta_0}{2}\right)\right]\right\}^2 \cot^2\left(\frac{\theta_0}{2}\right) \tag{15-59a}$$

$$\varepsilon_{ap}(n=4) = 40\left\{\sin^4\left(\frac{\theta_0}{2}\right) + \ln\left[\cos\left(\frac{\theta_0}{2}\right)\right]\right\}^2 \cot^2\left(\frac{\theta_0}{2}\right) \tag{15-59b}$$

$$\varepsilon_{ap}(n=6) = 14\left\{2\ln\left[\cos\left(\frac{\theta_0}{2}\right)\right] + \frac{[1-\cos(\theta_0)]^3}{3} + \frac{1}{2}\sin^2(\theta_0)\right\}^2 \cot^2\left(\frac{\theta_0}{2}\right) \tag{15-59c}$$

$$\varepsilon_{ap}(n=8) = 18\left\{\frac{1-\cos^4(\theta_0)}{4} - 2\ln\left[\cos\left(\frac{\theta_0}{2}\right)\right] - \frac{[1-\cos(\theta_0)]^3}{3} - \frac{1}{2}\sin^2(\theta_0)\right\}^2 \cot^2\left(\frac{\theta_0}{2}\right) \tag{15-59d}$$

1. There is only one reflector with a given angular aperture or *f/d* ratio which leads to a maximum aperture efficiency.
2. Each maximum aperture efficiency is in the neighborhood of 82–83%.
3. Each maximum aperture efficiency, for any one of the given patterns, is almost the same as that of any of the others.
4. As the feed pattern becomes more directive (n increases), the angular aperture of the reflector that leads to the maximum efficiency is smaller.

Directivity of Reflector

Directivity in the forward direction

$$D_0 = \left(\frac{\pi d}{\lambda}\right)^2 \varepsilon_{ap}$$

Directivity with phase error (*m* is the maximum phase deviation over the aperture of the reflector

$$D \geq \left(1 - \frac{m^2}{2}\right)^2 D_0$$

Illumination and Spillover Efficiency

Illumination efficiency or **taper efficiency** (uniformity of the amplitude distribution of the feed pattern over the surface of the reflector)

$$\varepsilon_t = 32\left(\frac{f}{d}\right)^2 \frac{\left|\int_0^{\theta_0} \sqrt{G_f(\theta')}\tan\left(\frac{\theta'}{2}\right)\, d\theta'\right|^2}{\int_0^{\theta_0} G_f(\theta')\sin\theta'\, d\theta'}$$

Spillover efficiency (fraction of the total power that is radiated by the feed, intercepted, and collimated by the reflecting surface)

$$\varepsilon_s = \frac{\int_0^{\theta_0} G_f(\theta')\sin\theta'\, d\theta'}{\int_0^{\pi} G_f(\theta')\sin\theta'\, d\theta'}$$

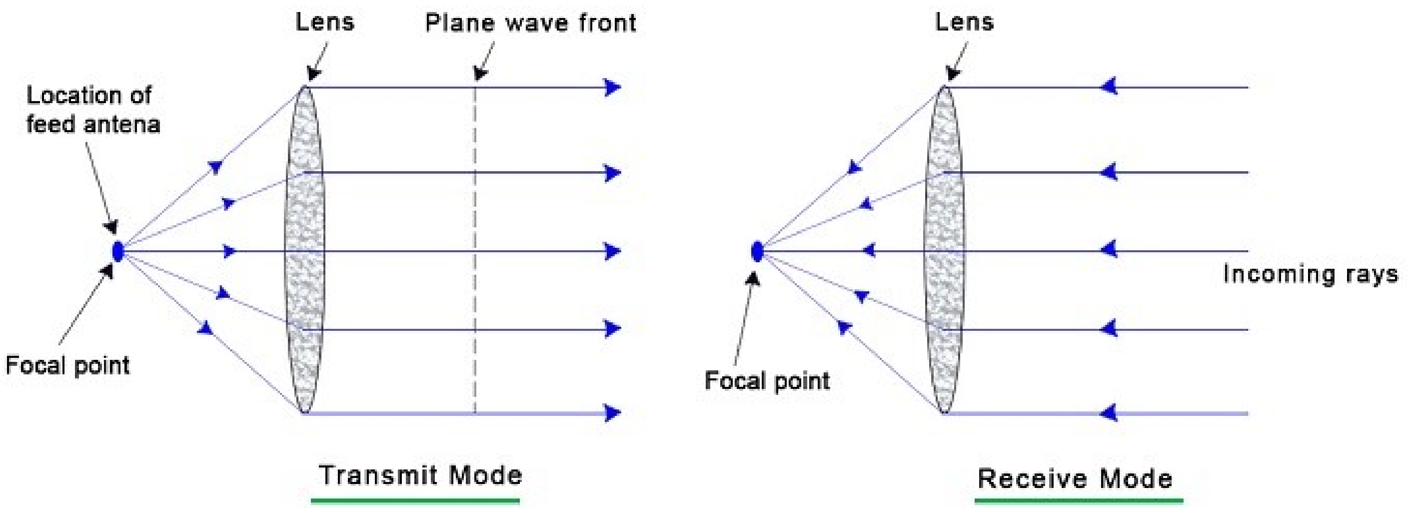
Parabolic Reflector Antennas

- Pros:
  - both as transmitting antenna and receiving antenna
  - feed in various modes with parabolic reflector vs. centre feed, cassegrain feed or offset feed. Each of these configurations have their respective benefits and applications.
  - Smaller size and low cost

- Cons:
  - Feed antenna and reflector disc blocking 1 to 2% of the main parabolic reflector antenna radiation
  - Complex design process
  - certain amount of power from feed slopping over the edges of parabolic reflector. This power responsible to form side lobes in the radiation pattern
  - Surface distortions occur in very large dish. Reduced by using wide mesh instead of continuous surface
  - feed should be placed exactly at the focus of the parabolic reflector antenna. This is difficult to achieve practically.

Lens Antennas

- uses the **convergence** and **divergence** properties of a lens to transmit and receive signals.
- consist of a **dipole** or **horn** antenna **followed by a lens**.
- The **size of the lens** used **depends on the operating frequency** - the higher the frequency the smaller the lens
- **used at high frequencies** as they can be quite bulky at lower frequencies.



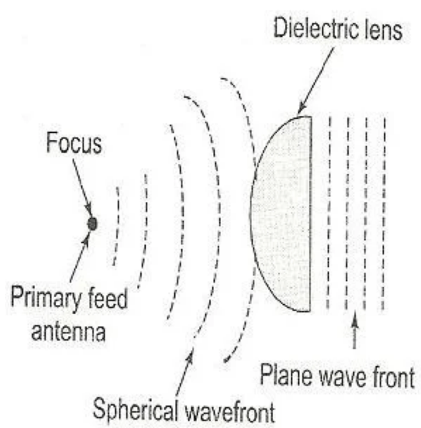
Lens Antennas

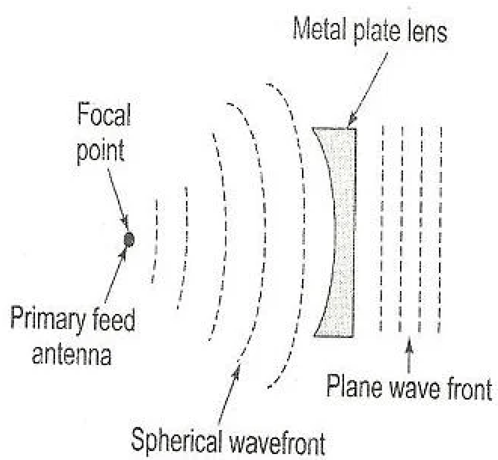
Two main types of lens antennas:

- **Metal plate lens antennas**.
- **Dielectric lens or Delay lens Antennas**

Frequency Range

- The frequency range of usage of lens antenna starts at 1000 MHz but its use is greater at 3000 MHz and above.

