Parabolic Dishes with Flat Subreflectors

Paul Wade

W1GHZ

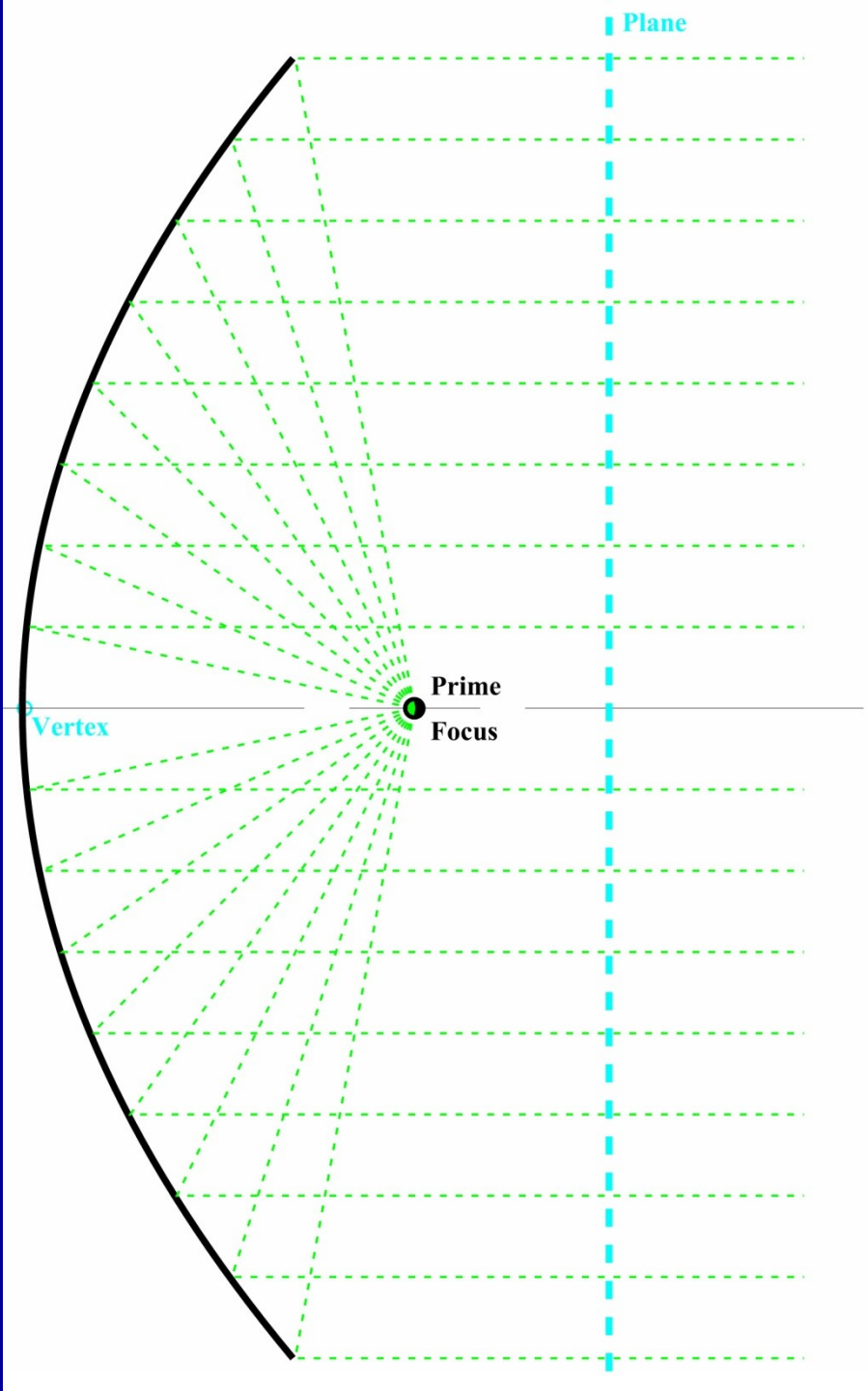
New W1GHZ QTH - Vermont



Multiple-reflector Antennas

- Cassegrain
  - *Convex*
- Gregorian
  - *Concave*
- Flat

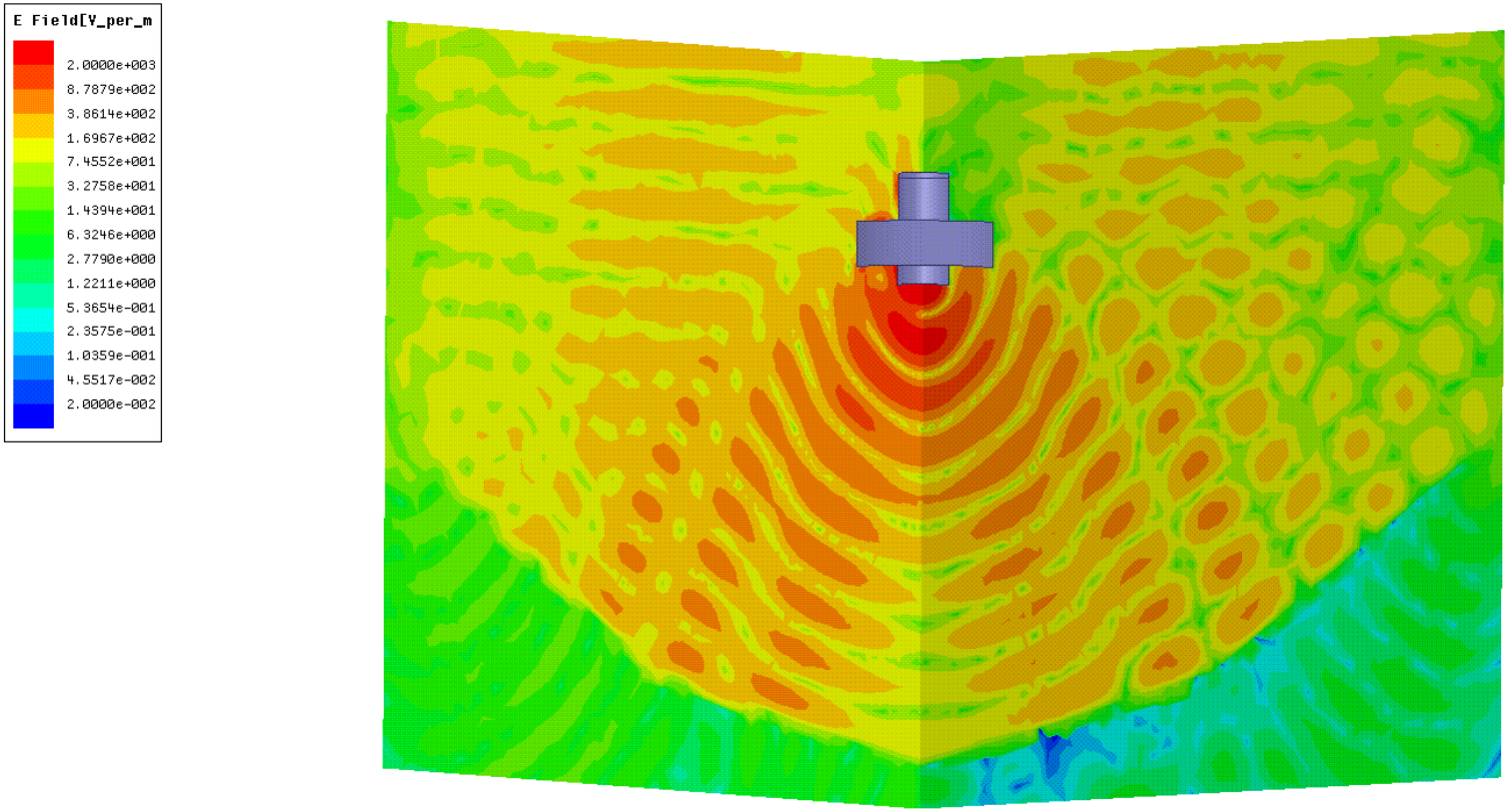




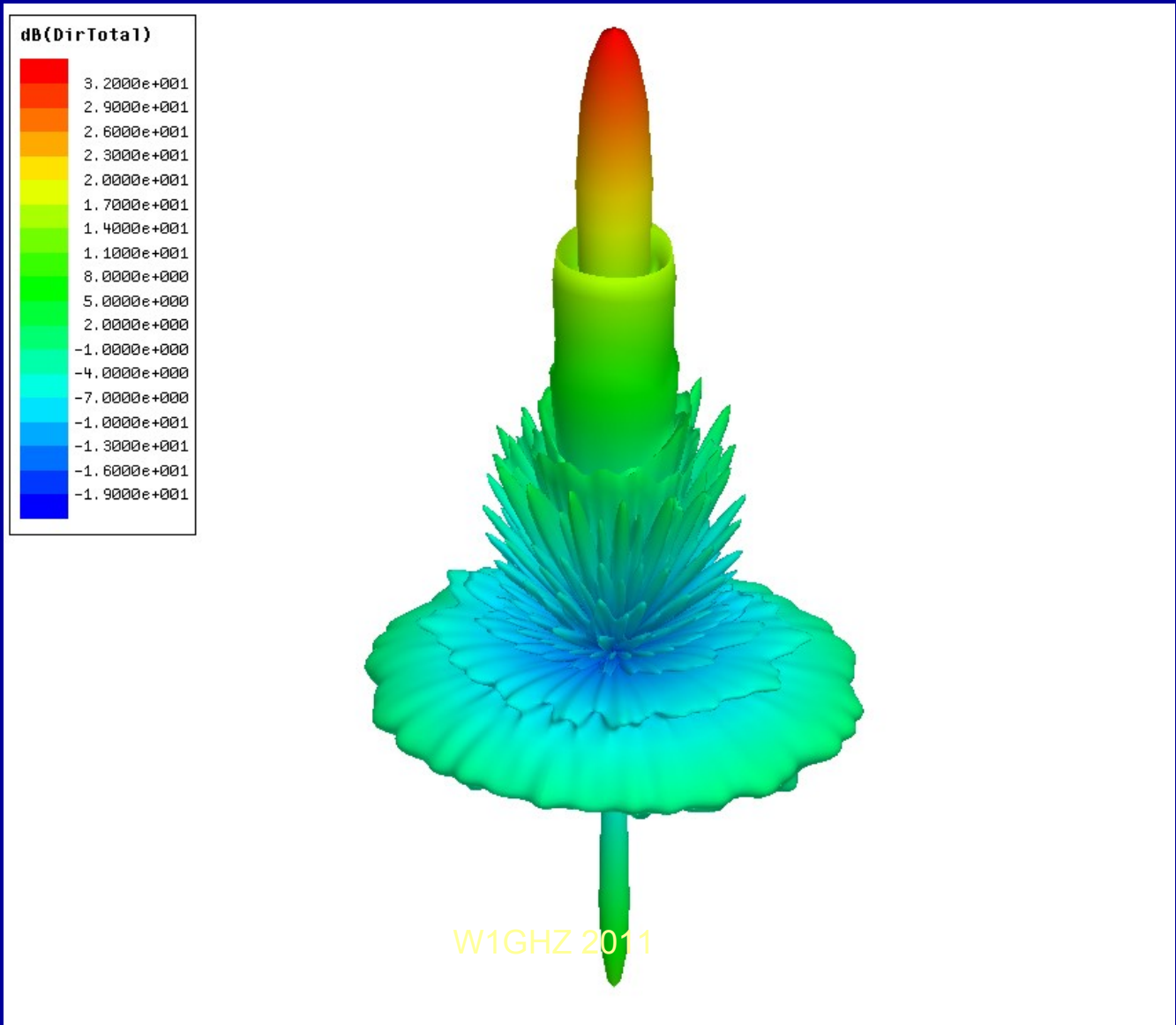
Parabolic reflector

- All paths from focus to plane are equal length
- ***IN PHASE***

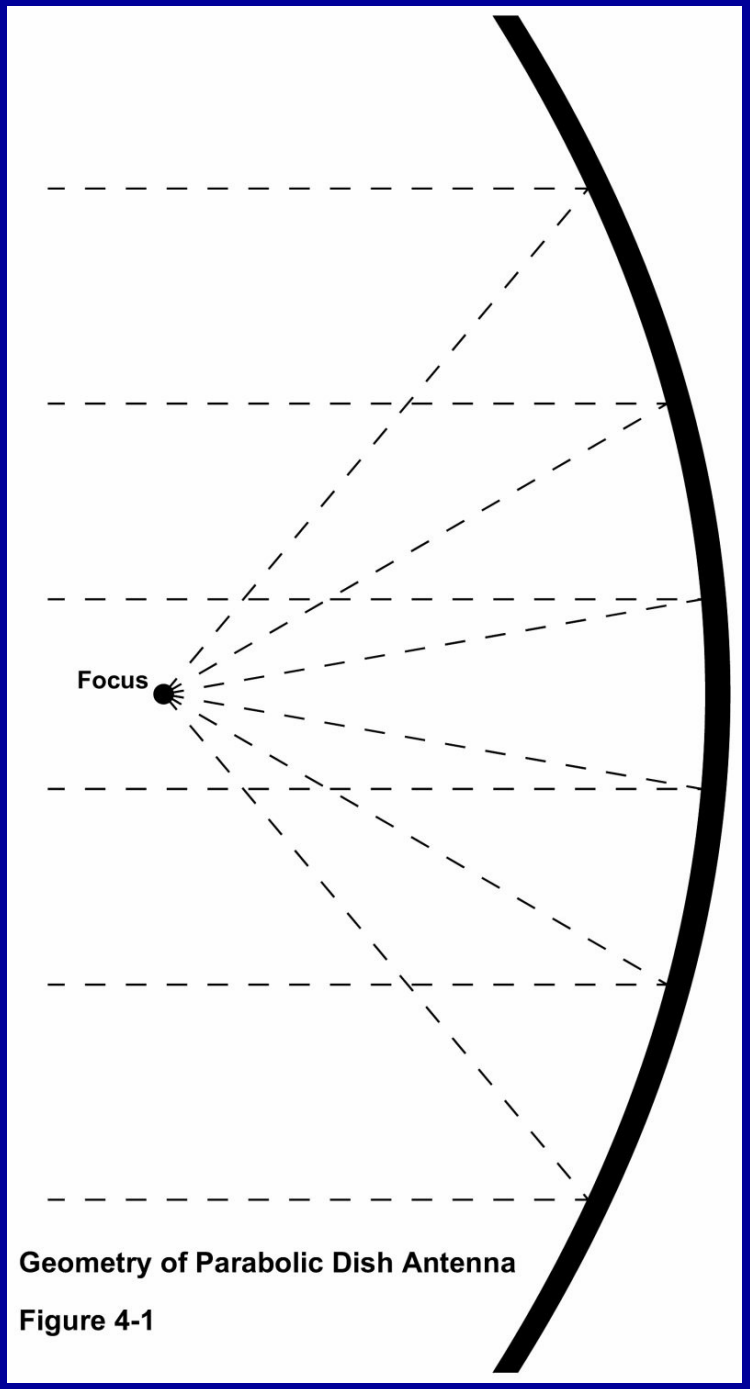
Parabolic Dish animated



Dish has narrow beam



Parabolic Dish Feed Review

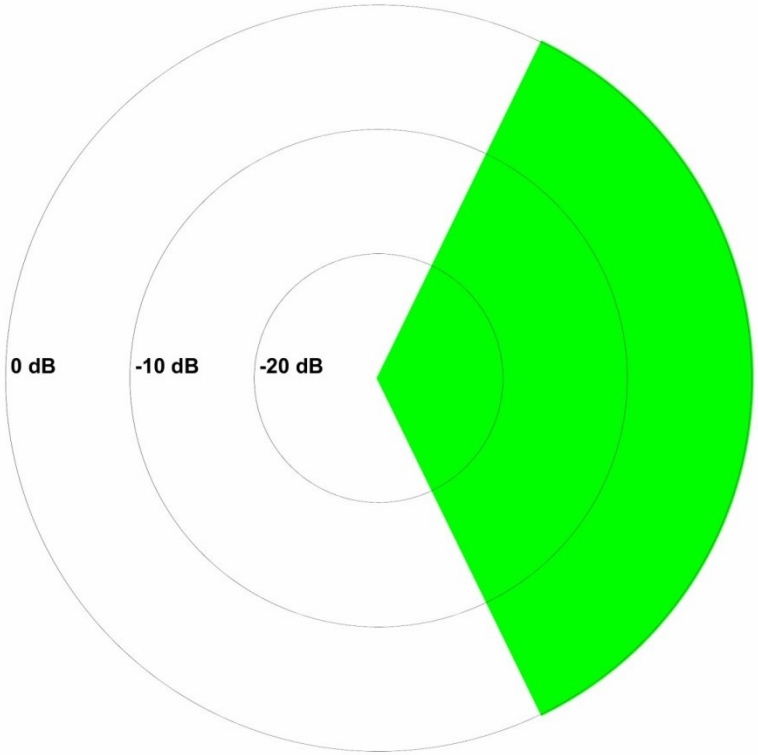


Geometry of Parabolic Dish Antenna

Figure 4-1

Uniform Illumination

