FEEDHORN ANALYSIS FOR PARABOLIC DISH G/T

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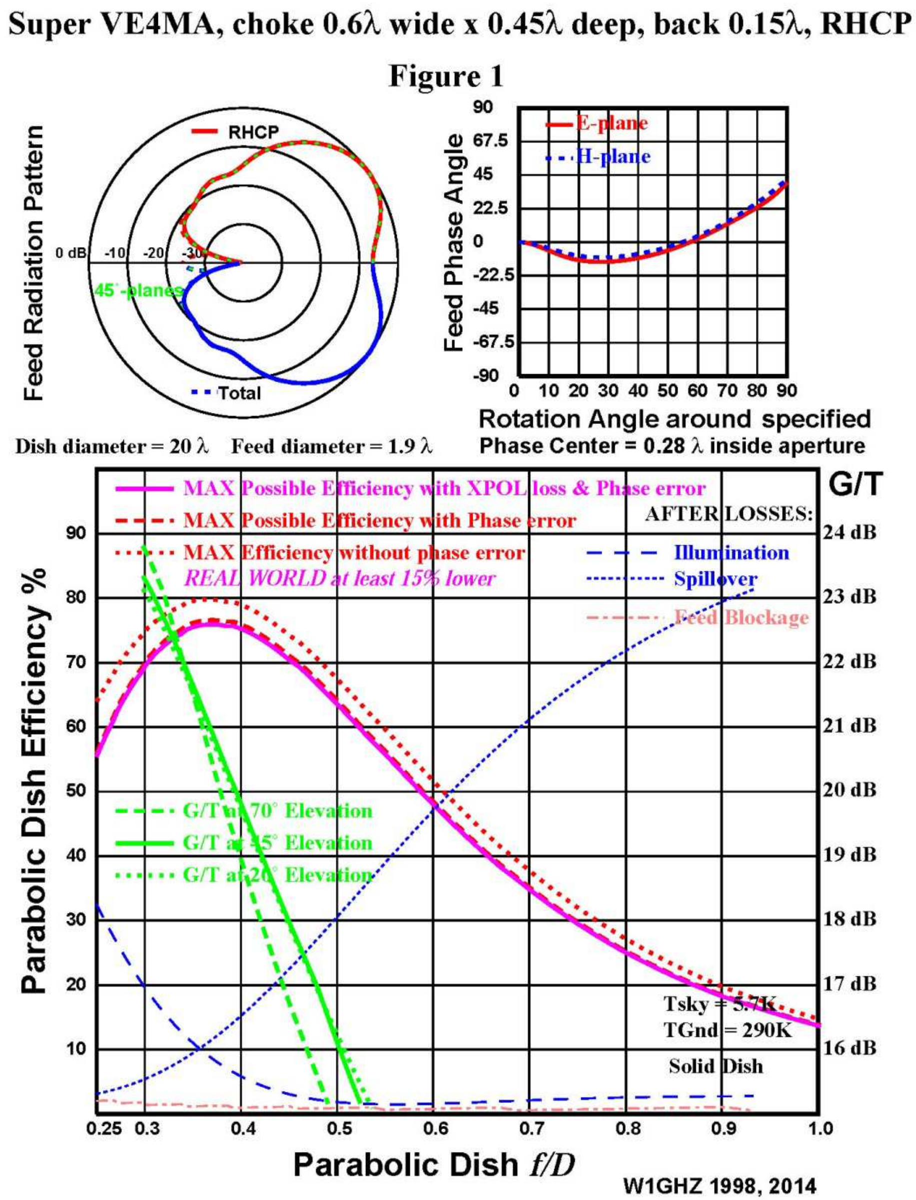
EME 2014

Parabolic Dish Feedhorn Analysis

- Traditionally for efficiency – maximum gain
  - OK for Terrestrial
- G/T calculations
  - OE9PMJ – 1984
  - OE5JFL – 1992
  - OM6AA – 2009, 2011
  - RA3AQ – 2013
  - ONLY for a few feeds and f/D
- Need rapid calculation to compare feedhorns
  - Feed_GT program

Add G/T to Efficiency Plot



G/T

- $$\frac{G}{T} = \frac{Antenna\ Gain}{Noise\ Temperature\ (K)} \rightarrow \frac{\text{Signal}}{\text{Noise}}$$

- Antenna
  - $$\frac{G}{T} = \frac{Antenna\ Gain}{Antenna\ Temperature}$$

- System
  - $$\frac{G}{T} = \frac{Antenna\ Gain}{Antenna\ Temperature + Receiver\ Noise\ Temperature}$$

Calculations

- Dish Efficiency

$$\eta = \frac{\iint_{reflector} U_{CP}(\theta,\emptyset) sin\theta d\theta d\emptyset}{\iint_{all\ pol} U_{all}(\theta,\emptyset)\ sin\theta d\theta d\emptyset} = \frac{Desired\ polarization\ on\ reflector}{all\ polarizations\ 360°}$$

- Gain

$$G = \eta \frac{4\pi}{\lambda^2} \text{Area} = \text{Efficiency} * \text{Aperture Gain}$$

- Temperature

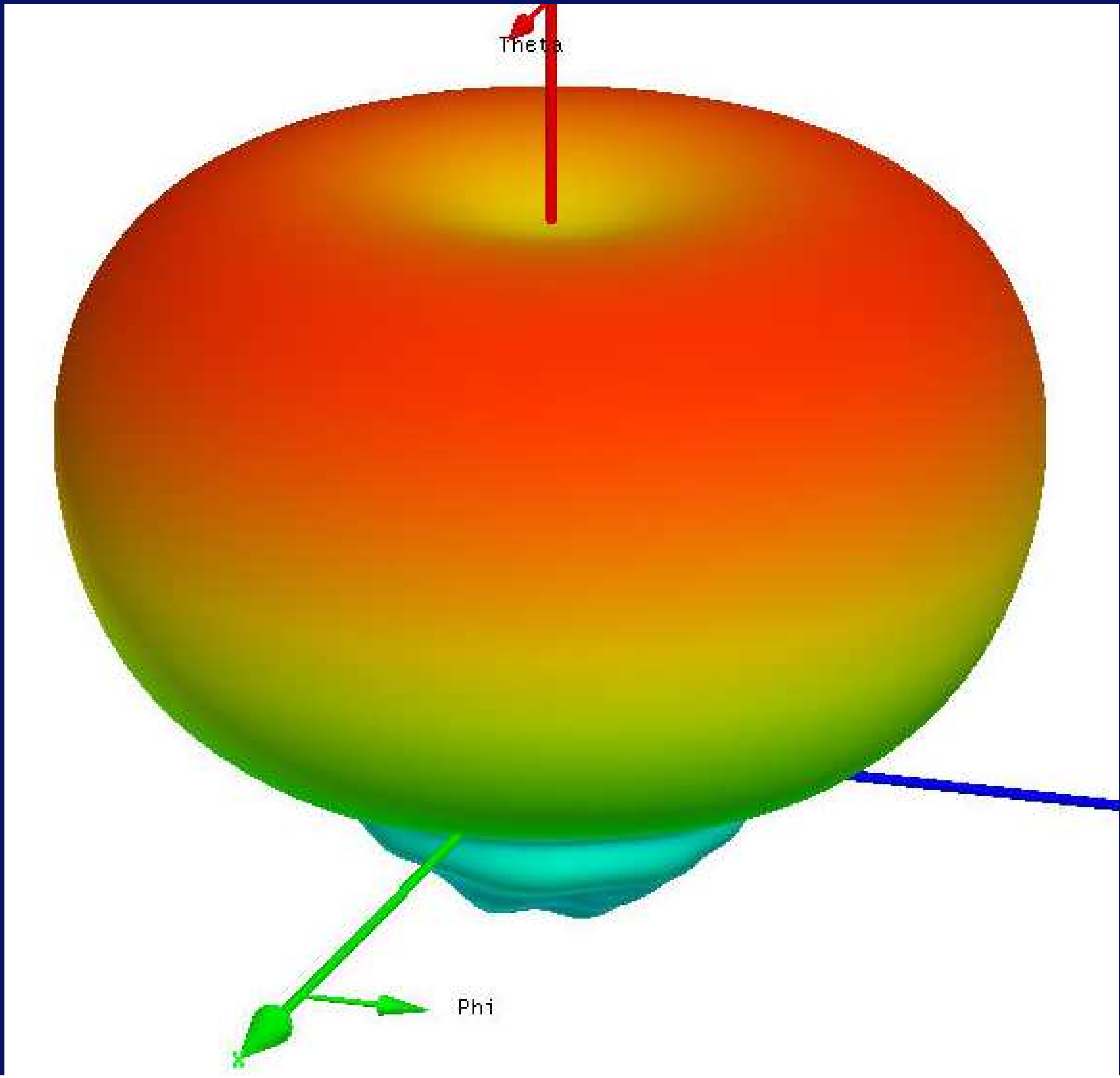
$$T = \iint_{all\ pol} Noise(\theta,\emptyset) U_{all}(\theta,\emptyset) sin\theta d\theta d\emptyset$$

