EVLA Receiver Bands and Feed Parameters

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Selection of Bands

- Minimize number of receivers
- Use existing technology
- Acceptable performance at the band edges – feeds, polarizes, amplifiers, etc.

Selection of Feed Type and Parameters

- Nominal taper of -13 dB at 9.25 degrees
- Compact horns where space is limited
- Ring-loaded corrugations (except for Q-band)
- Number of corrugations/wavelength = 4.0

EVLA Receiver Bands

Band	Freq. (GHz)	Bandwidth Ratio	Feed Type
L	1-2	2:1	Compact Horn
S	2-4	2:1	Compact Horn
C	4-8	2:1	Compact Horn
X	8-12	1.5:1	Linear Taper Horn
Ku	12-18	1.5:1	Linear Taper Horn
K	18-26	1.44:1	Linear Taper Horn
Ka	26-40	1.53:1	Linear Taper Horn
Q	40-52	1.3:1	Linear Taper Horn
Note: All horns are corrugated horns.			

Ring-Loaded Corrugations

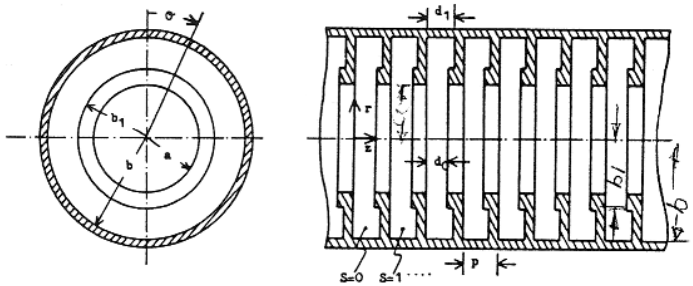


Fig. 1. Ring-loaded corrugated waveguide.

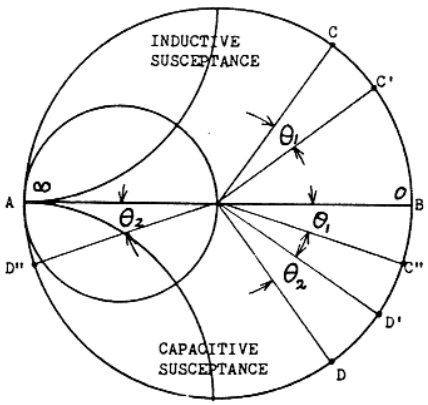


Fig. 2. Admittance chart.

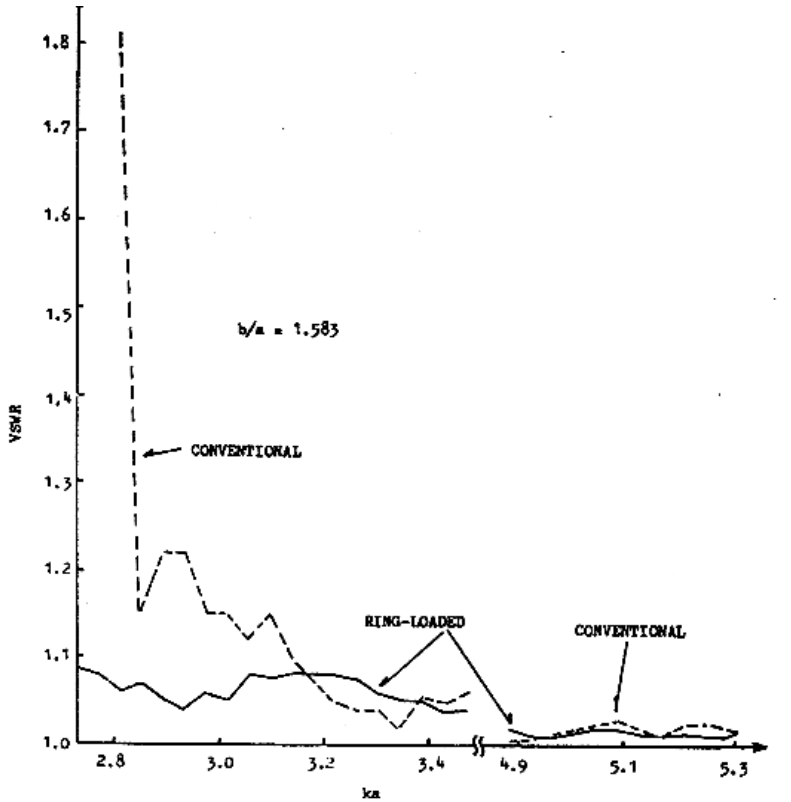


Fig. 5. VSWR for the transformers shown in Fig. 4(a) and (b).

Linear Taper vs Compact (Profile Taper) Horn

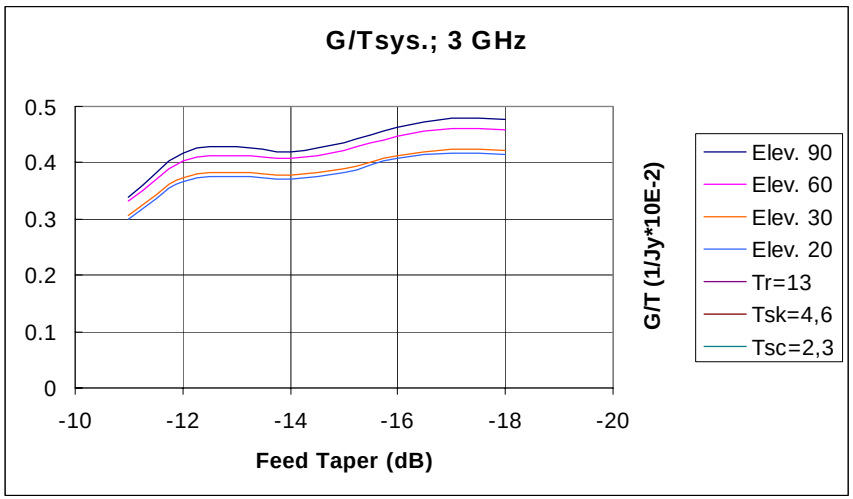
1. For a given taper of –13 dB at 9.3 degrees, a linear taper horn has an aperture diameter of 15λ, while a compact horn has an aperture diameter of 11.2λ (75%).

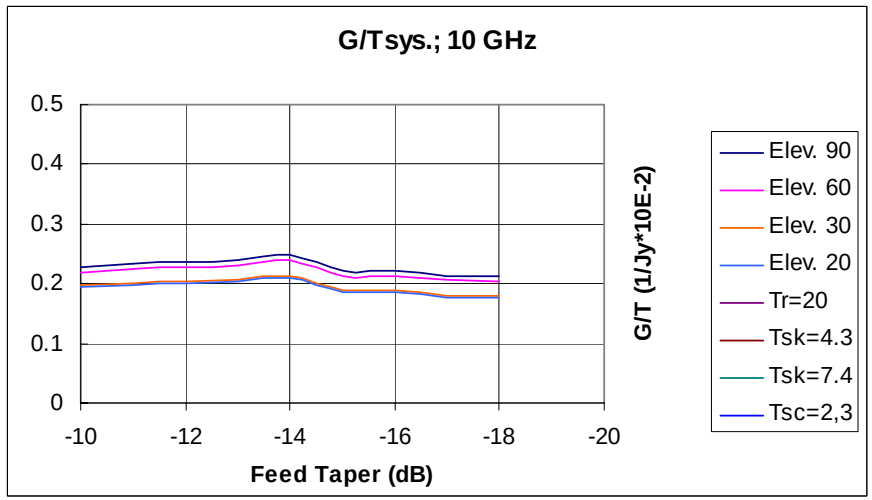
2. The length of the linear taper horn is 47λ, as compared to 32.5λ for the compact horn (69%).

3. Because of the changing profile in the compact horn, HE_{11} mode is converted to HE_{12} mode, which results in a reduction of aperture efficiency by about 7%. By making the horn longer, the conversion to HE_{12} mode can be reduced.

4. The phase center travels by about 12λ over the 2:1 bandwidth in the case of the compact horn. The linear taper horn has a relatively stable phase center.

G/T Results at 3 & 10 GHz





Conclusions from G/T Analysis:

- 3 GHz: Peak at -17 dB feed taper
  Too large at L, S and C bands
  L, S, C bands -13 dB
  G/T reduction by 10%
- 10 GHz: Peak at -14 dB feed taper
  X, Ku bands – -14 dB
- 30 GHz: Peak at -13 dB feed taper
  K, Ka, Q bands – -13 dB

L-Band Feed

Design and Prototype Tests

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Note: All horns are corrugated horns.			

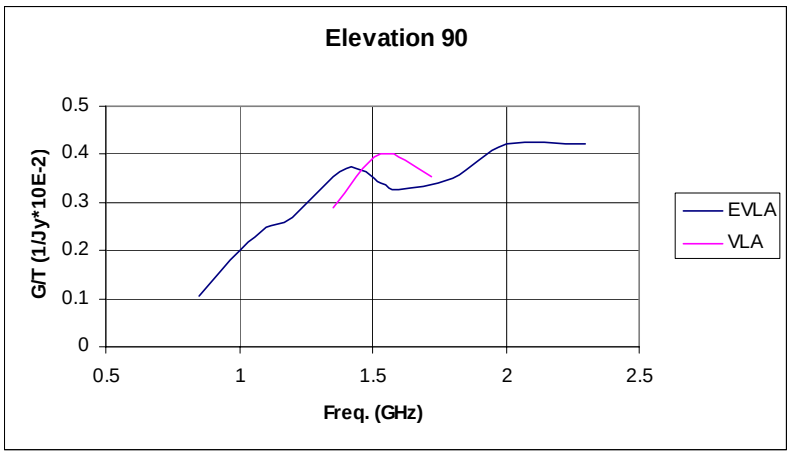
L-BAND ANALYSIS:

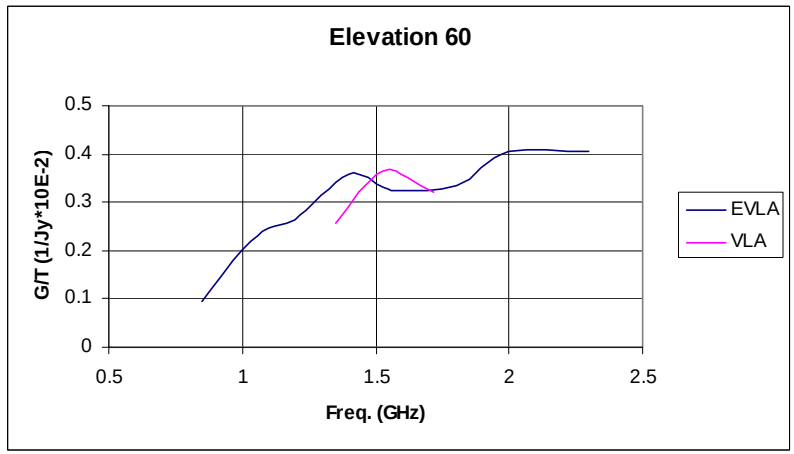
- The most critical part of the upgrade exercise was at L-band because the layout of different feeds on the feed circle depended on the size of the L-band feed. For a –13 dB taper at the edge of the subreflector (9.25°), the OD of the L-band feed would have to be 96". The space limitation on the feed cone allowed a maximum outer diameter of 75". However, the length of the feed (192") was prohibitive in that it required major structural changes on the antenna. It was then decided to raise the low end of the band from 1.0 GHz to 1.2 GHz, thus making the feed smaller by a factor of 1.2. The OD is 64" and the length is 160".

Taper & X-pol: Theory

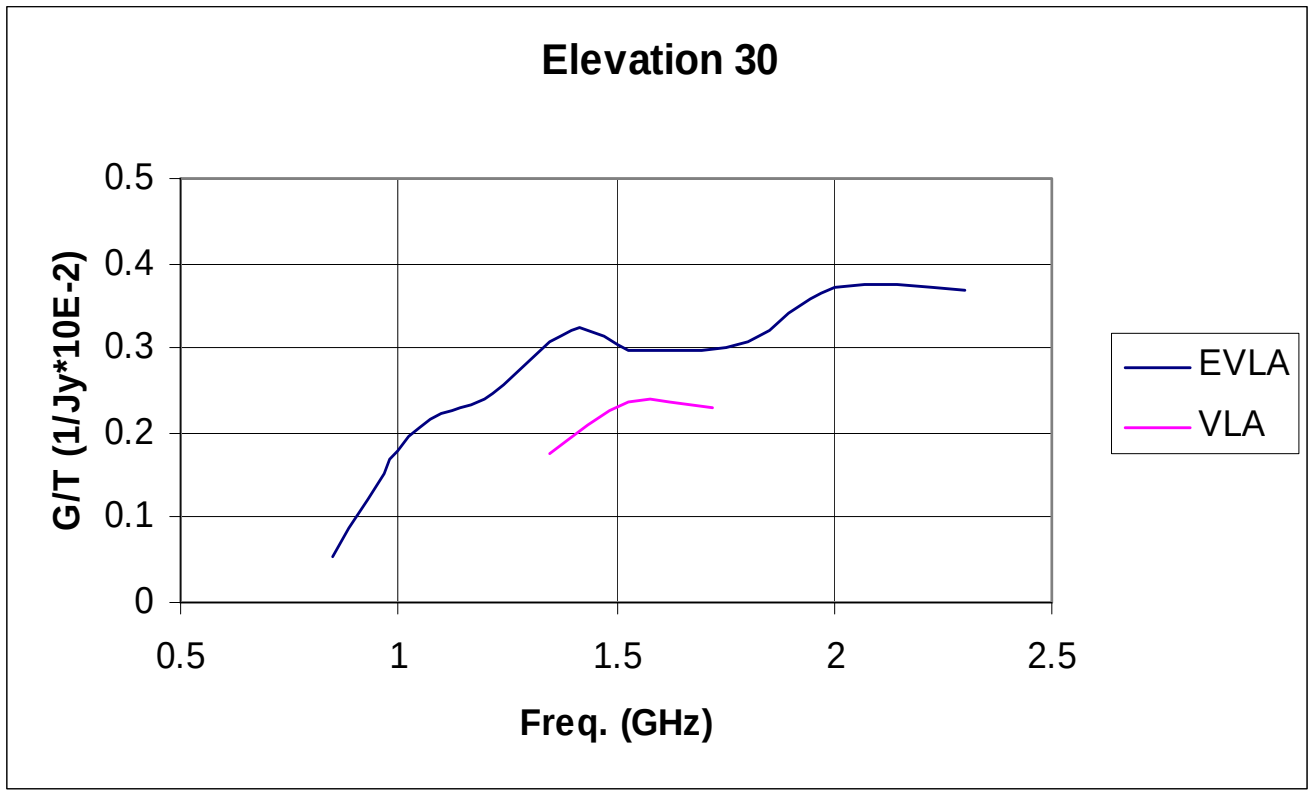
Feed Taper at 9.25 Degrees (dB)			
Freq. (GHz)	62" OD		
	H	E	X
0.85	-3.9	-6.9	-14.1
1.0	-5.4	-5.1	-30
1.1	-6.3	-6.2	-36
1.2	-7.7	-7.4	-42
1.4	-10.5	-10.5	-33
1.6	-10.5	-11.6	-27
1.8	-10.8	-10.2	-35
2.0	-12.7	-12.4	-43
2.3	-9.2	-10.1	-22.4
	1-2 GHz Average taper -9.1 dB 1.2-2 GHz Average taper -10.4 dB		