At feed

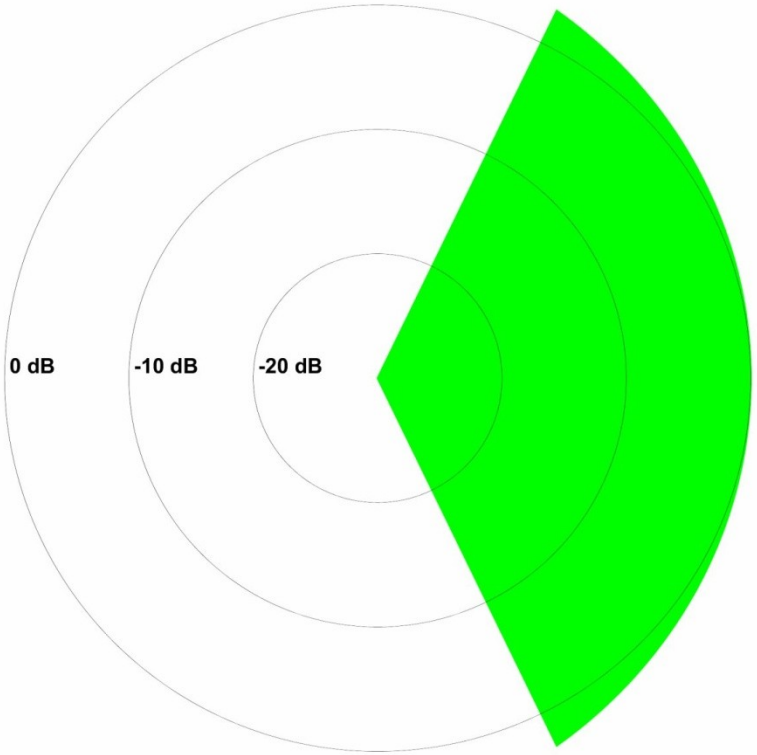


Parabolic Dish Antenna with Uniform Feed Illumination

Figure 4-2

N1BWT 1994

On Reflector

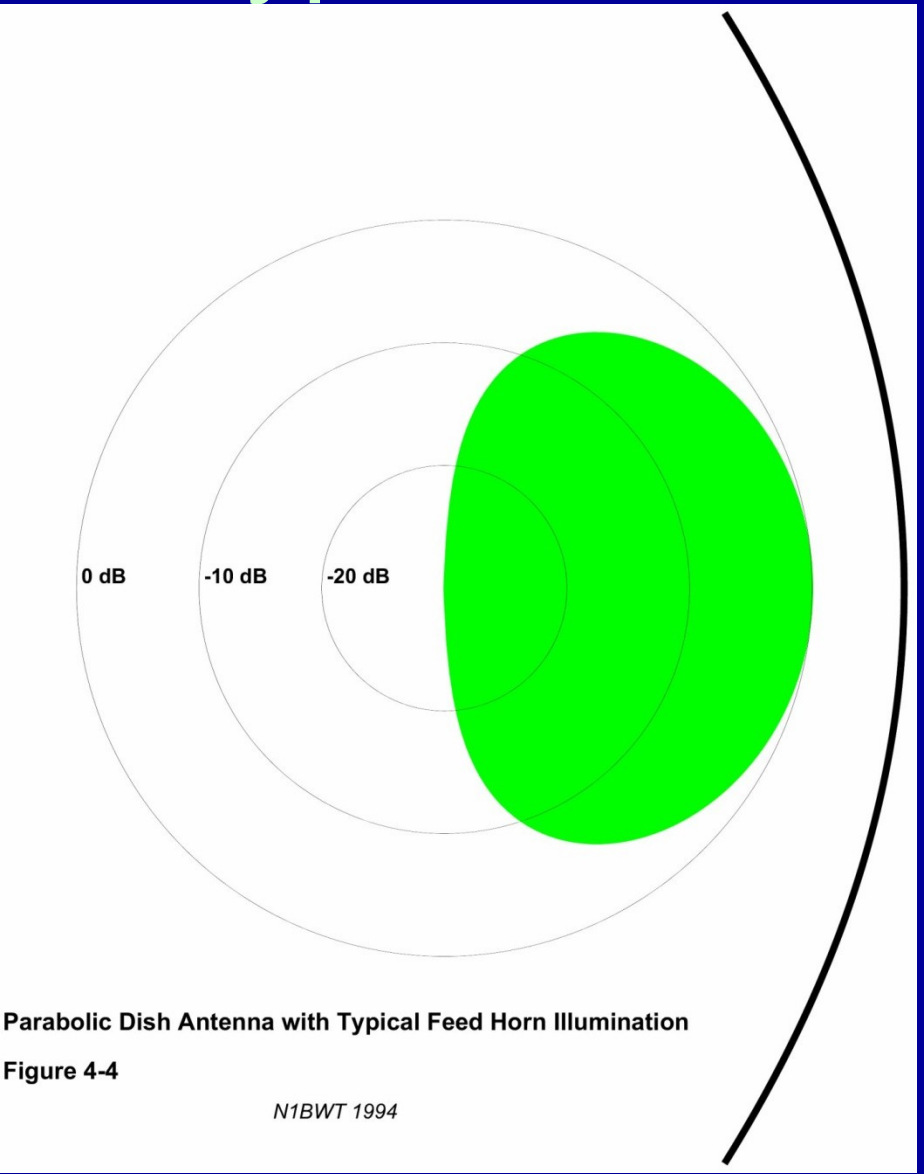


Desired Dish Illumination - Uniform Reflector Illumination

Figure 4-3

N1BWT 1994

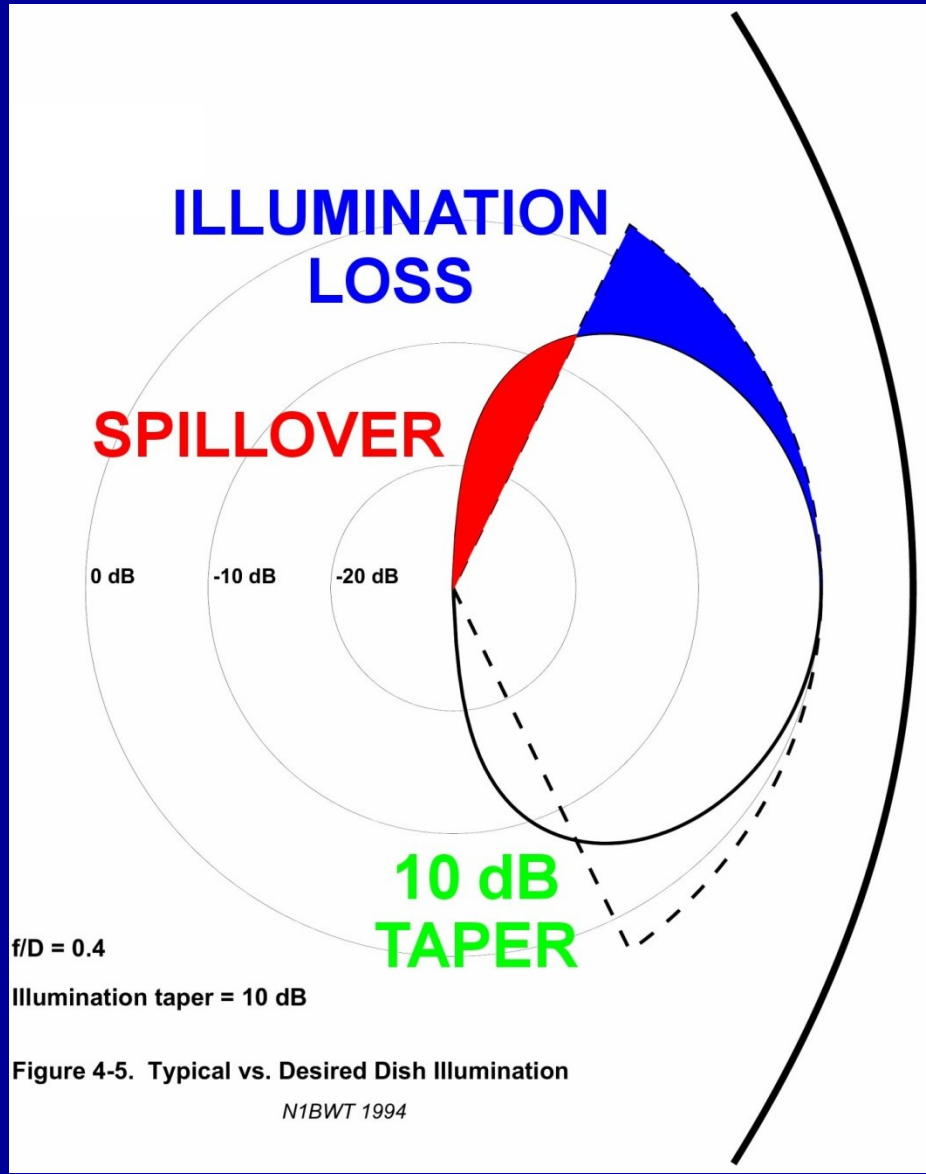
Typical illumination vs. desired



Parabolic Dish Antenna with Typical Feed Horn Illumination

Figure 4-4

N1BWT 1994



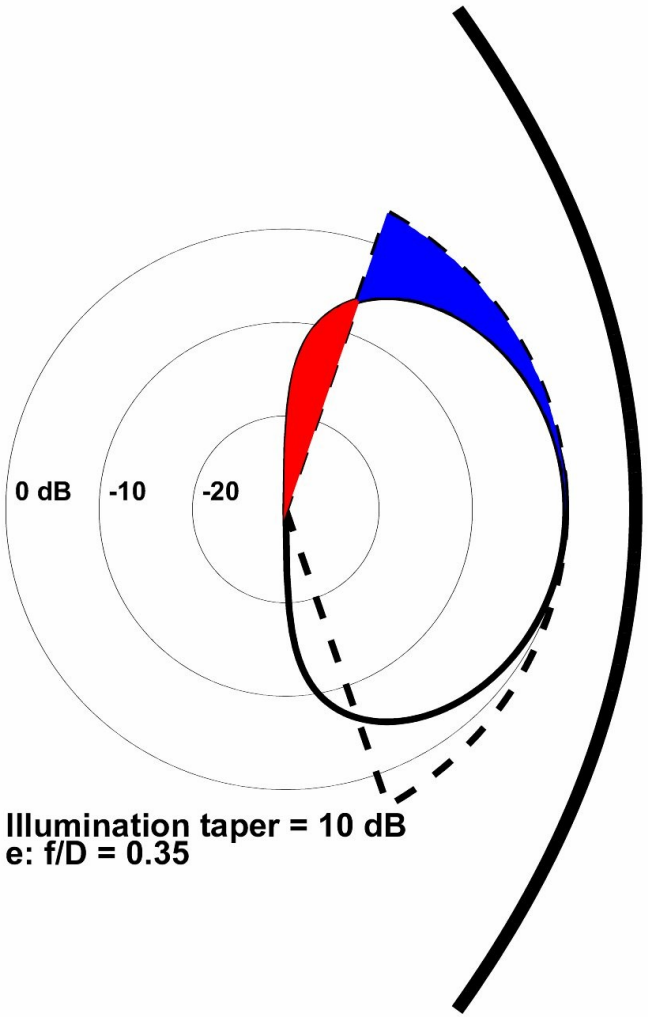
f/D = 0.4

Illumination taper = 10 dB

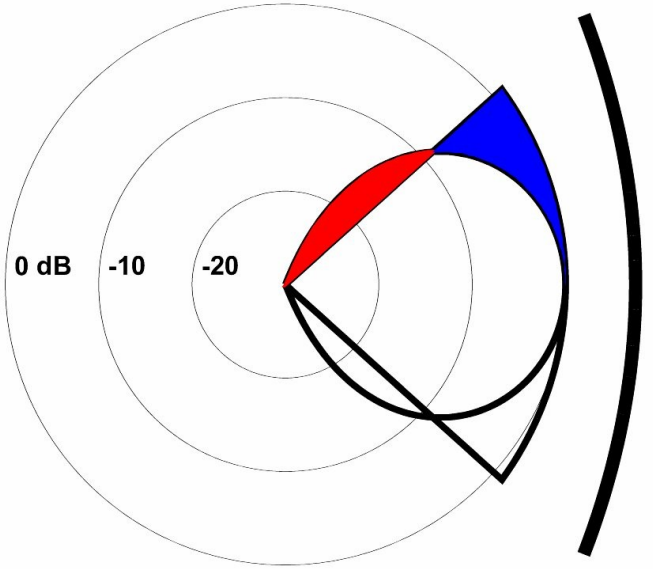
Figure 4-5. Typical vs. Desired Dish Illumination