- $\frac{G}{T}$ -> in dB, $10log\left(\frac{G}{T}\right)$

Approximations

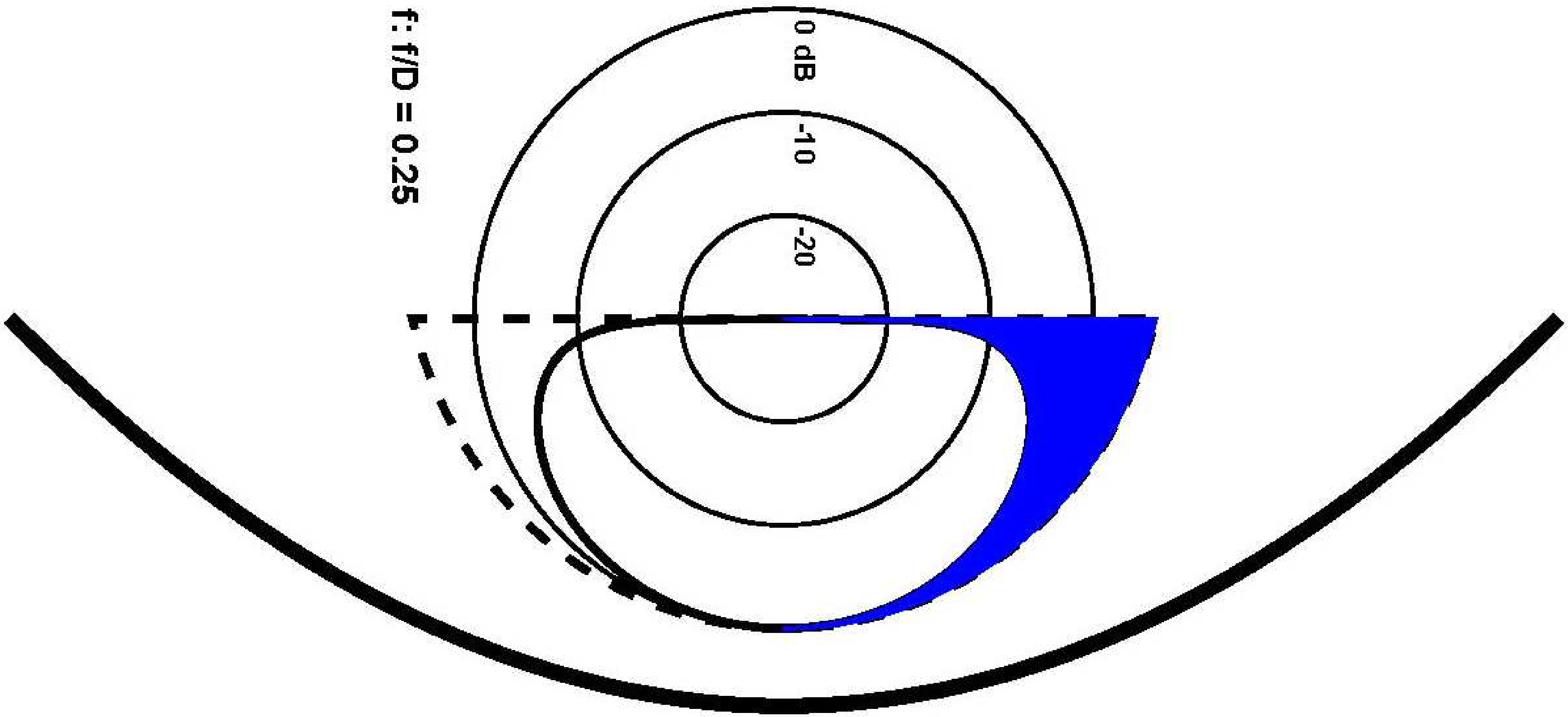
- Well behaved CP feeds
  - Only 0, 45, and 90 degree pattern cuts needed
- No edge diffraction calculation
  - Noise calculation optimistic for very deep dishes
- Sky noise is uniform
  - OK at higher elevation angles
- No interaction between feed and reflector
  - Small effect for large dishes