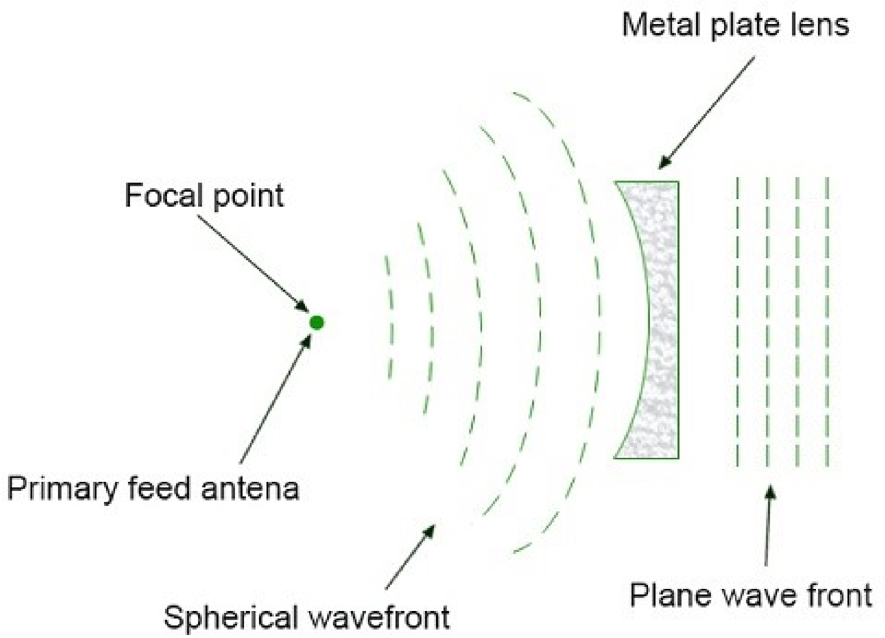




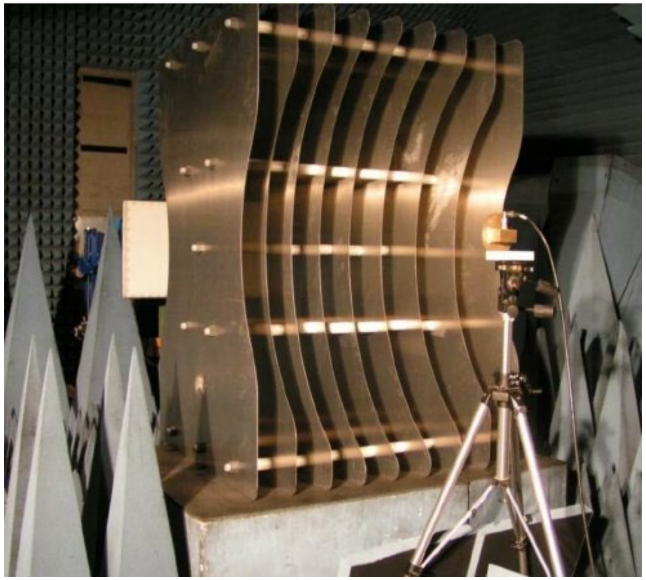
Lens Antennas

Metal plate lens antennas.

- a series of thin metal plates with air between them
- the curvature of the edges of the plates forms the lens
- the space between the plates forms a series of waveguides
- fast wave



Metal Plate Lens Antenna

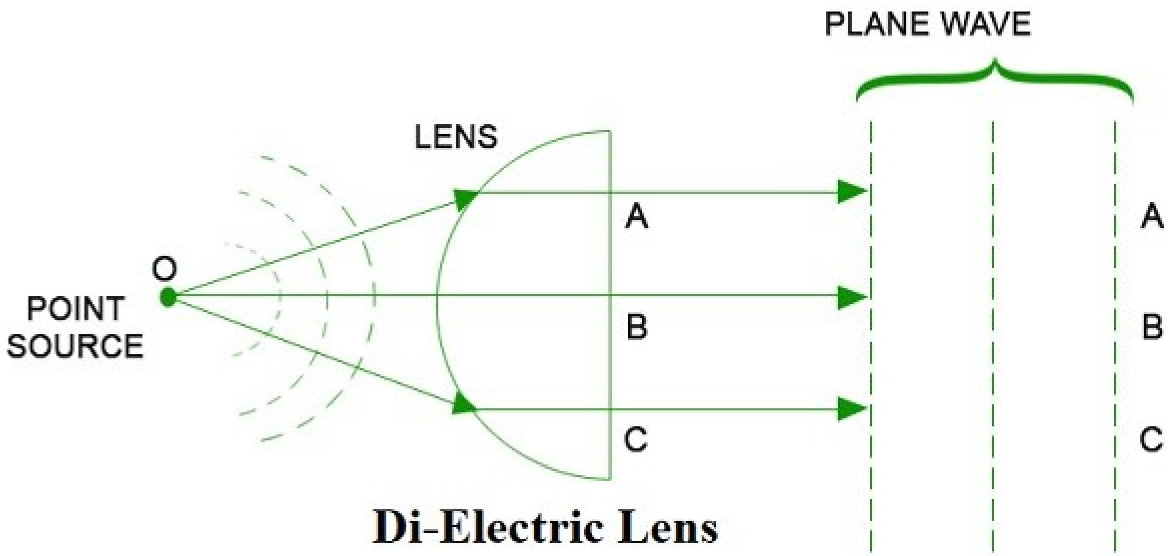


High power L-band metal-plate lens. Metal Lens are concave lens – EM wave moves faster in waveguides

Lens Antennas

Dielectric lens antennas

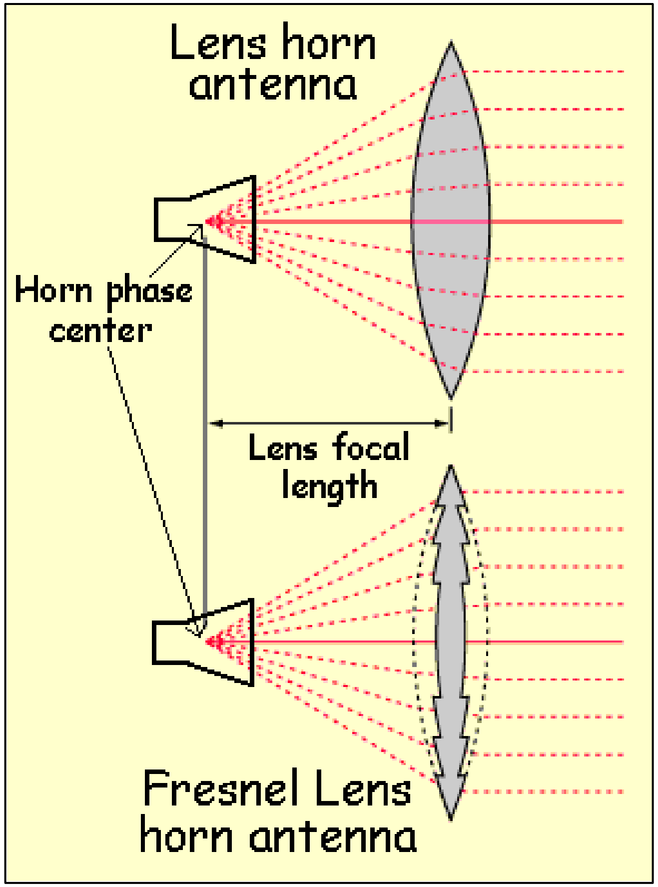
- travelling waves are delayed by lens media (slow wave)
- usually made up of polystyrene (聚苯乙烯) or Lucite (树脂) and polyethylene (聚乙烯)
- usually in microwave and mm-Wave frequencies as for frequencies less than 3 GHz they become heavy and bulky.



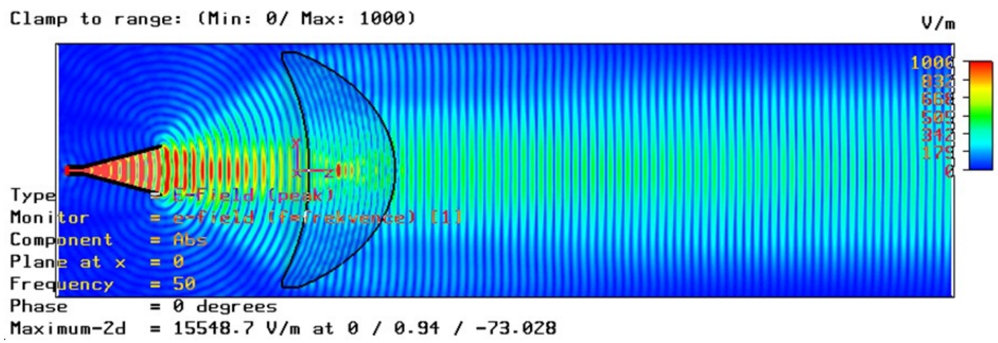
Di-Electric Lens

Lens Antennas

- usually used at higher frequency than reflectors because **less sensitive to mechanical tolerances**, but they have **more weight and volume**
- no **blockage effects** but they add **dielectric losses** and **unwanted reflections** in the discontinuities



Lens Antenna Simulations (Elliptic Lens)



Horn antenna with elliptic lens, E-field intensity.