N1BWT 1994

Deep *f* / D vs Shallow

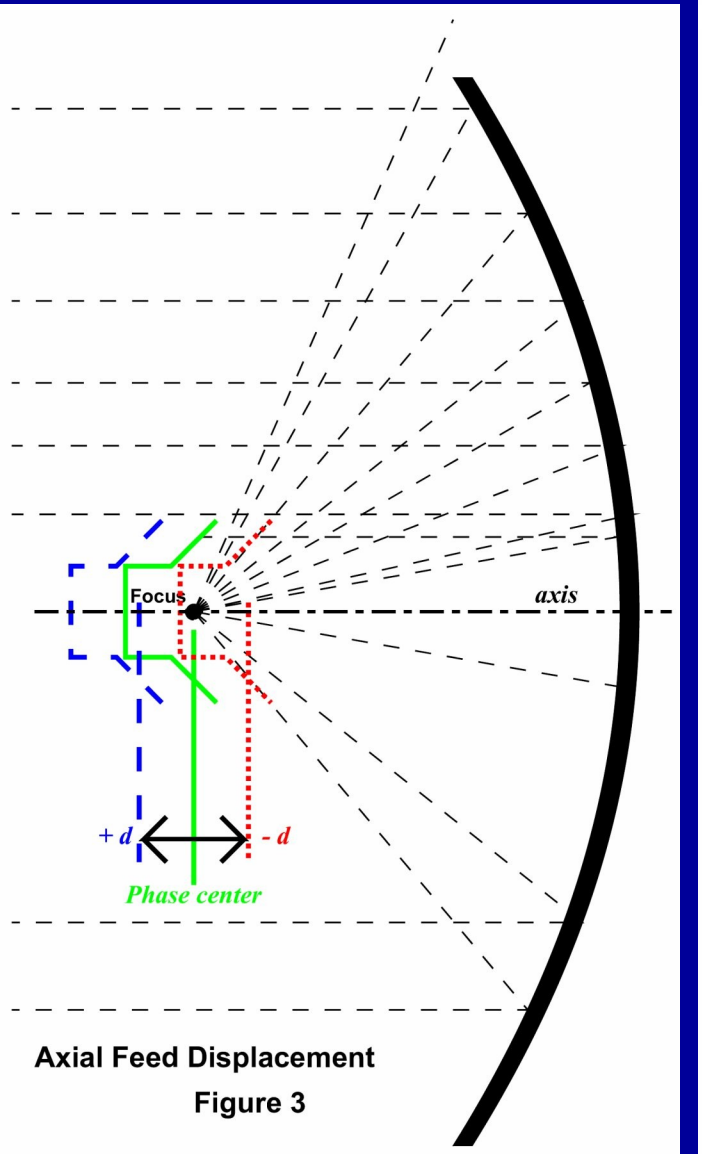


Illumination taper = 10 dB
e: f/D = 0.35



Illumination taper = 10 dB
b: f/D = 0.65

Focus critical



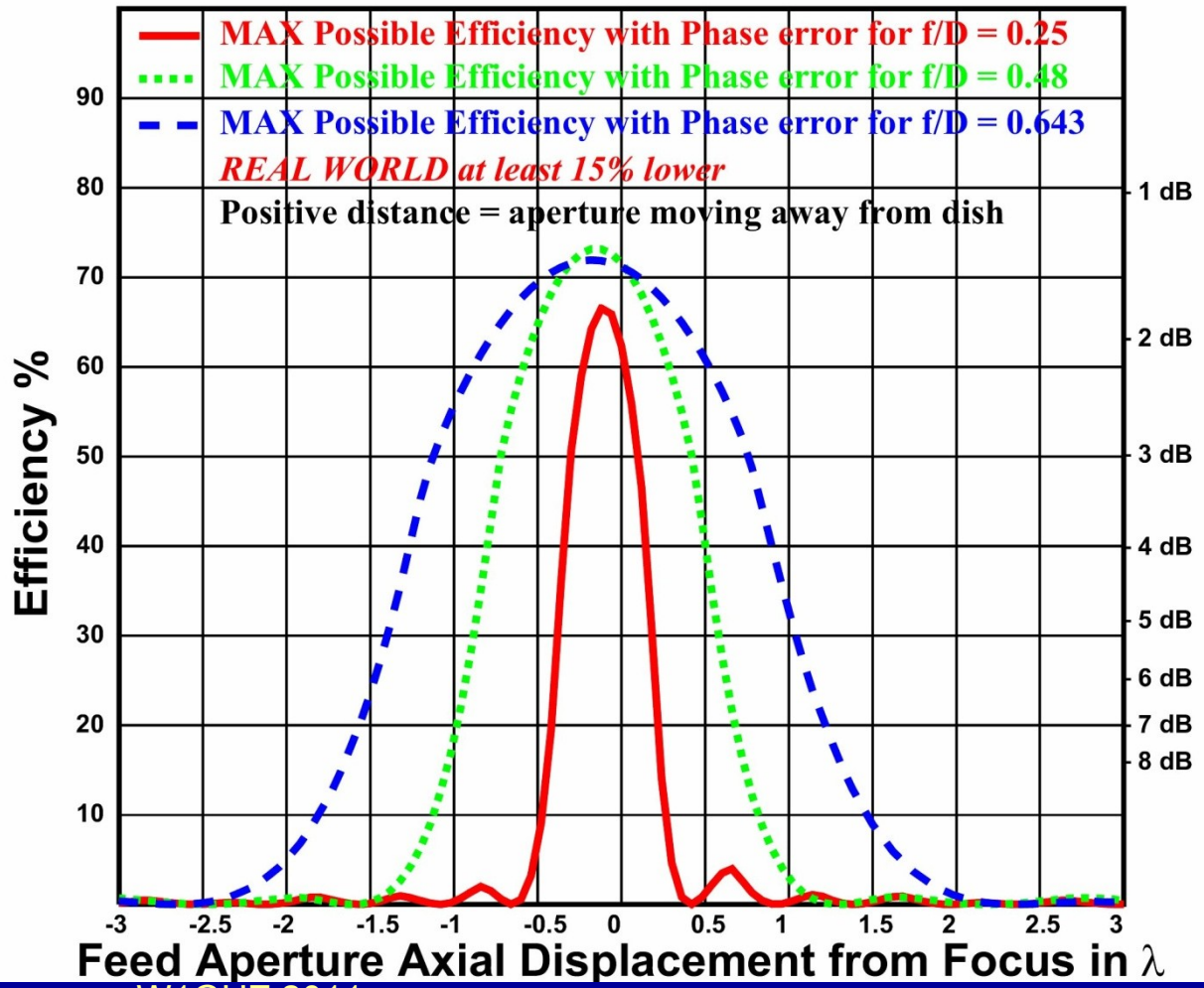
Axial Feed Displacement

Figure 3

f/D = 0.25: RSGB dipole-splasher feed, by NEC2

f/D = 0.48: EIA dual-dipole feed, by NEC2

f/D = 0.64: WR-90 horn for DSS offset dish at 10.368 GHz, by P.O.



Parabolic Feed Summary

1. Feed Phase Center at Focus
   - *Error -> many dB*
2. Match feed to *f*/D
   - *Error -> dBs*
3. Minimize losses and blockage
   - *Error -> tenths of dB*

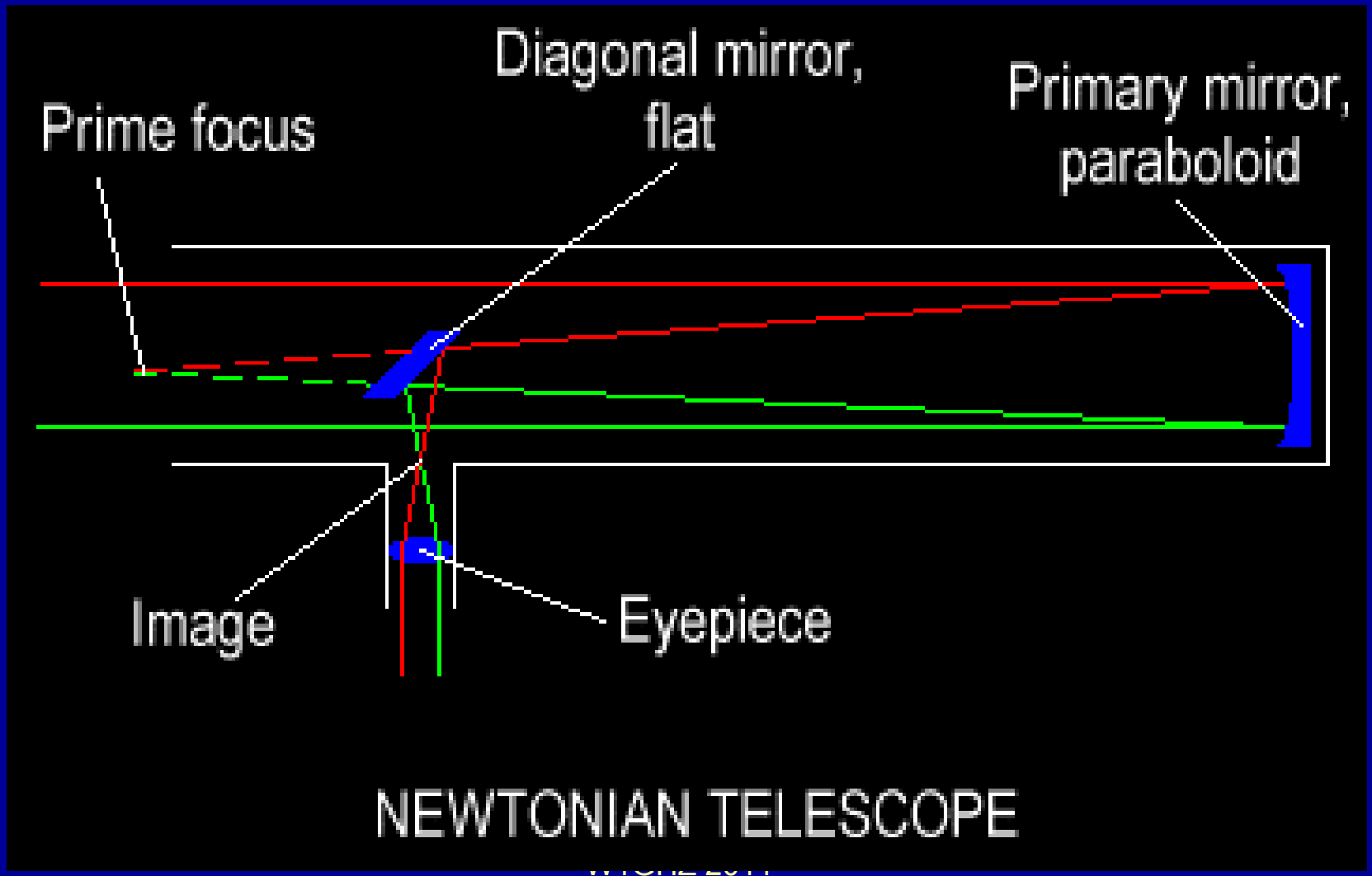
Why multiple reflectors?

- Reverse feed
  - A convenience – *feedline loss*
- Reshape feed pattern
  - + ***REAL ADVANTAGE***
  - No good prime feeds for deep dishes
- Reduced ground noise - ***EME***

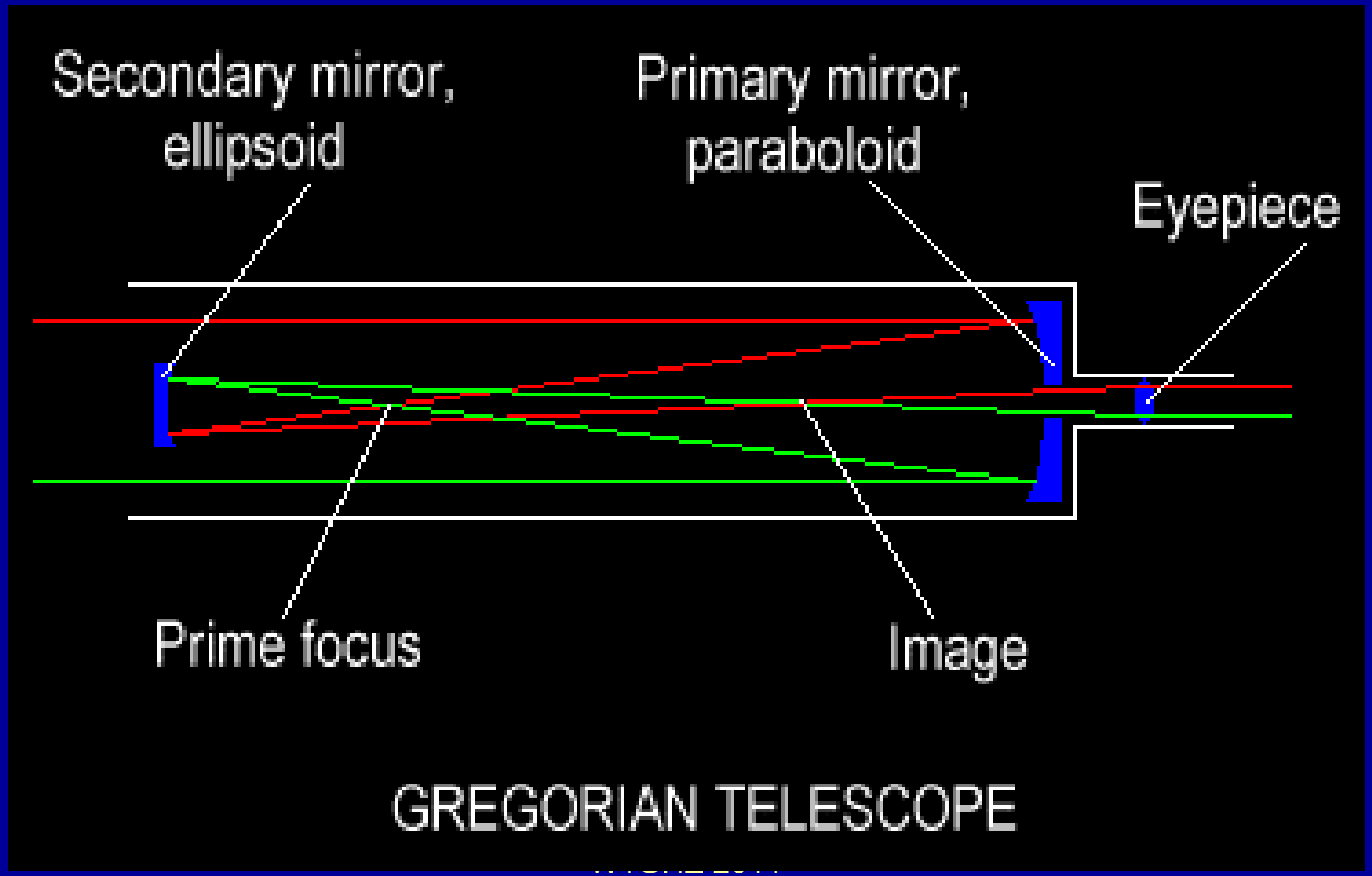
Derived from Telescopes

- Newtonian – flat subreflector
- Gregorian – elliptical subreflector
- Cassegrain – hyperbolic subreflector
- Schmitt-cassegrain – Spherical main reflector, correcting lens

