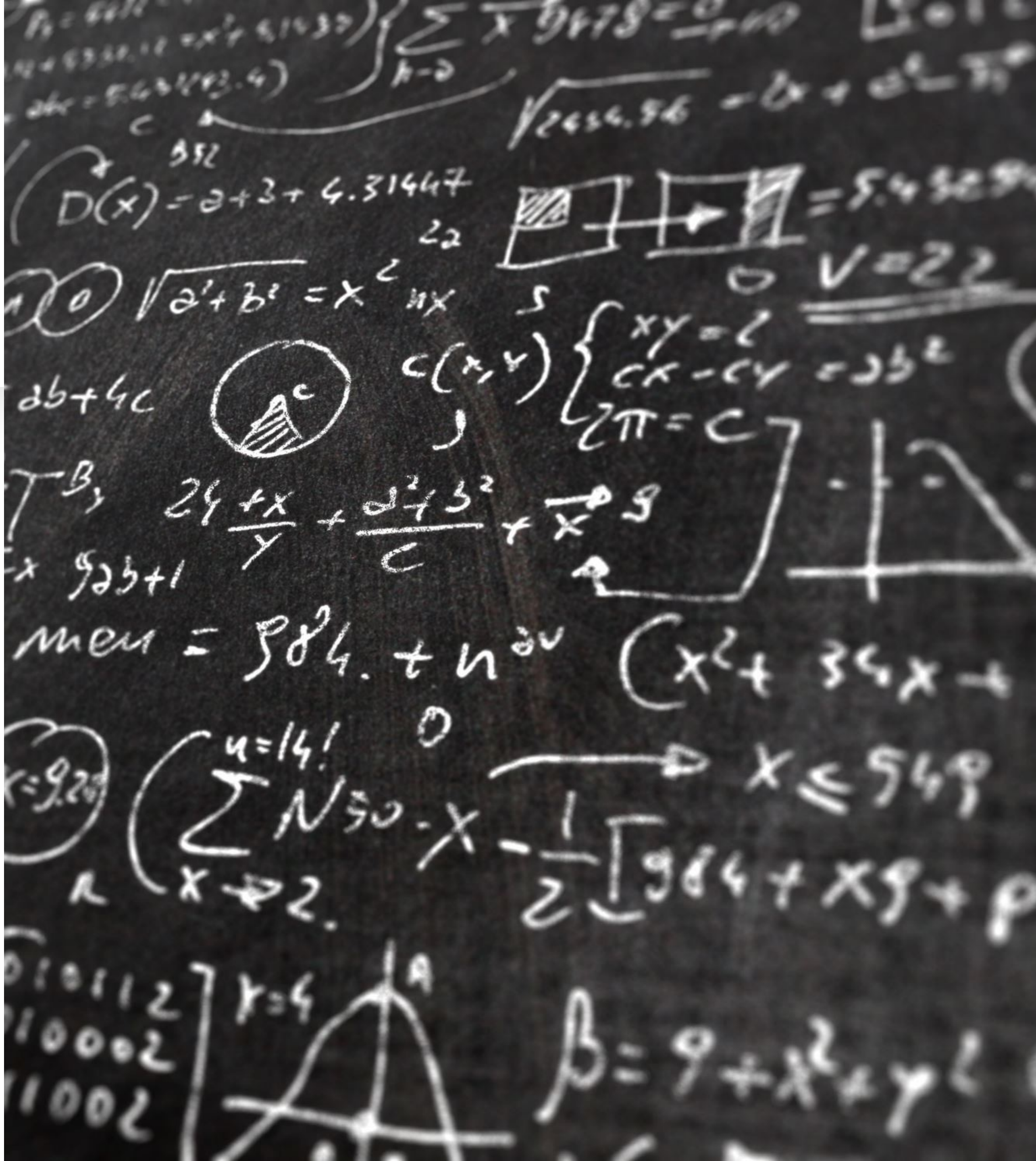
An intuitive tour of parabolic reflector antennas