Comparison: EVLA & VLA Feeds





Comparison: EVLA & VLA Feeds

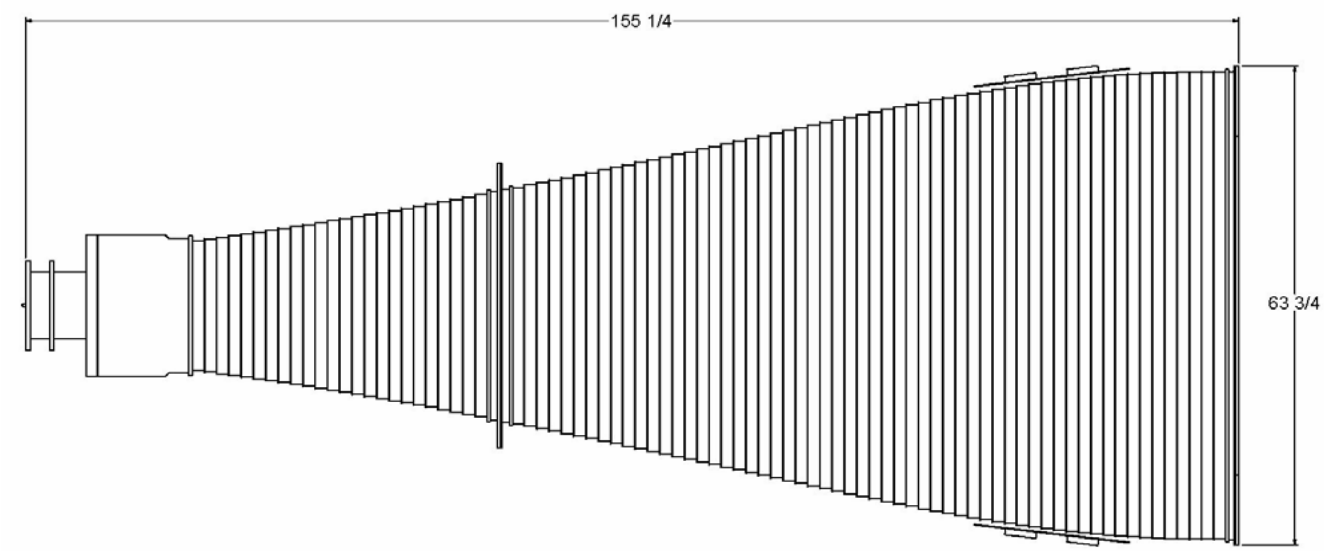


L-Band Feed Details

Aperture ID = 57.772 (7.34λ)
Aperture OD = 63. 750
Length = 155.3 (20λ)
Input Dia. = 7.5
Θ input = 8°
Θ max = 13°

(all dimensions = inches)

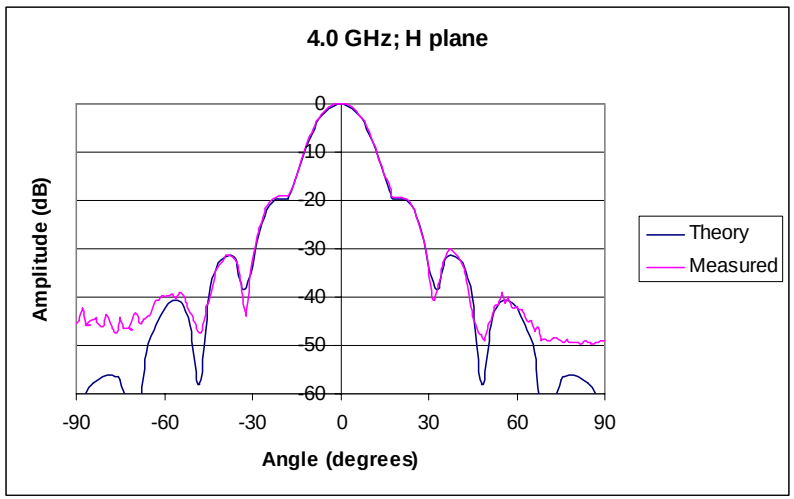
Corrugations
Total = 93
Ring-loaded = 7
Pitch = 1.575
Flange width = 0.090
Corrug. width = 1.485
No. per λ = 5

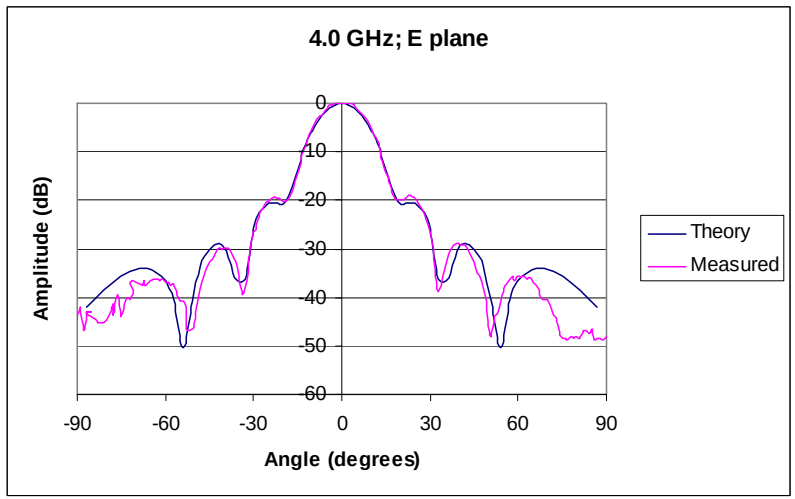


Prototype of L-Band Feed (scaled: 4 to 8 GHz)

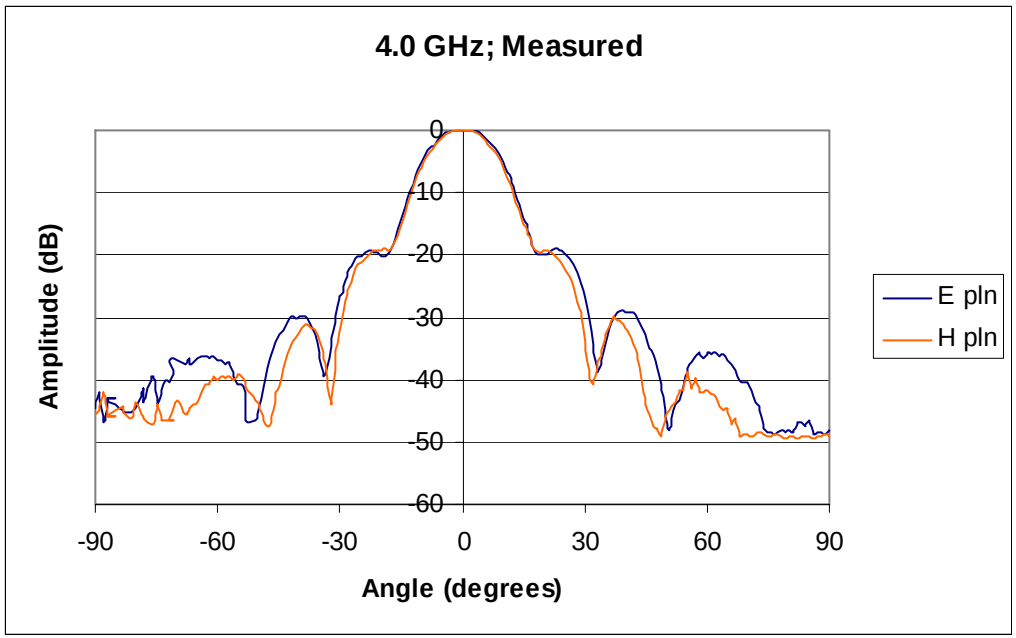
- Aperture dia. = 14.45″
  Length ≈ 40″
  Pitch = 0.394″
  Flange thickness = 0.023″
  Input dia. = 1.930″
- Transition
  1.93 dia. to WR–187 (3.95 to 5.85 GHz);
  WR–159 (4.9 to 7.05 GHz)

Theory & Measured
4 GHz (1 GHz)

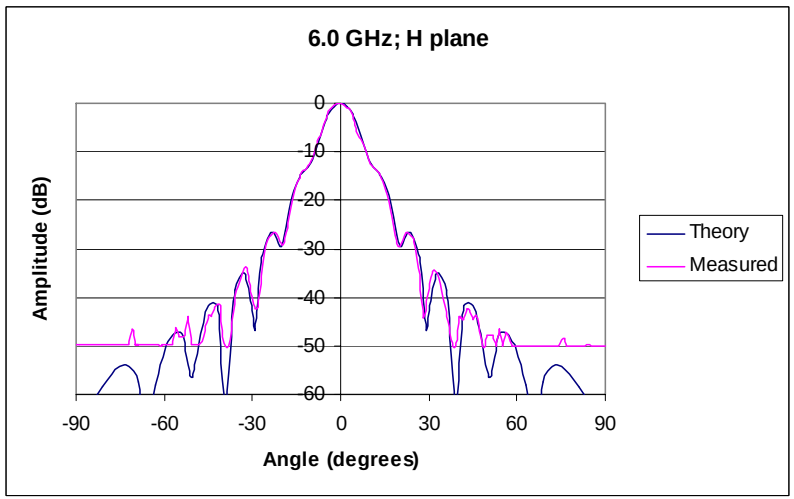


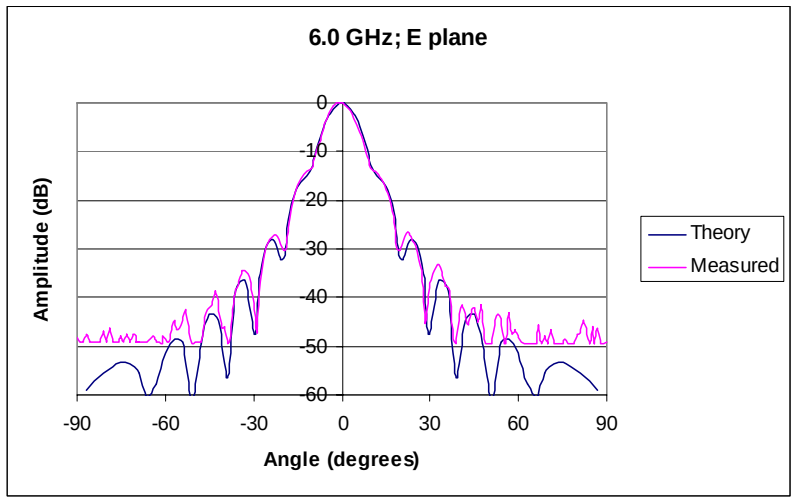


Measured 4 GHz (1 GHz)

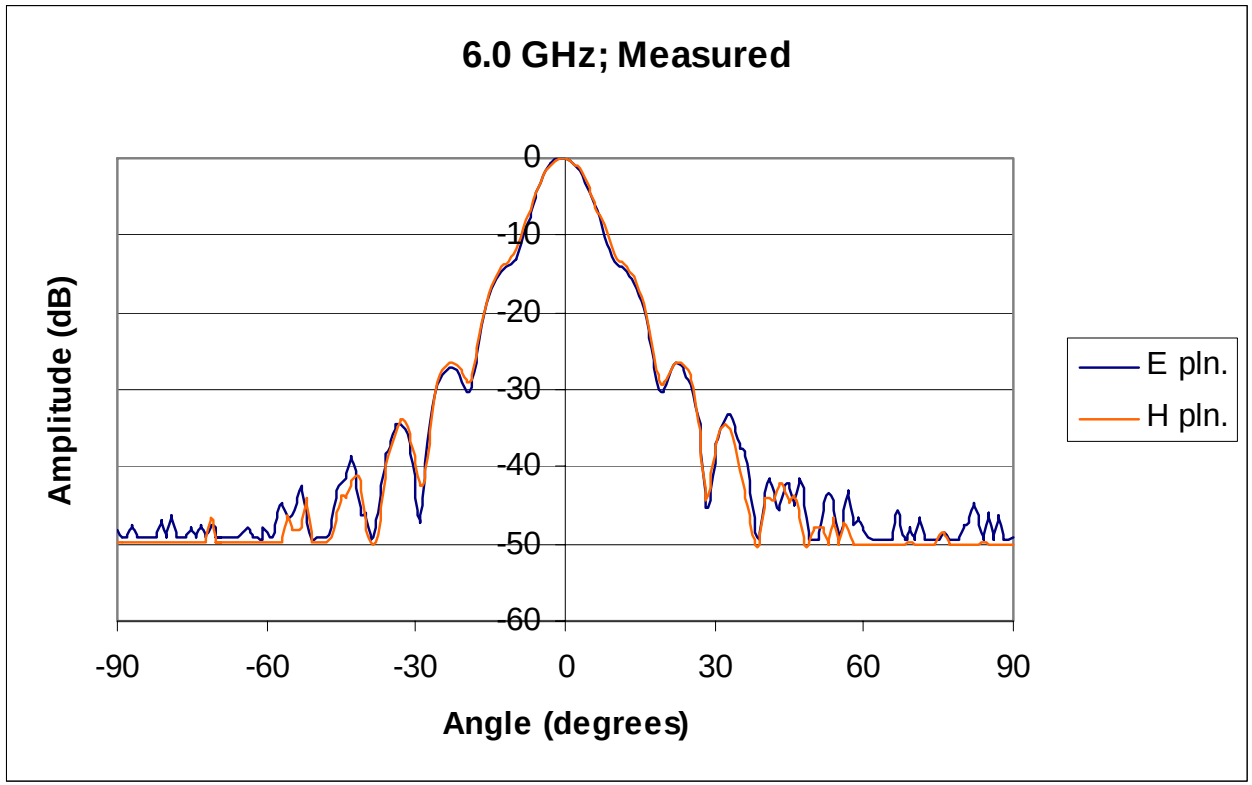


Theory & Measured
6 GHz (1.5 GHz)