Well-behaved CP feed pattern

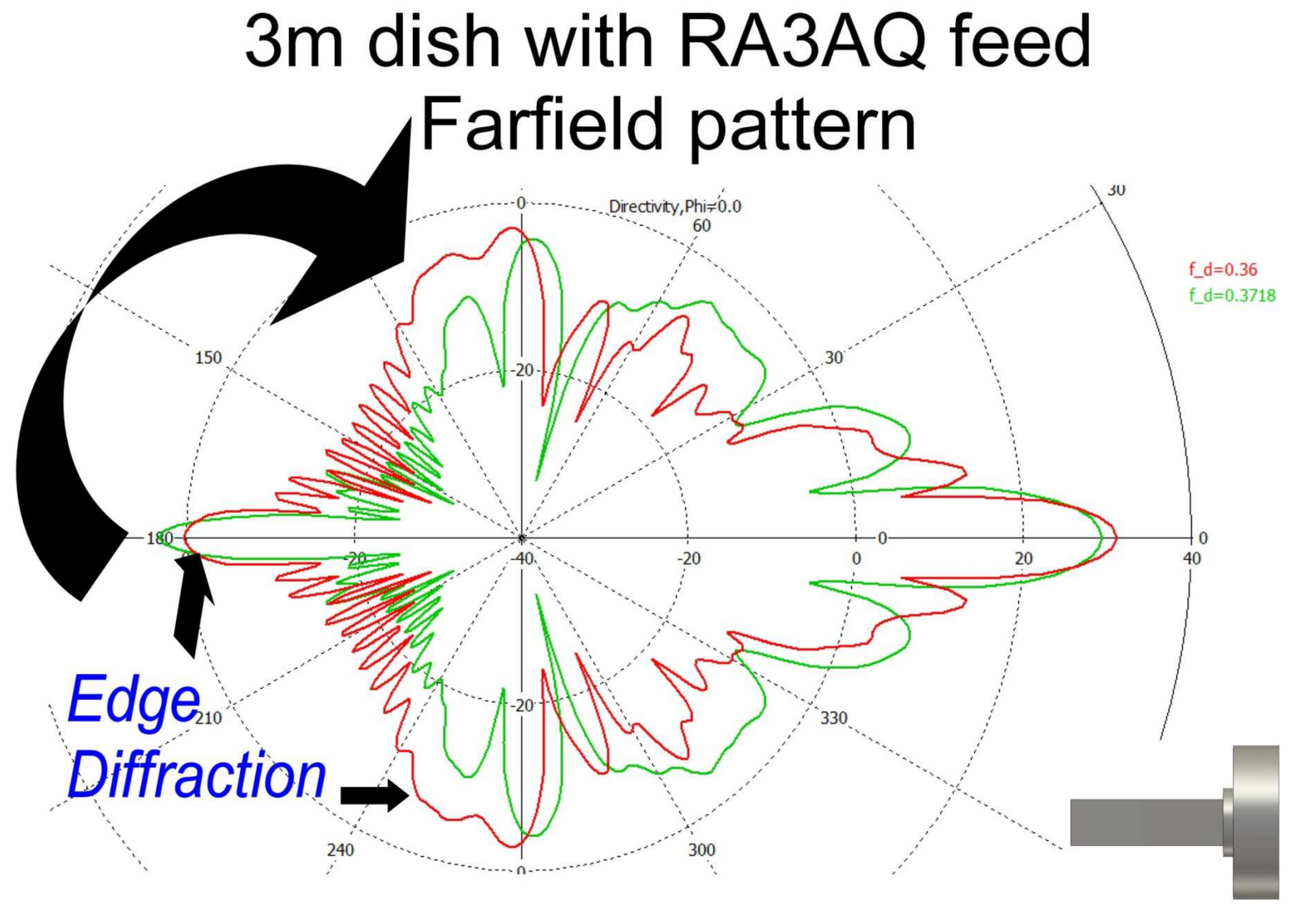


Edge Diffraction - Deep Dishes

Reflector shields feed from ground noise



Edge Diffraction



Edge Diffraction

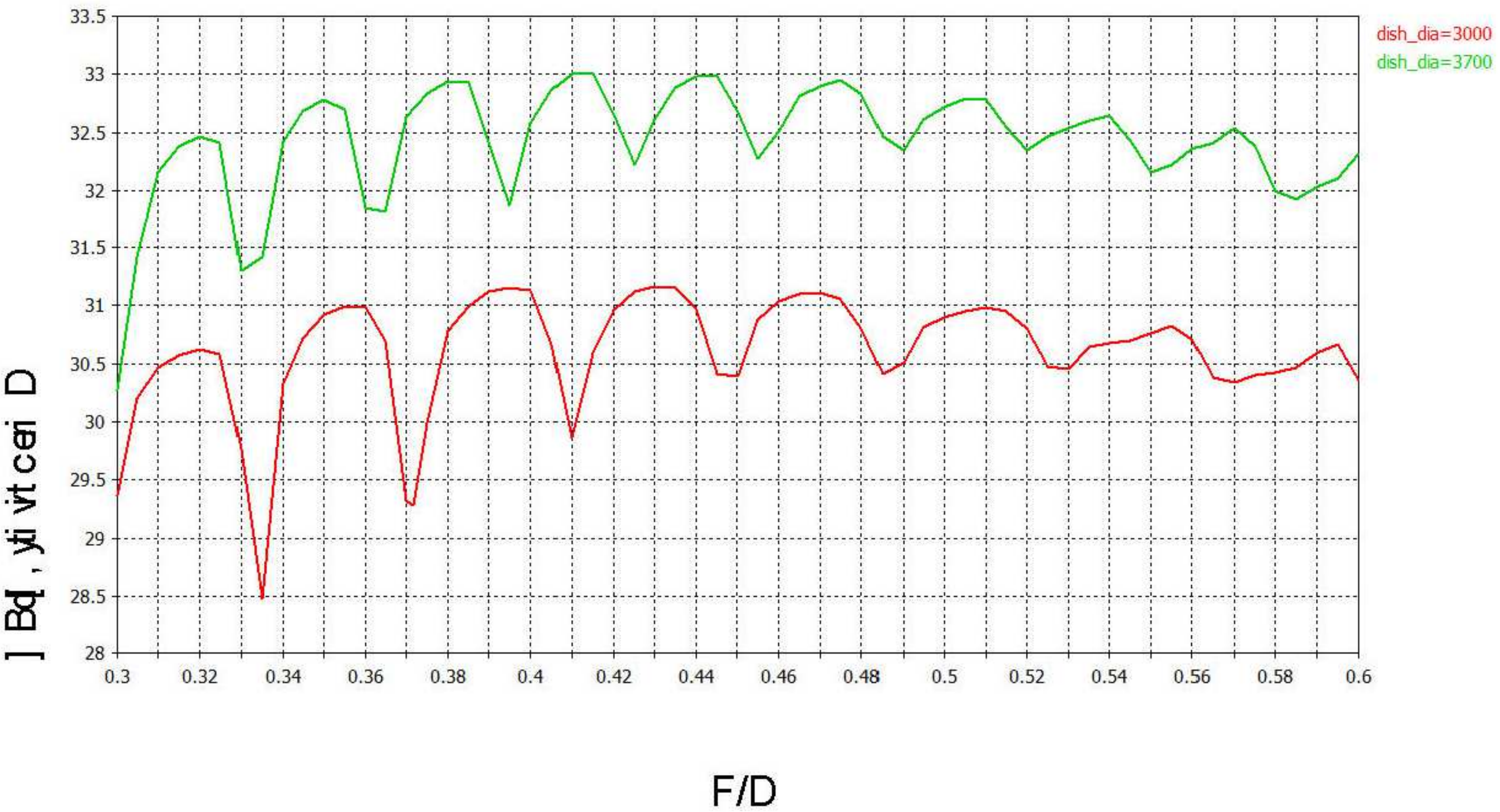
- Edge Diffraction Lobes at 90 and 180 degrees
  - Added ground noise
- Extremely difficult to calculate
- Very deep dishes shield feed from ground
  - Optimistic G/T without Edge Diffraction

- G/T not plotted for f/D < 0.3

Interaction between feed and reflector (Mirror Reaction – RA3AQ)

Directivity vs FD for 3m and 3.7m dish

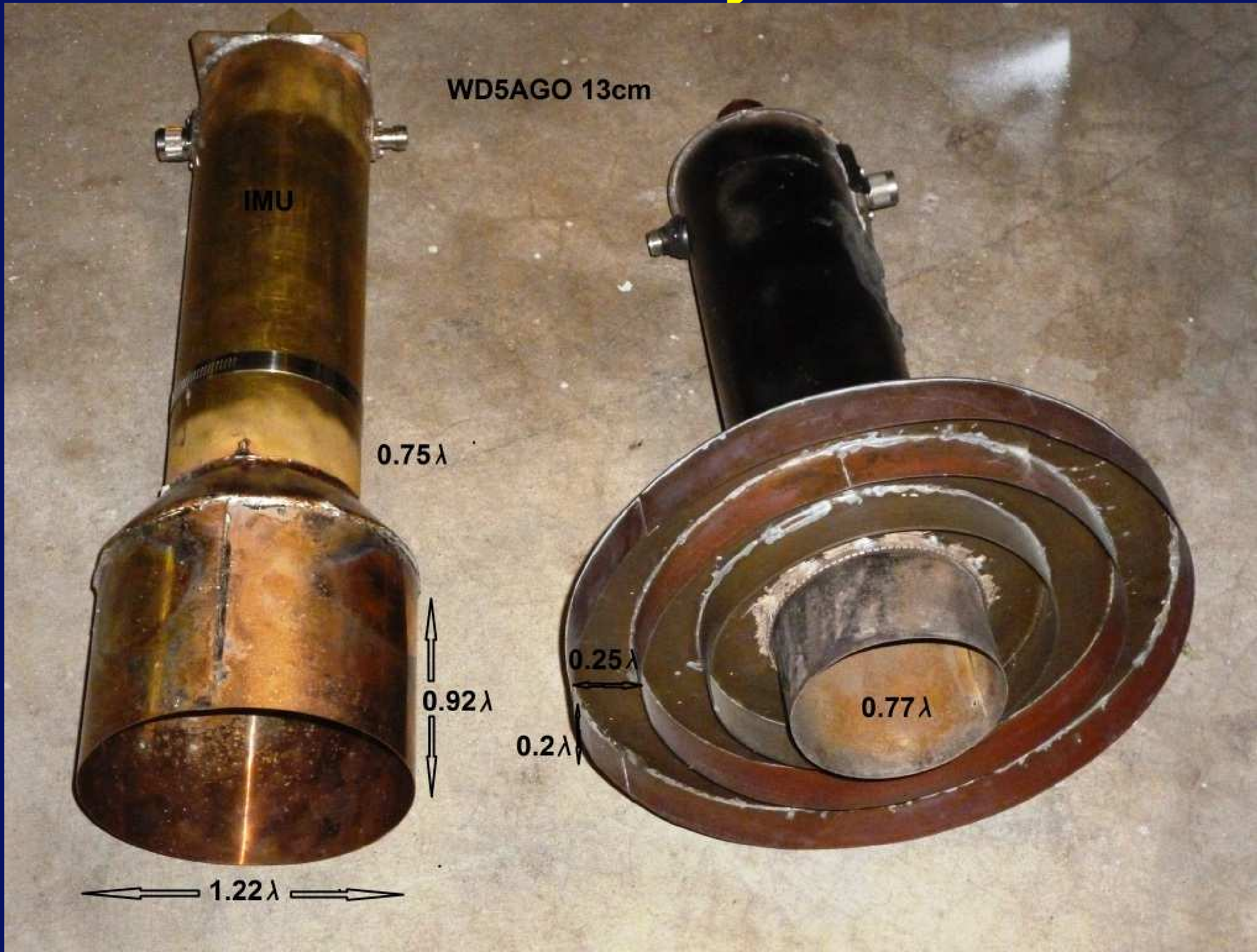
Interaction less for big dishes



Interaction between feed and reflector (Mirror Reaction)