By K6MG

Introduction

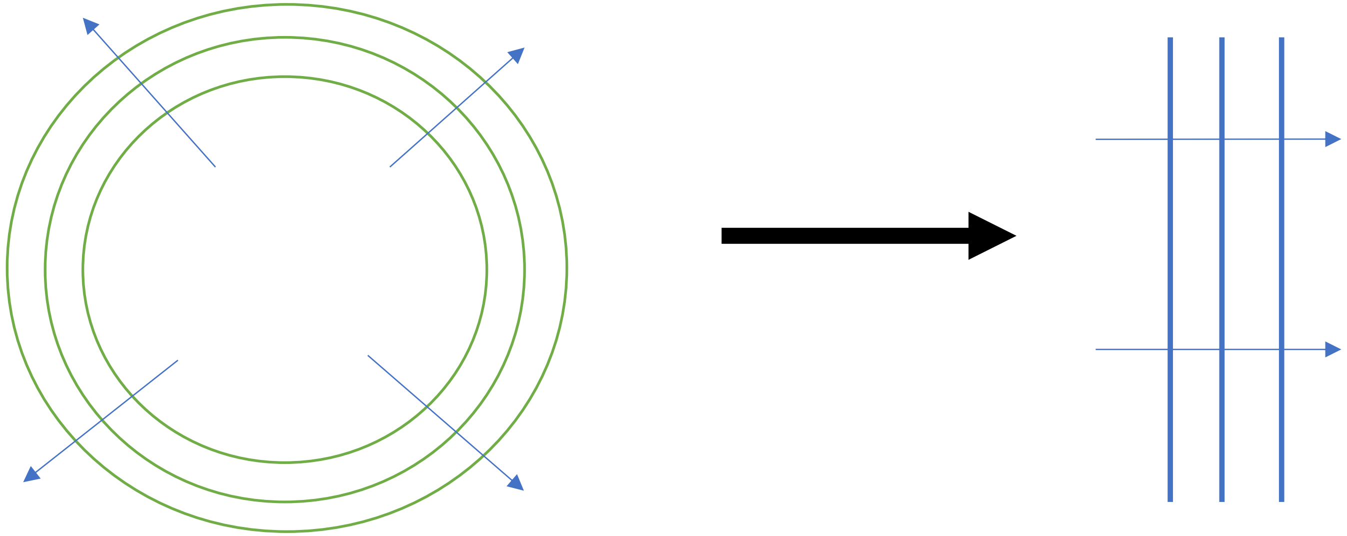
- No equations will be used in this presentation, however several equations were harmed in the preparation
- Why a parabola reflector ?
- The full parabola
- The offset parabola
- Multiple reflectors
- The ADE
- Reflectarray and Fresnel reflectors