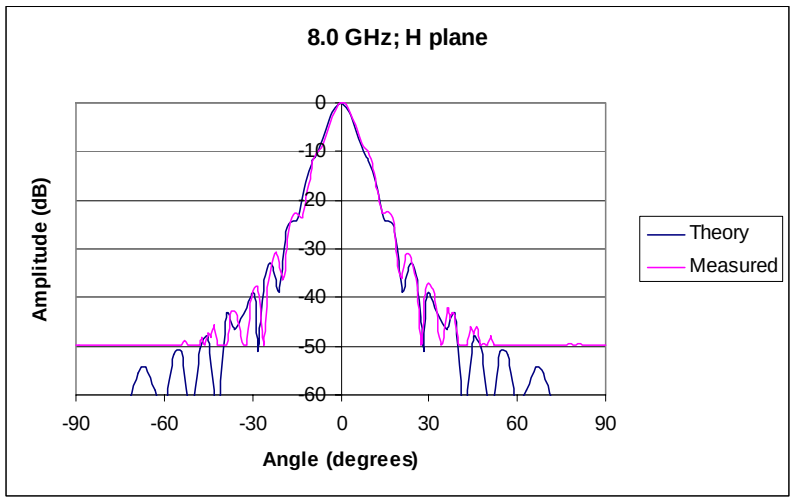


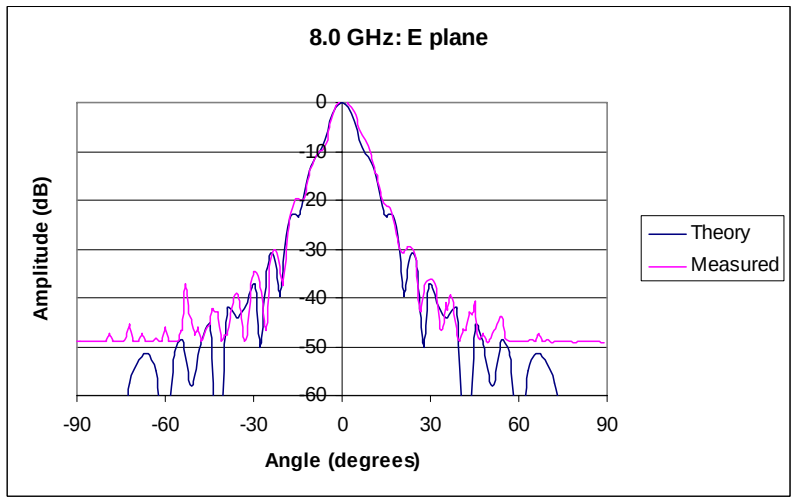


Measured 6 GHz (1.5 GHz)

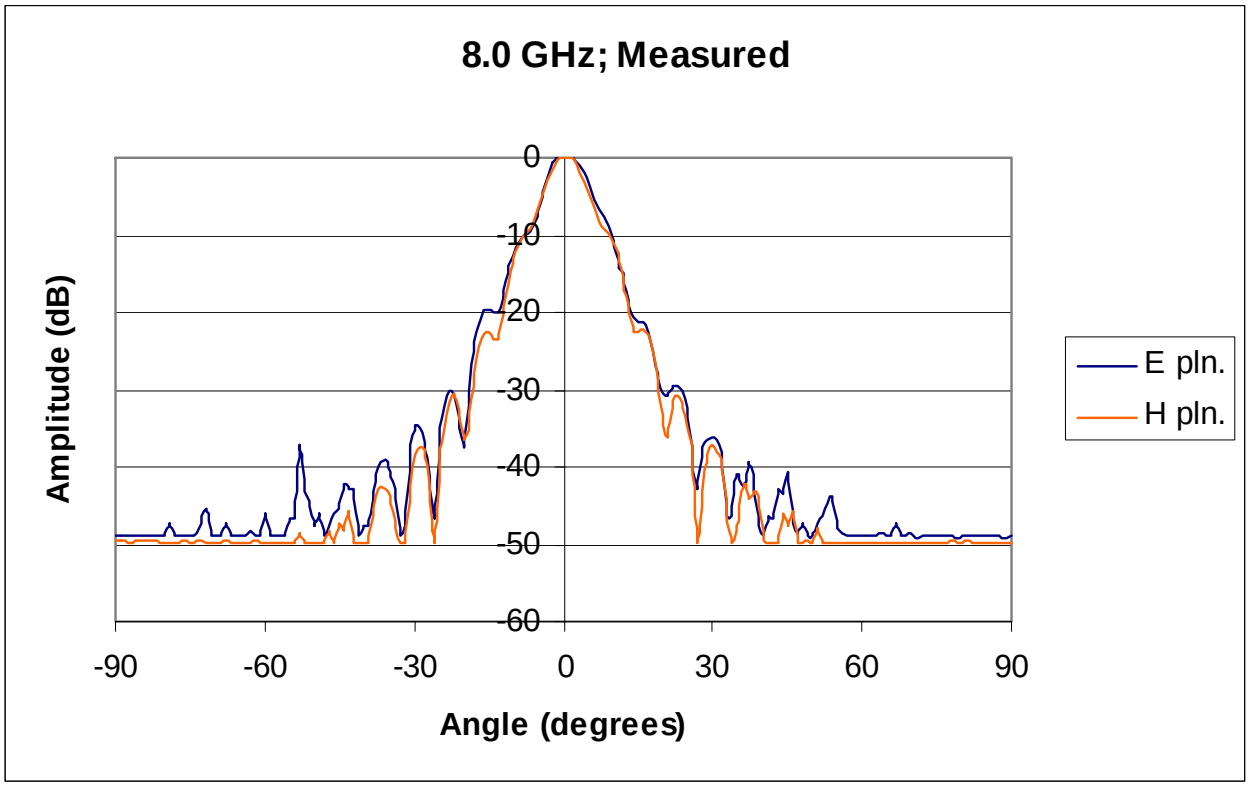


Theory & Measured
8 GHz (2 GHz)

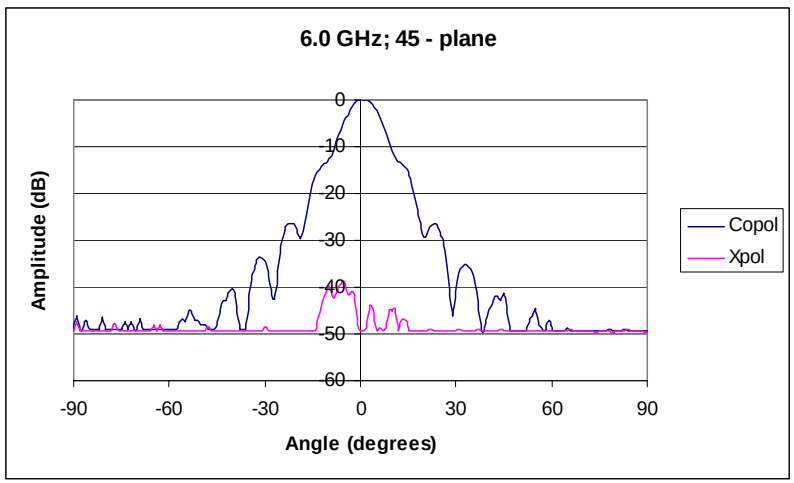


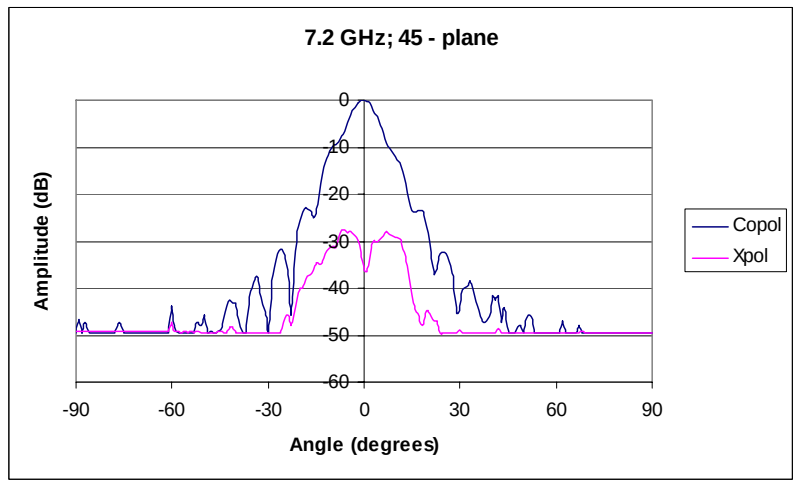


Measured 8 GHz (2 GHz)

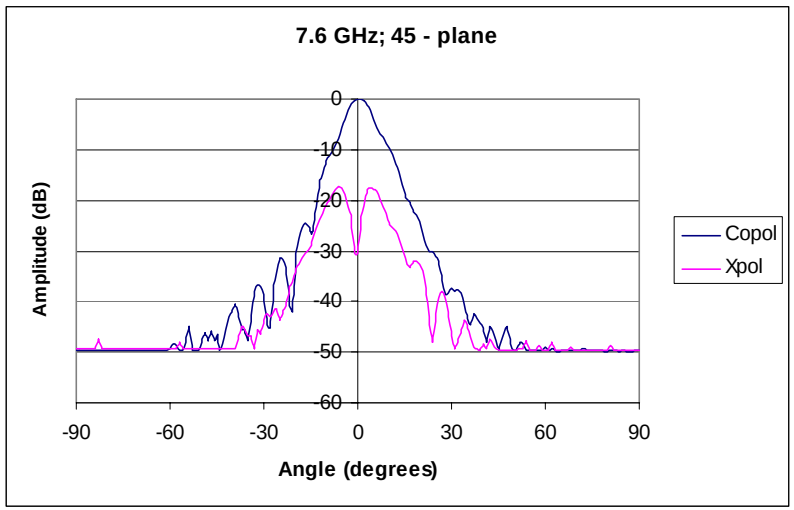


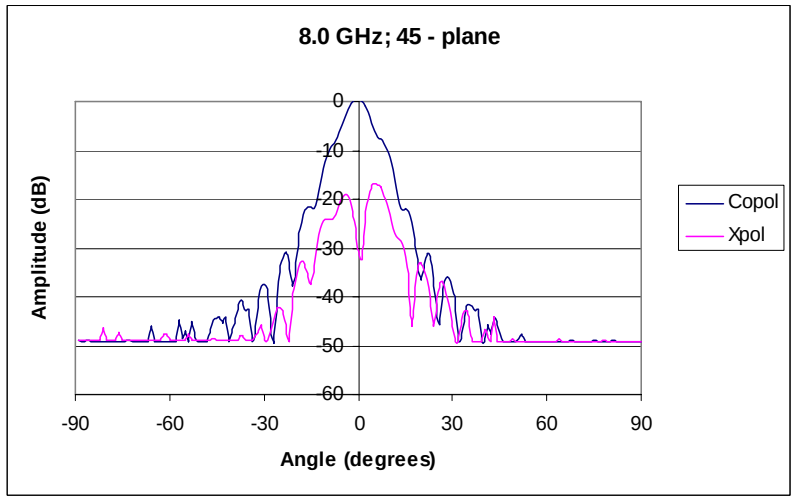
X-pol. 6 (1.5) GHz & 7.2 (1.8) GHz



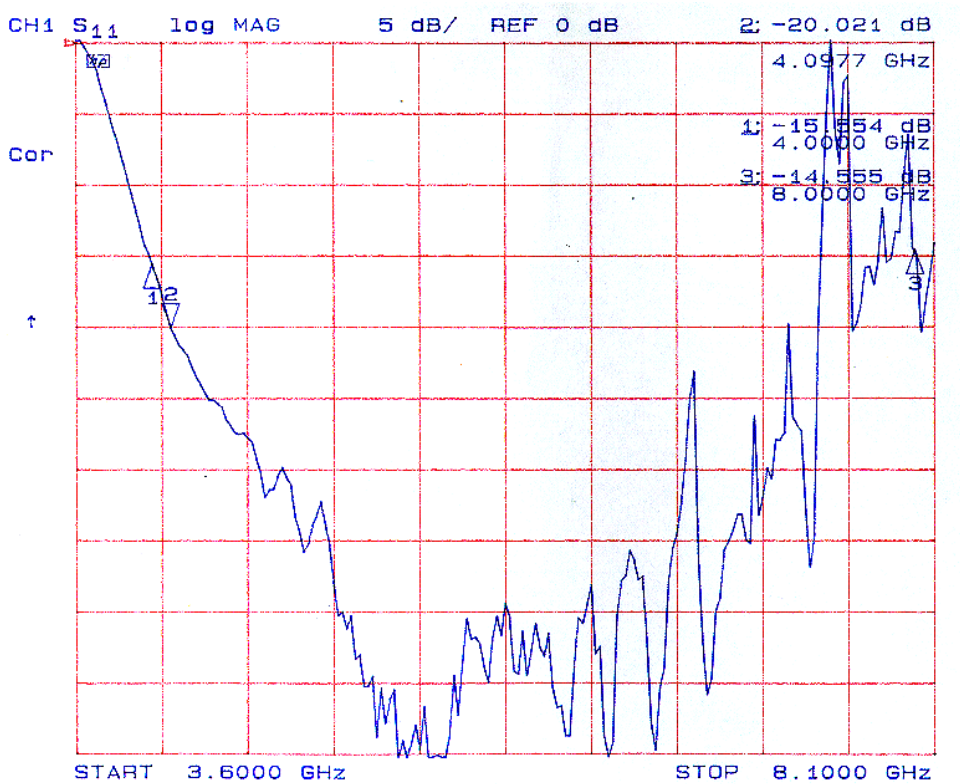


X-pol. 7.6 (1.9) GHz & 8 (2) GHz





Measured Return Loss



L-Band Prototype Feed Before & After Outer Coating

Test Adapters

- 0.95 to 1.50 GHz

  Need: 7.5 dia. to WR–770 (7.7 x 3.85)