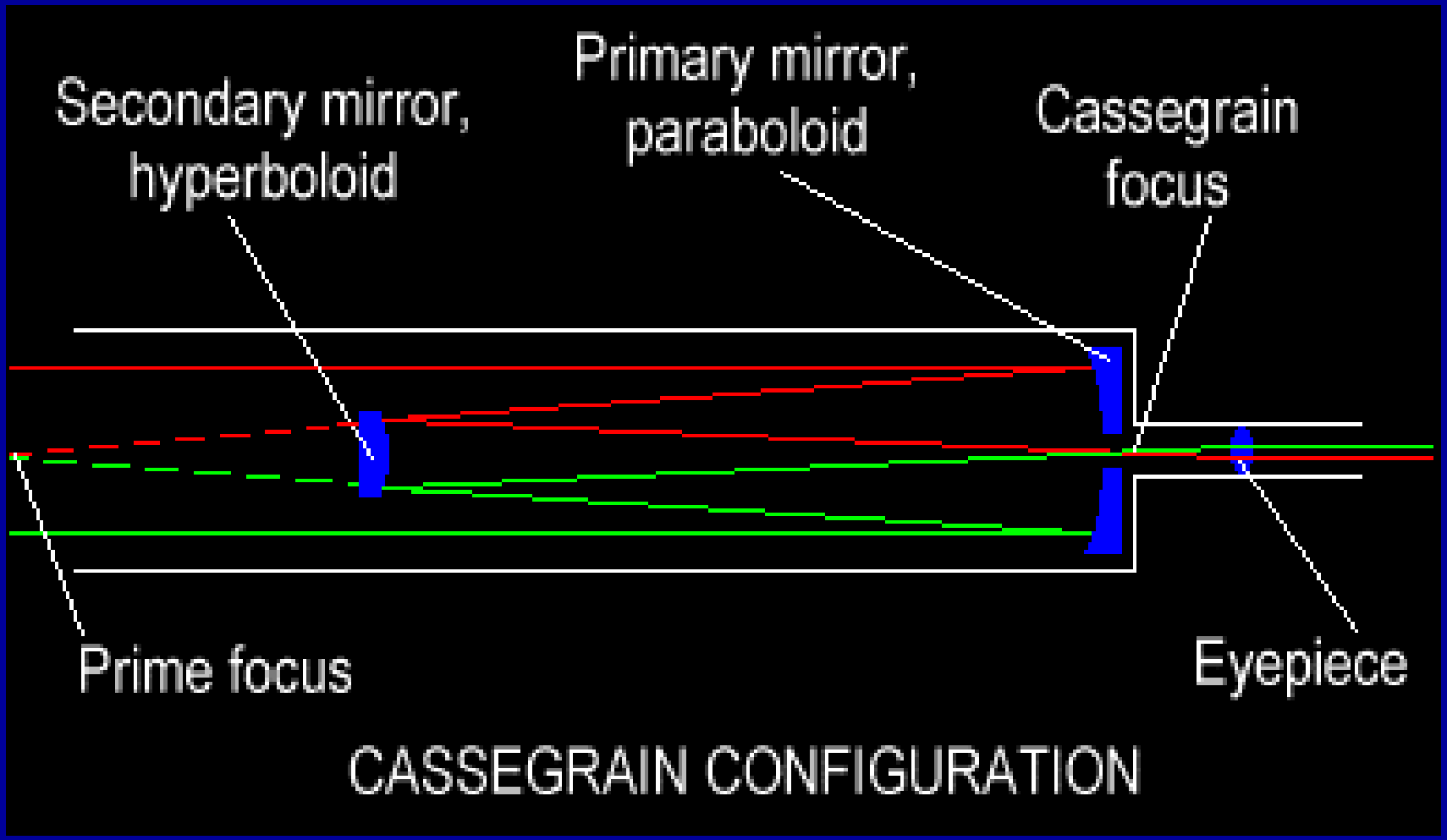
Newtonian telescope



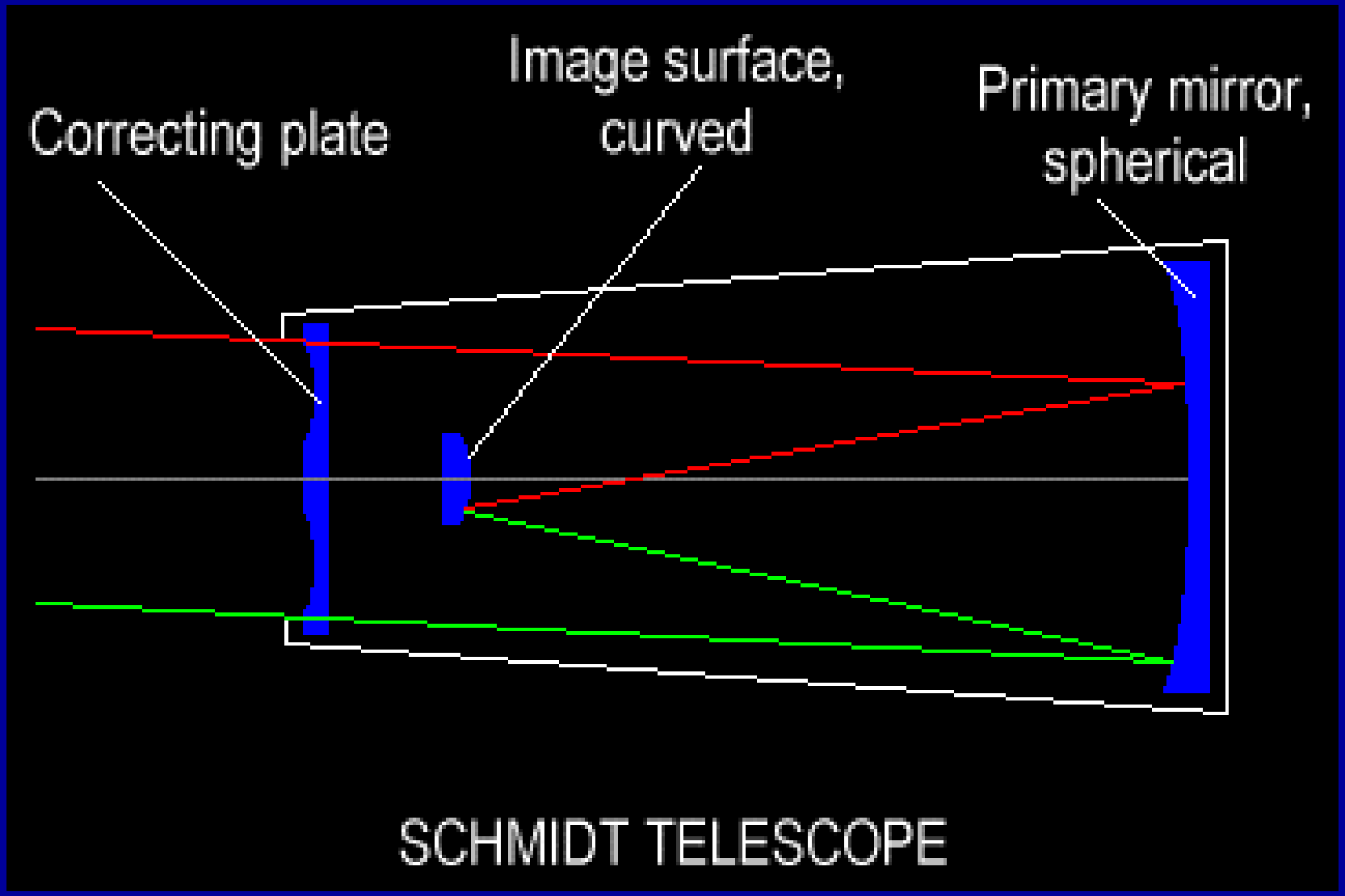
Gregorian Telescope



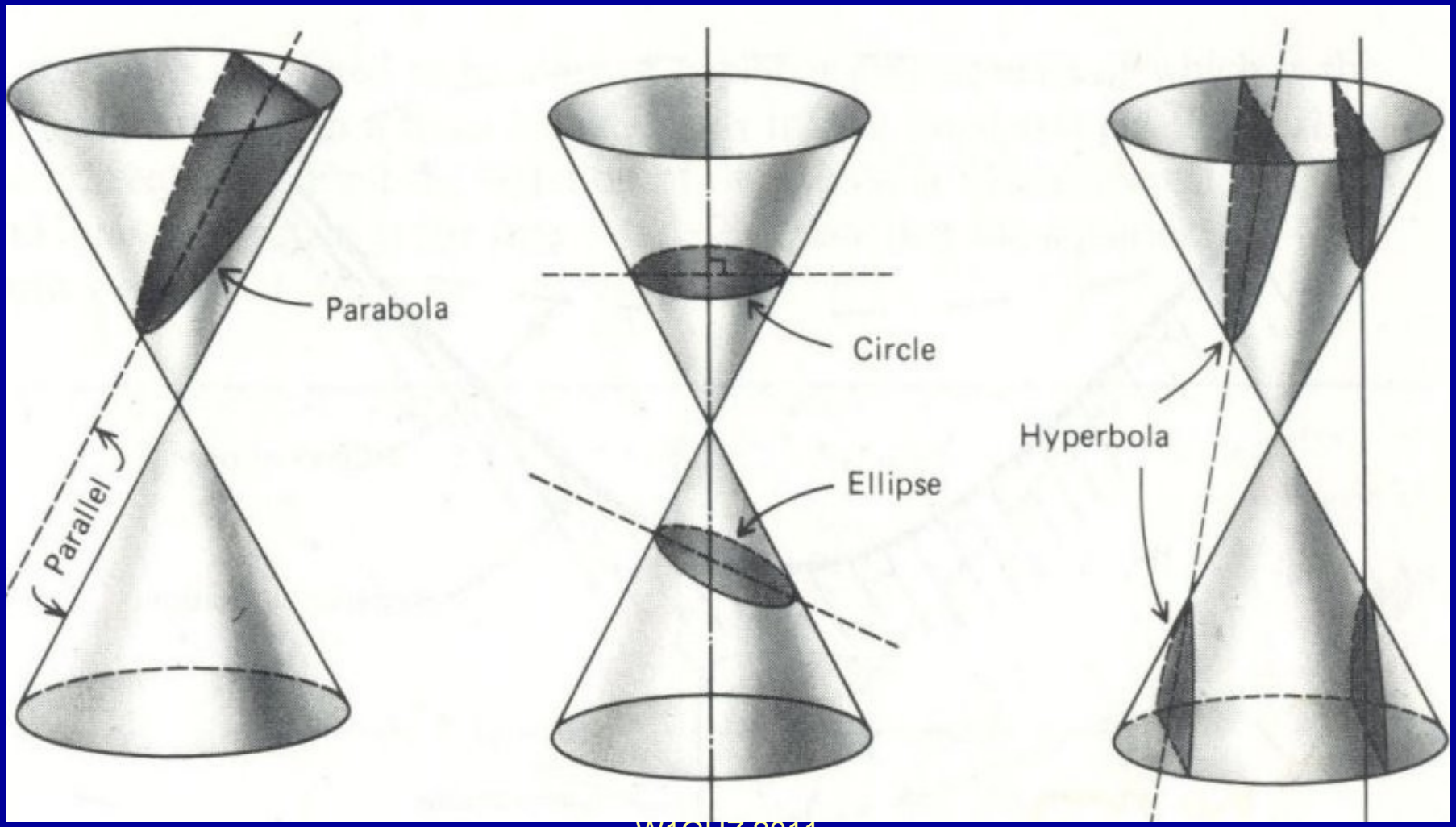
Cassegrain telescope



Schmitt-cassegrain telescope



Conic sections



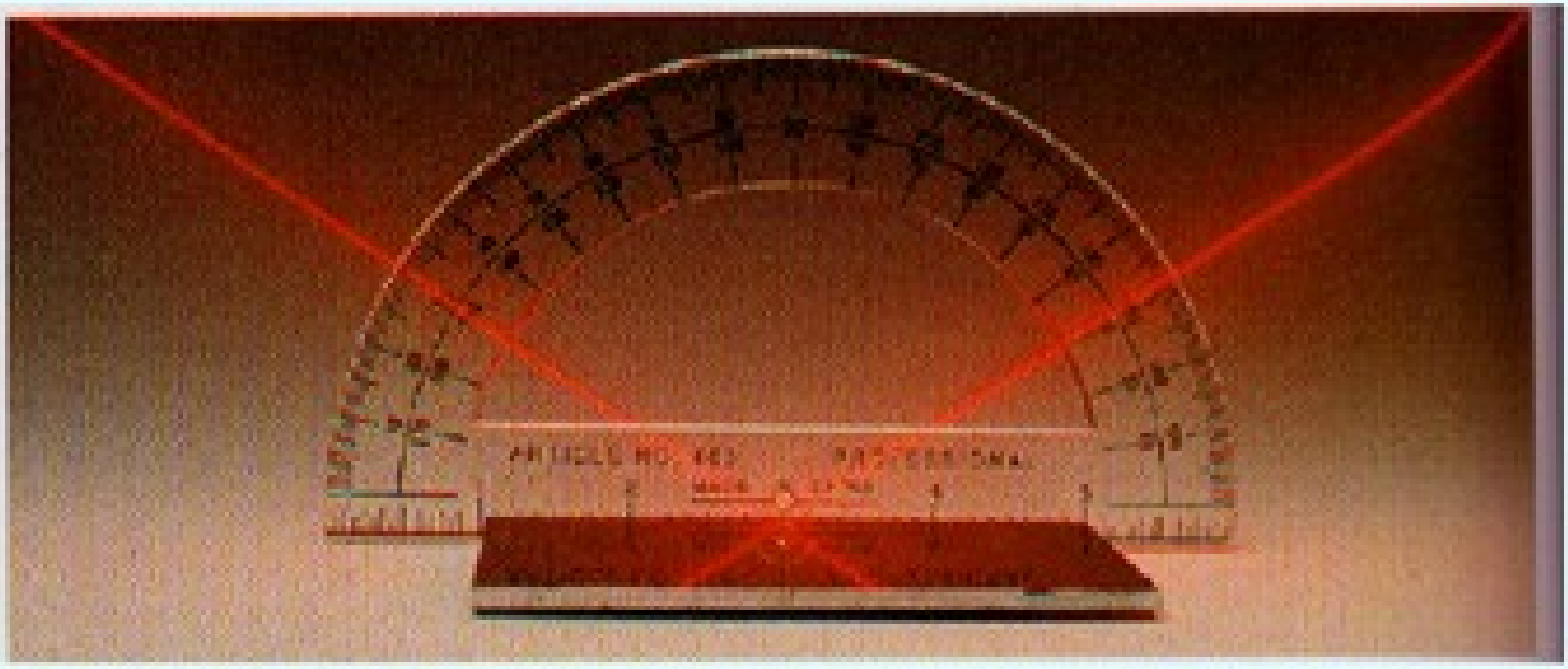
Geometric optics approximation

- Wavelength → zero
- Waves travel in straight lines – Rays
- Curvature >> wavelength
- Reflection from flat surfaces
  - Angle of incidence = Angle of reflection
- Refraction follows Snell's Law

Law of Reflection

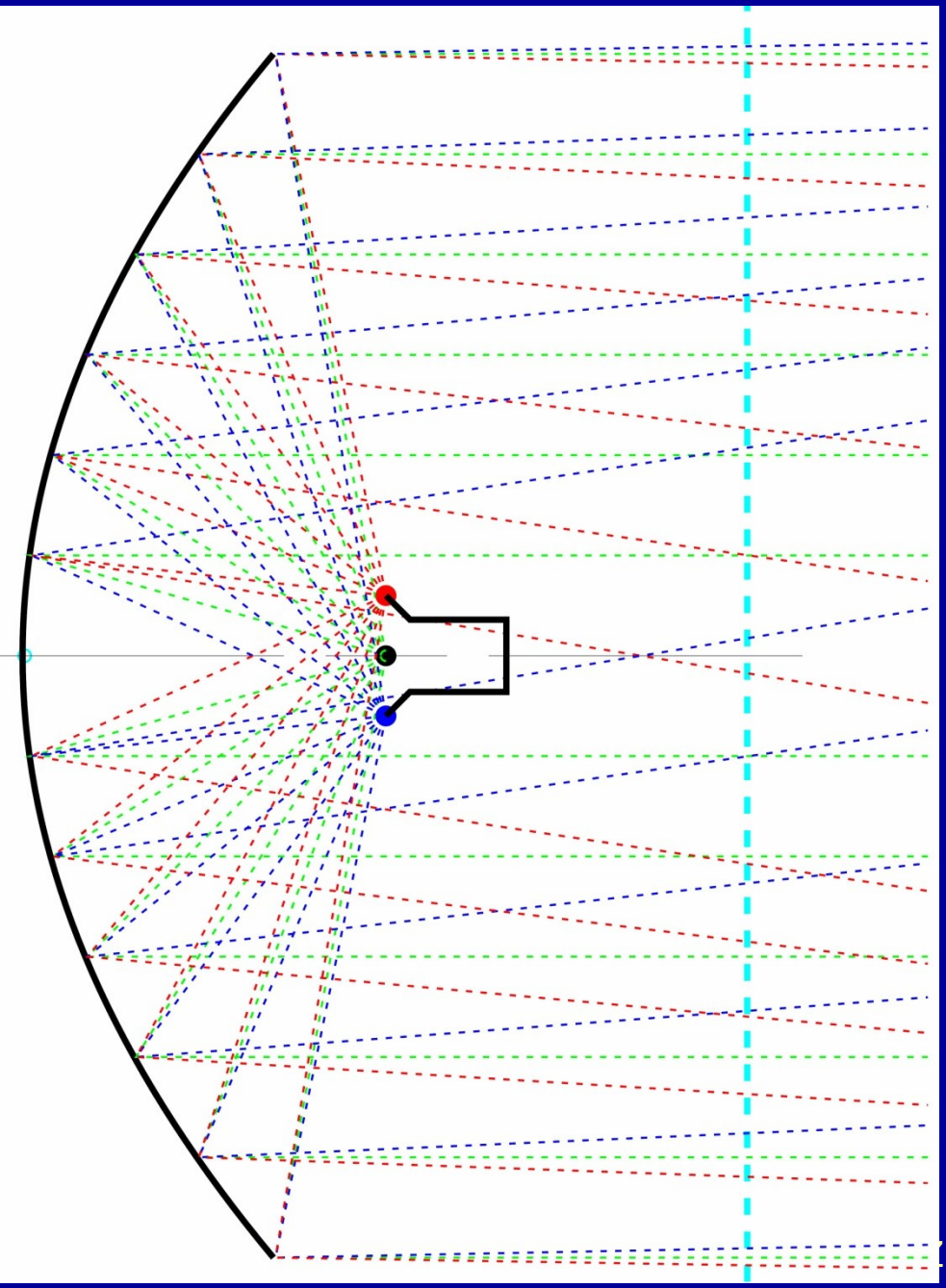
Reflection:

The angle of incidence = the angle of reflection.



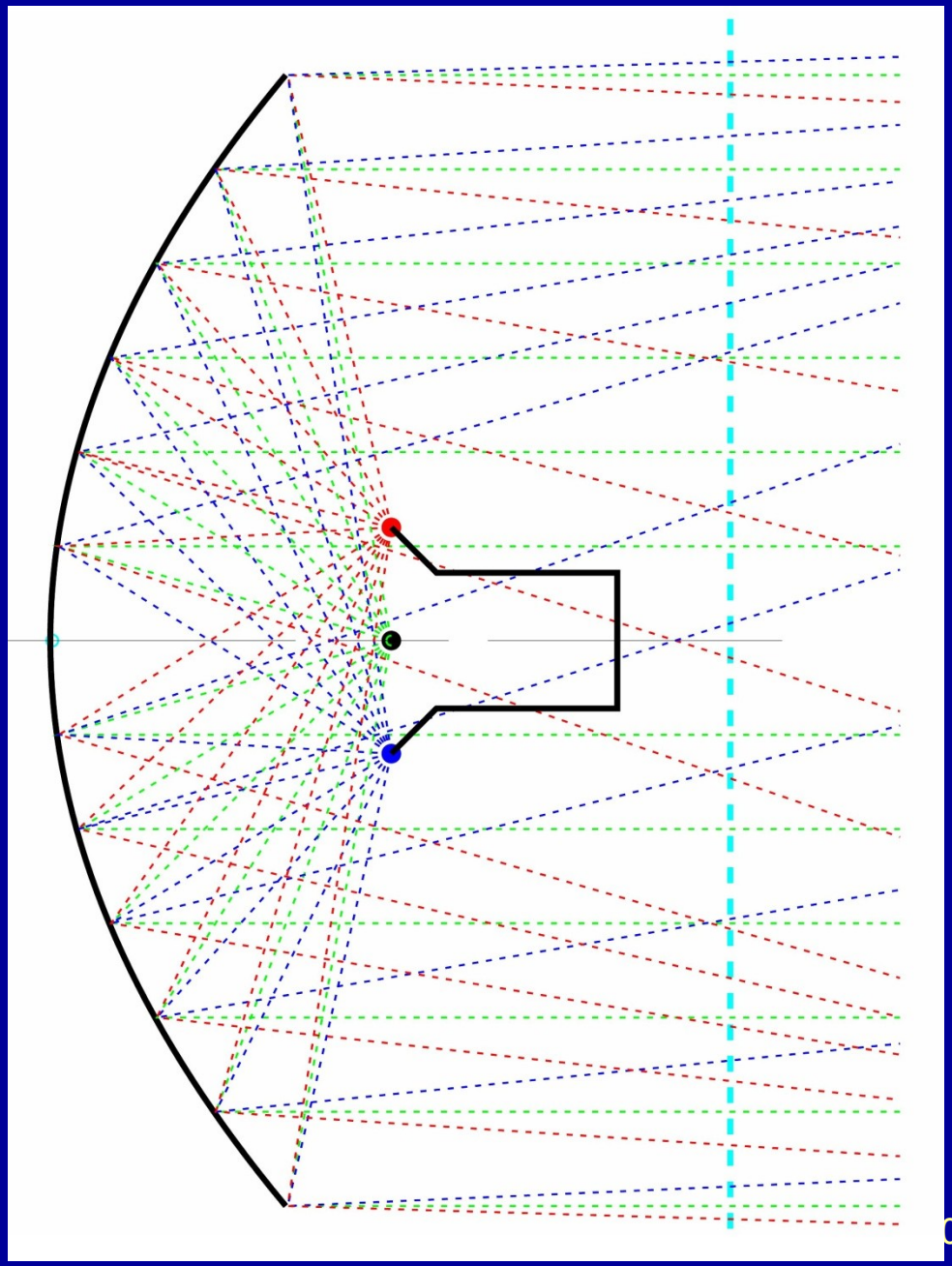
Diffraction
or
Why small dishes don't work well