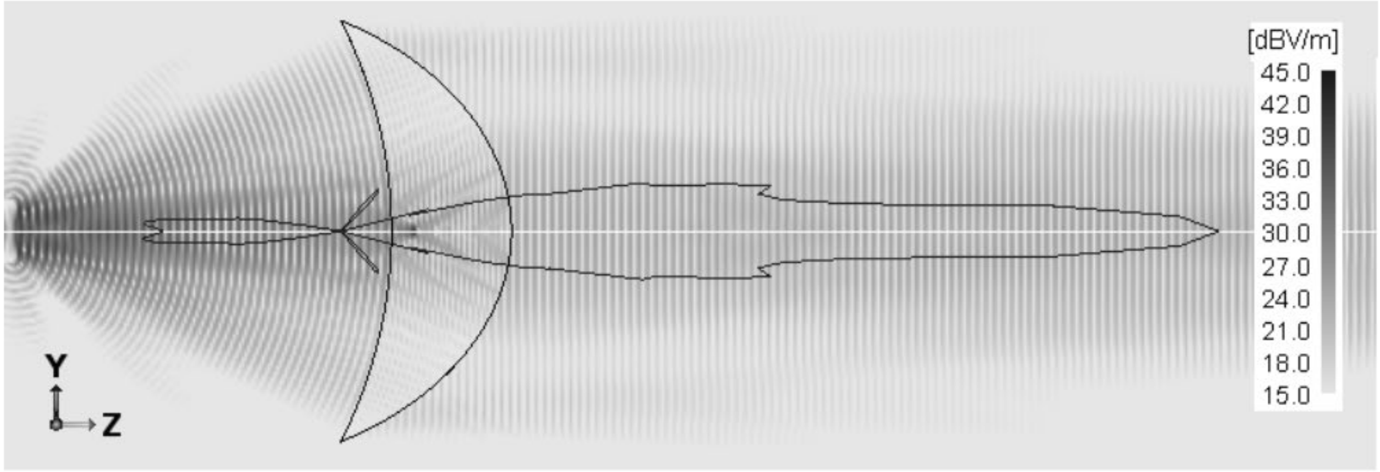
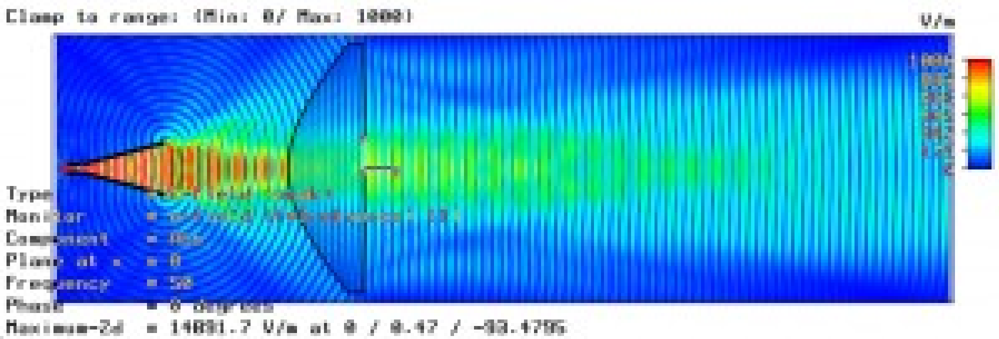


Fig. 2. Modeled distribution of waveforms and far-field radiation pattern in case of the elliptic lens at 90 GHz.

Lens Antenna Simulations (Hyperbolic Lens)



Horn antenna with hyperbolic lens, E-field intensity.

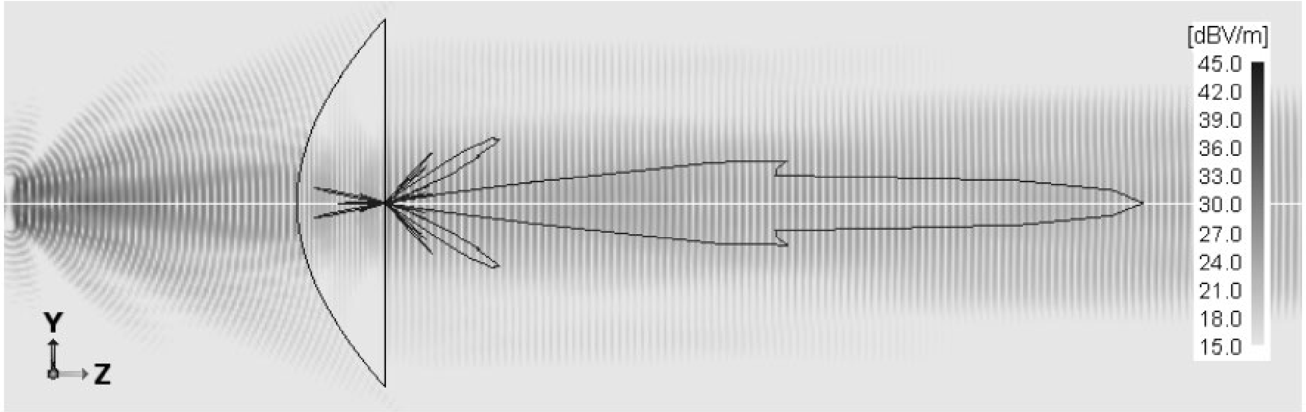
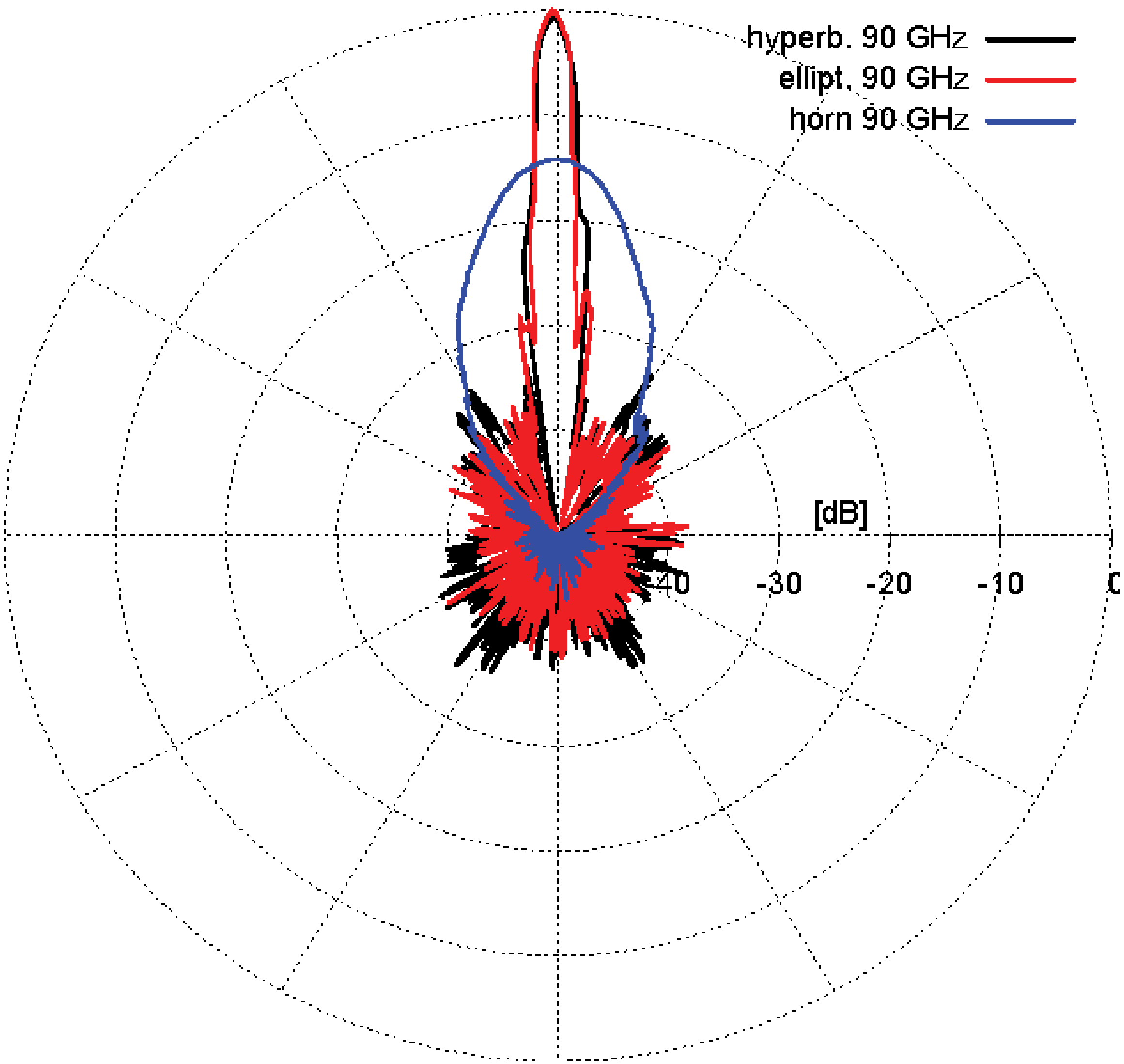


Fig. 4. Modeled distribution of waveforms and far-field radiation pattern in case of the hyperbolic lens at 90 GHz.