  Built: 7.5 dia. to WR–770 stepped transition; 12 sections; 40″ long; S_{11} < -20 dB

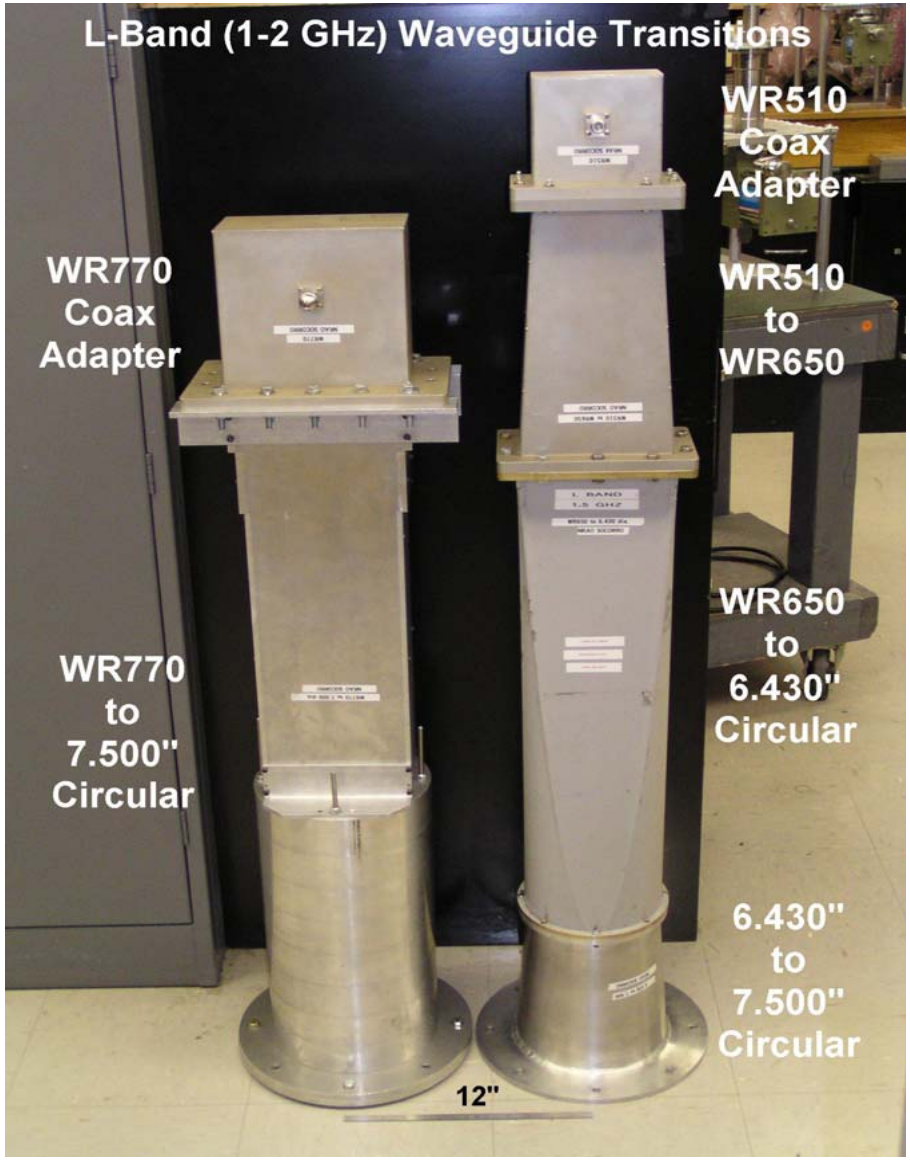
- 1.45 to 2.20 GHz

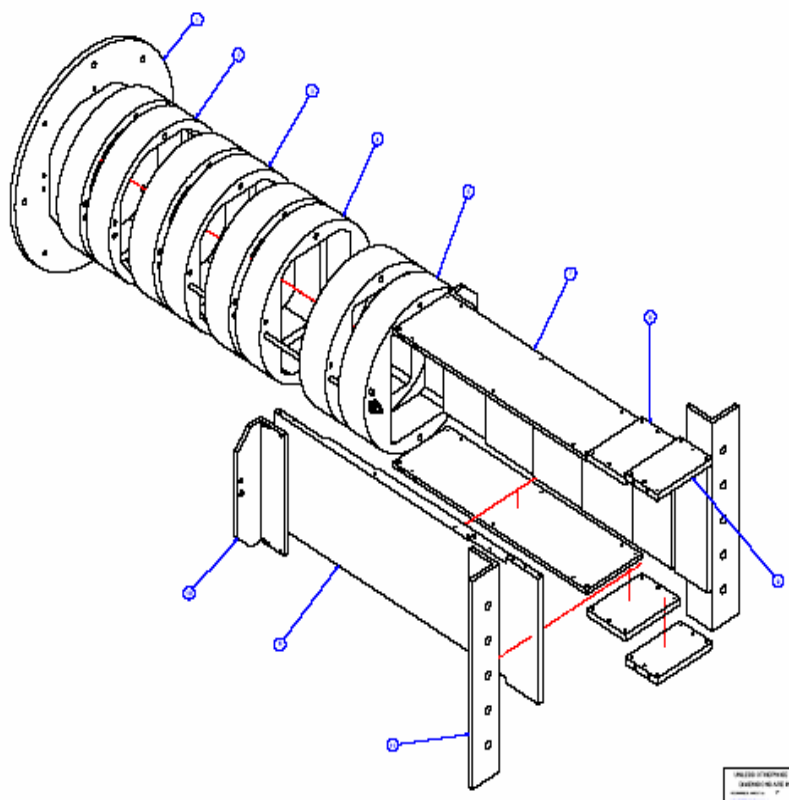
  Need: 7.5 dia. to WR-510 (5.1 x 2.55)

  Available: 6.43 dia. to WR-650 (6.5 x 3.25)

  Built: (a) 7.5 dia. to 6.43 dia. linear transition

  (b) WR-650 to WR-510 linear transition


L-Band (1-2 GHz) Waveguide Transitions
WR510
Coax
Adapter
WR770
Coax
Adapter
WR510
to
WR650
WR650
to
6.430"
Circular
WR770
to
7.500"
Circular
6.430"
to
7.500"
Circular
12"



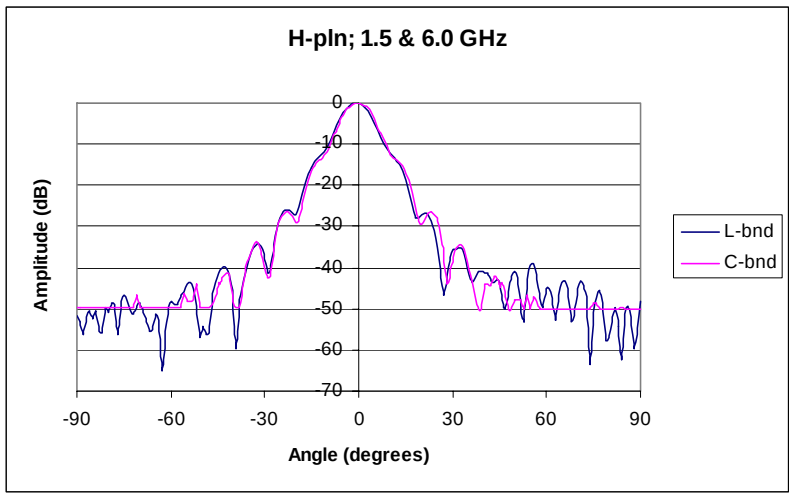
Test at Composite Optics, Inc.

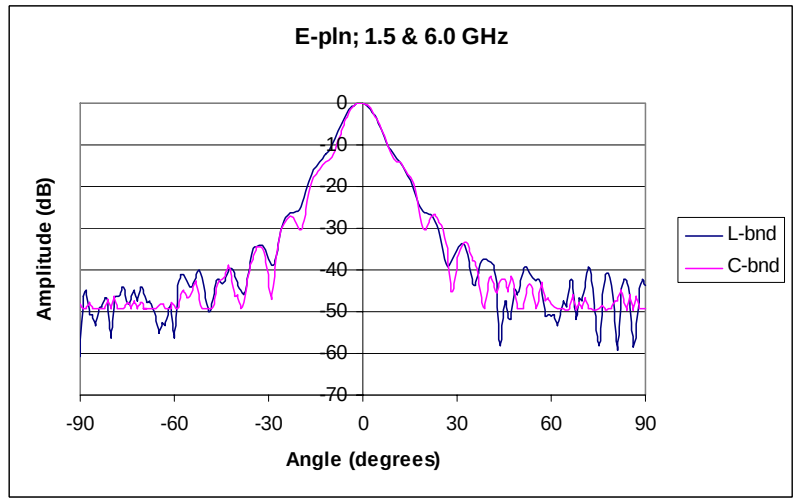
- Center of rotation 84″ behind aperture; axis of feed 12.5′ above ground

- Near-field:
  Distance between Tx. horn and COR 328″
  0.95 – 1.50 GHz; 1.40 – 2.20 GHz;
  $\Delta f = 0.05$ GHz; -180 to 180°; $\Delta\theta = 0.5°$
  E- & H-plane

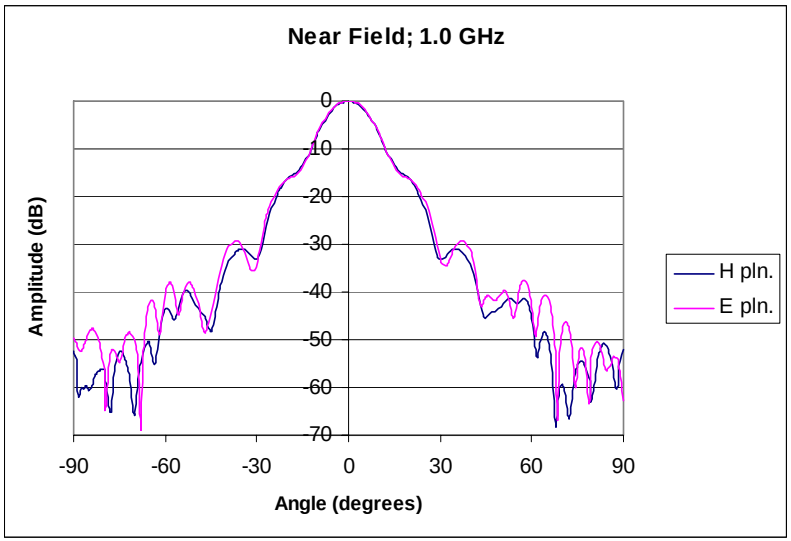
- Far-field:
  Distance to Tx. horn 130′
  0.95 – 1.50 GHz; time gating; $\Delta f = 0.005$ GHz
  -90 to 90°; $\Delta\theta = 1°$
  1.40 – 2.20 GHz; $\Delta f = 0.05$ GHz;
  -180 to180°; $\Delta\theta = 0.5°$
  E-, H-, & 45°-plane