Goal: directivity

Spherical wavefront

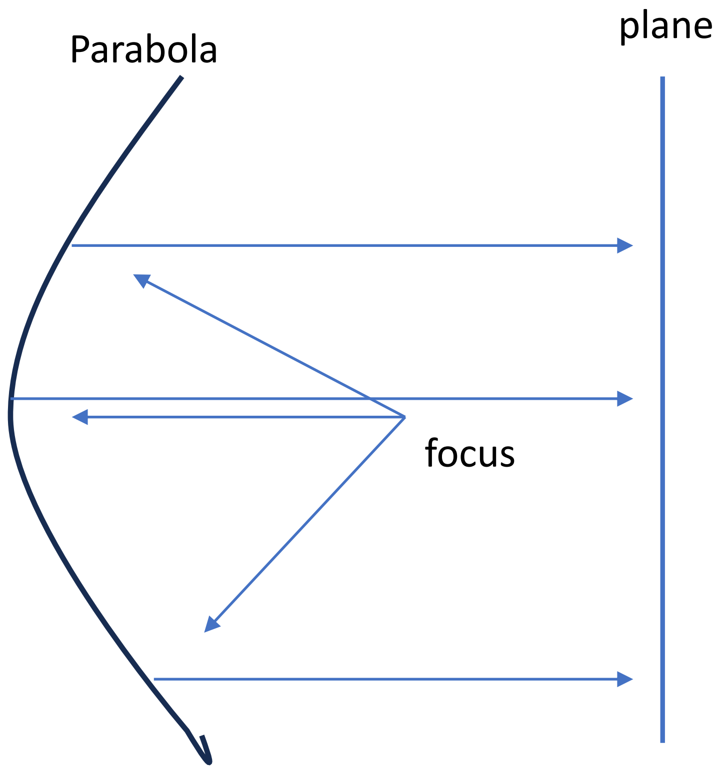
Planar wavefront



Wavefront: constant phase across the surface

Propagation through space and time

Conversion from spherical to planar wavefronts



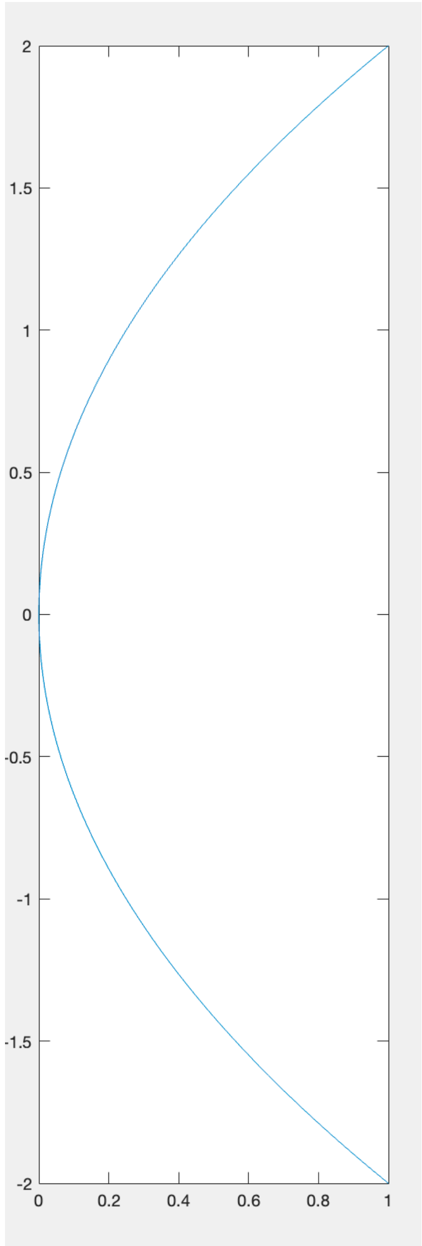
Constant distance from the focus to the plane at all angles

Canonical full parabola

- Diameter 4 units
- Focal length 1 unit
- F/D 0.25

- Were only interested in parabolas with F/D > 0.25 since smaller F/D becomes too deep

- Any parabola of interest can be made from this curve by truncating the diameter to get the desired F/D and scaling the units to the desired size

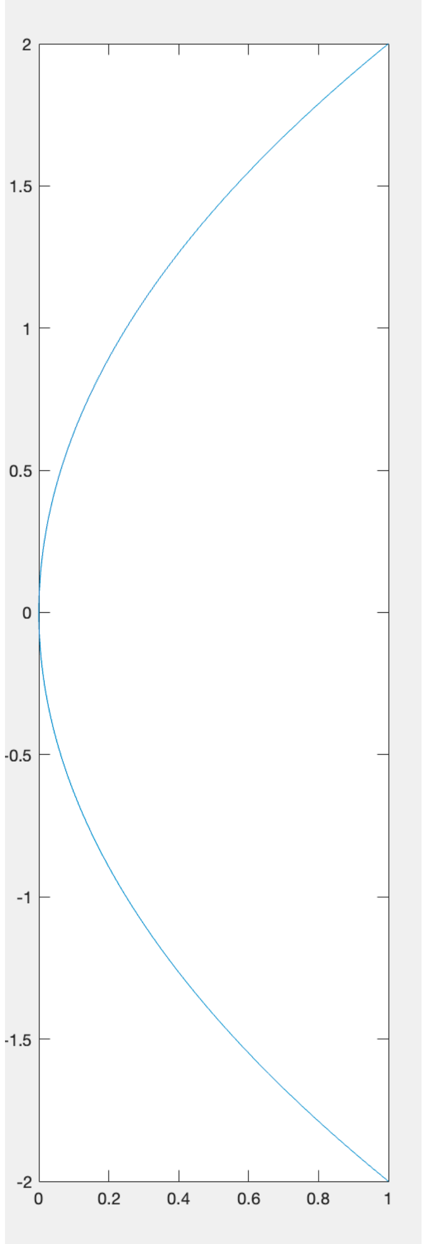


Things to notice

- Truncating the diameter for higher F/D results in a “shallower” curve: the focus stays at the same place but the parabola edges pull back toward zero

- At 0.25 F/D the edges are in the same plane as the focus

- The angle of incidence == the angle of reflection, at 0 degrees the surface of the parabola is perpendicular to the wavefront, at 90 degrees the surface of the parabola is 45 degrees to the wavefront