- Interaction is power reflected from dish back into feed
- $\Gamma_m = \frac{G_0 \lambda}{4 \pi f}$
- Reflected power mismatch interacts with system Γ
- $\frac{\Delta T}{T} = 4 \Gamma_m \Gamma$
- Noise increase
- Mismatches can be tuned to cancel
- ***BUT*** – CP reverses polarization when reflected
  - Signal goes to other port
  - Noise is not polarized – reflected back

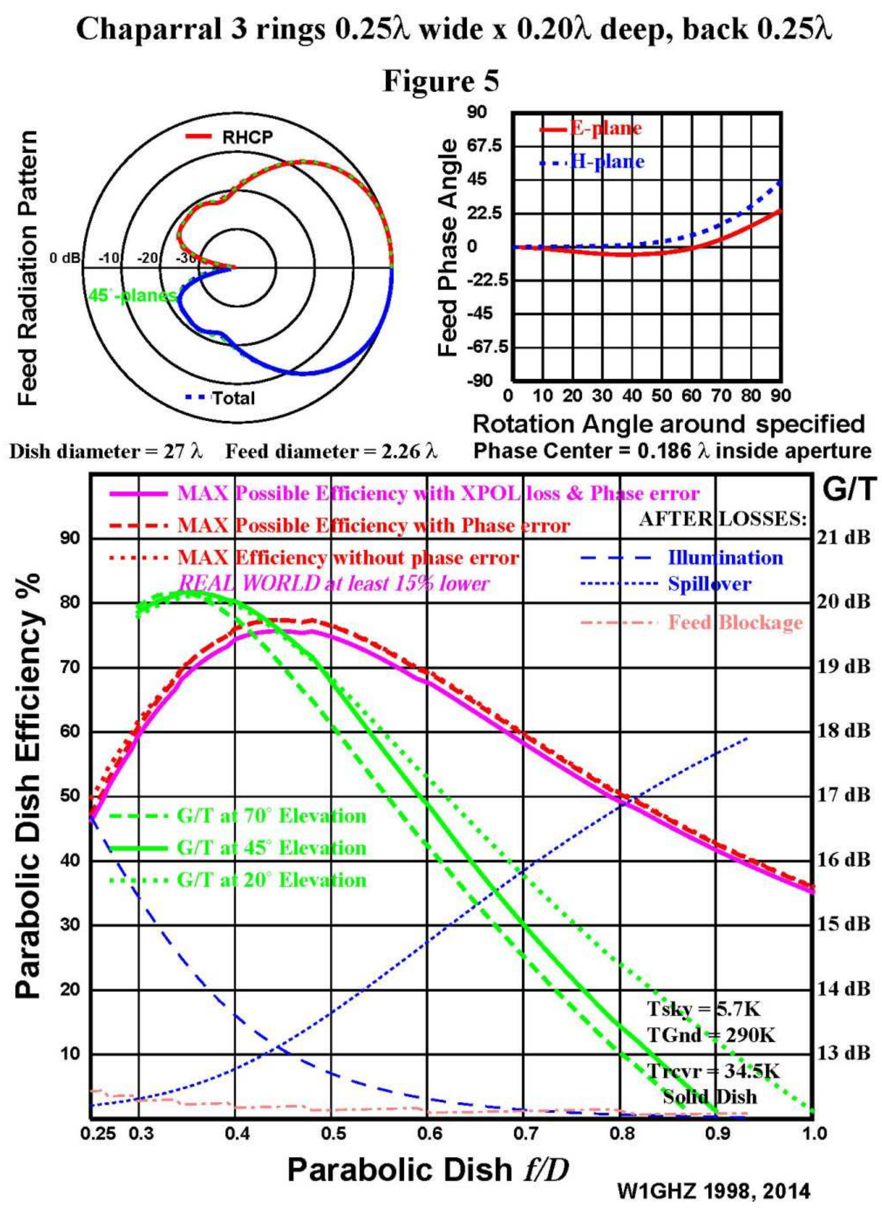
Measurements by WD5AGO



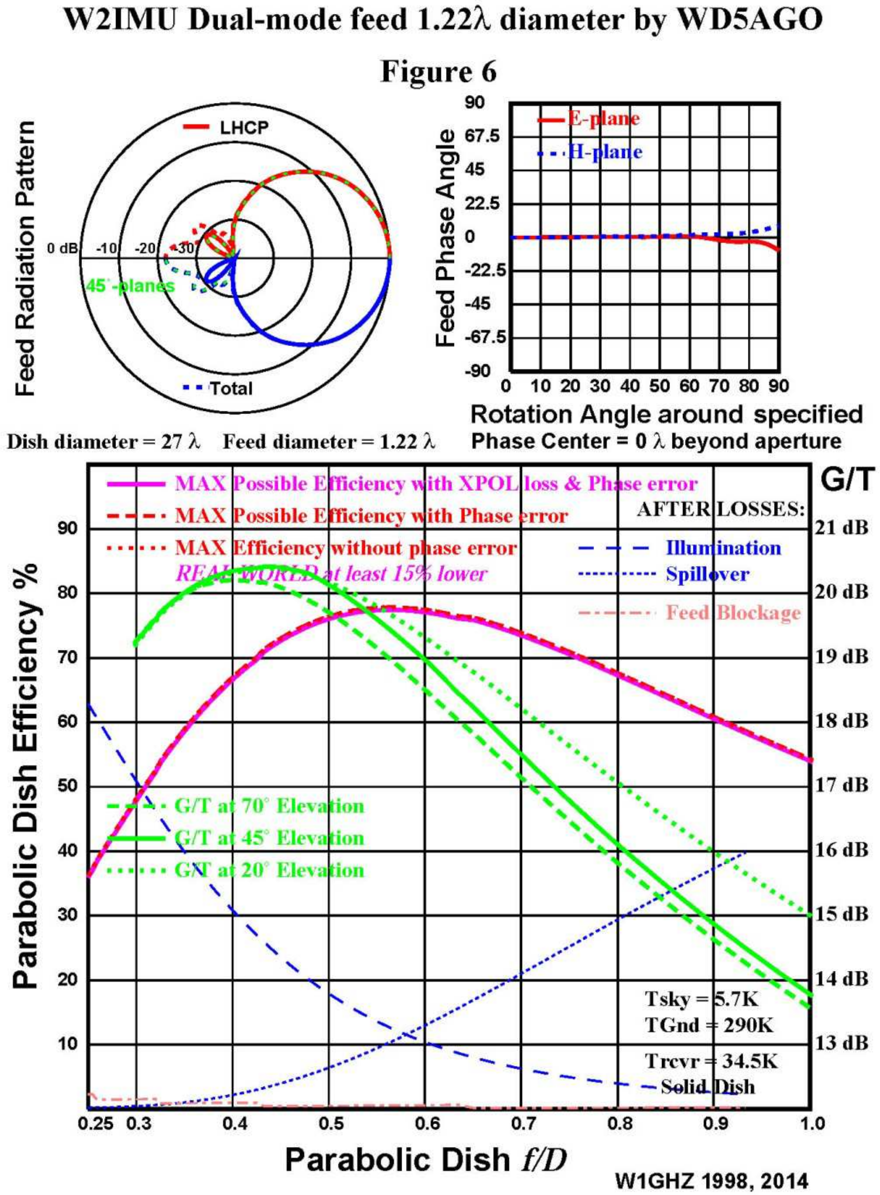
W2IMU

Chaparral

Chaparral 3 rings



W2IMU 1.22λ



W2IMU Dual-mode feed 1.22λ diameter by WD5AGO
Figure 6
LHCP
Feed Radiation Pattern
0 dB -10 -20 -30
45° planes
Total
E-plane
H-plane
Feed Phase Angle
90 67.5 45 22.5 0 -22.5 -45 -67.5 -90
0 10 20 30 40 50 60 70 80 90