Lens Antenna Simulations

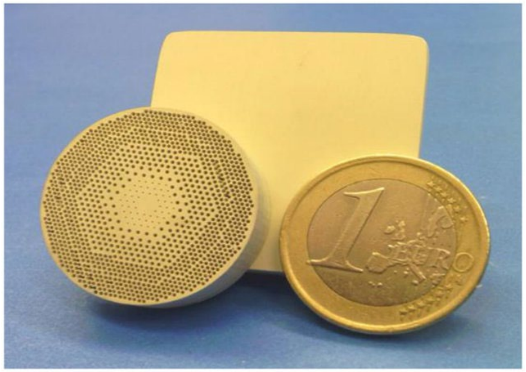


Measured radiation pattern (H-plane) of horn antenna and horn antenna with elliptic or hyperbolic lens at 90 GHz

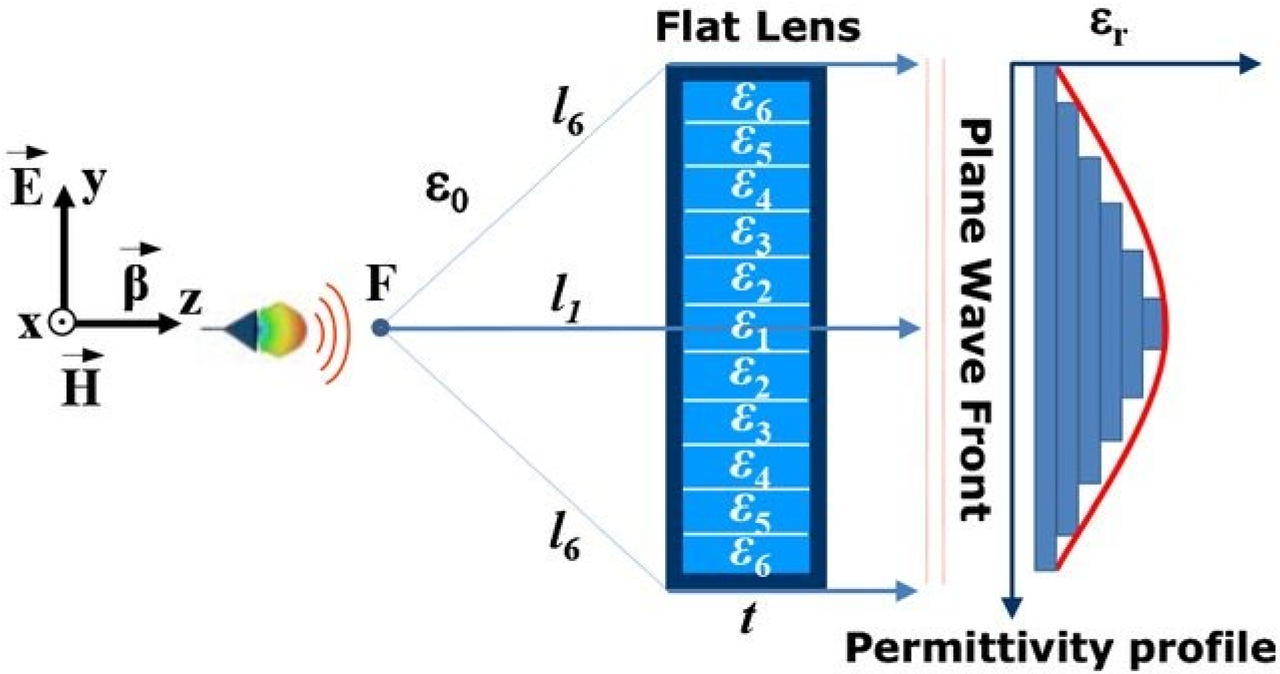
normalized to maximum gain of elliptic lens.

Gradient-index Lens Antenna

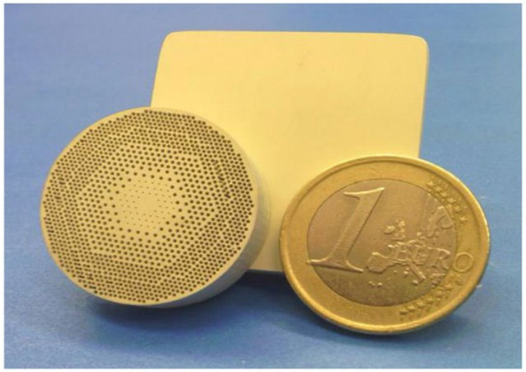
- Gradient index lens antennas use a gradient refractive index material to focus or collimate electromagnetic waves.
- The refractive index of the material varies continuously across the lens surface.
- This creates a smooth variation in propagation delay, which produces desired beam shaping properties.



Gradient-index Lens Antenna



Dielectric flat lens antenna functioning principle.

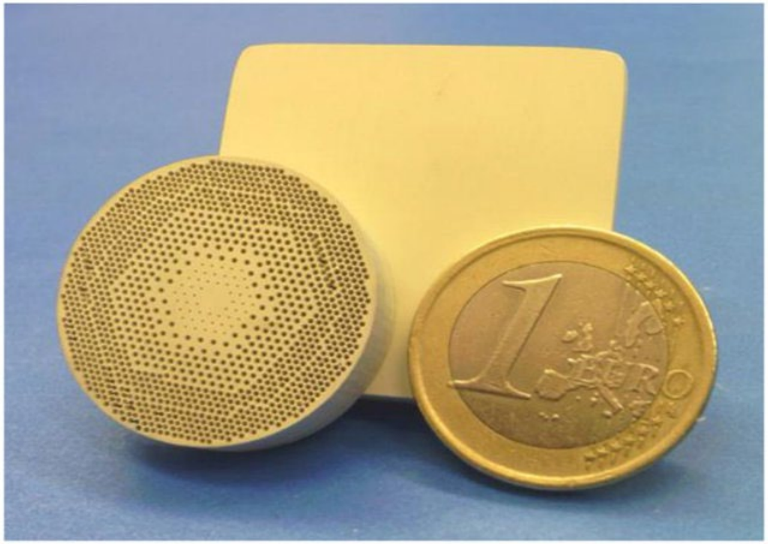


https://www.researchgate.net/publication/265382222_Design_and_Performance_Evaluation_of_a_Dielectric_Flat_Lens_Antenna_for_Millimeter-Wave_Applications

Gradient-index Lens Antenna

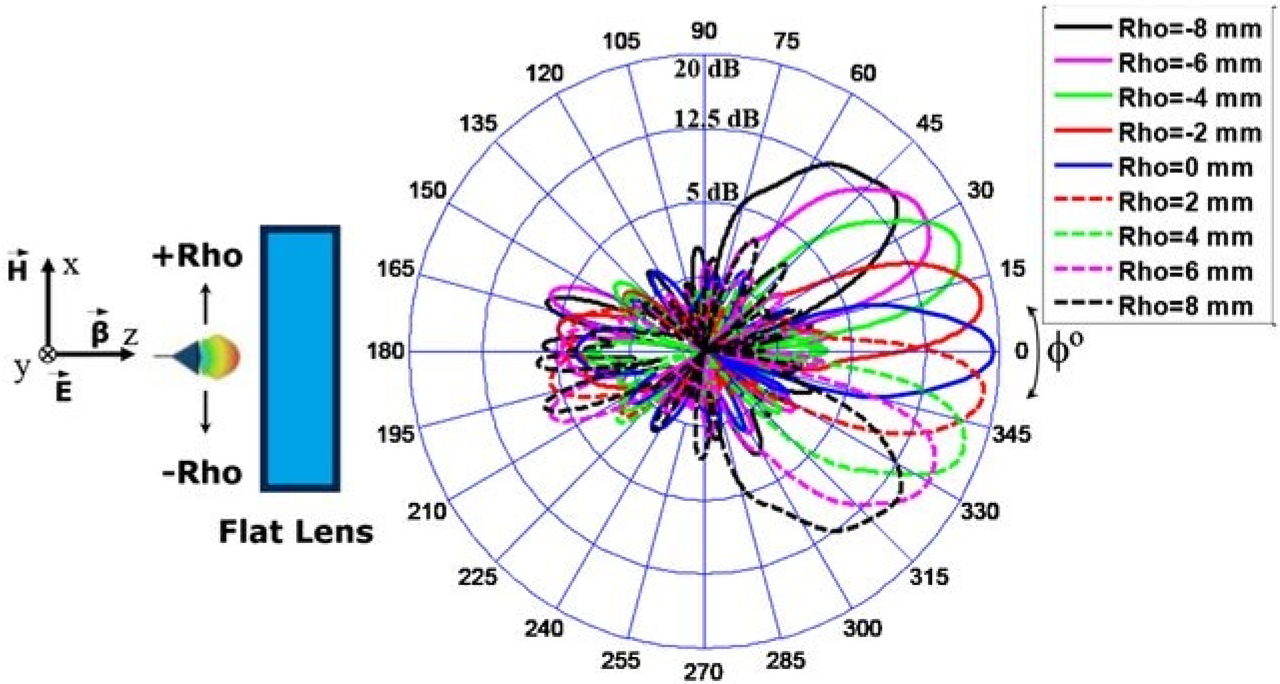
mm-wave Dielectric Flat Lens Antenna

- inhomogeneous gradient-index dielectric flat lens
- up to 18.3 dB of broadside gain
- beam-steering capabilities in both planes from -30° to +30° with around 15 dB of gain
- and up to ±45° with around 14 dB of gain, with low sidelobe levels.



https://www.researchgate.net/publication/265382222_Design_and_Performance_Evaluation_of_a_Dielectric_Flat_Lens_Antenna_for_Millimeter-Wave_Applications

Gradient-index Lens Antenna



H-plane gain (dB) radiation pattern CST simulation results at 60 GHz for each Rho feeding position