The offset parabola

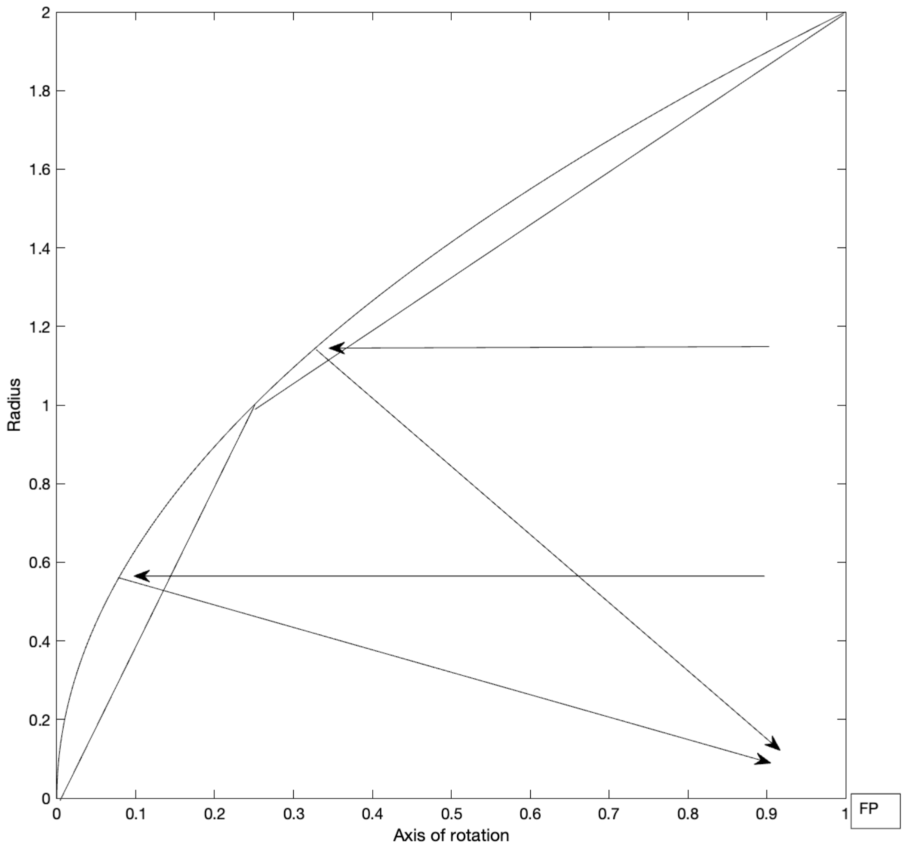
Uses at most half of the parabolic curve

The “offset” can be >0 by starting the curve >0

The focal length is defined as the distance from the lower edge of the curve to the focal point

The tilt angle is the angle from vertical of the plane across the edges

The “diameter” is defined as the aperture of the incoming/outgoing planar wavefront