Rotation Angle around specified
Phase Center = 0 λ beyond aperture
Dish diameter = 27 λ Feed diameter = 1.22 λ
MAX Possible Efficiency with XPOL loss & Phase error
MAX Possible Efficiency with Phase error
MAX Efficiency without phase error
REAL WORLD at least 15% lower
G/T
AFTER LOSSES:
Illumination
Spillover
Feed Blockage
Parabolic Dish Efficiency %
G/T at 70° Elevation
G/T at 45° Elevation
G/T at 20° Elevation
21 dB 20 dB 19 dB 18 dB 17 dB 16 dB 15 dB 14 dB 13 dB
Tsky = 5.7K
TGnd = 290K
Trcvr = 34.5K
Solid Dish
0.25 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Parabolic Dish f/D
W1GHZ 1998, 2014

Measurements by WD5AGO
27λ dish at 13 cm

Chaparral – 3 ring

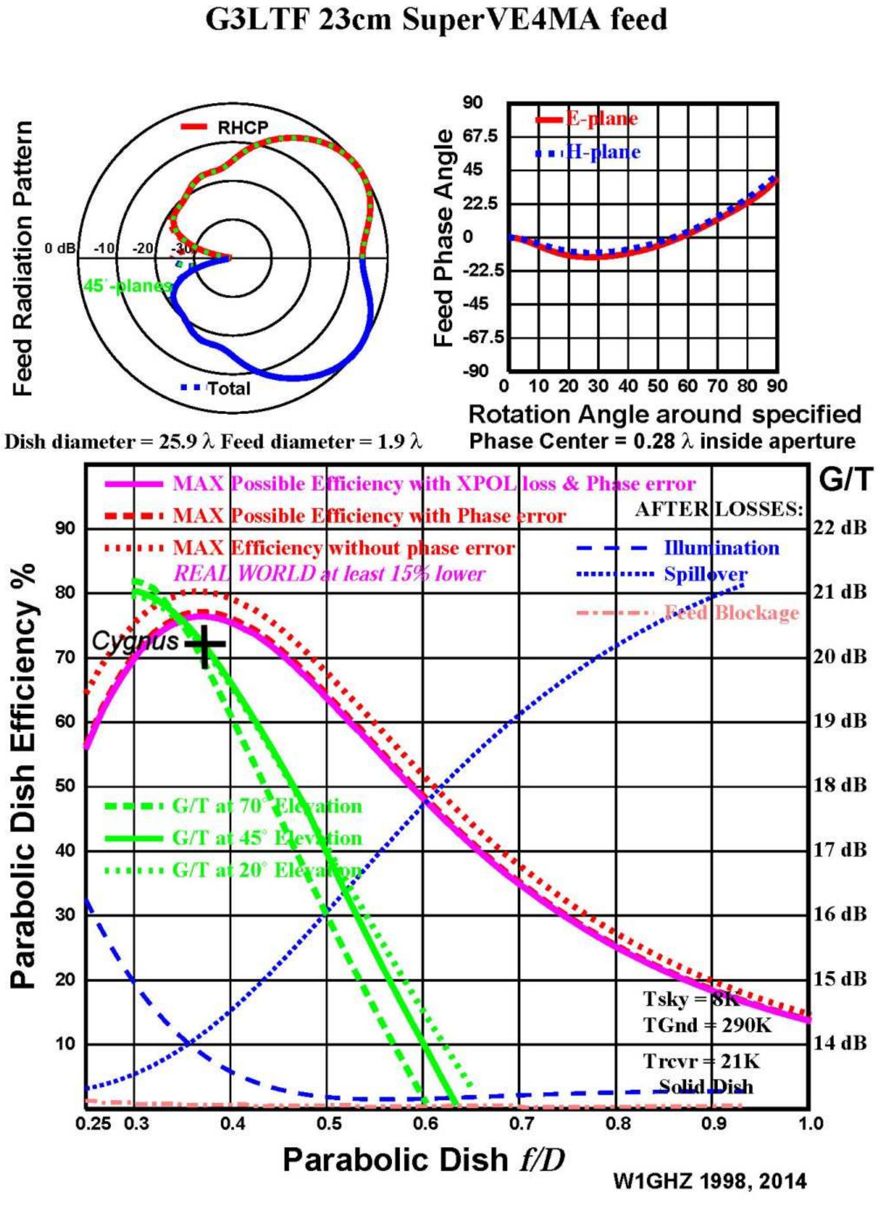
- Sun – 16 dB
- Moon – 0.4 dB
- Cygnus A – 0.12 dB