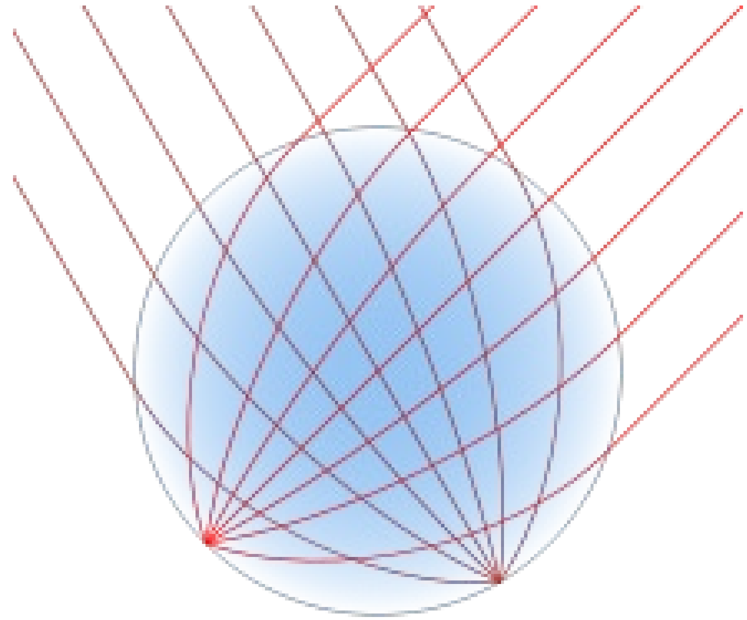
https://www.researchgate.net/publication/265382222_Design_and_Performance_Evaluation_of_a_Dielectric_Flat_Lens_Antenna_for_Millimeter-Wave_Applications

Gradient-index Lens Antenna

Video 9’22’’

Luneburg lens

- spherically symmetric [gradient-index lens]
- refractive index n decreases radially from the center to the outer surface.



Luneburg reflectors (the marked protrusion) on an F-35

Type 984 3D radar on HMS *Victorious*, 1961, using a Luneburg lens

Removable Luneburg lens type radar reflectors are sometimes attached to military aircraft in order to make stealth aircraft visible during training operations, or to conceal their true radar signature.

Gradient-index Lens Antenna

Luneburg lens

$$\varepsilon_r(r) = 2 - \left(\frac{r}{R}\right)^2$$

Lens Antenna

Pros:

- In lens antennas, feed and feed support, do not obstruct the aperture.
- It has greater design tolerance.
- Larger amount of wave, than a parabolic reflector, can be handled.
- Beam can be moved angularly with respect to the axis

Cons:

- Lenses are heavy and bulky, especially at lower frequencies
- Complexity in design
- Costlier compared to reflectors, for the same specifications

Applications:

- Used as wide band antenna
- Especially used for Microwave frequency applications

Homework

Use the formulars of the reflector analysis in this lecture to solve the following problem

[UG]

A small parabolic reflector of 1 m diameter is operated at 3 GHz. The taper efficiency is 80 percent; the spill over efficiency is 85 percent. Assume no other losses. Find

a) the total efficiency of the antenna in dB,

b) the directivity in dB.

[PG]

The 140-ft (42.672-m) paraboloidal reflector at the National Radio Astronomy Observatory, Green Bank, W. Va, has an *f/d* ratio of 0.4284. Determine the

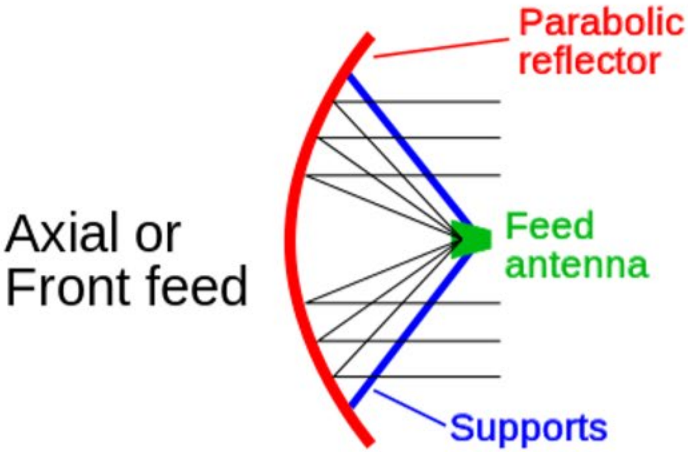
(a) subtended angle of the reflector

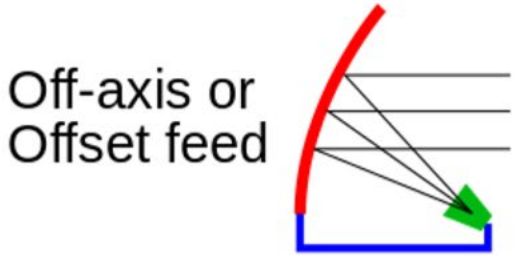
(b) aperture efficiency assuming the feed pattern is symmetrical and its gain pattern is given by $2\cos^2(\theta'/2)$, where θ' is measured from the axis of the reflector

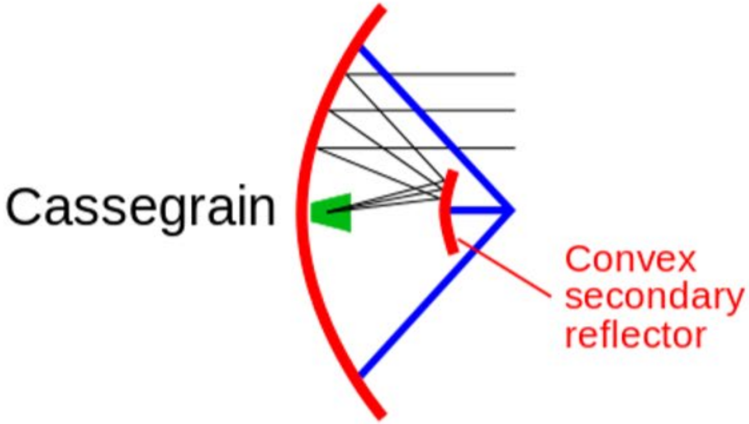
(c) directivity of the entire system when the antenna is operating at 10 GHz, and it is illuminated by the feed pattern of part (b)

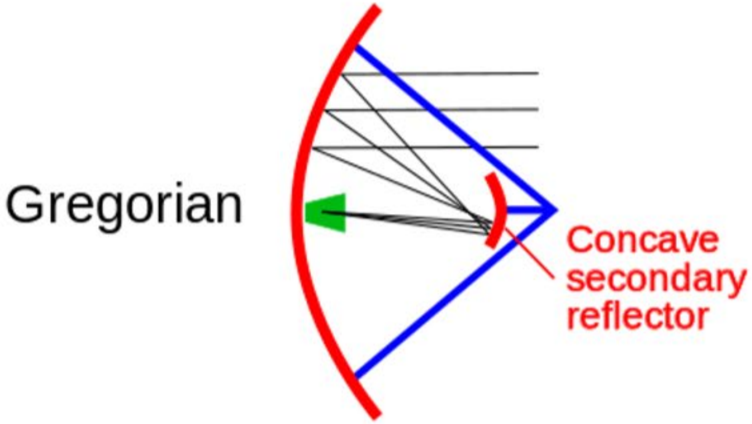
(d) directivity of the entire system at 10 GHz when the reflector is illuminated by the feed pattern of part (b) and the maximum aperture phase deviation is $\pi/16$ rad