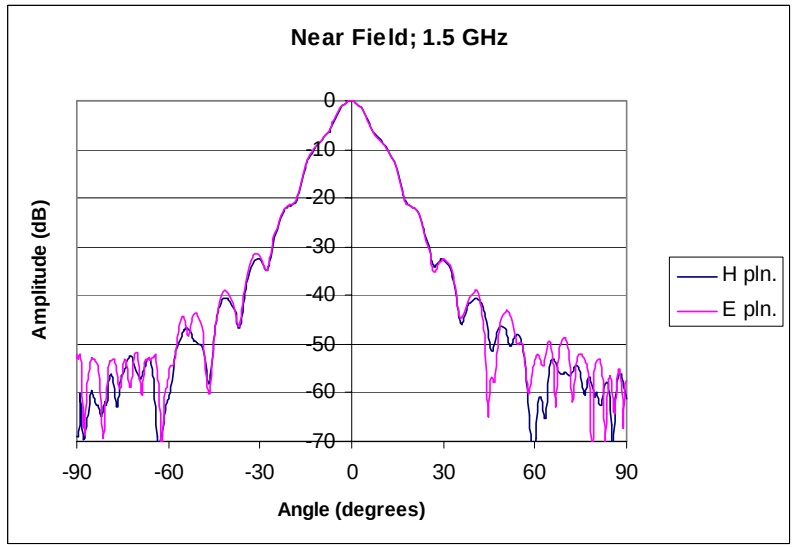
Compare C- & L-Band Prototypes



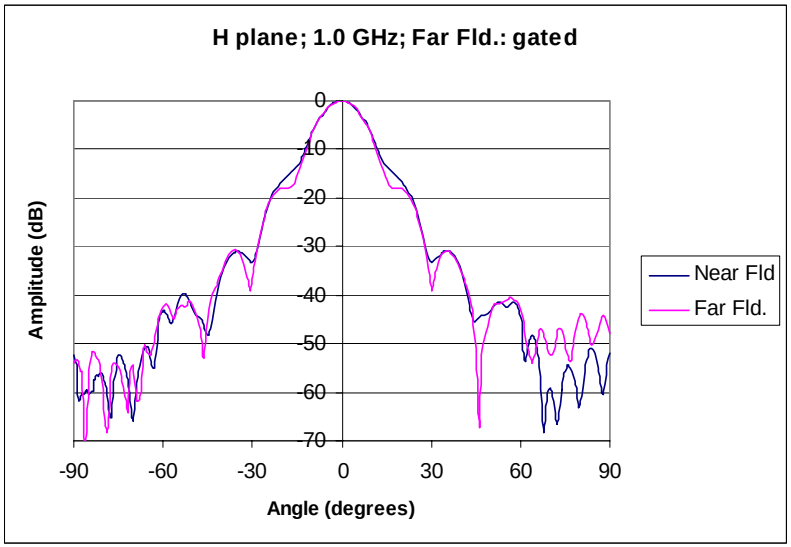


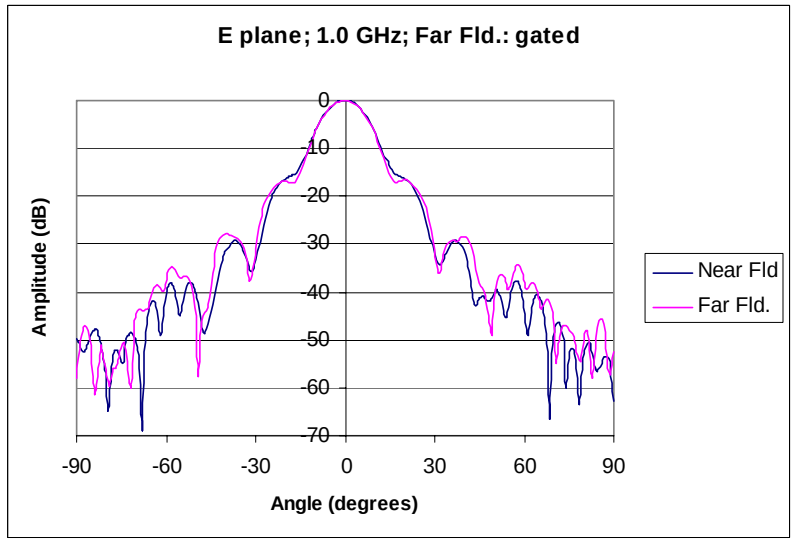
Near-Field
E- & H-Planes



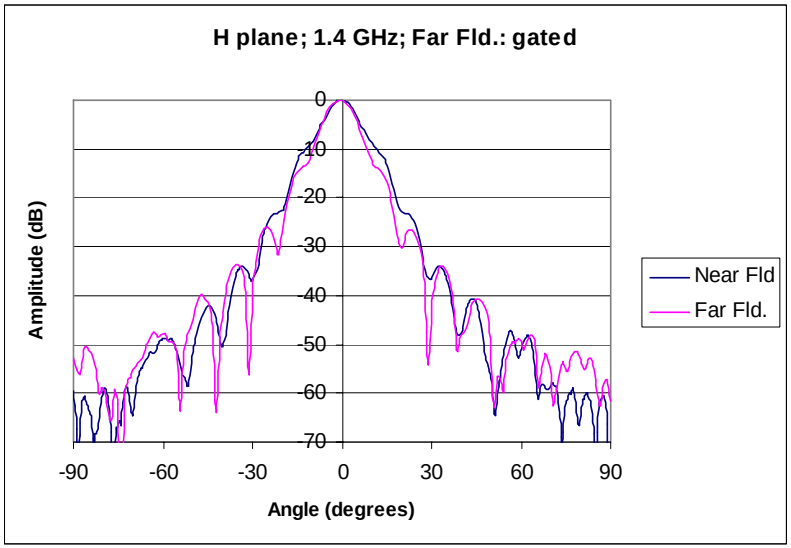


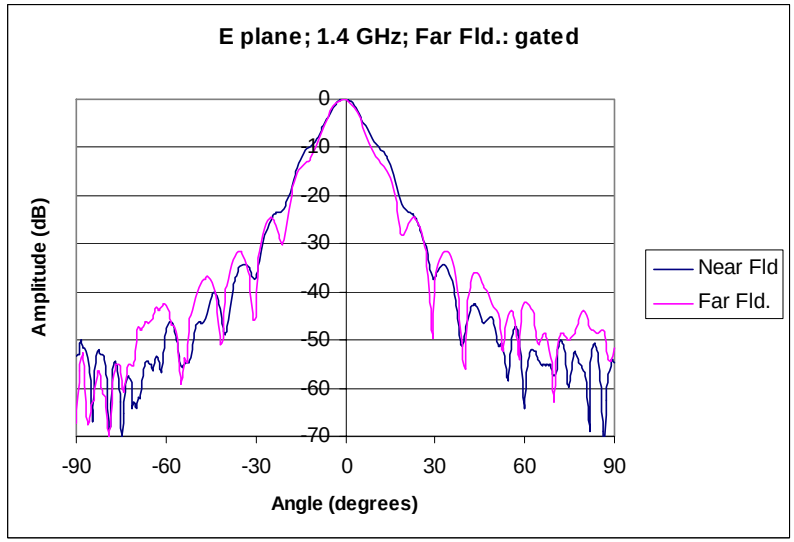
Compare Near- & Far-Fields



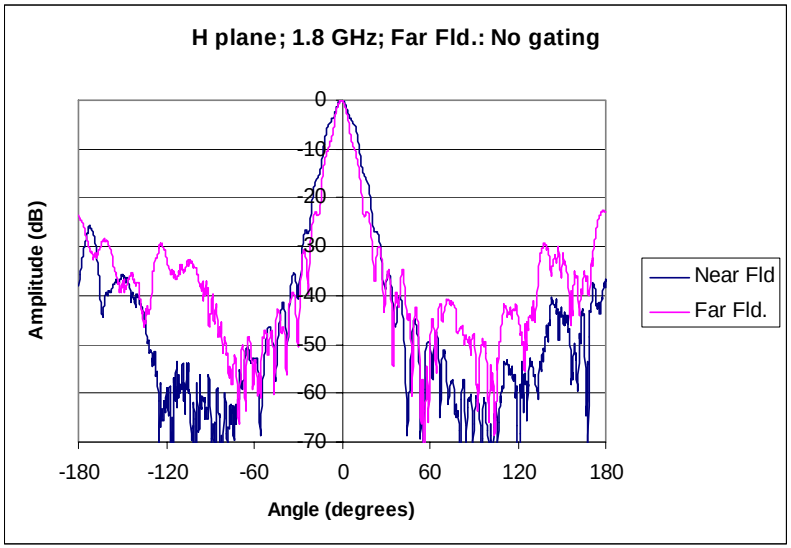


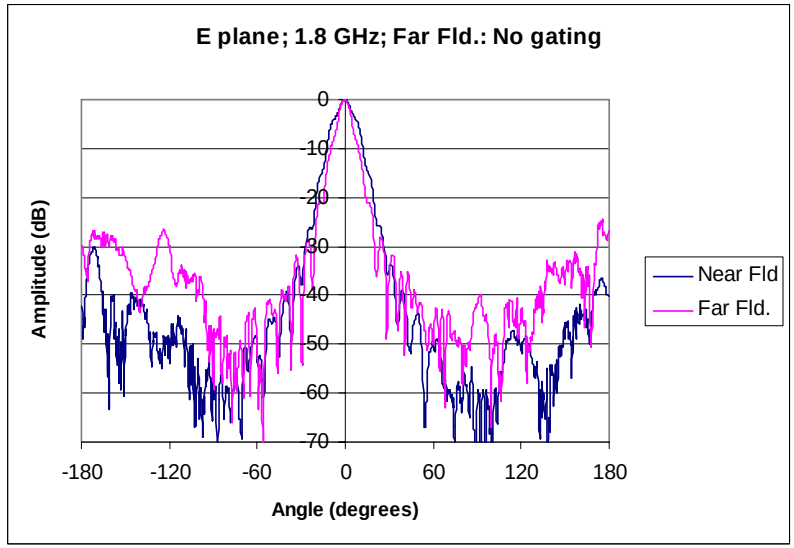
Compare Near- & Far-Fields



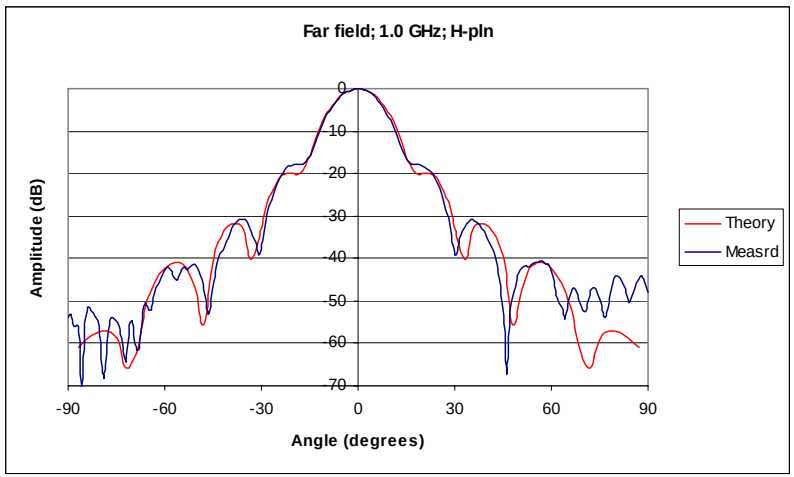


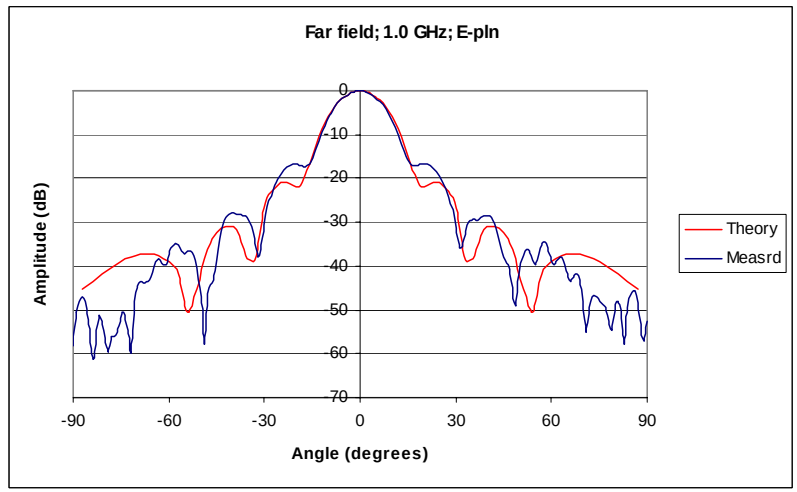