W2IMU – 1.22λ

- Sun – 15.6 dB
- Moon – 0.35 dB
- Cygnus A – 0.10 dB

G3LTF Cygnus A Measurement

Y = 0.94 dB

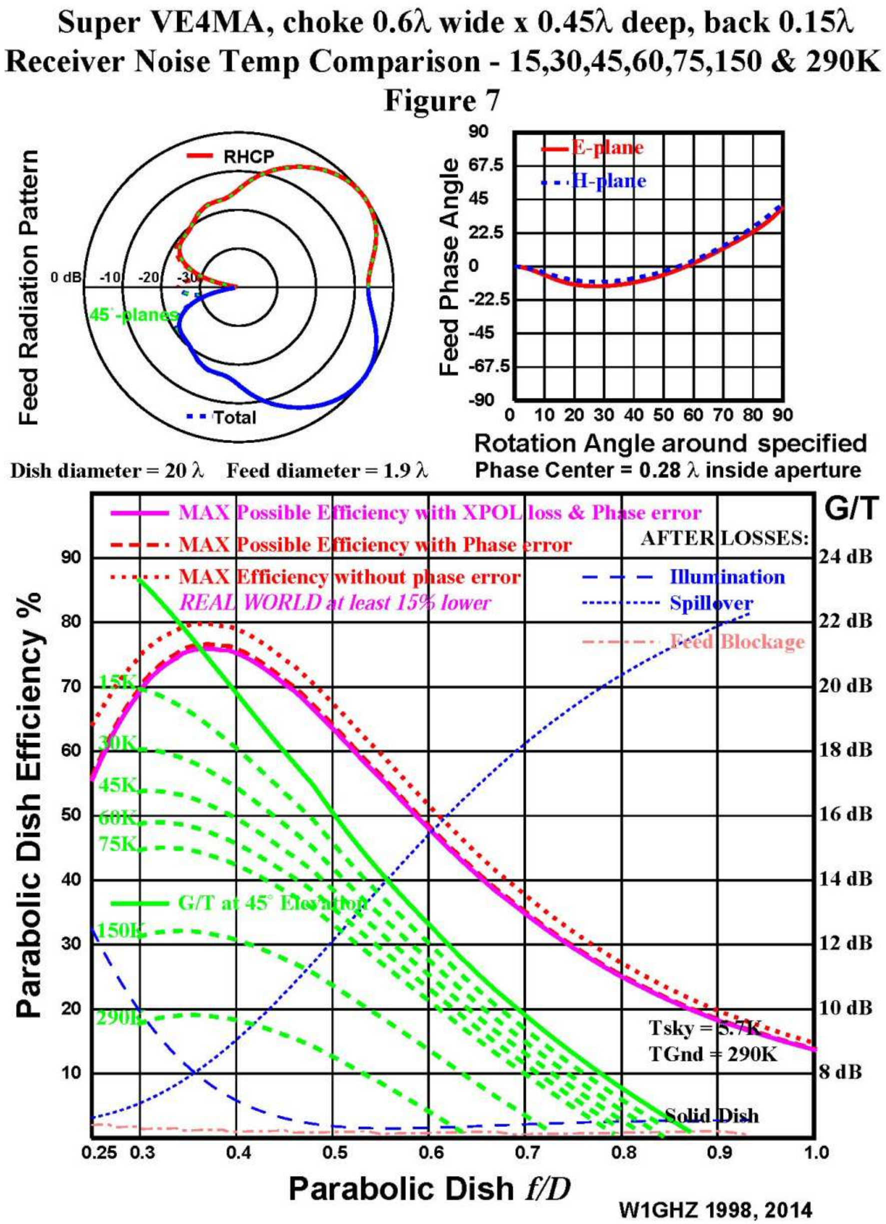


Little Difference between Feeds

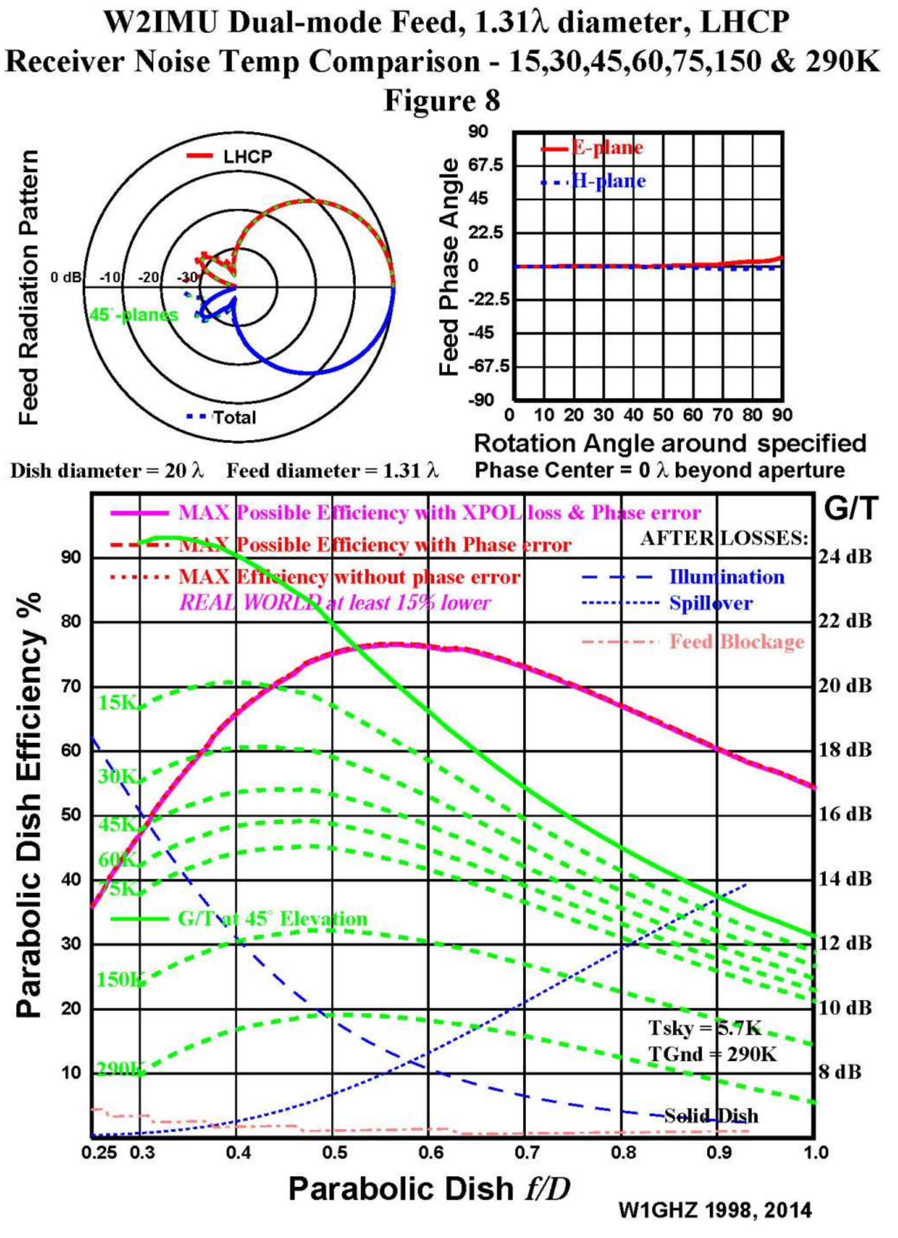
- Good feeds have low sidelobes, thus low noise
- Difference is efficiency at various f/D
- Gain proportional to efficiency
  - 60% to 75% = 1 dB
  - 50% to 60% = 0.8 dB
- *Only* a few dB

- Bad feeds have lower efficiency, higher sidelobes

Effect of Receiver Noise Temperature



Effect of Receiver Noise Temperature



Effect of Receiver Noise Temperature

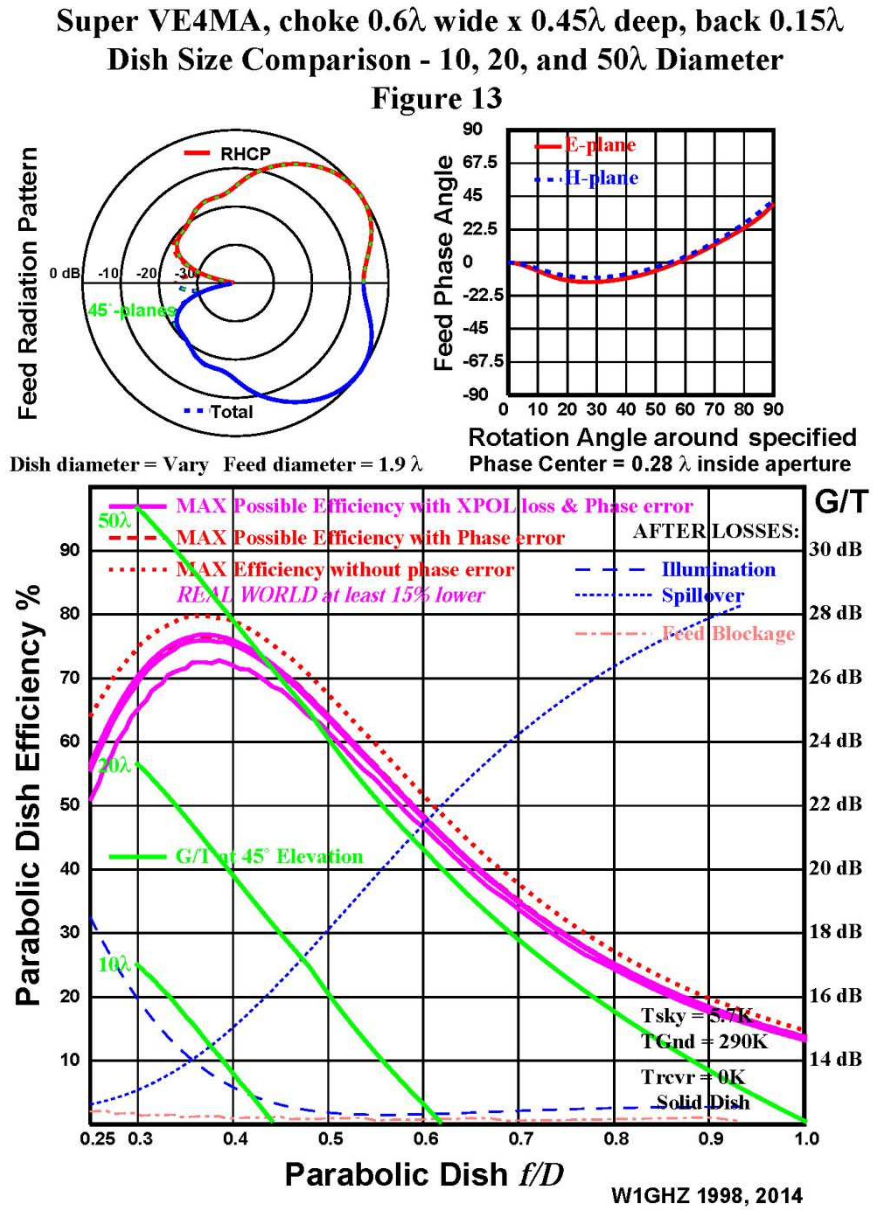
- Very low noise temperatures make a huge difference
- 0.1 dB change in NF → 1 dB change in G/T
- Serious LNA should be specified in K, not NF