Reflector Antenna Configurations



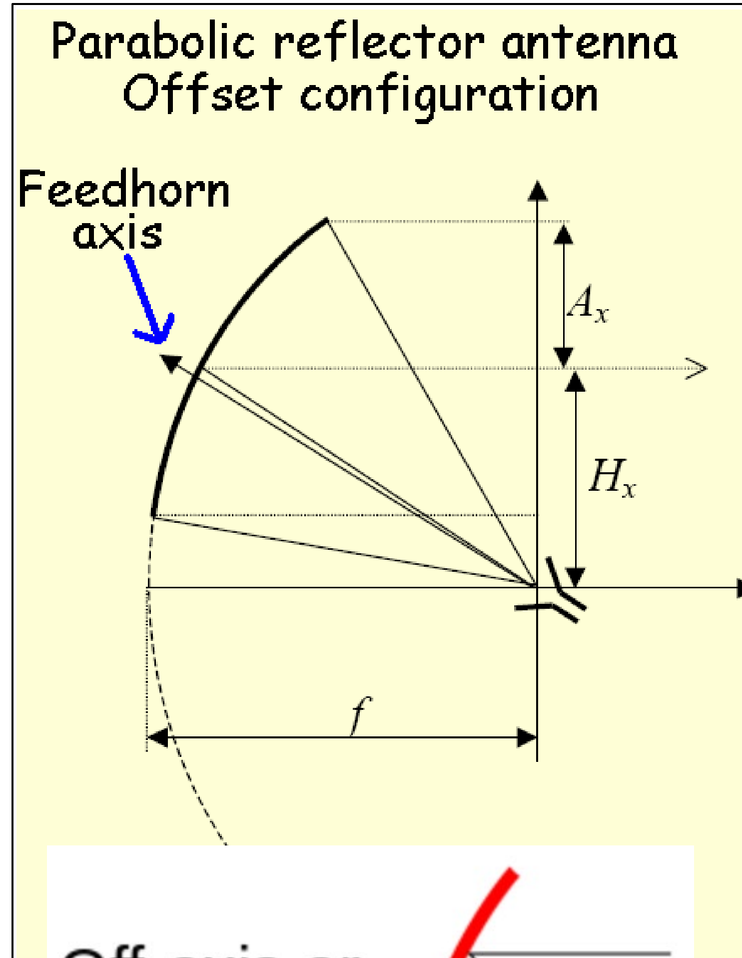


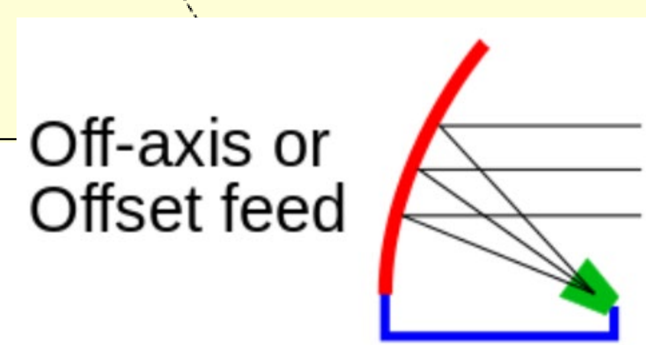




Offset Reflector Antennas

- The purpose: to move the feed antenna and its supports **out of the path** of the incoming radio waves. (avoid a “shadow” of the feed antenna)
- the radiation pattern of the feed-horn is symmetric, the reflector surface distribution will not be symmetric. This aspect will determine some of the antenna electrical characteristics



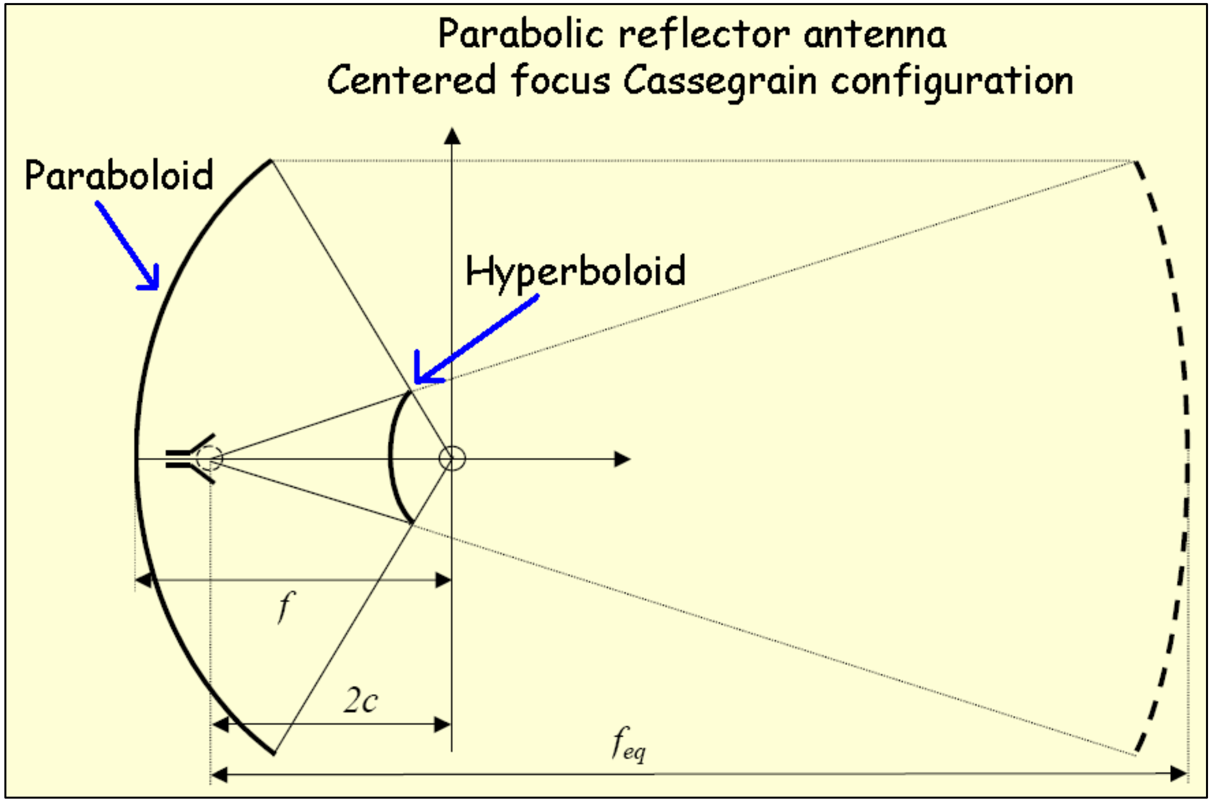


Offset Reflector Antennas

The advent in the 1970s of computer design tools which could easily calculate the radiation pattern of offset dishes has removed this limitation, and efficient offset designs are being used more and more widely in recent years.

Reflector Antennas

- In the **Cassegrain configuration**, the feed-horn presents a more directive radiation pattern to illuminate the parabolic surface through an hyperbolical sub-reflector.



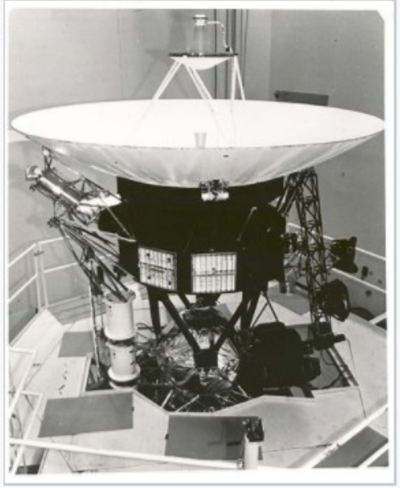
Reflector Antennas

- In the **Cassegrain configuration**, the feed-horn presents a more directive radiation pattern to illuminate the parabolic surface through an hyperbolical sub-reflector.

Cassegrain satellite communication antenna in Sweden. The convex secondary reflector can be seen suspended above the dish, and the feed horn is visible projecting from the center of the dish.

Closeup of the convex secondary reflector in a large satellite communications antenna in Pleumeur-Bodou, France

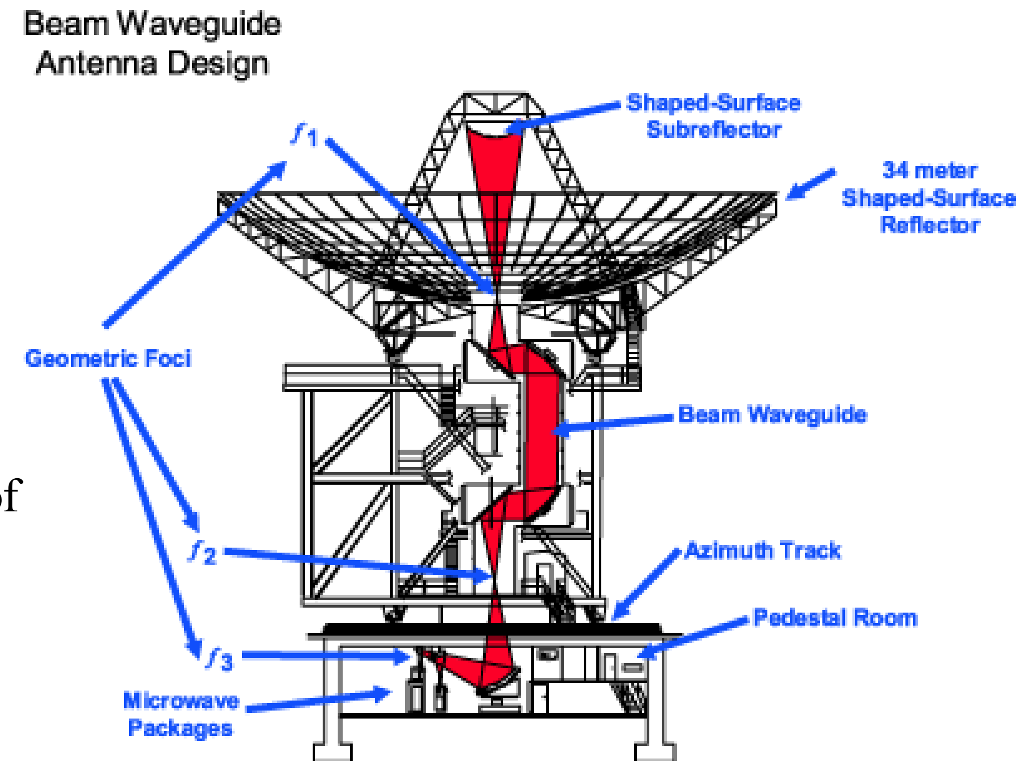
Cassegrain spacecraft communication antenna in Canberra, Australia, part of NASA's Deep Space Network. The advantage of the Cassegrain design is that the heavy complicated feed structure *(bottom)* doesn't have to be suspended over the dish.