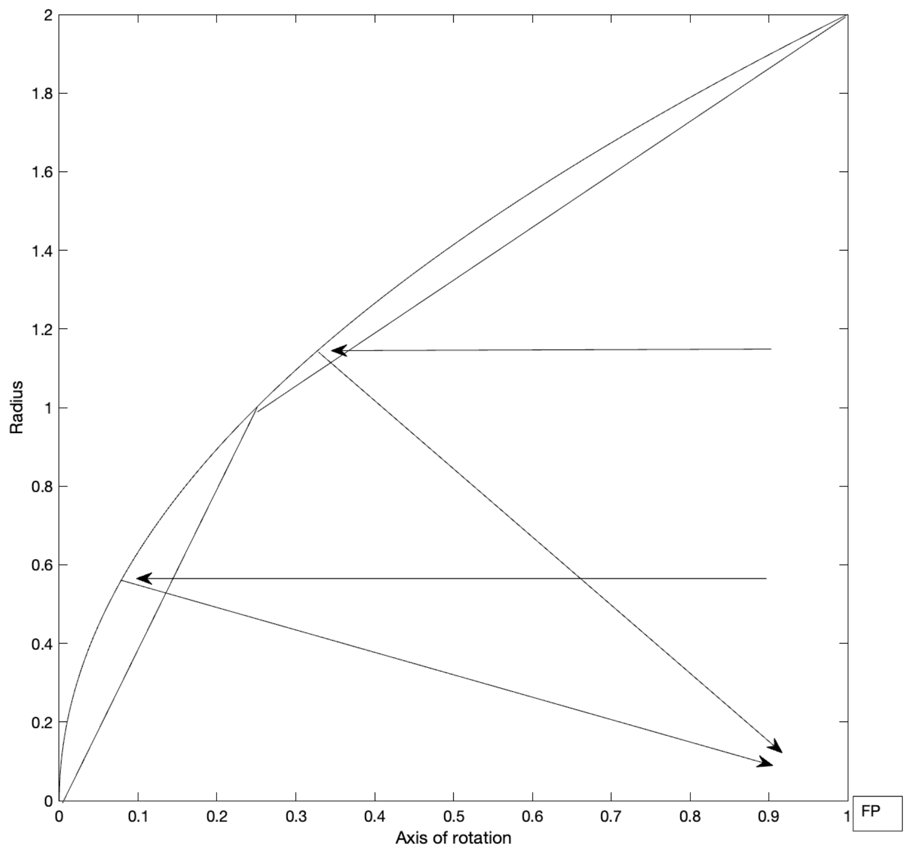


Things to notice

The tilt angle is a function of F/D for any given offset, only one tilt angle is possible for an F/D

Offsets >0 require a larger segment of the curve to achieve the same aperture

A zero offset parabola has exactly double the F/D of the equivalent full parabola, the focal length is the same as the full parabola



Offset tilt vs. F/D

Tilt Angle	F/D
14.5	1
15.25	0.95
16	0.9
17	0.85
18	0.8
19.25	0.75
20.8	0.7
22.6	0.65
24.5	0.6
27	0.55
30	0.5

Inefficiencies

Illumination – nonconstant energy across the dish surface

Spillover – feed energy spills over the edge of the dish

Blockage – feed and supports block part of the aperture

Ohmic – reflective surface is not a perfect conductor

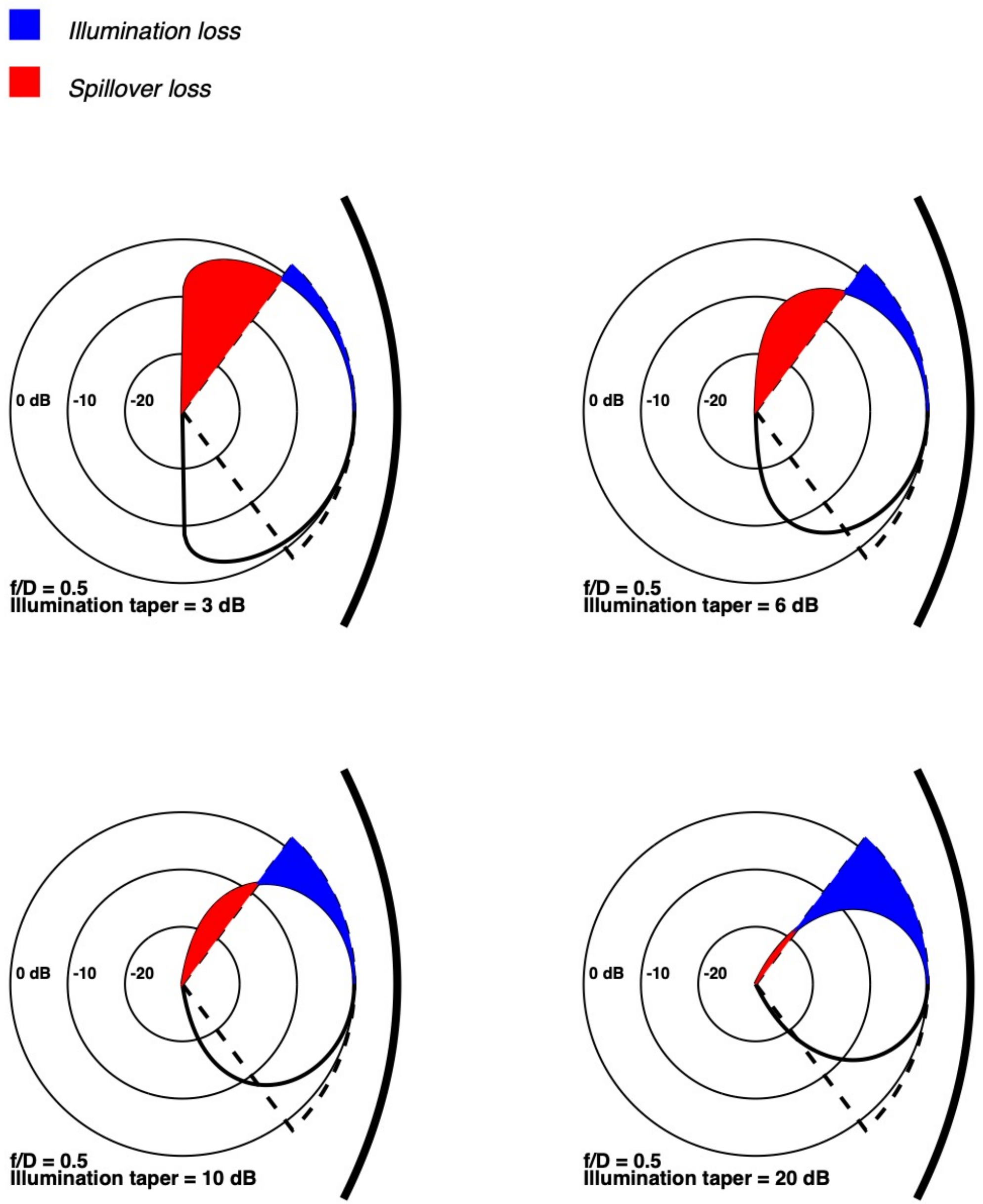
Surface – surface shape deviates from a perfect parabola