Dish Size

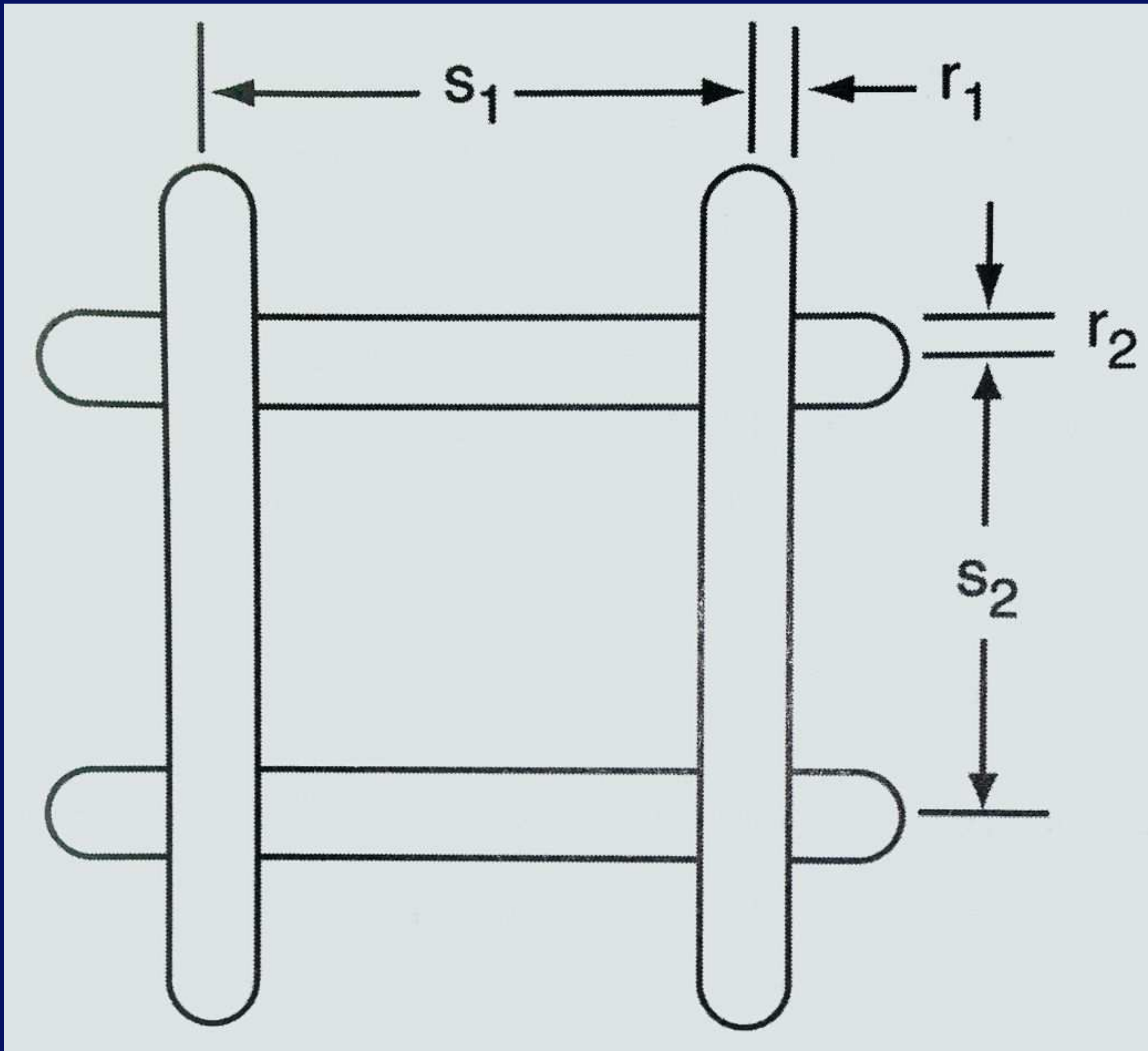
Gain proportional to size

Slight change in efficiency due to feed blockage

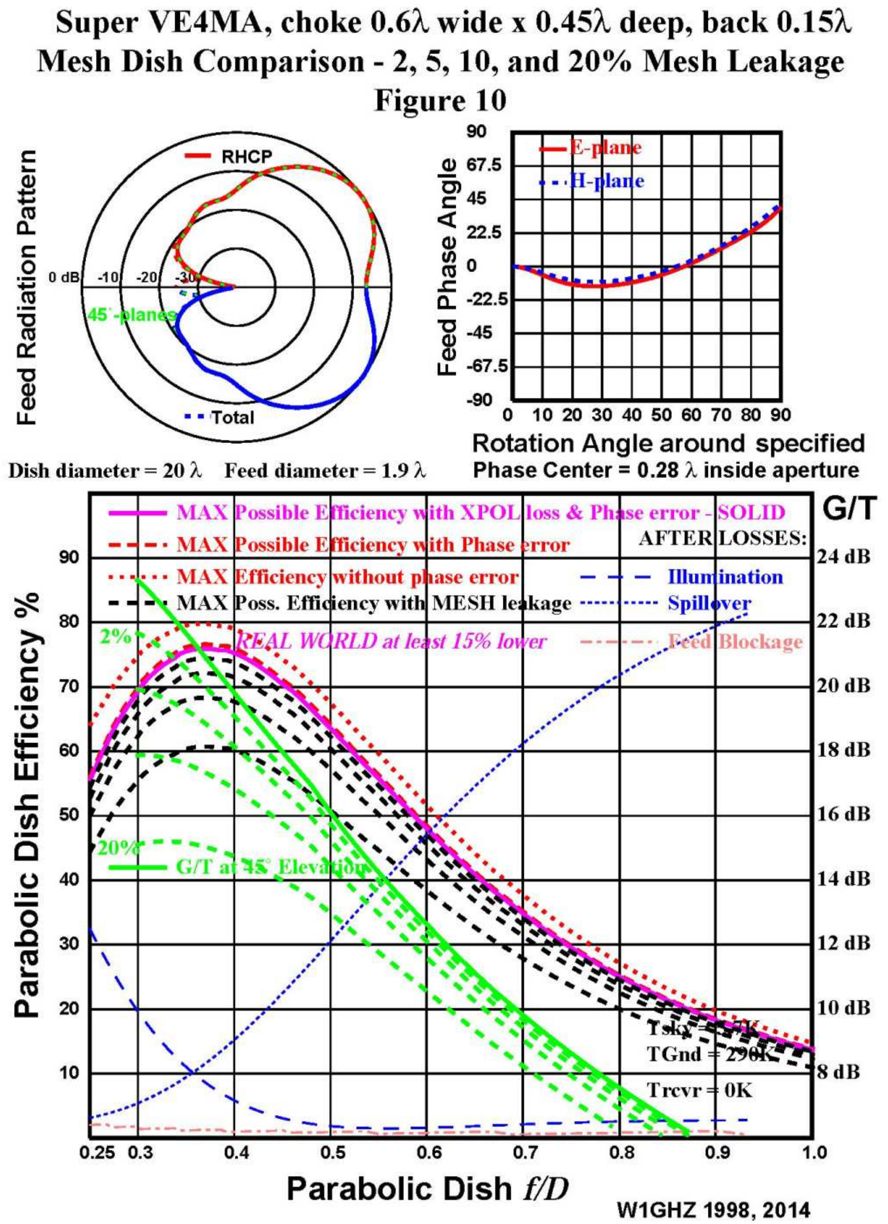
G/T follows gain



Mesh Reflector Leakage



Mesh Reflector

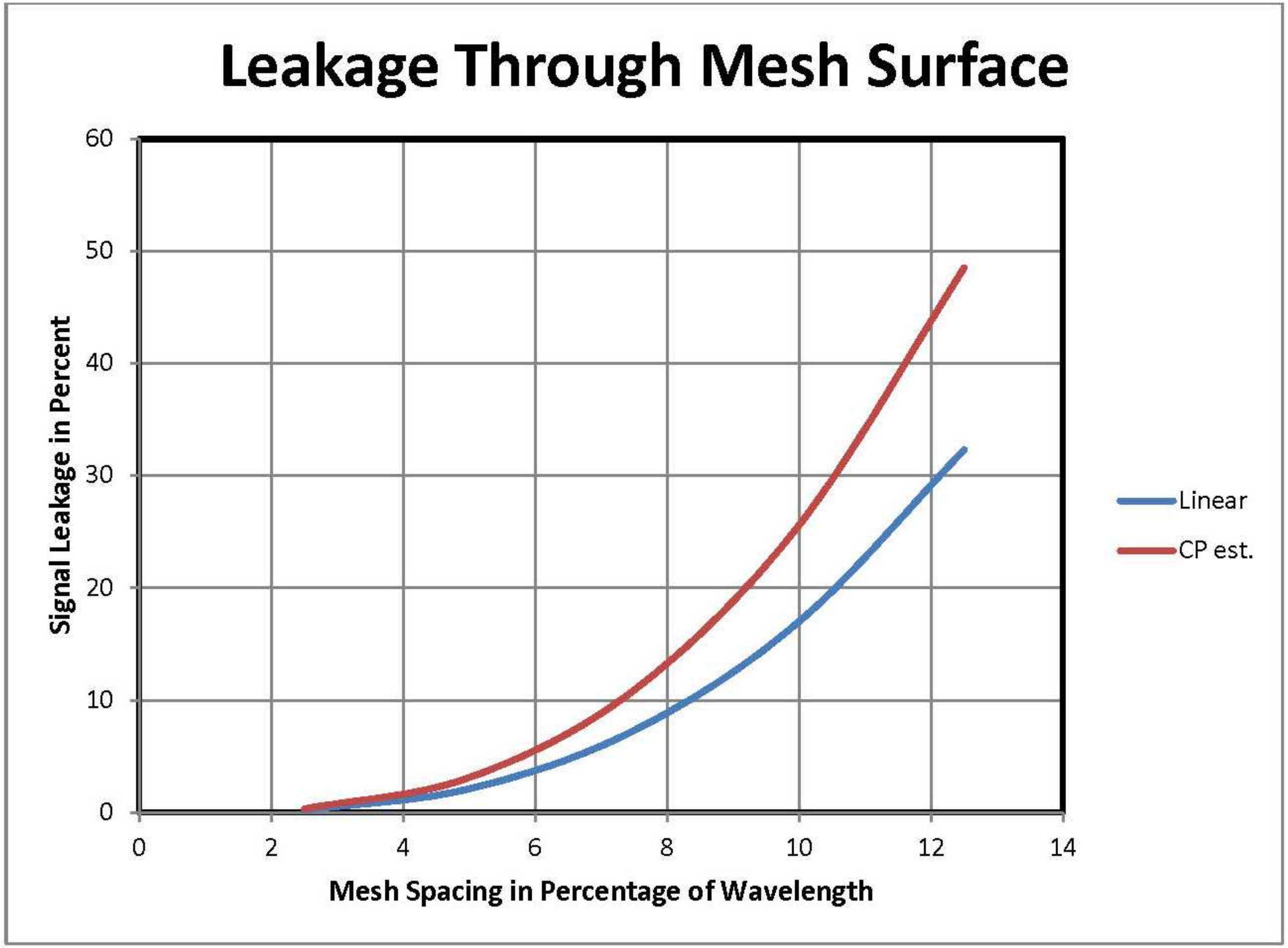


Mesh Reflector

- Mesh leakage reduces efficiency and gain
- Noise leaks through from ground at ~290K
- 20% leakage reduces gain by 1 dB, G/T by ~6 dB

- Adding mesh around edge without changing feedhorn
  - Reduces spillover noise – even with leakage
  - No effect on gain
  - Better G/T
  - Then increase TX power

Mesh Reflector Leakage Calculator on CD – from Otoshi



Feeds on CD

- VE4MA
- Super-VE4MA
- W2IMU dual-mode – several sizes
- RA3AQ – 042 (2008)
- Skobelev optimum dual mode – two sizes