Cassegrain antenna on the Voyager spacecraft

Reflector Antennas

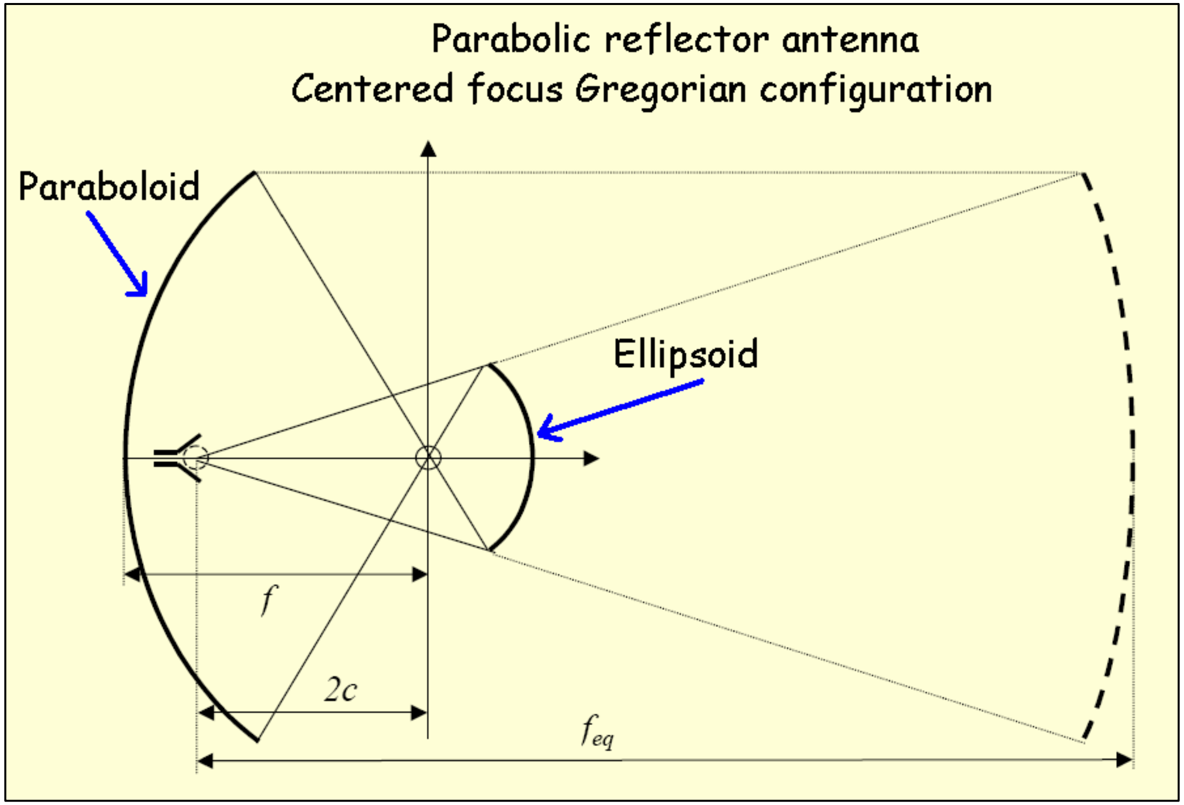
- In the **Cassegrain configuration**, the feed antennas and associated equipment can be located on or behind the dish, rather than suspended on the supporting beam. Therefore, this design is used for antennas with bulky or complicated feeds.



A beam waveguide antenna, a type of Cassegrain design, showing the complicated signal path.

Reflector Antennas

- The **Gregorian configuration** presents a more directive feed-horn to illuminate the parabolic surface through an elliptical sub-reflector.



Reflector Antennas

- The **Gregorian configuration** presents a more directive feed-horn to illuminate the parabolic surface through an elliptical sub-reflector.

Kratos 9.4m C- (3-6GHz) or Ku-band (12-18GHz) Earth Station Antenna

This antenna system is used worldwide in broadcast applications and high density data, voice and communications

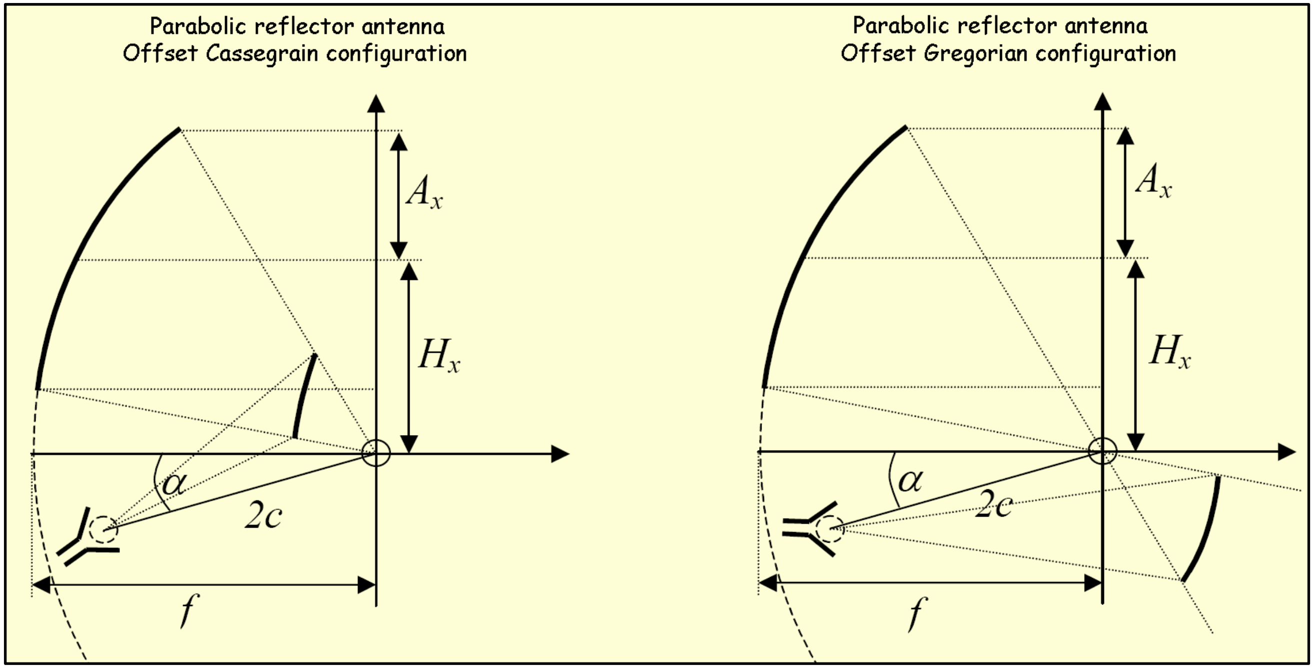
Features

- Rugged aluminum and steel construction
- Superior Pointing Accuracy
- Advanced Gregorian optics
- 3 Year Warranty on all Structural Components
- Configured for C-Band, X-Band, Ku-Band and K-Band Tx and Rx

https://sky-brokers.com/product/kratos-9-4m-c-or-ku-band-earth-station-antenna/

Reflector Antennas

- The **off-set** versions are also possible to reduce blockage.
- An adequate selection of an angle improves the aperture illumination symmetry (Mizugutch condition*)



*Dragone-Mizuguchi condition set the tilting of the subreflector axis with respect the main reflector axis in order to cancel the cross-polarization.

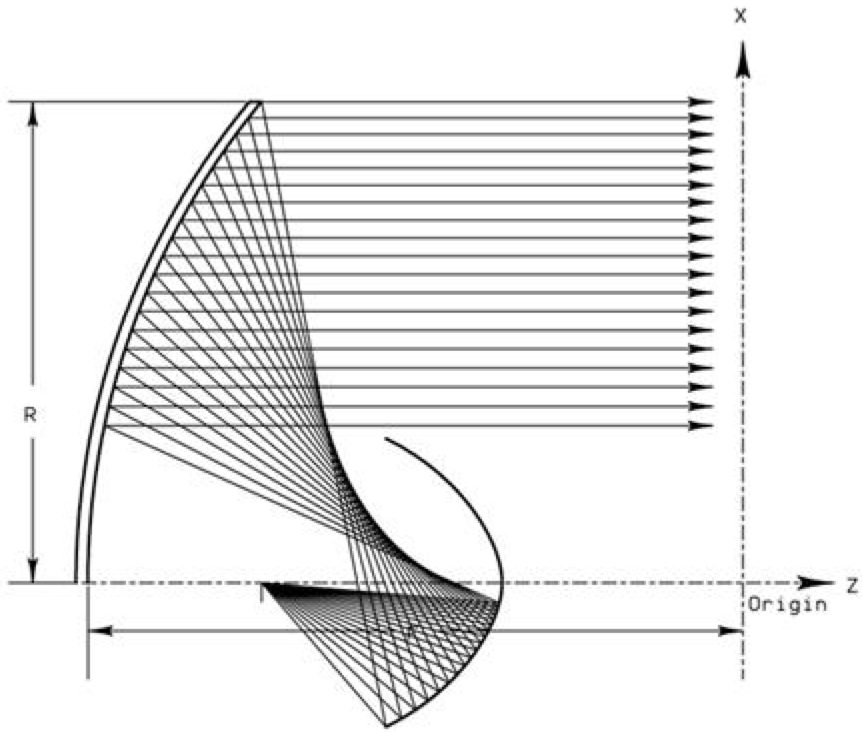
Reflector Antennas

- The **off-set** Gregorian versions are also possible.