- Wavelength is not zero
- Objects and curvatures ~ wavelength
- J. B. Keller
  - Geometric Theory of Diffraction

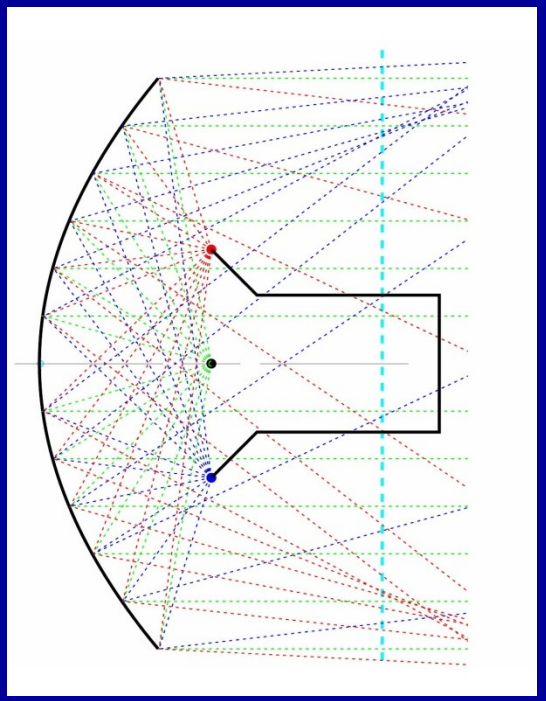


Small dishes

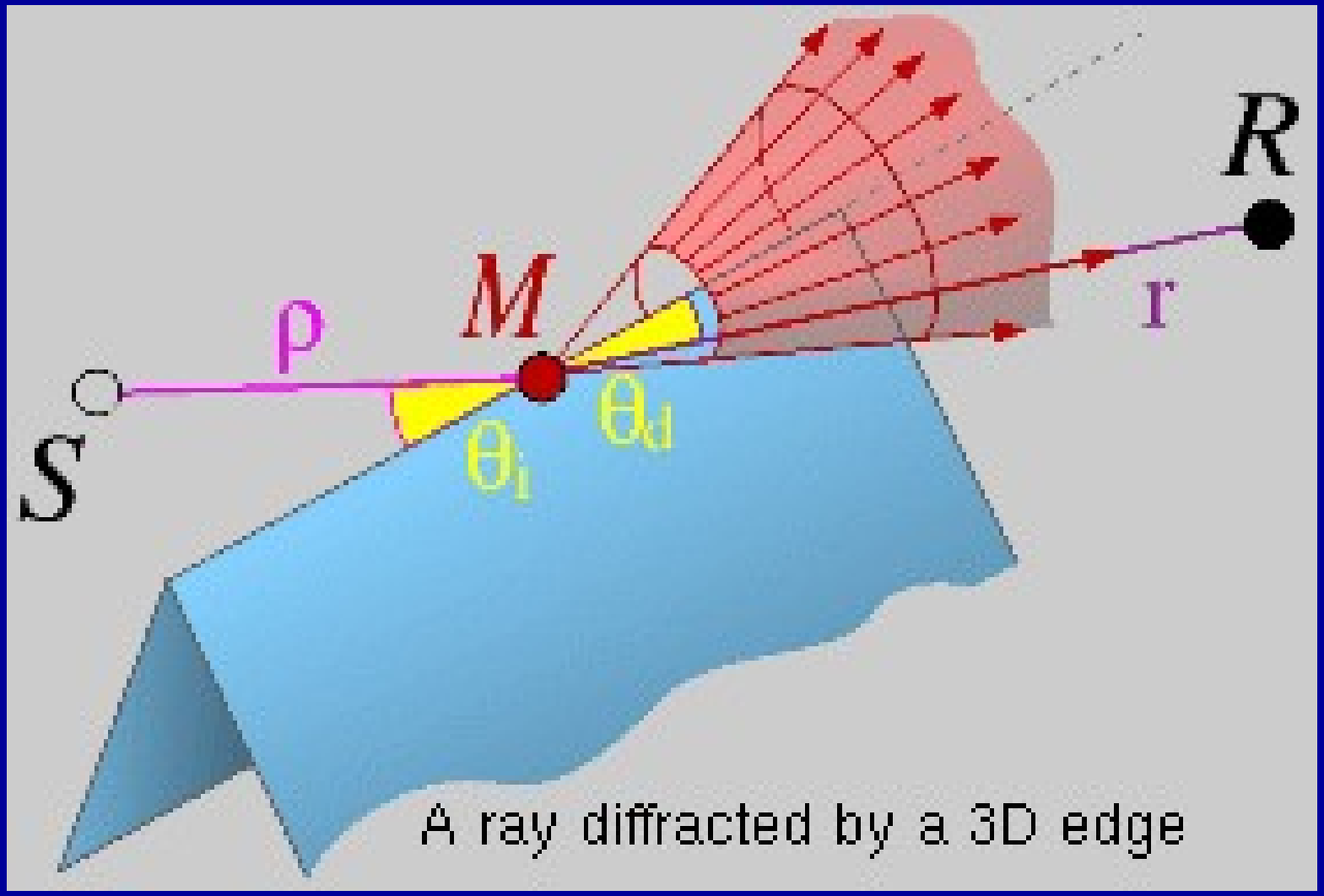
- Feed is not a point source
- *Huygen's Principle:*
  - Each point on feed aperture acts as a radiating source



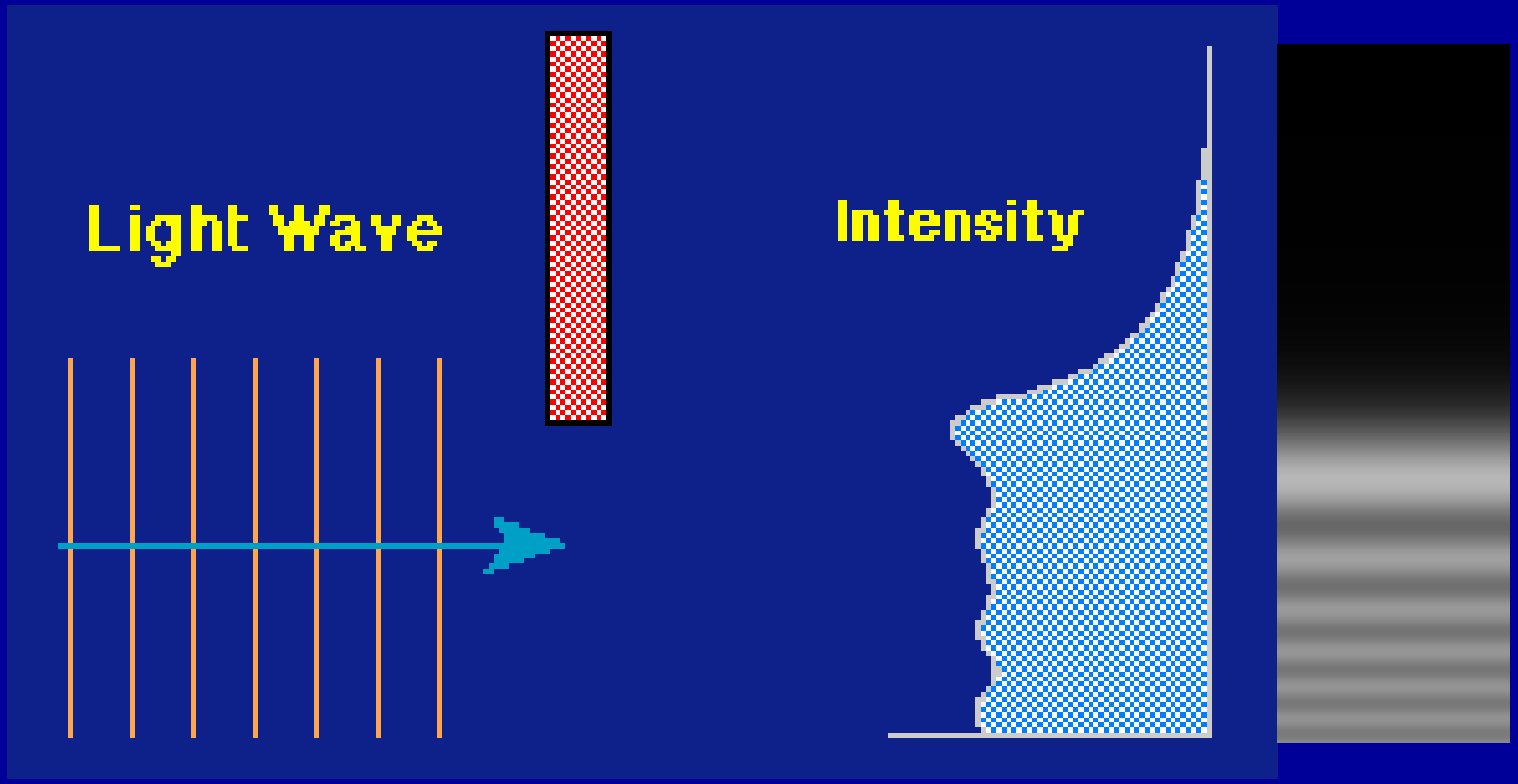
Very small dishes: 5λ and 2.5 λ



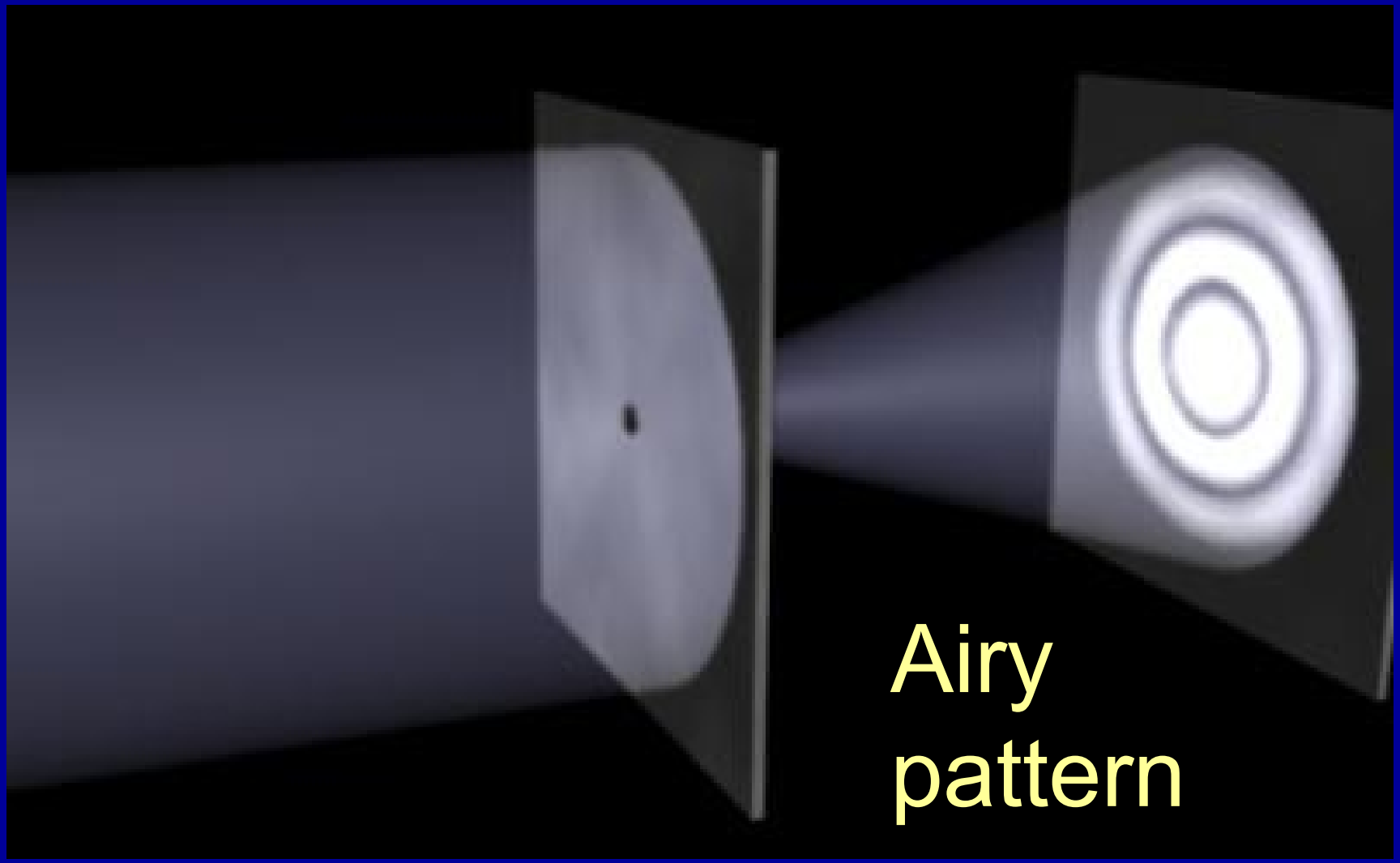
Diffraction – Keller cone



Edge Diffraction



Diffraction thru a hole



Diffraction from a strut



Prime focus feeds

- Good efficiency for deep dishes
  - *f*/D ~ 0.35 to 0.45 (*circular waveguides*)
- Poor efficiency for very deep dishes
  - *f*/D ~ 0.25 (*Penny feed*)
- Very good for shallow dishes
  - *f*/D > 0.5 (*Dual-mode feeds*)

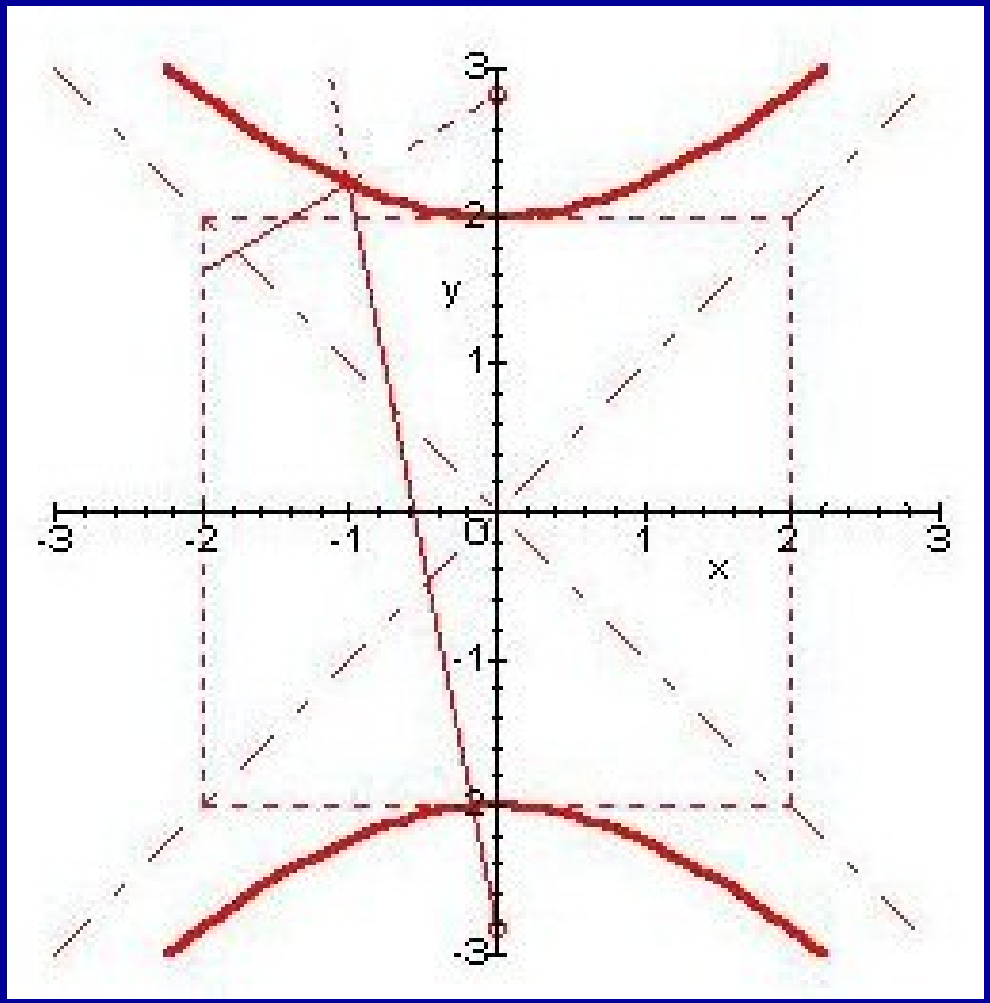
Low efficiency – *where does it go?*

- Energy must illuminate dish to contribute to gain – otherwise, reduced gain and efficiency
- LOSSES:
  - Sidelobes and backlobes
  - Poor illumination
  - Diffraction
  - Phase errors
  - Power reflected back into feedhorn
- *Power in the wrong places*