Compare Near- & Far-Fields



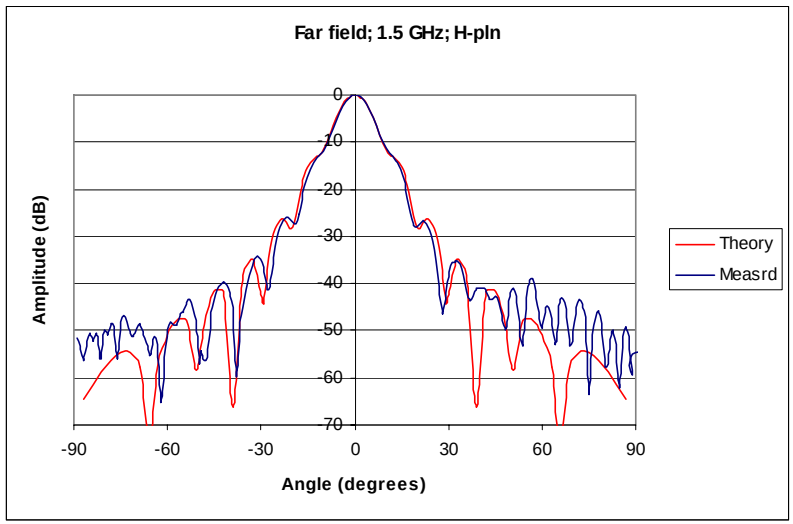


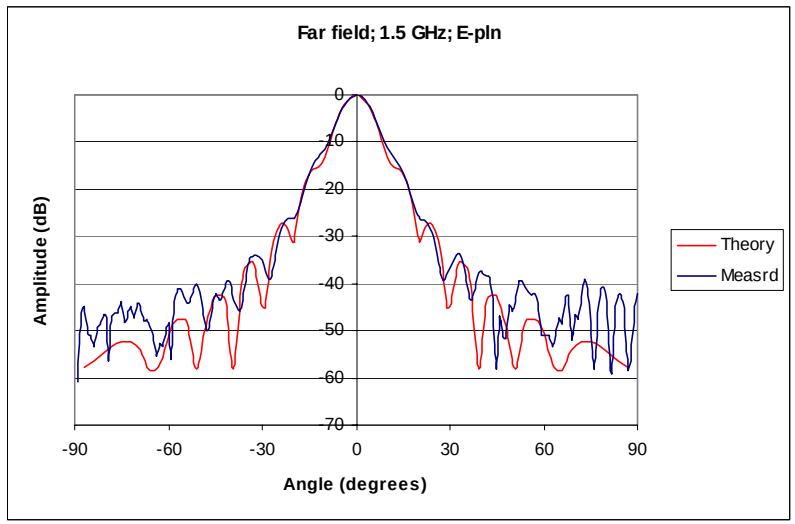
Theory & Measured 1.0 GHz



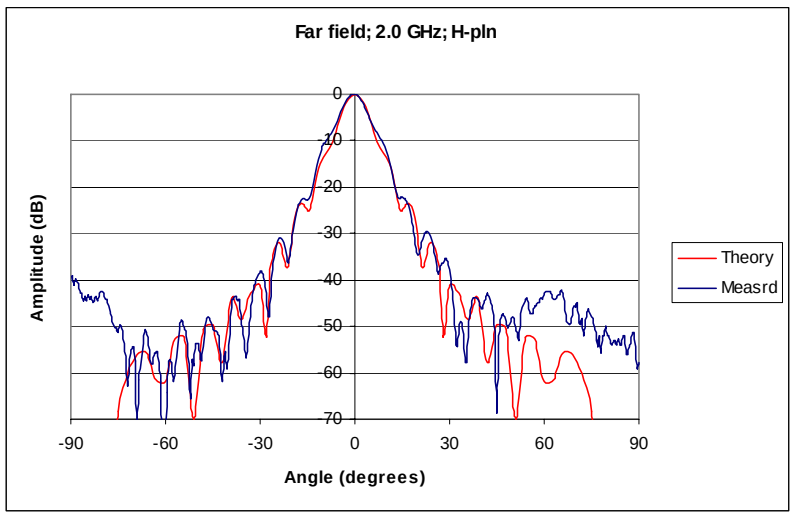


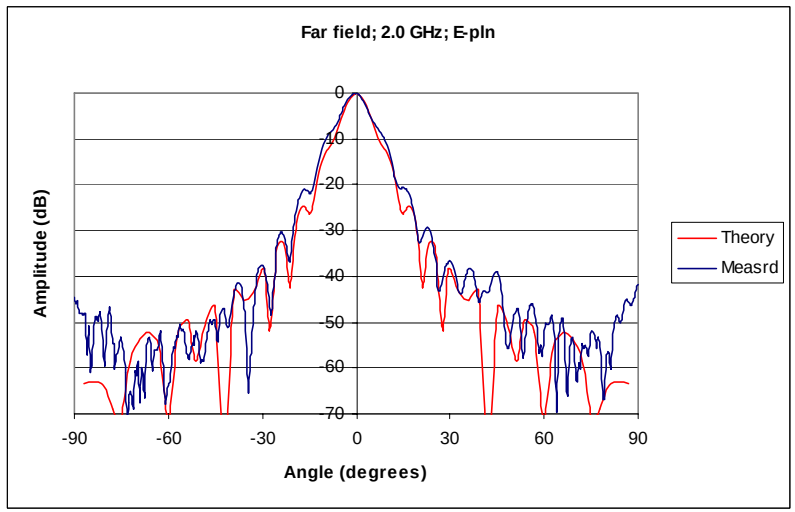
Theory & Measured 1.5 GHz



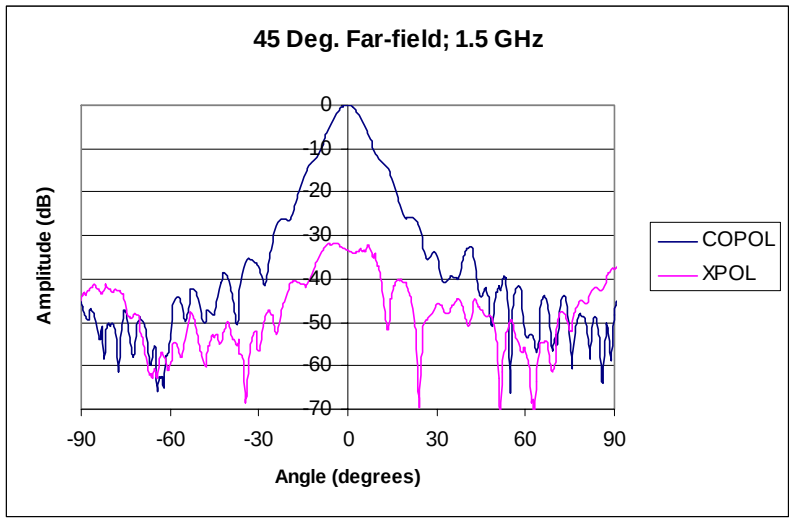


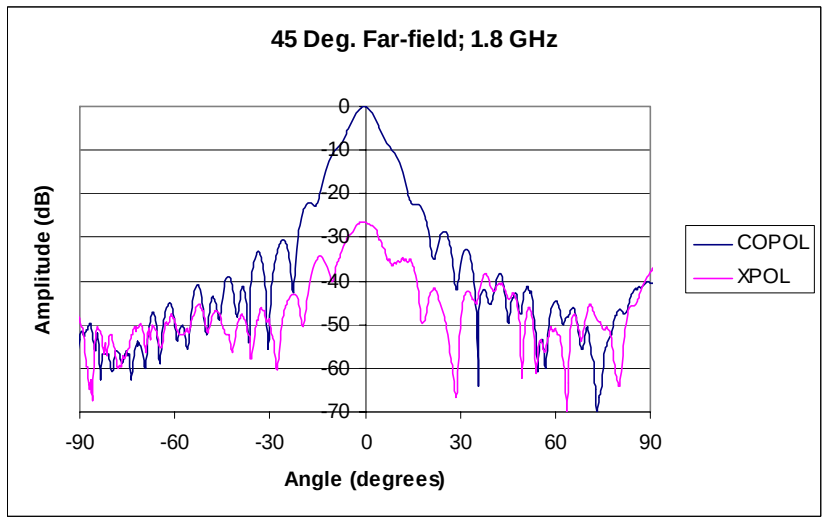
Theory & Measured 2.0 GHz



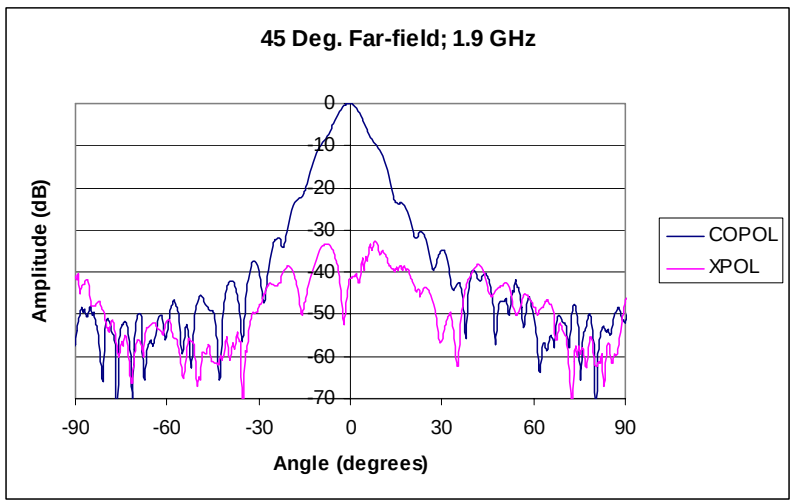


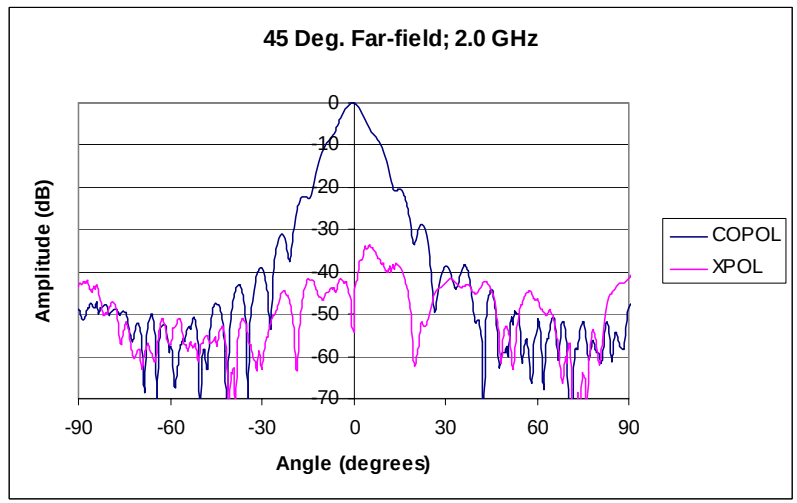
Co- & X-Polarized Field Patterns - Measured