- SM6FHZ CP Patch
- Coffee can (cylindrical waveguide)
- N2UO round septum - bare
- WA9HUV – cylindrical horn with flange
- OK1DFC square septum – bare and with flange

Program

- Feed_GT.exe
  - Plots efficiency and G/T from feed patterns
  - Writes data to .csv file for spreadsheet
  - Feed pattern data available
  - Pattern data for new feeds

- Available at www.w1ghz.org

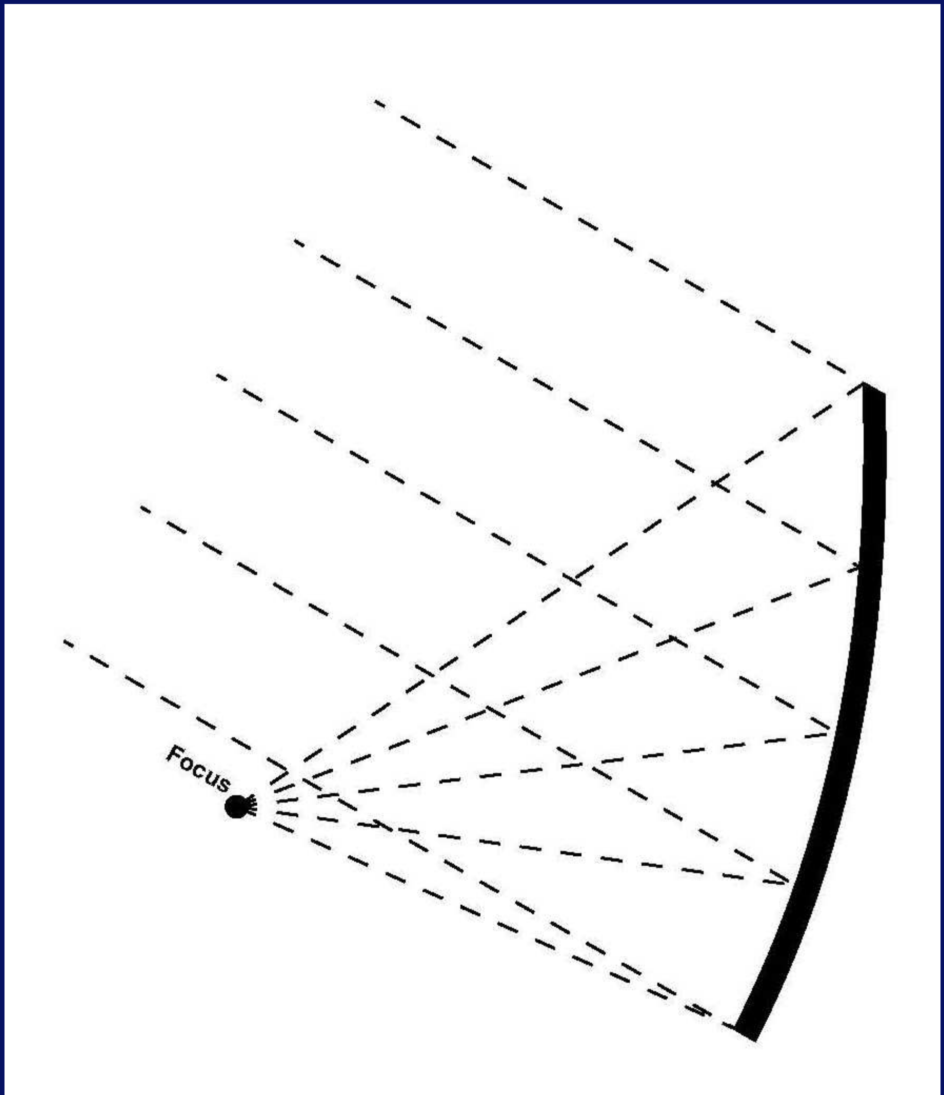
Offset Dishes

More complex geometry

Elevation tilt more complicated

- Spherical geometry

Have not written code yet



G/T Summary

- Slight under-illumination for best G/T
- Optimize feed in dish
- Minimum Tsys
  - Preamp
  - Loss from feed to preamp
- Measure
- Serious EME dish should measure Celestial sources
  - Cassiopeia
  - Taurus
  - Cygnus

www.w1ghz.org