Subreflector

- **Curved subreflector reshapes shallow dish feed pattern to illuminate deep dish**
- **Flat subreflector only redirects feed pattern, no reshaping, no efficiency improvement.**
- **Only additional blockage and diffraction losses – how much?**

Cassegrain Antenna Design



- **Hyperbolic subreflector**
- Rays from one focus are reflected so that they appear to radiate from second focus
- Feed P.C. at first focus
- Second focus is prime focus of dish

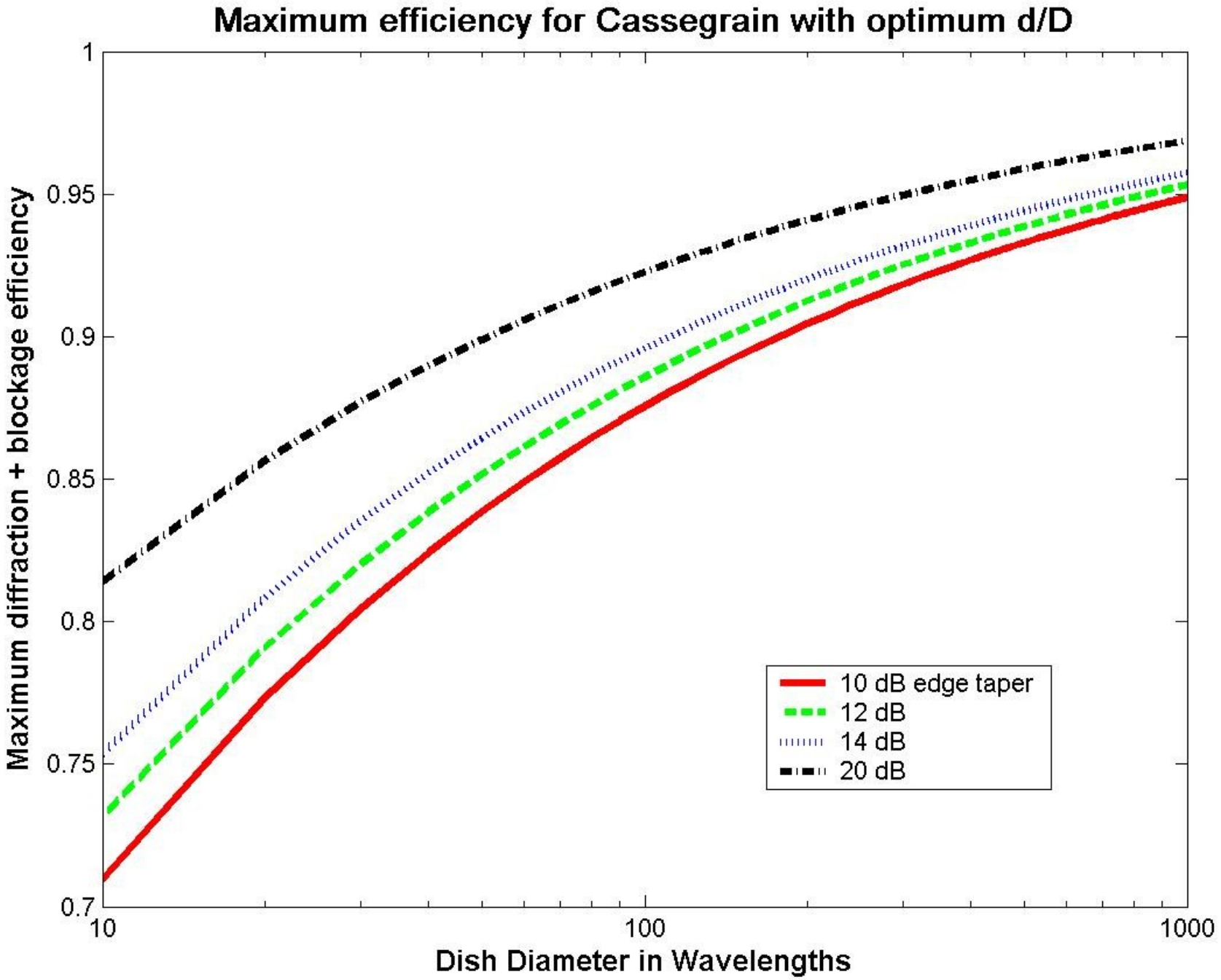
Small Cassegrain Antennas

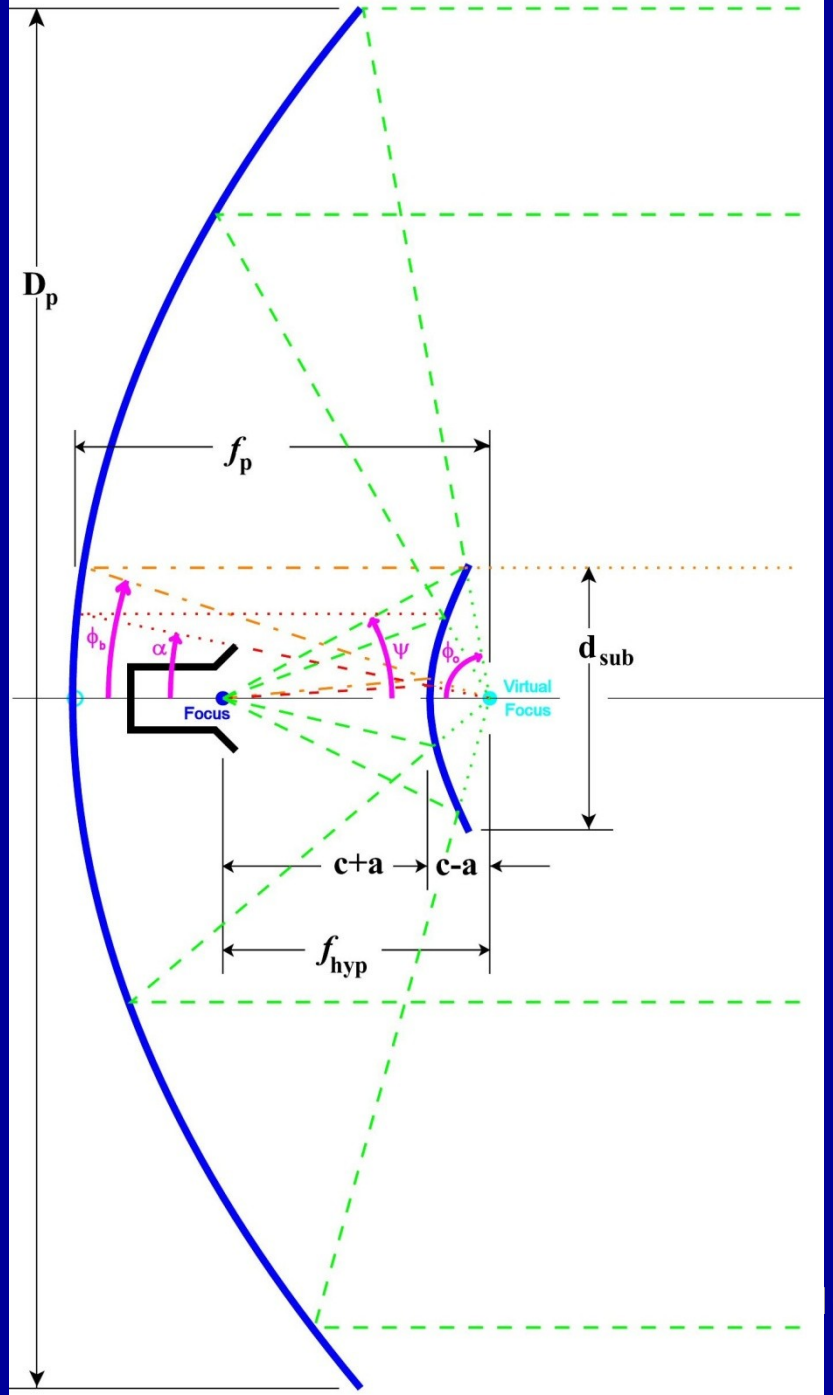
- Subreflector size tradeoff
  - Large subreflector → Blockage loss
  - Small subreflector → Diffraction loss

- Kildal – design procedure to balance losses
- Small is dish < 200λ

Cassegrain Design Procedure

1. Optimum Edge Taper
2. Optimum Subreflector Size
3. Estimate Subreflector Efficiency
4. Choose a Feedhorn
5. Hyperbola focal length
6. Feed blockage
7. Subreflector geometry


Maximum efficiency for Cassegrain with optimum d/D
Maximum diffraction + blockage efficiency
Dish Diameter in Wavelengths
1
0.95
0.9
0.85
0.8
0.75
0.7
10
100
1000
10 dB edge taper
12 dB
14 dB
20 dB



Cassegrain Geometry

- Ray paths must have equal lengths
- Feed blockage less than subreflector
- Subreflector in far field of feed