Diffraction – feed, supports and dish edges diffract some of the energy

Feedline – energy loss between the radio and the feed

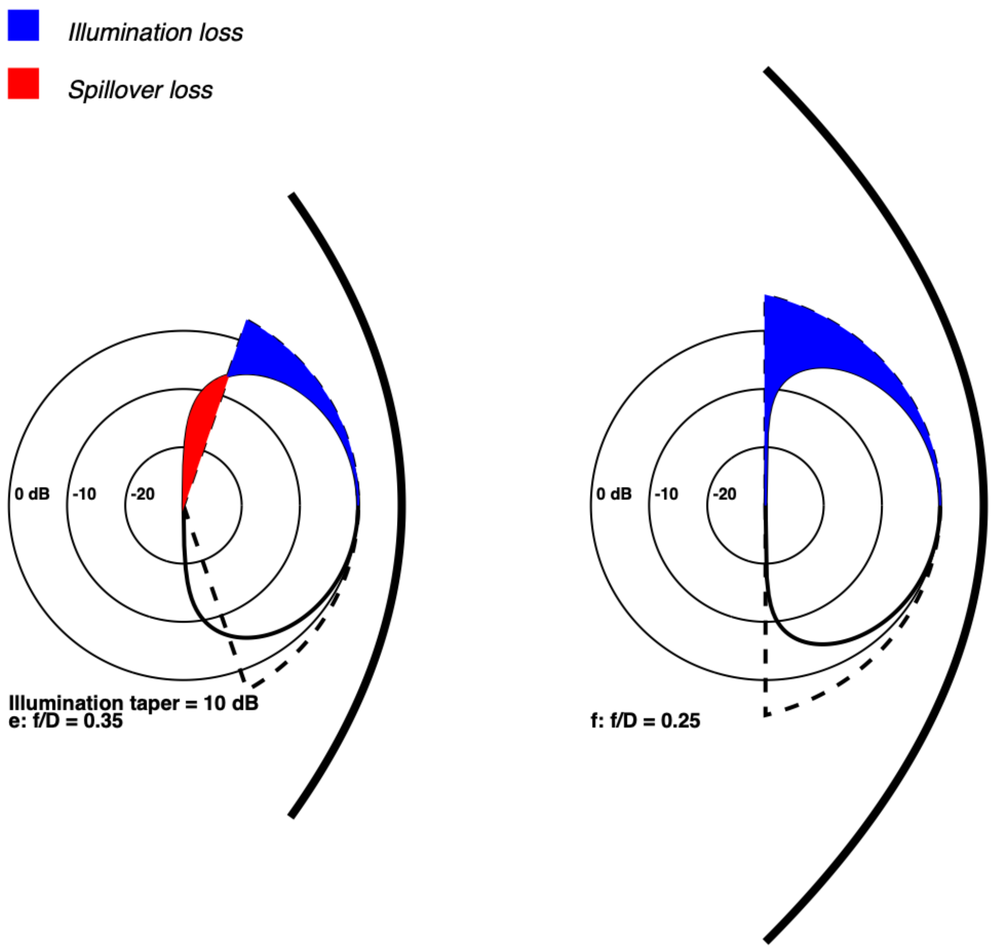
Inefficiency	Prime focus	Offset
Illumination	0.88	0.88
Spillover	0.88	0.88
Blockage	0.90	0.97
Ohmic	0.99	0.99
Surface	0.97	0.97
Diffraction	0.95	0.98
Feedline	0.90	0.98
	57%	69%
	-2.4 db	-1.6 db