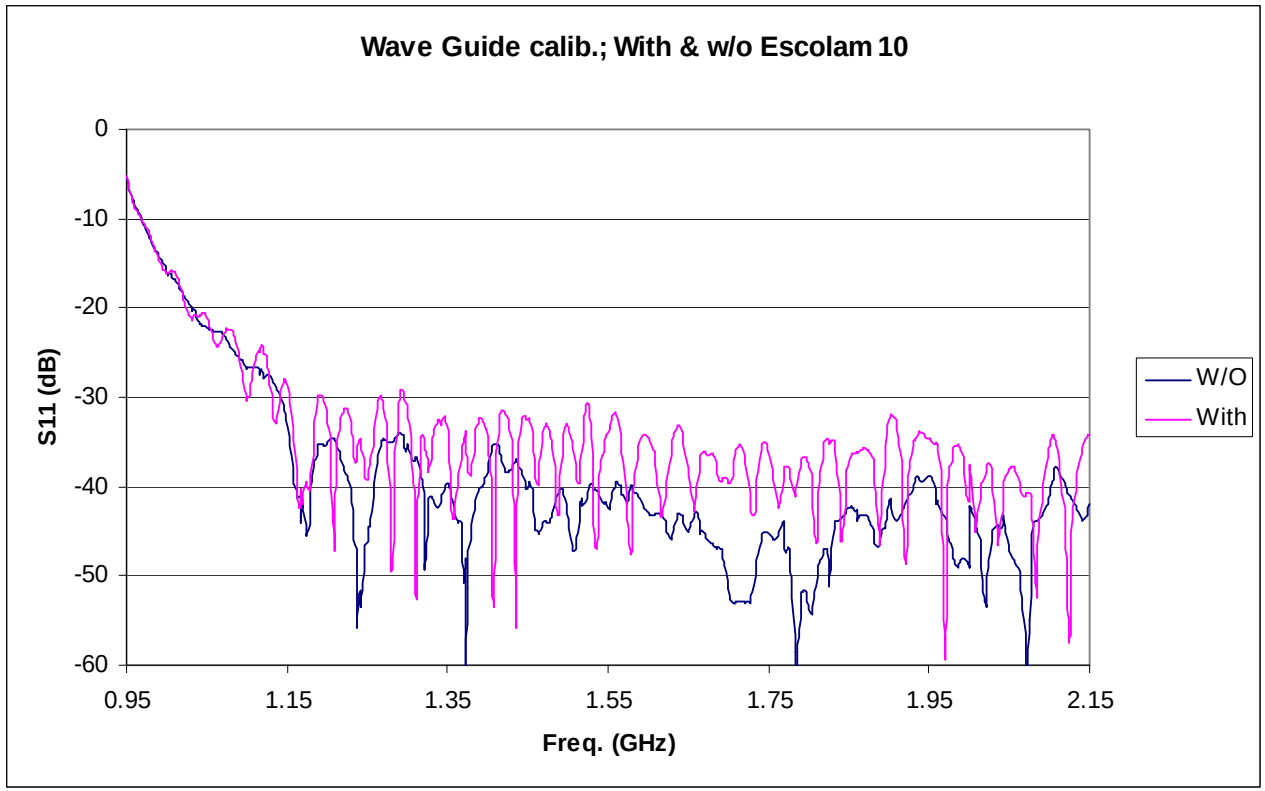


Co- & X-Polarized Field Patterns - Measured

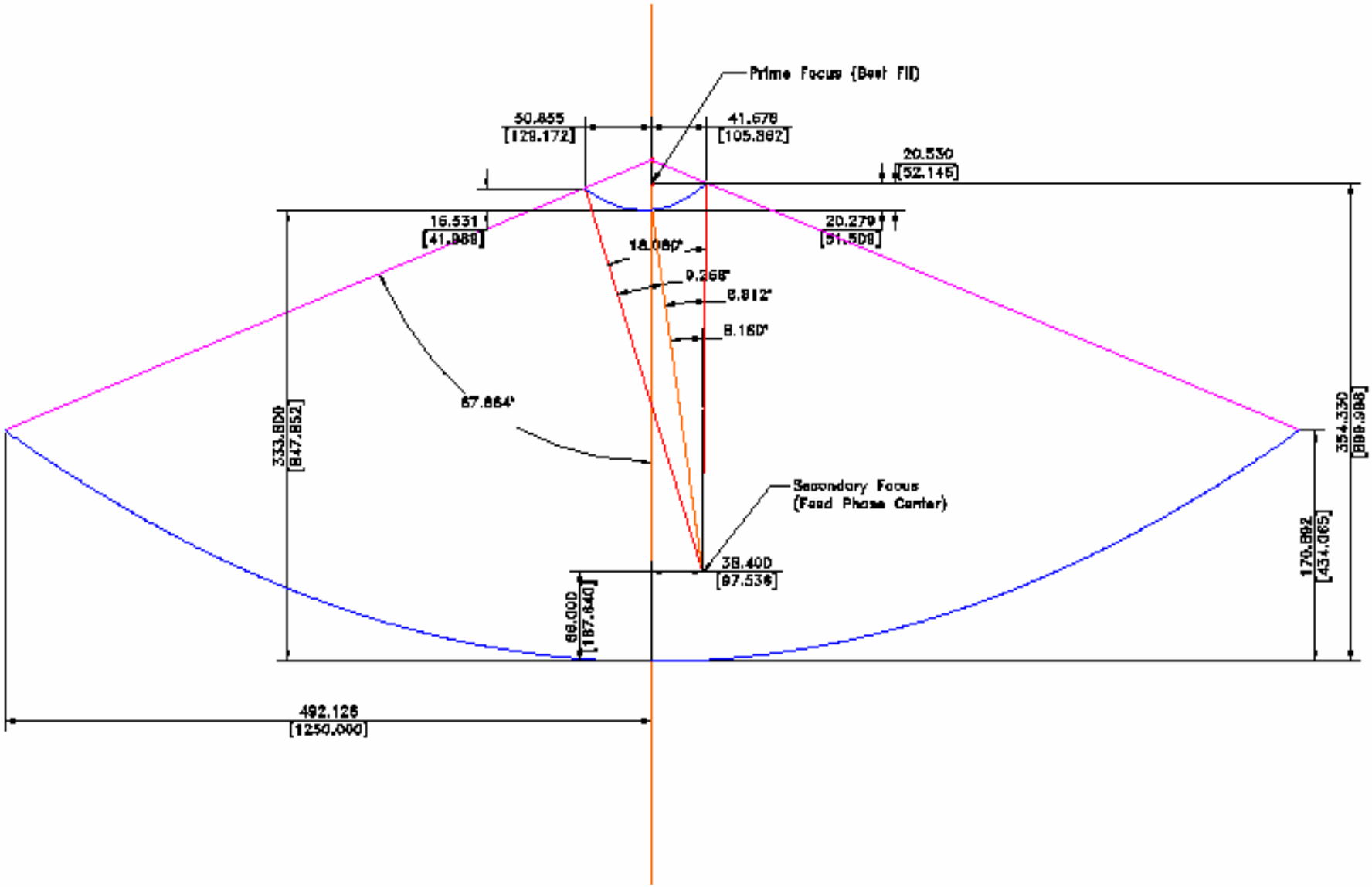




Measured Return Loss



VLA Cassegrain Geometry Drawing



Physical Optics Analysis

1. Feed patterns - measured amplitude and phase

2. H-fields on the reflector surface - Spherical Wave Expansion

3. Integrate currents to obtain far-field patterns

4. Two steps - subreflector scattered pattern, main reflector pattern

5. Coordinate transformation - Cartesian to Polar
   Multivariate Interpolation Routine - R. J. Renka

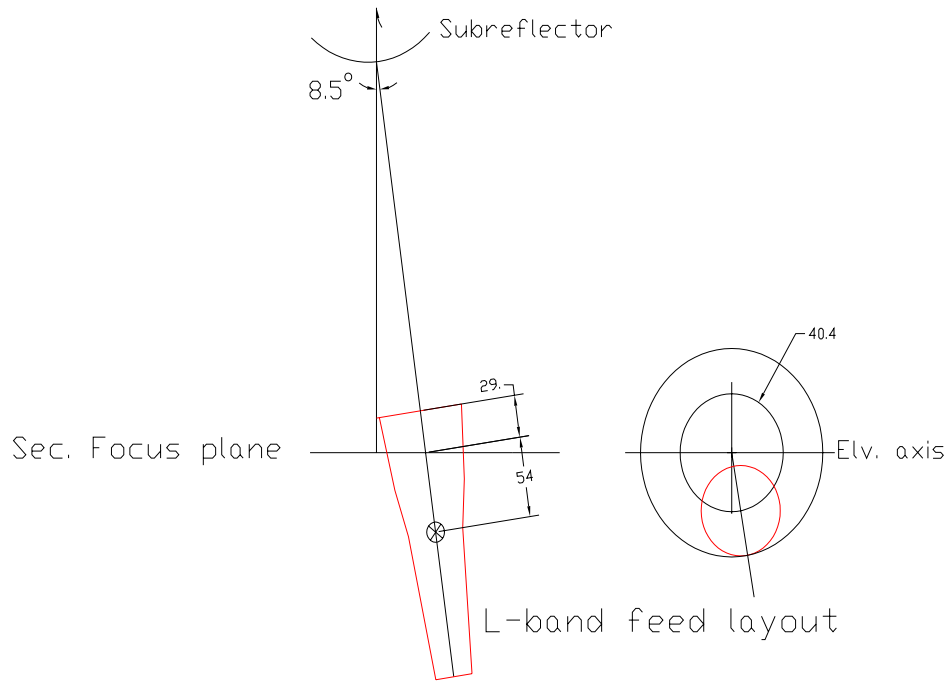
Physical Optics Analysis

6. Grids on the reflector surface

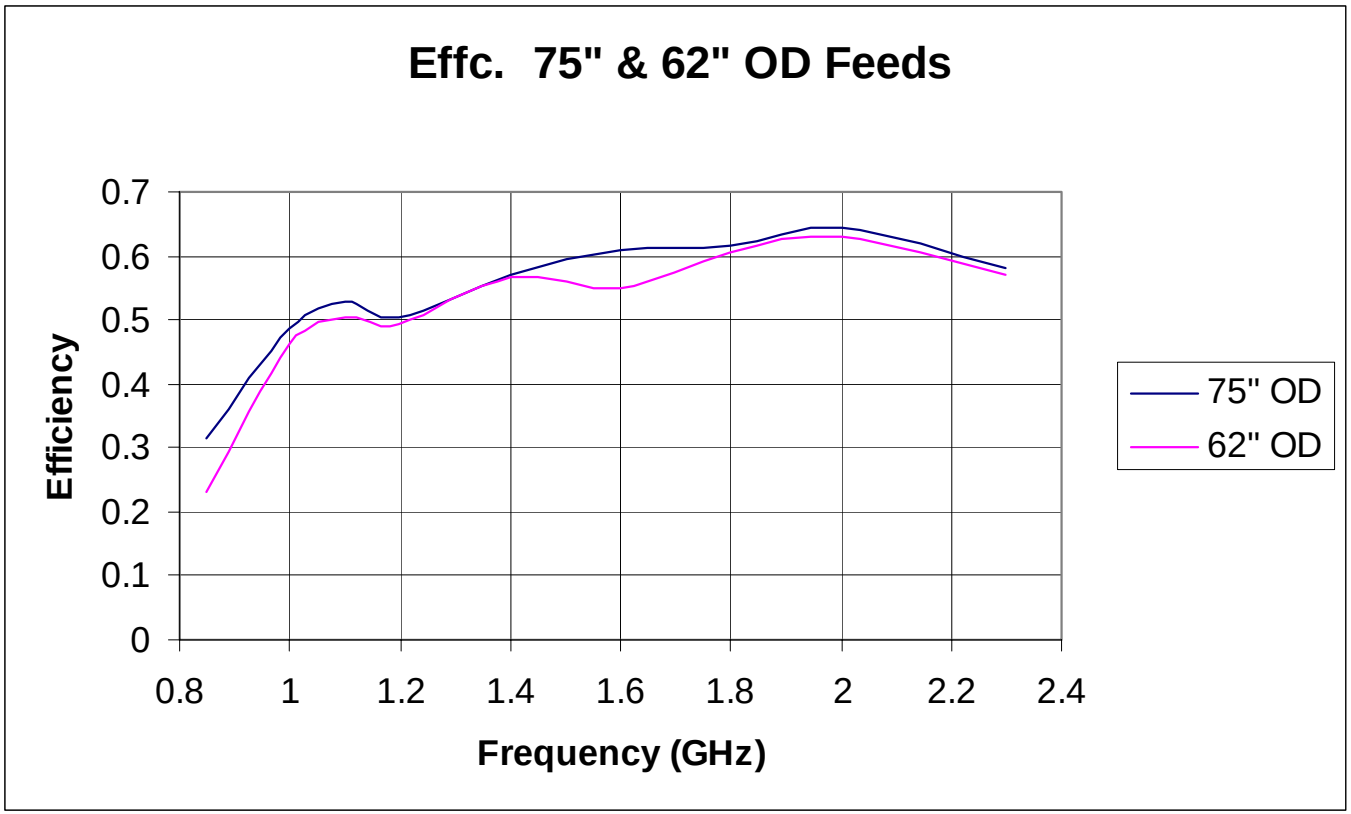
$$\Delta\Theta = \lambda/\rho_{max} \quad \Delta\phi = \Delta\Theta/\sin\Theta_{max}$$

Freq. (GHz)	$\Delta\theta$	$\Delta\phi$	Number of Points (sub)	Actual Used	Number of Points (main)	Actual Used
2	1	5	720	1800	5,040	12,600
10	0.2	1.0	18,000		126,000	
30	0.05	0.30	240,000		1,680,000	

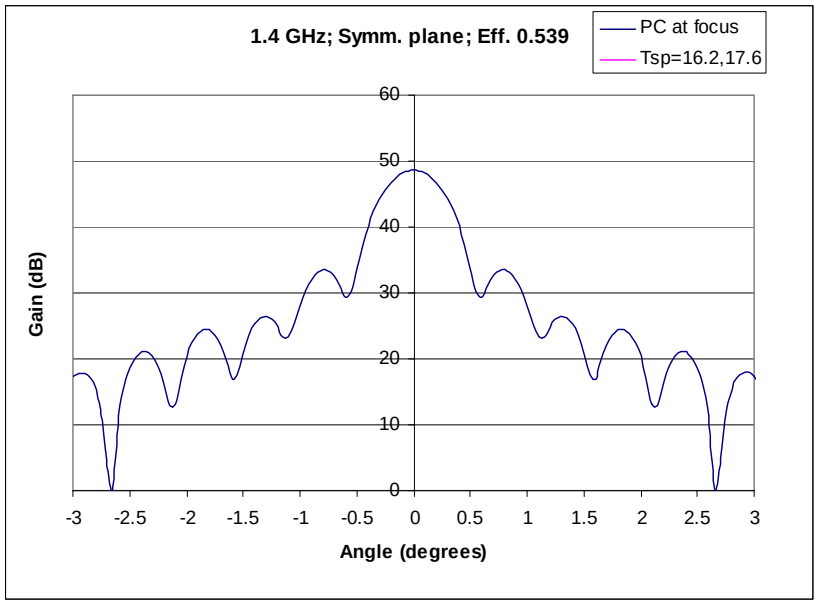
Feed As Installed On the Antenna

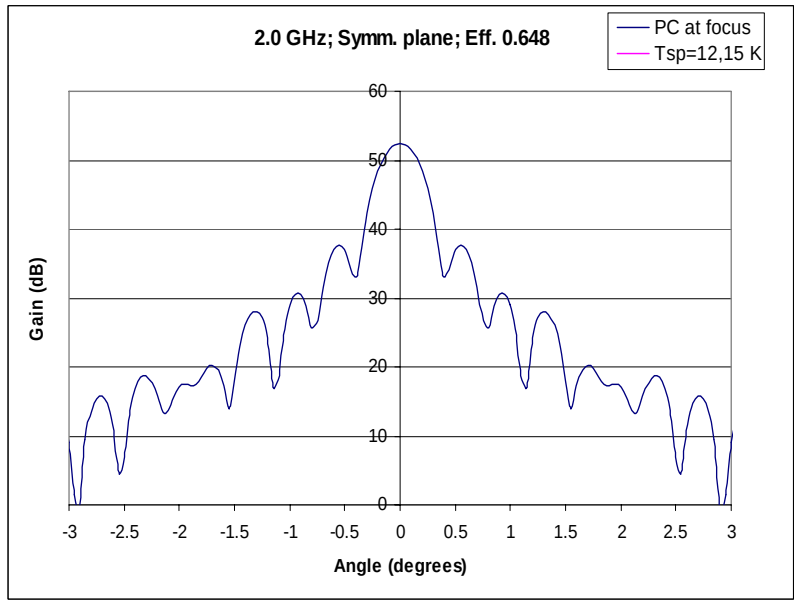


Comparison of 75" OD and 62" OD Feeds

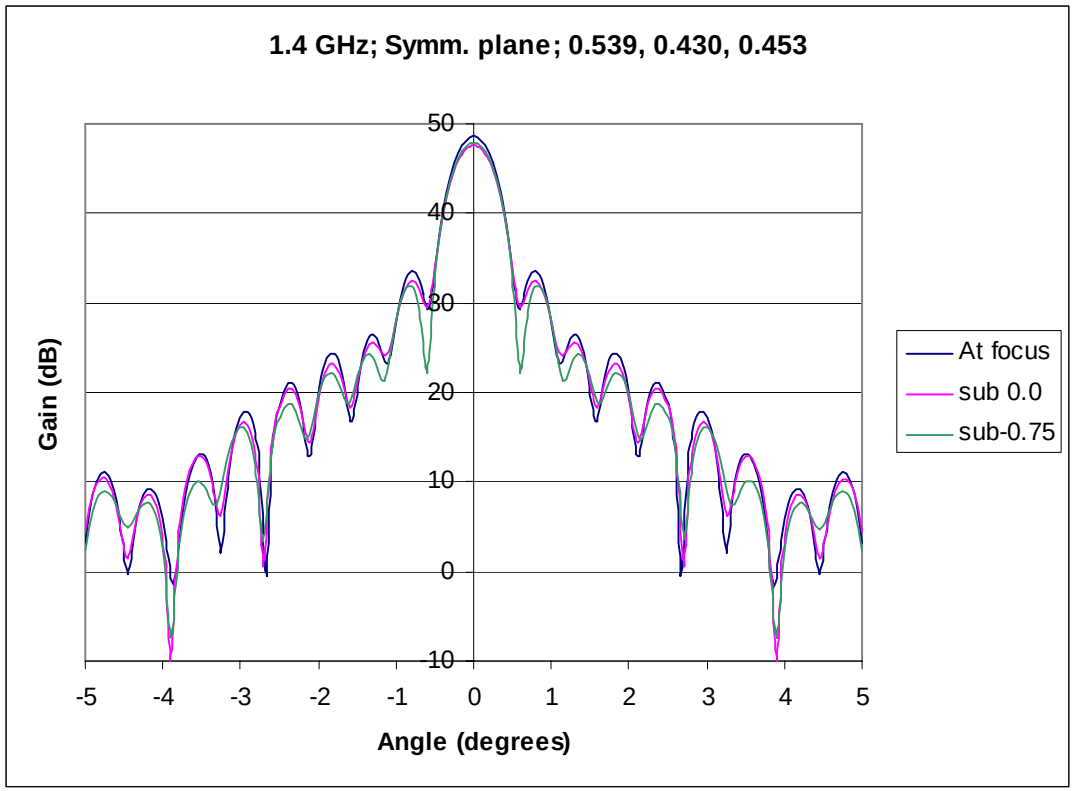


Calculated Antenna Beam (Ideal Case)