Rayleigh Distance =

$2D^2 / \lambda$

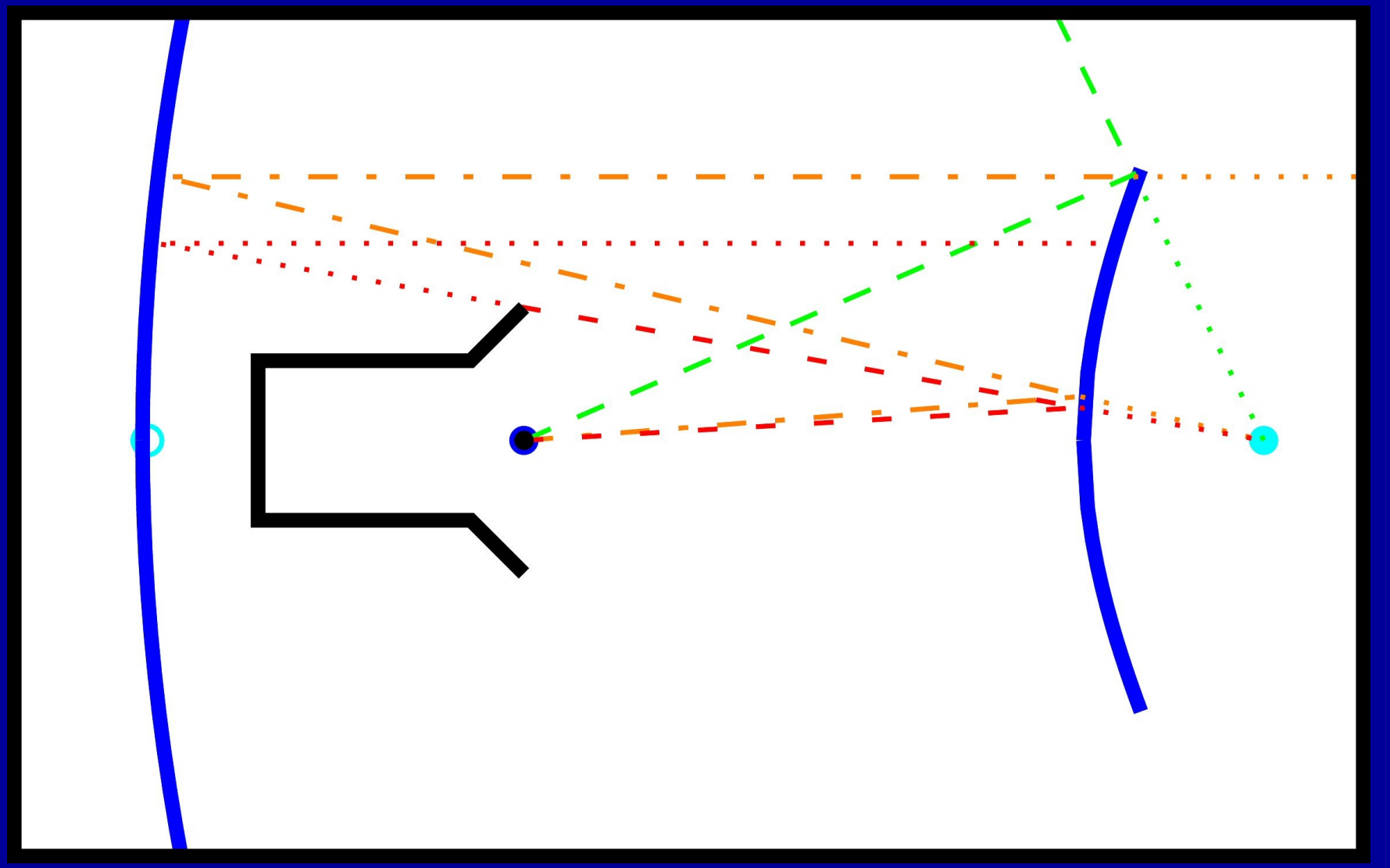
Feed reshaping

Magnification factor **M**

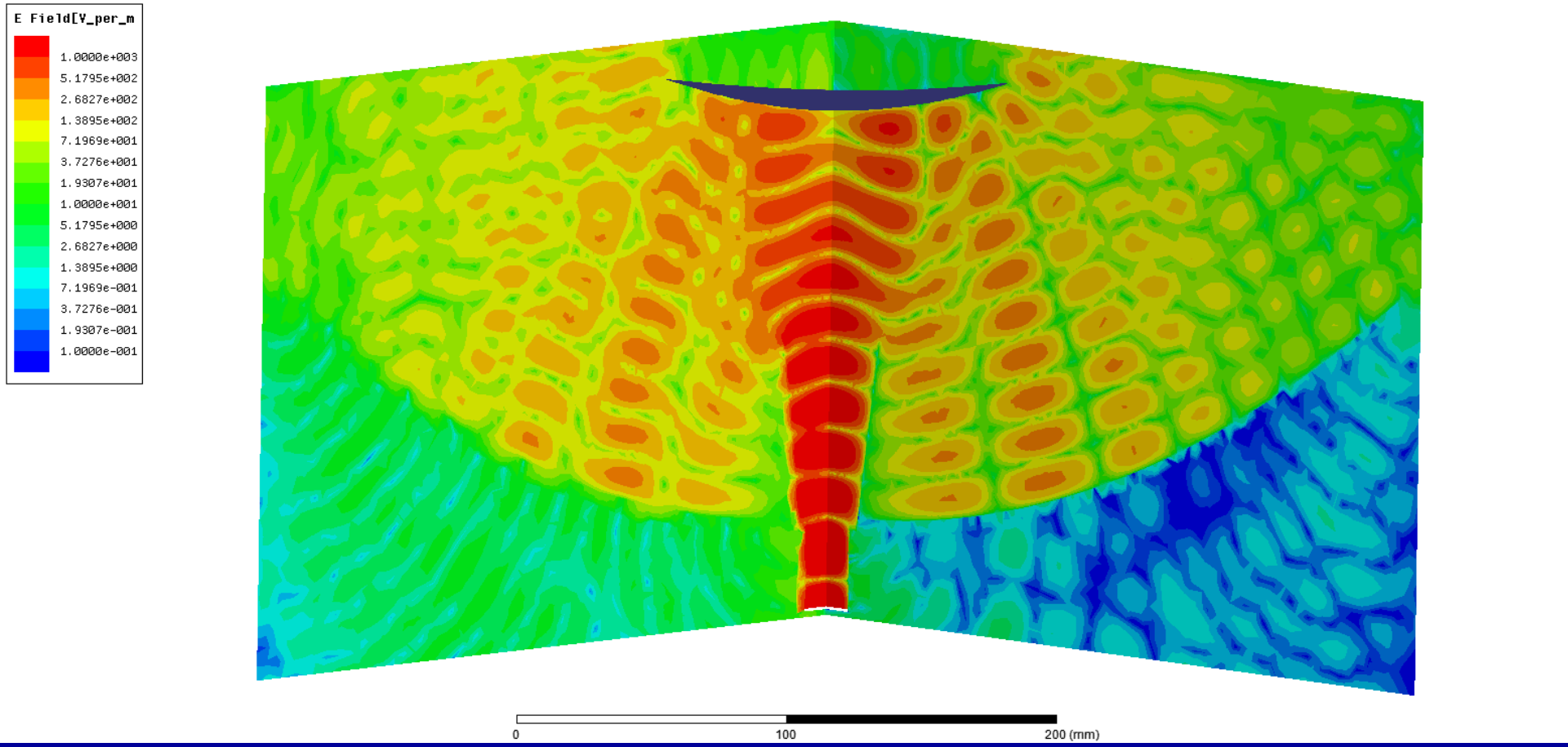
M = feed ***f*/D** **/** Dish ***f*/D**

Good feedhorn with deep dish

Subreflector and feed blockage



Cassegrain animated



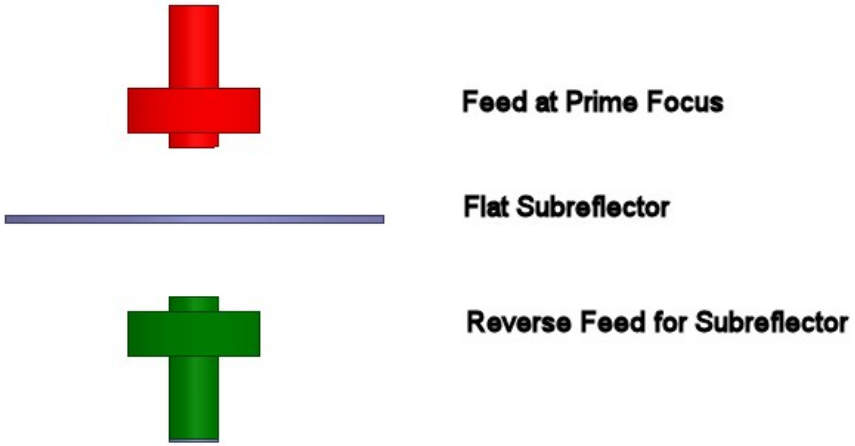
Cassegrain Design Procedure

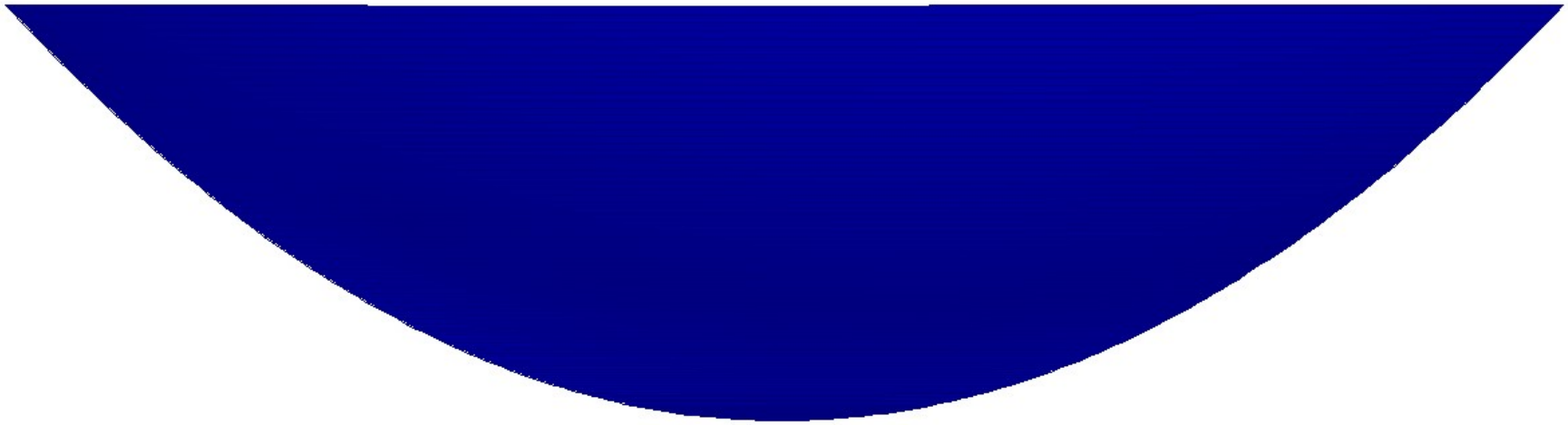
1. Optimum Edge Taper
2. Optimum Subreflector Size
3. Estimate Subreflector Efficiency
4. Choose a Feedhorn
5. Hyperbola focal length
6. Feed blockage
7. Subreflector geometry

24 GHz *and up*

- Feedline loss is high, even in waveguide
- Equipment not suitable for feedpoint mount
- Reverse feed minimizes feedline length
- Cassegrain requires accurate hyperbolic curvature, and accurate focusing
- Flat surface is easy, and easier to focus
- *How much worse is Flat subreflector?*

Flat Subreflector

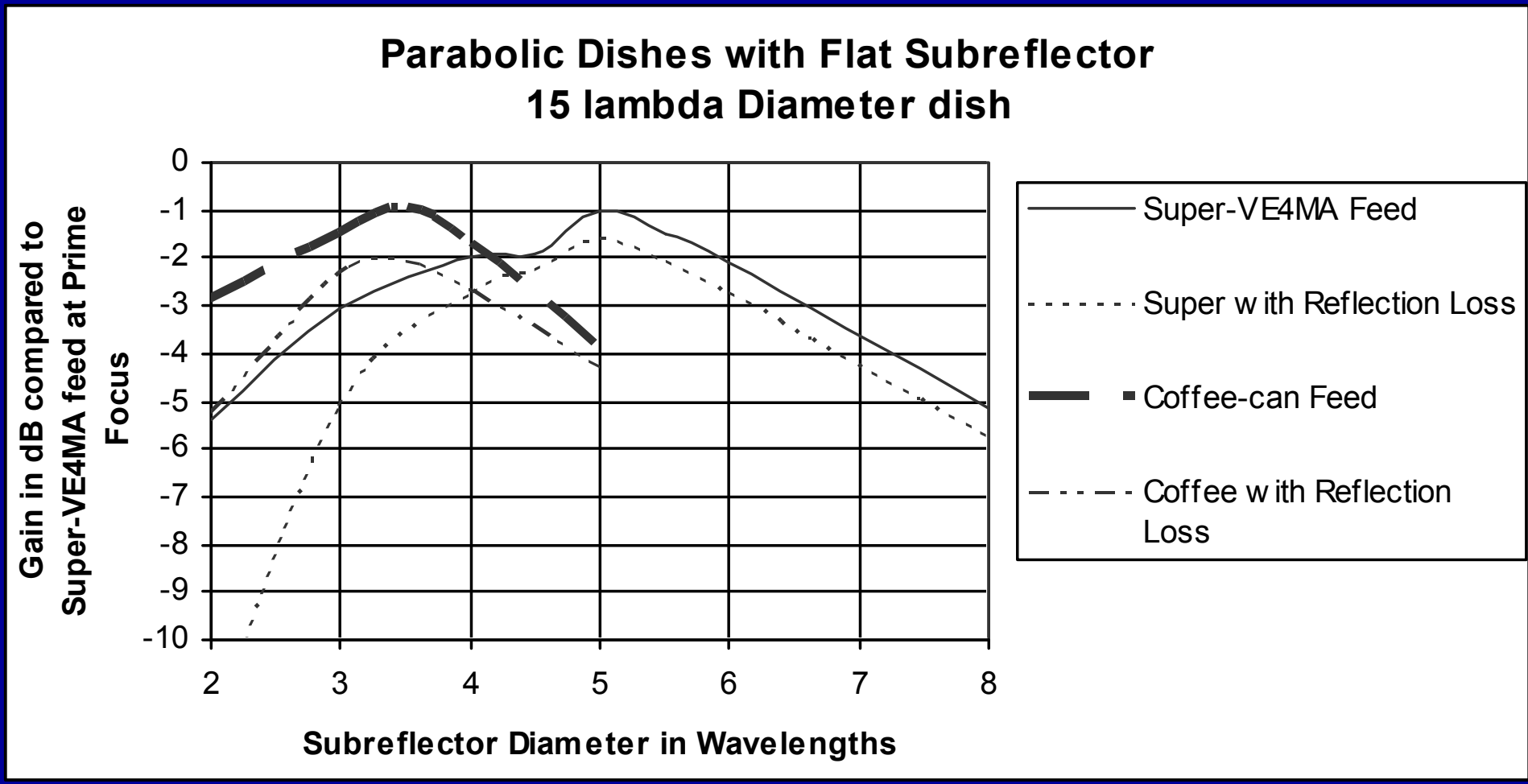




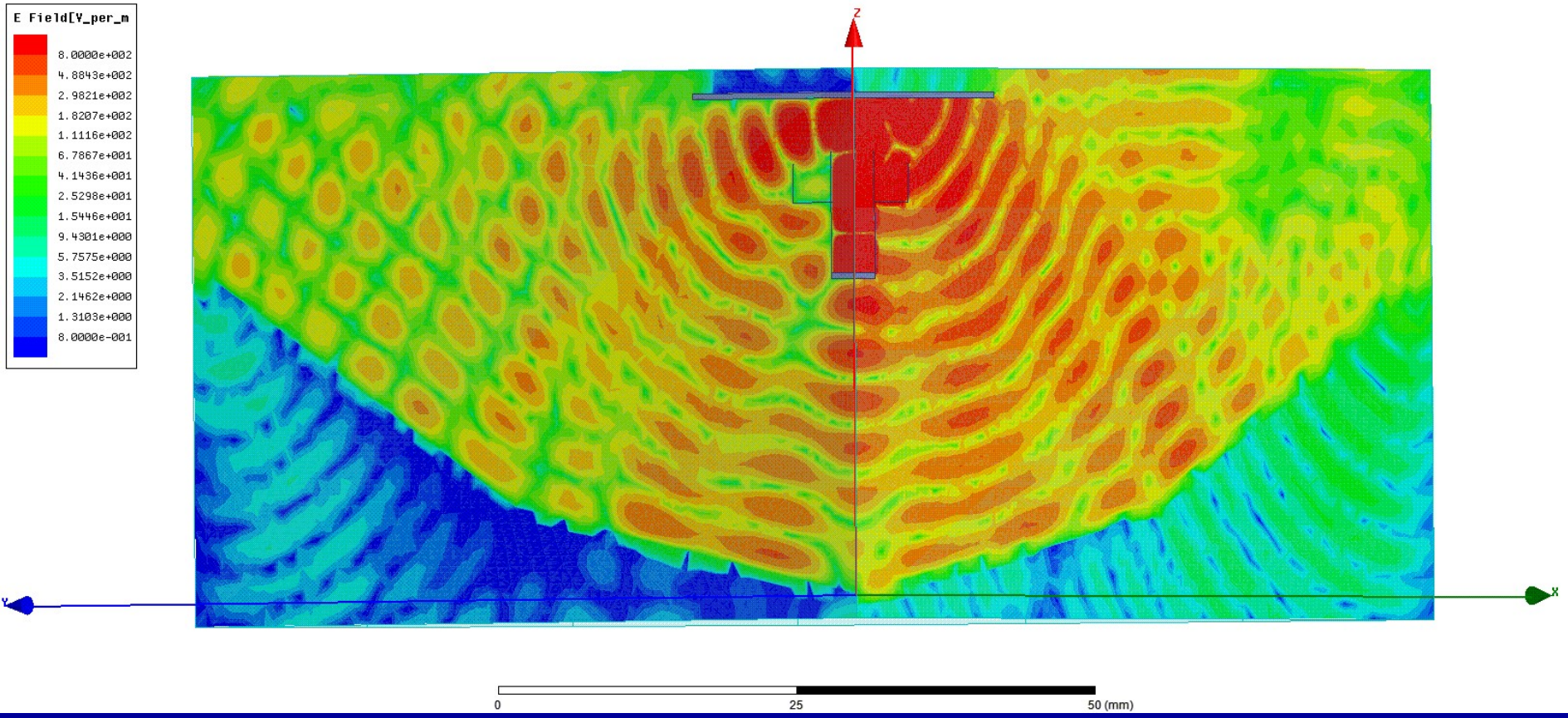
Flat Subreflector

- Flat subreflector is mirror
- Focal length is the same
- Small subreflector
  - Feedhorn close to subreflector
  - Power reflected back into feedhorn
- Large subreflector
  - High blockage loss
- Diffraction at subreflector edge

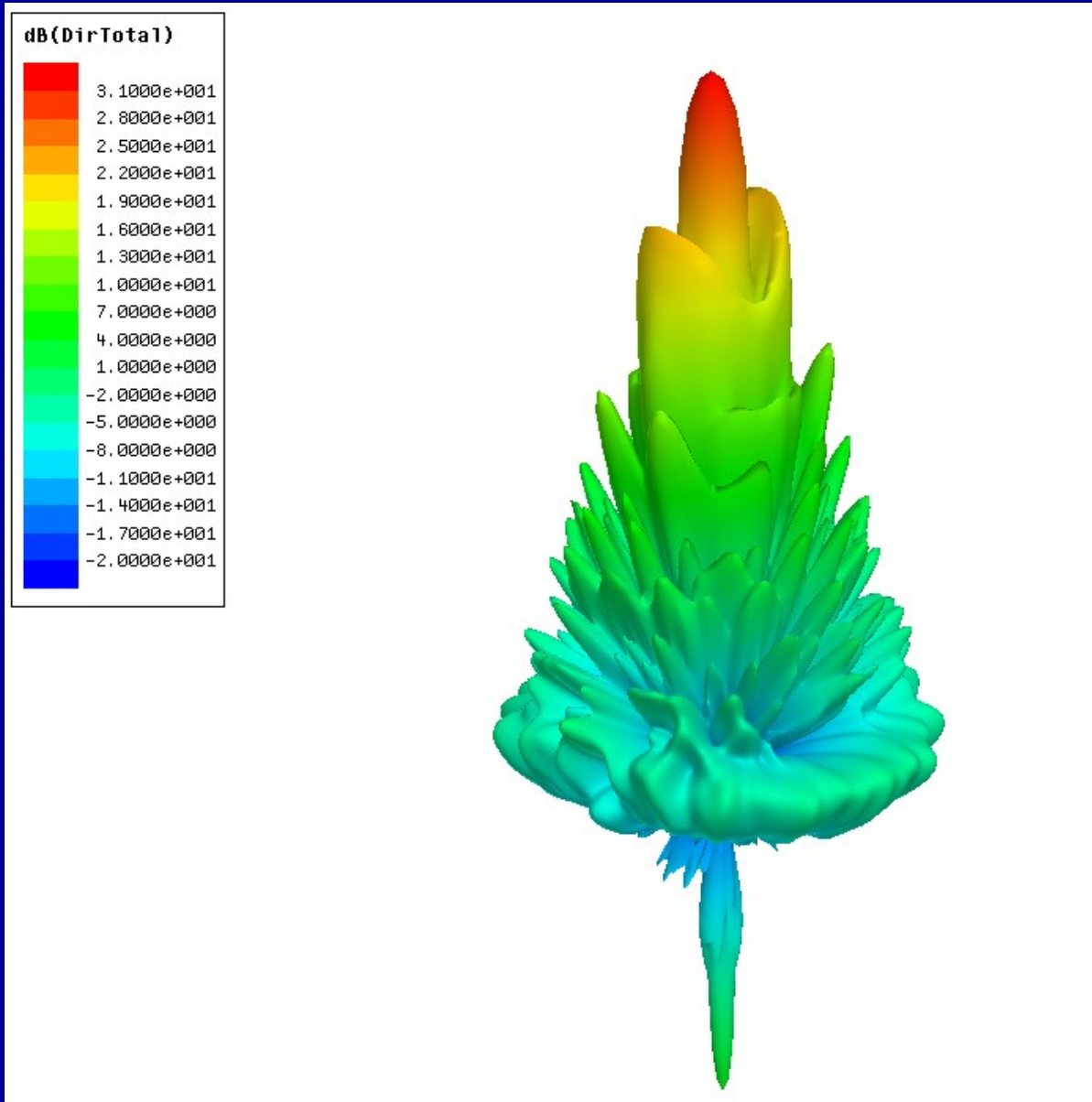
Small Dish - 15λ, *f*/D = 0.33 Flat Subreflector