Illumination and Spillover



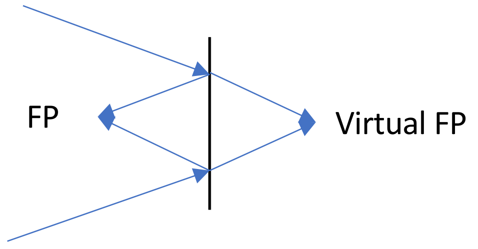
Illumination and Spillover

Illumination and Spil

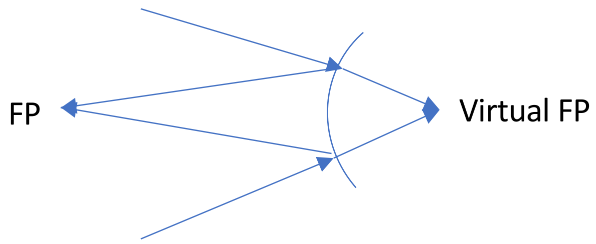


Multiple Reflectors

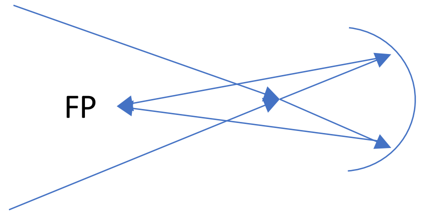
Newtonian – flat sub-reflector



Cassegrain – hyperbolic sub-reflector



Gregorian – elliptical sub-reflector



Why??

- + Reduce feedline loss by moving the FP back toward the dish
- + Cassegrain and Gregorian multiply the F/D improving illumination efficiency of low F/D dishes
- - for small dishes blockage increases significantly
- - double diffraction, spillover and ohmic losses

Example Cassegrains

18” diameter main
2.75” diameter sub
2.5% sub blockage
40 GHz min

10 GHz min
10” diameter sub
31% sub blockage

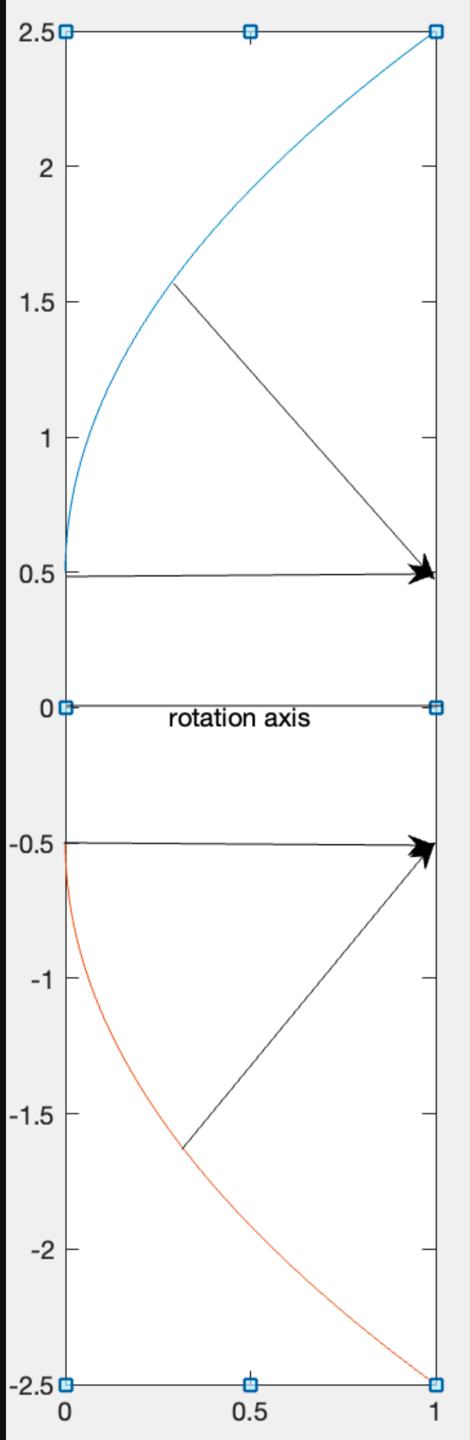
36” diameter main
4” diameter sub
1.4% sub blockage
24 GHz min

Axially Displaced Ellipse (Gregorian)