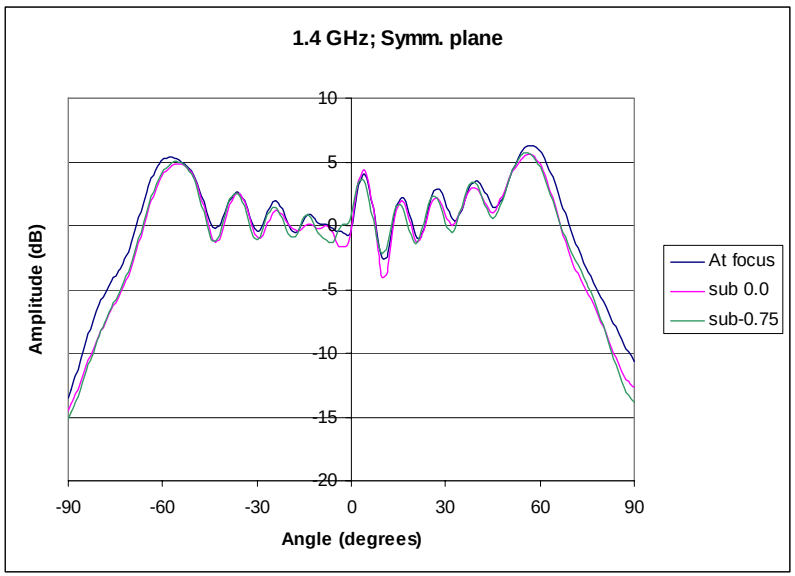


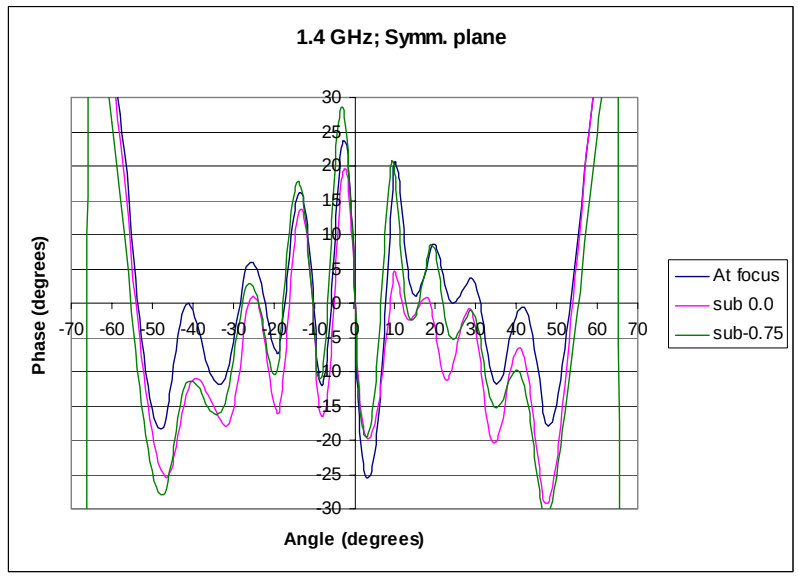


Calculated Antenna Beam at 1.4 GHz

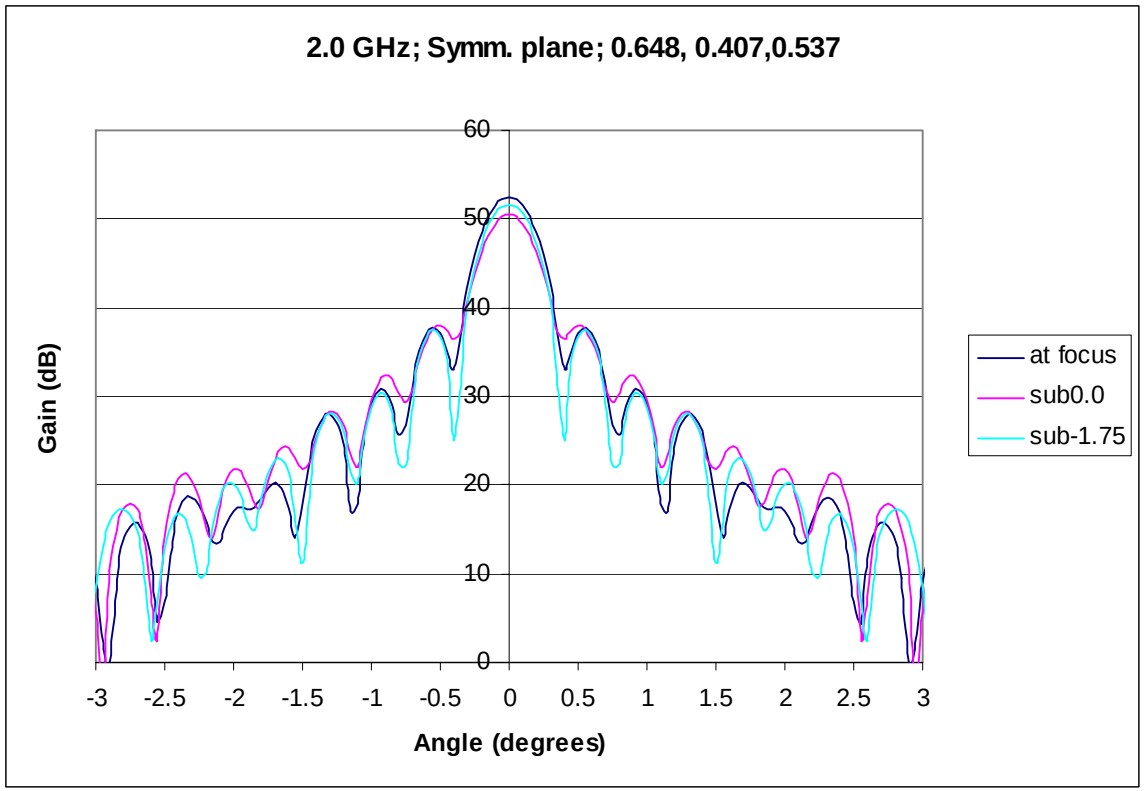


Calculated Subreflector Beam at 1.4 GHz

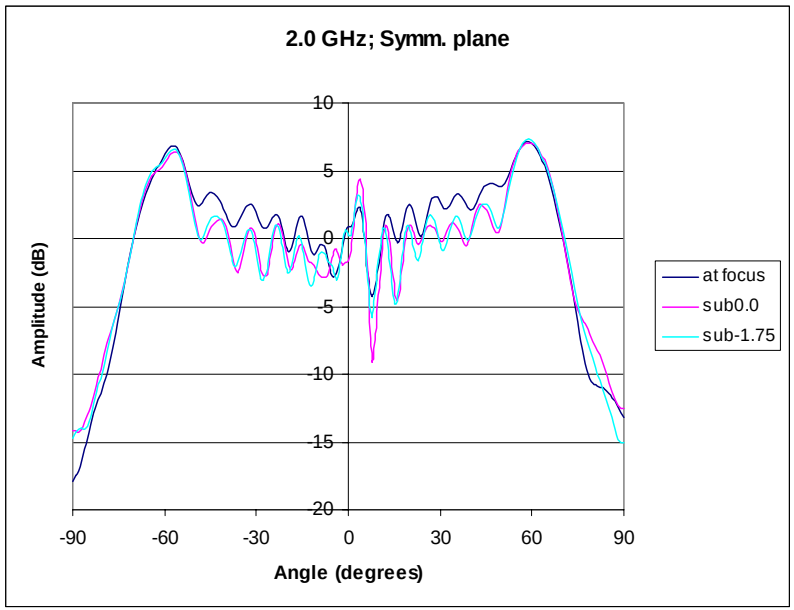


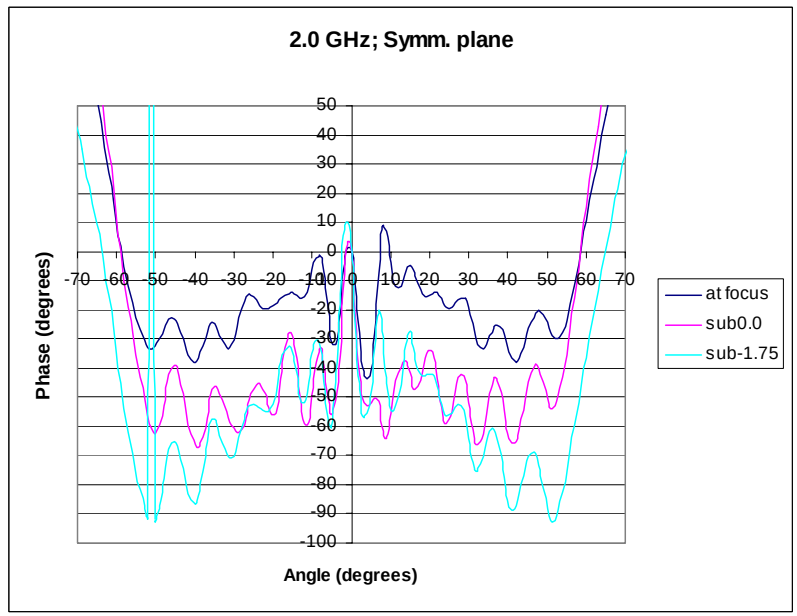


Calculated Antenna Beam at 2.0 GHz

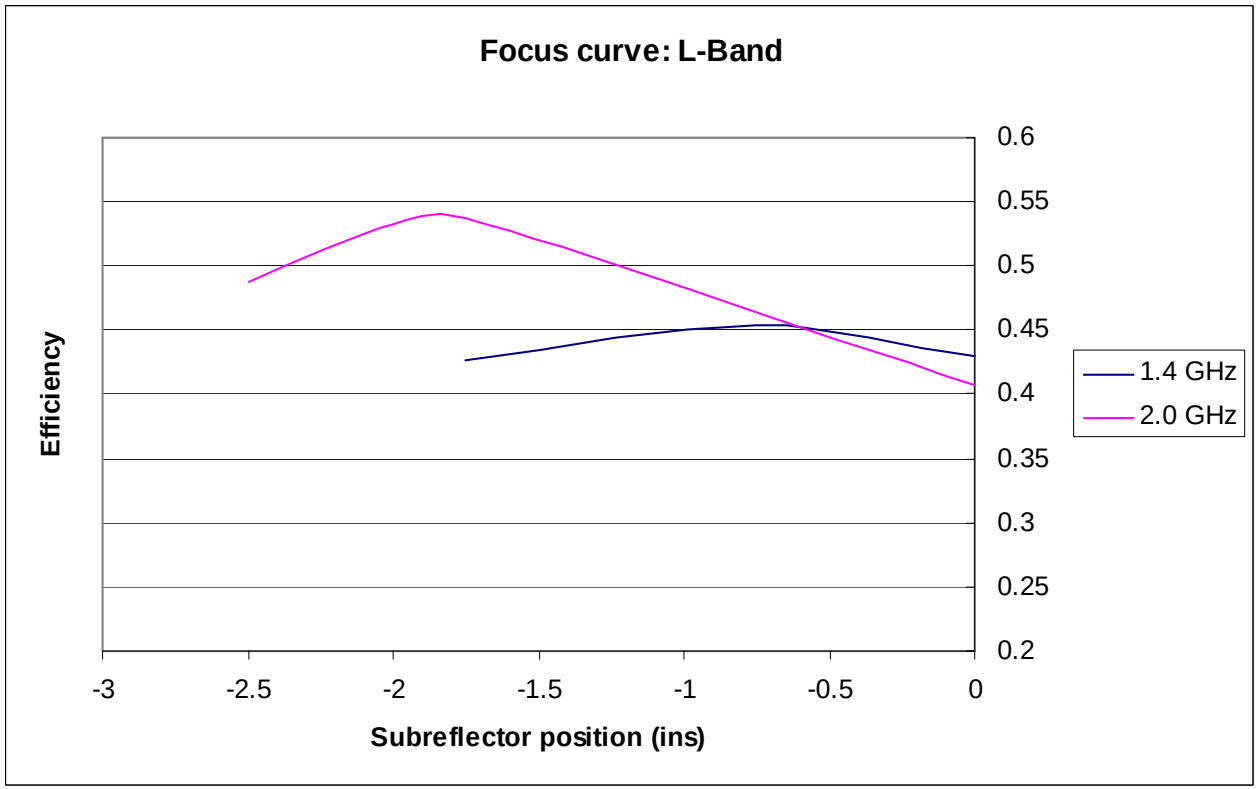


Calculated Subreflector Beam at 2.0 GHz

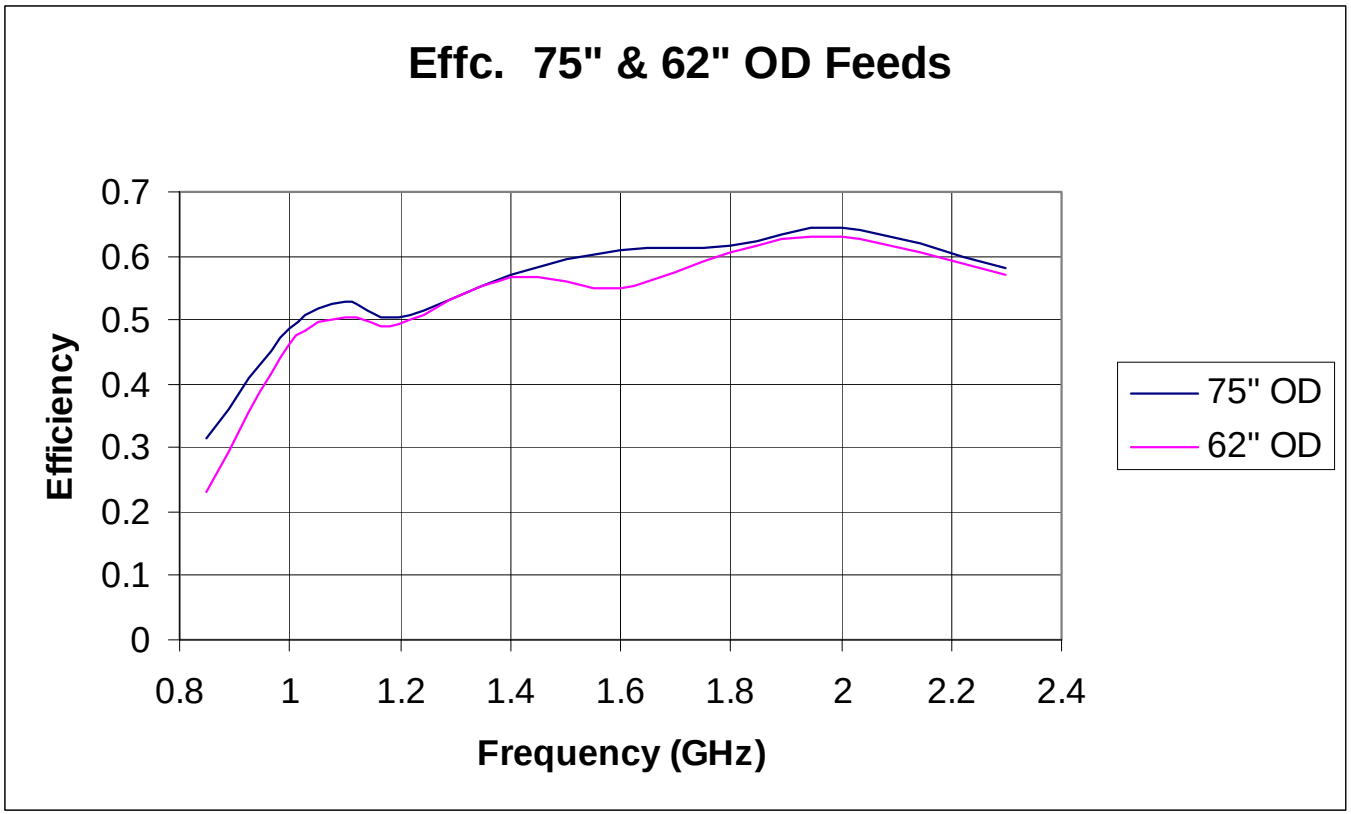




Focus Curve


Focus curve: L-Band
Efficiency
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
-3
-2.5
-2
-1.5
-1
-0.5
0
Subreflector position (ins)
1.4 GHz
2.0 GHz

Comparison of 75" OD and 62" OD Feeds



L-Band Feed Summary

Freq. (GHz)	Taper at 9.3° (dB)		X-pol (dB)	P.C. below Aperture (ins)
	H	E		
1.0	-6.1	-5.7	-29	27
1.1	-6.8	-6.0	-29	28
1.2	-8.2	-8.0	-26	43
1.4	-10.6	-10.0	-26	63
1.6	-11.2	-11.4	-29	81
1.8	-10.2	-10.0	-27	103
2.0	-10.6	-10.0	-34	123