Flat Subreflector animated



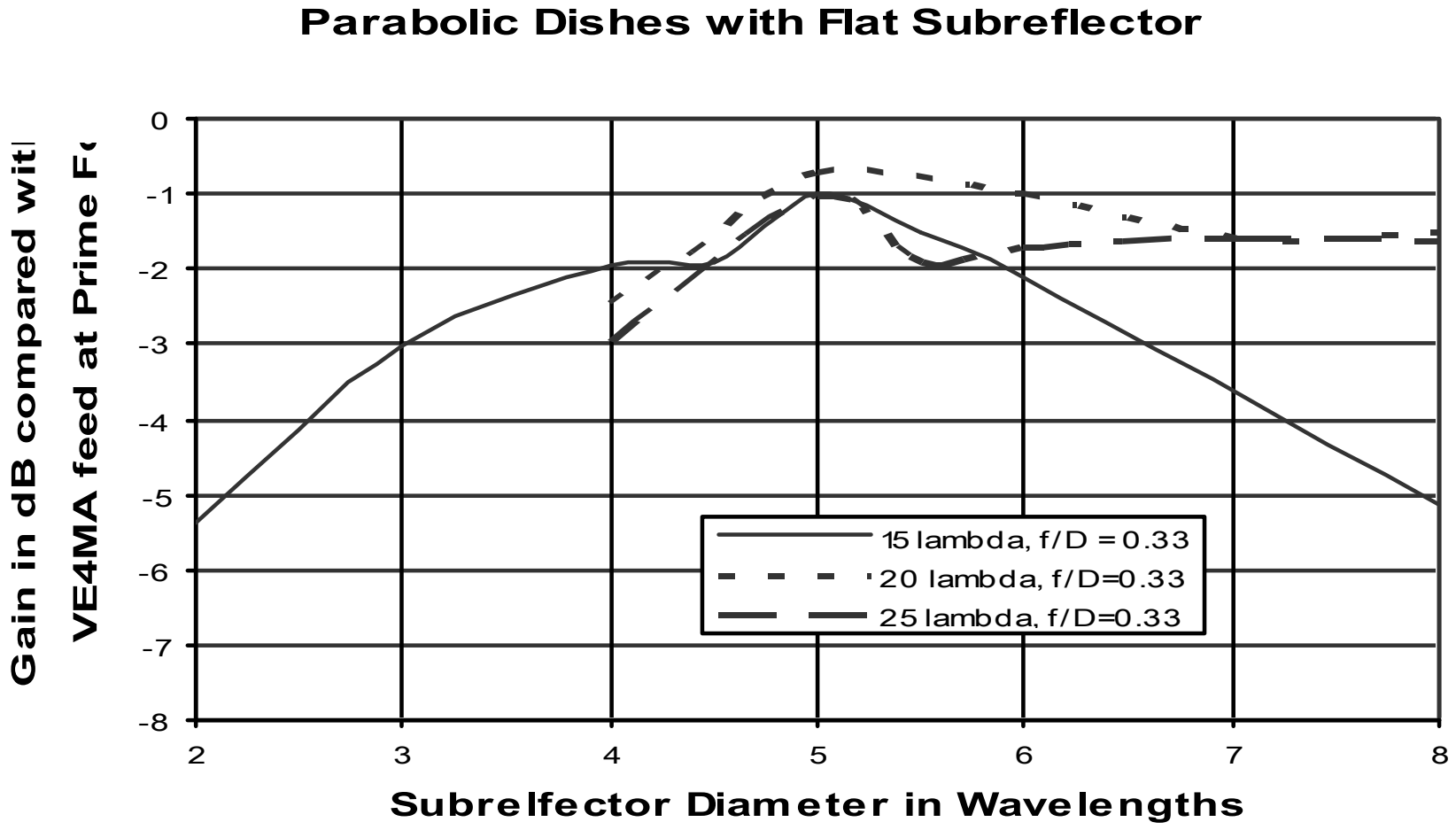
Flat Subreflector Dish Pattern



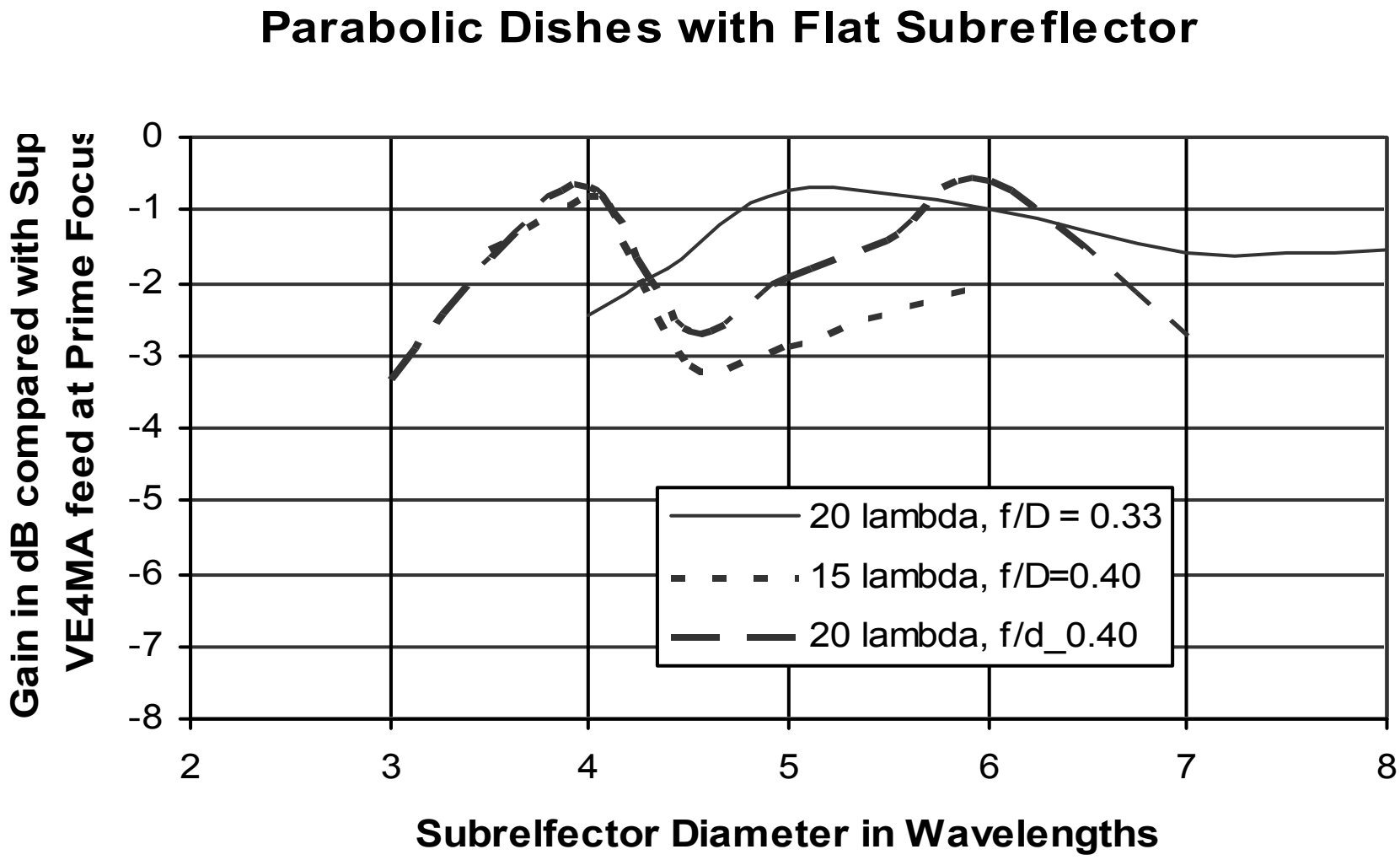
Small Dish, Flat Subreflector

- Pattern Degradation – 1+ dB
- Power reflected back into feed – 1++ dB
- VSWR can be tuned out, but dish area still blocked
- Interaction between feedhorn and subreflector
- Diffraction at Subreflector edge = sidelobes
- Coffee-can feed nearly as good
  - Smaller shadow = less blockage

Small Dishes - 15, 20, 25λ Flat Subreflector



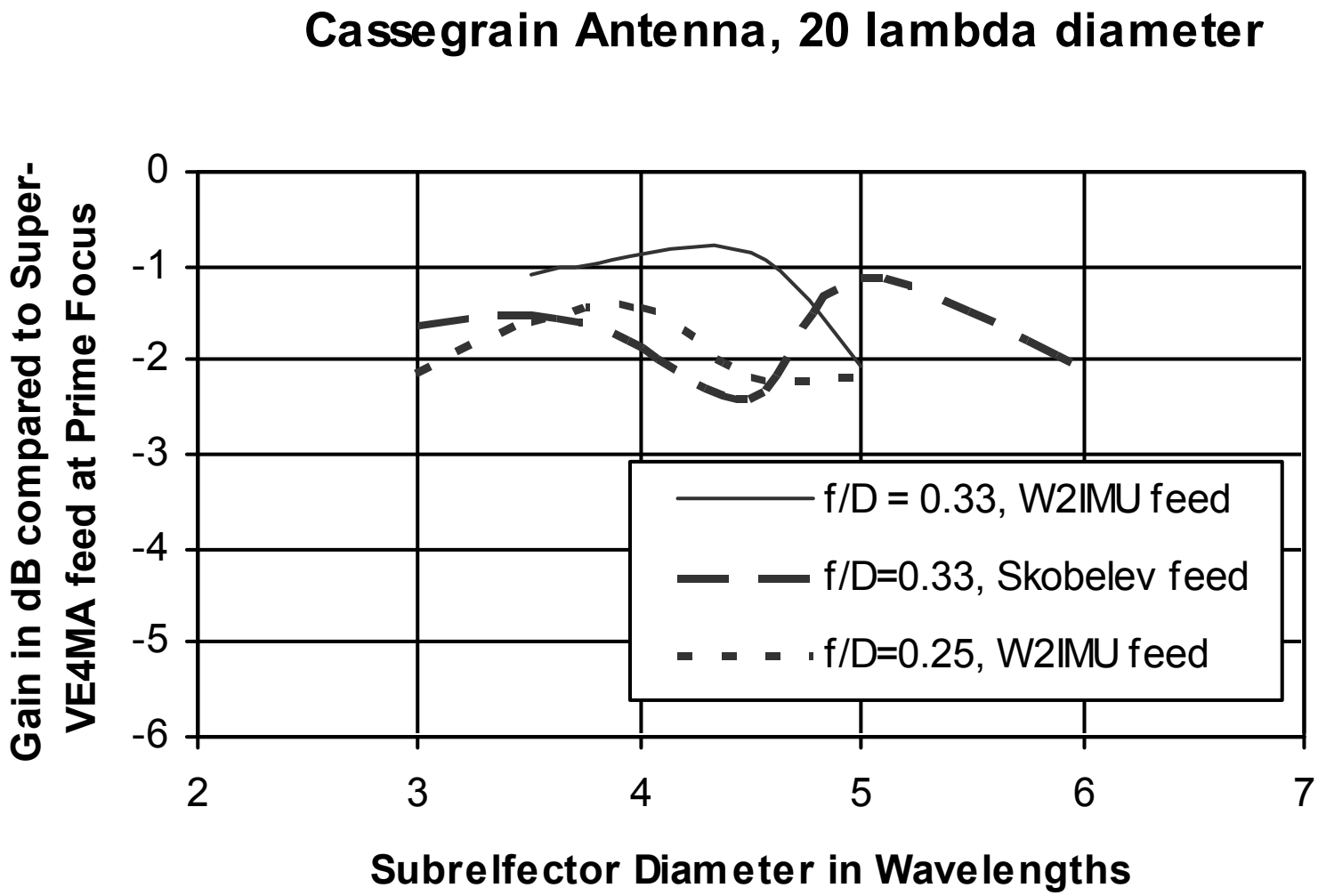
Small Dish – *f*/D = 0.4 Flat Subreflector



Small dish, Flat Subreflector

- Increasing dish size reduces losses
  - Less subreflector blockage
  - Feed spaced farther from subreflector
    - Less power reflected into feed
    - <½ dB loss from reflected power
- *f*/D doesn't make much difference
- *Bottom line (best case) –*
- *Flat Subreflector costs 1.5 to 2 dB*

Small Deep Dish - 20λ Cassegrain Subreflector



Small Dish, Cassegrain Subreflector

- Cassegrain Subreflector loss 1 to 2 dB
- Comparable to Flat Subreflector *for small dish*
- More feed choices – can improve spacing
- Good performance with very deep dish

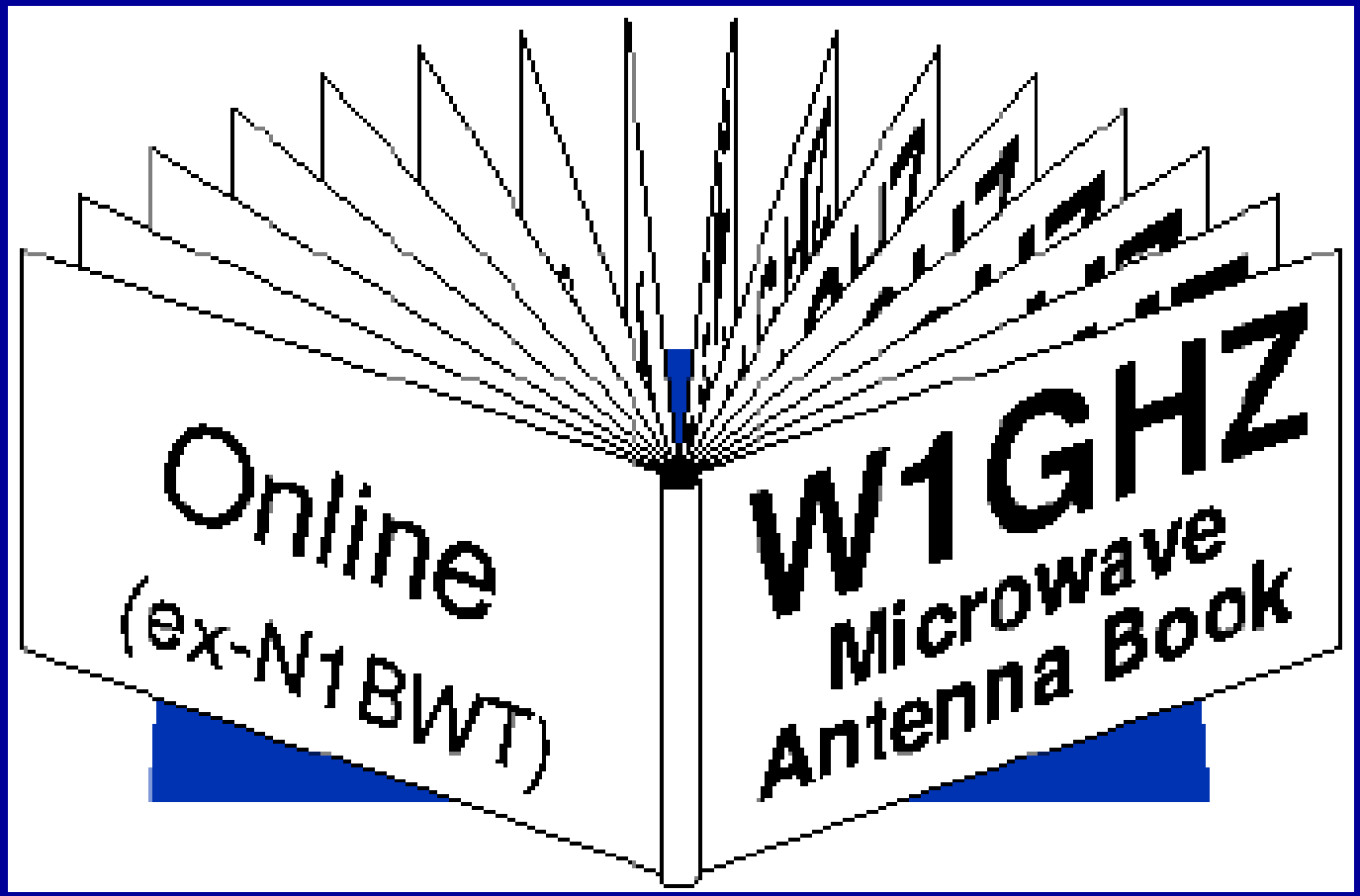
Summary - Flat Subreflector

- Cost is *at least* 1 to 2 dB
- At high microwave frequencies, may be less than feedline loss
- Convenience and simplicity factor

- Different answer for EME – dB are precious

So, what's the best antenna?


RCA
Whatever gets you on the air



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