Step 1: displace the parabola from the origin opening up a hole in the center

This creates a circular ring of focus rather than a point focus

In the example the parabola is displaced 0.5 from the origin

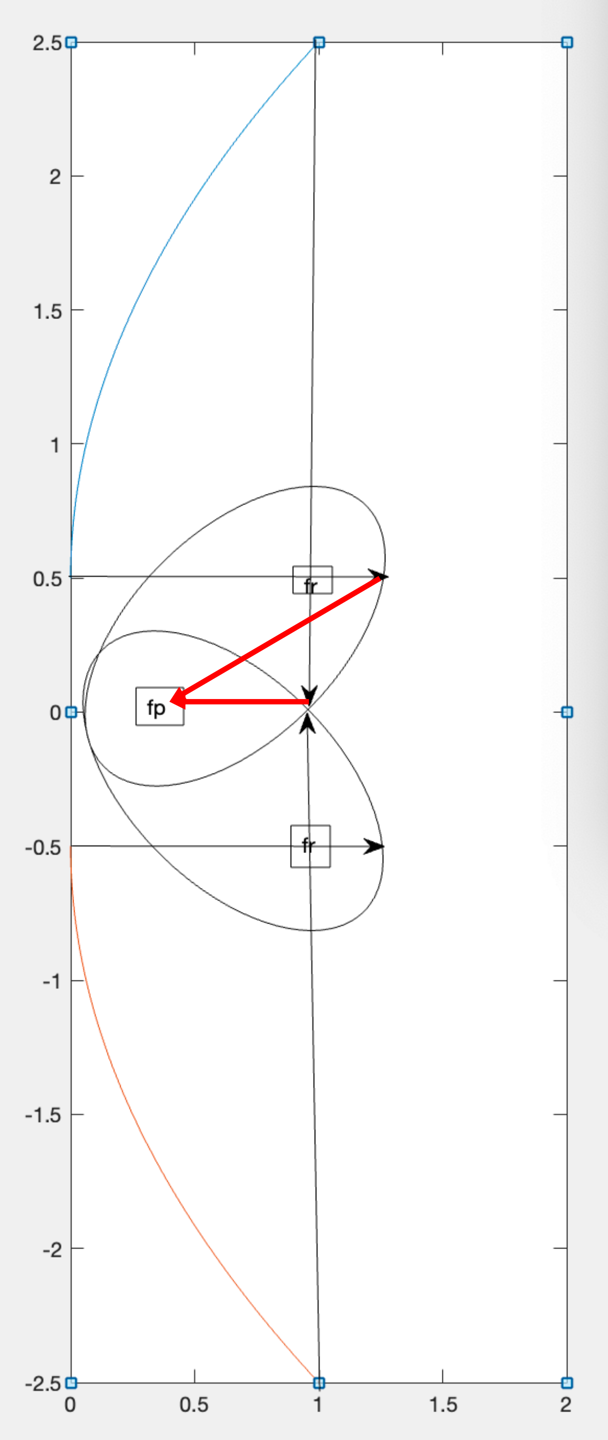


ADE

Step 2: use a rotated tilted ***ellipse*** to convert the focus ring to a focus point

Note that at the focus ring the wavefronts to the inner and outer edges of the displaced parabola cross

The crossing distributes the highest energy density of the feed to the outer edges of the parabola



Inefficiencies ADE vs. Offset

Inefficiency	ADE	Offset
Illumination	0.96	0.88
Spillover	0.96	0.88
Blockage	0.96	0.97
Ohmic	0.99	0.99
Surface	0.97	0.97
Diffraction	0.98	0.98
Feedline	0.98	0.98
	82%	69%
	-0.9 db	-1.6 db

Shaped multiple reflectors

Don’t have to use conic sections (Parabola,ellipse,hyperbolic) as long as the ray traced distance from the feedpoint to the planar wave is constant

Shaping the sub-reflector and the main reflector enables better energy distribution to be achieved like the ADE

Efficiencies of up to 85% have been measured

Reflectarray

- Don’t have to make all the path lengths equal!!!
- It’s the constant phase at the plane that ensures directivity
- Equal path lengths produce an in-phase wavefront at all frequencies
- If we can operate narrow band other reflector structures become possible
- For instance: a planar array of dipole reflectors that use passive or active phase tuning to produce an in-phase reflected wavefront

Fresnel reflector

A Fresnel dielectric plate in front of a flat reflector can be used to generate the phase shifts needed to result in a planar wavefront

The dielectric thickness is kept low in order to minimize absorption loss

Efficiencies of <= 30% are typical for this type of structure

Conclusions

- There are a wide range of parabolic type reflector antennas with various tradeoffs:

  Efficiency

  Ease of construction

- Efficiencies higher than a good offset parabola while possible are less than 1 db