Reflector Antenna Design

Generalized Dual Reflector

The antenna has a main reflector that ranges from a sphere (k = 0) to a parabola (k = 1) finally to a plane (k = 2). The parameter k various continuously but sphere and plane can be only approached asymptotically.



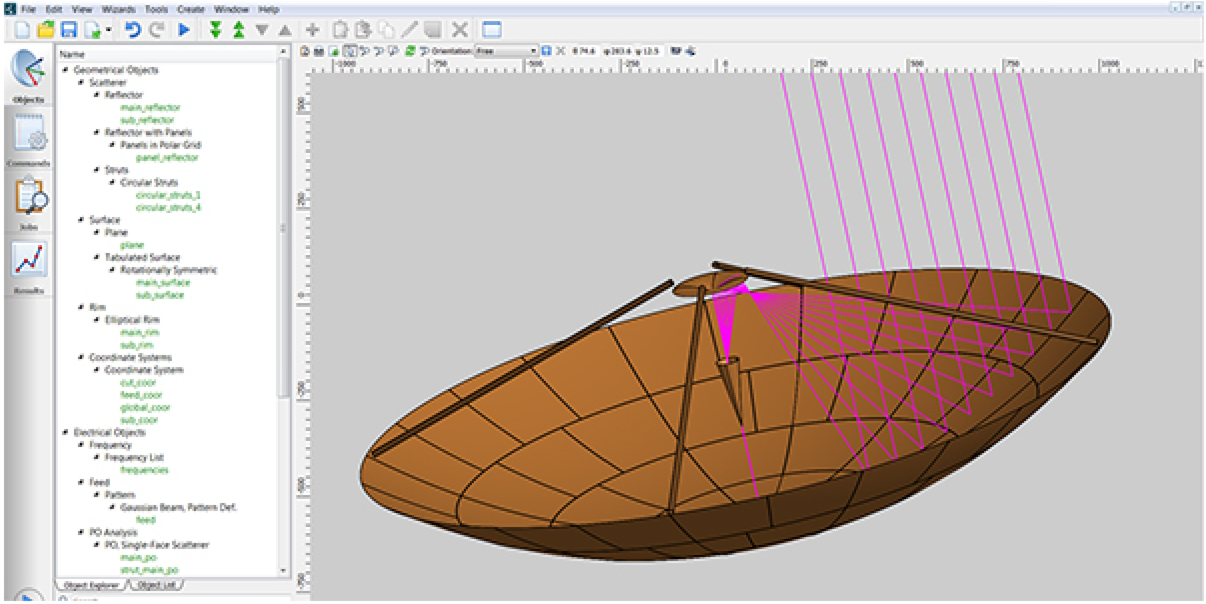
The October 2012 issue of *IEEE Antenna and Propagation Magazine,* Vol. 54, No. 5 contains the article Generalized Dual-Reflector Axisymmetric Antennas by Norayr R. Khachatryan, Ruben V. Ter-Antonyan which discusses an approach to this antenna. Equations are given for a subreflector that focuses rays to a feed point. An executable gerdual that runs in a DOS window designs the antenna and generates input files to GRASP.

Reflector Antenna Design

Analysis and design of reflector antenna systems (GRASP)

Dedicated software for reflector systems, enabling fast and accurate analysis and design of the most advanced reflector antenna systems. Multiple antennas may be defined within the same project, and the general command structure enables the user to define which of those will be considered during a given analysis. This opens for the possibility of making advanced scattering analysis of clusters of antennas. GRASP offers an advanced PO (Physical Optics) algorithm as the baseline analysis method, supplemented by optional GTD (Geometrical Theory of Diffraction) and Moment Method solvers for advanced applications.

How to setup GRASP 3’52”

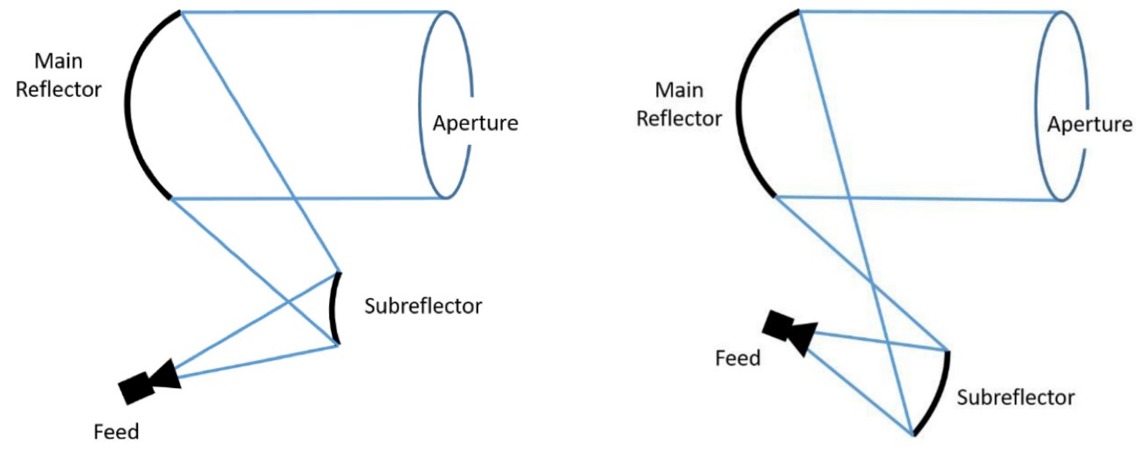


Reflector Antenna Design

Analysis and design of reflector antenna systems (CST)

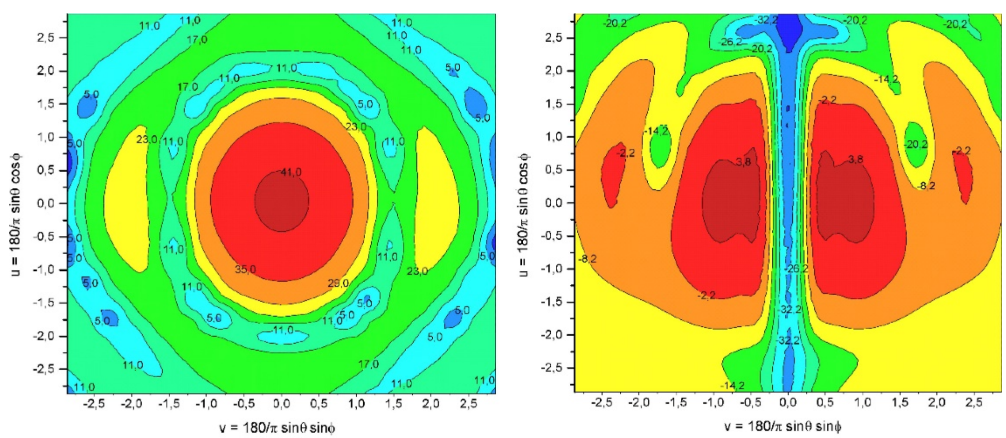
CST Tutorial: Complete Parabolic Reflector (Dish) Antenna Design & Simulation (Tensorbundle Lab)

Offset Reflector Antennas



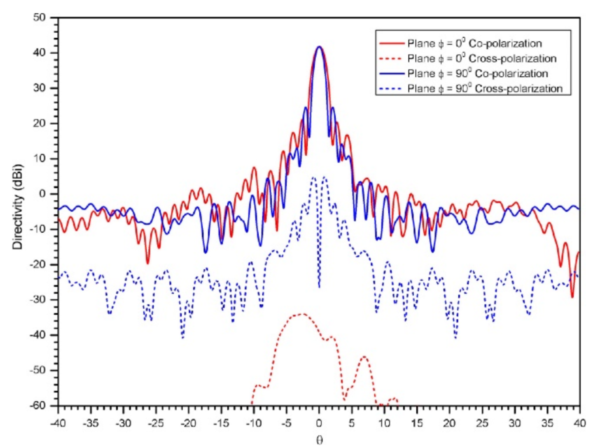
(a) (b)

Offset dual-reflector antennas: (a) Cassegrain and (b) Gregorian configurations.



(a) (b)

(a) Co-polar and (b) cross-polar radiation patterns in the *uv*-plane at 11.725 GHz.



Radiation patterns of the shaped offset dual reflectors at 11.725 GHz.

https://www.scielo.br/scielo.php?pid=S2179-10742020000200177&script=sci_arttext&tlng=en

Summary of Reflector Analysis

- Centered focus configurations: **symmetrical** than offset configurations so they present **lower cross-polar levels** but **suffer from blockage**
- The double reflector offset configurations: can **reduce the cross-polar levels** if they are designed with the Mizugutch condition (negligible cross polarization at the center of the field of view)
- The double reflector configuration need **higher directivity feeds** and present **less spillover losses** so their noise temperature* is lower.

* noise temperature is a parameter that describes how much noise an antenna produces in a given environment.