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

<table>
<thead>
<tr>
<th>Band</th>
<th>Freq. (GHz)</th>
<th>Bandwidth Ratio</th>
<th>Feed Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1-2</td>
<td>2:1</td>
<td>Compact Horn</td>
</tr>
<tr>
<td>S</td>
<td>2-4</td>
<td>2:1</td>
<td>Compact Horn</td>
</tr>
<tr>
<td>C</td>
<td>4-8</td>
<td>2:1</td>
<td>Compact Horn</td>
</tr>
<tr>
<td>X</td>
<td>8-12</td>
<td>1.5:1</td>
<td>Linear Taper Horn</td>
</tr>
<tr>
<td>Ku</td>
<td>12-18</td>
<td>1.5:1</td>
<td>Linear Taper Horn</td>
</tr>
<tr>
<td>K</td>
<td>18-26</td>
<td>1.44:1</td>
<td>Linear Taper Horn</td>
</tr>
<tr>
<td>Ka</td>
<td>26-40</td>
<td>1.53:1</td>
<td>Linear Taper Horn</td>
</tr>
<tr>
<td>Q</td>
<td>40-52</td>
<td>1.3:1</td>
<td>Linear Taper Horn</td>
</tr>
</tbody>
</table>

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).

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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 $15\lambda$, while a compact horn has an aperture diameter of $11.2\lambda$ (75%).

2. The length of the linear taper horn is $47\lambda$, as compared to $32.5\lambda$ 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 $12\lambda$ 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

[Graphs showing G/Tsys. for 3 GHz and 10 GHz for different elevations and feed tapers]

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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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NRAO/Charlottesville
# EVLA Receiver Bands

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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)

<table>
<thead>
<tr>
<th>Freq. (GHz)</th>
<th>62&quot; OD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>E</td>
</tr>
<tr>
<td>0.85</td>
<td>-3.9</td>
<td>-6.9</td>
</tr>
<tr>
<td>1.0</td>
<td>-5.4</td>
<td>-5.1</td>
</tr>
<tr>
<td>1.1</td>
<td>-6.3</td>
<td>-6.2</td>
</tr>
<tr>
<td>1.2</td>
<td>-7.7</td>
<td>-7.4</td>
</tr>
<tr>
<td>1.4</td>
<td>-10.5</td>
<td>-10.5</td>
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<tr>
<td>1.6</td>
<td>-10.5</td>
<td>-11.6</td>
</tr>
<tr>
<td>1.8</td>
<td>-10.8</td>
<td>-10.2</td>
</tr>
<tr>
<td>2.0</td>
<td>-12.7</td>
<td>-12.4</td>
</tr>
<tr>
<td>2.3</td>
<td>-9.2</td>
<td>-10.1</td>
</tr>
</tbody>
</table>

1-2 GHz Average taper -9.1 dB
1.2-2 GHz Average taper -10.4 dB
Comparison: EVLA & VLA Feeds

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Comparison: EVLA & VLA Feeds

![Comparison Graph](image)

**Graph Title:** Elevation 30

- **Axes:**
  - Y-axis: G/T (1/Jy*10^-2)
  - X-axis: Freq. (GHz)

- **Legend:**
  - EVLA
  - VLA

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L-Band Feed Details

Aperture ID = 57.772 (7.34\(\lambda\))
Aperture OD = 63.750
Length = 155.3 (20\(\lambda\))
Input Dia. = 7.5
\(\Theta\) input = 8°
\(\Theta\) max = 13°

(All dimensions = inches)

Corrugations
Total = 93
Ring-loaded = 7
Pitch = 1.575
Flange width = 0.090
Corrug. width = 1.485
No. per \(\lambda\) = 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)

4.0 GHz; H plane

4.0 GHz; E plane

Amplitude (dB)

Angle (degrees)

Theory

Measured
Measured 4 GHz
(1 GHz)

4.0 GHz; Measured

Amplitude (dB)

Angle (degrees)

E pln
H pln

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Theory & Measured
6 GHz (1.5 GHz)

6.0 GHz; H plane

6.0 GHz; E plane

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Measured 6 GHz
(1.5 GHz)

6.0 GHz; Measured

Amplitude (dB)

Angle (degrees)

E pln.  H pln.
Theory & Measured
8 GHz (2 GHz)

8.0 GHz: H plane

8.0 GHz: E plane

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Measured 8 GHz
(2 GHz)

8.0 GHz; Measured

Amplitude (dB)

Angle (degrees)

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

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

7.6 GHz; 45 - plane

8.0 GHz; 45 - plane

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Measured Return Loss

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L-Band Prototype Feed Before & After Outer Coating

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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; S₁₁ < -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

WR770 Coax Adapter
WR770 to 7.500" Circular

WR510 Coax Adapter
WR510 to WR650

WR650 to 6.430" Circular

6.430" to 7.500" Circular
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;
  Δf = 0.05 GHz; -180 to 180°; Δθ = 0.5°
  E- & H-plane

- Far-field:
  Distance to Tx. horn 130’
  0.95 – 1.50 GHz; time gating; Δf = 0.005 GHz
    -90 to 90°; Δθ = 1°
  1.40 – 2.20 GHz; Δf = 0.05 GHz;
    -180 to180°; Δθ = 0.5°
  E-, H-, & 45°-plane
Compare C- & L-Band Prototypes

H-pln; 1.5 & 6.0 GHz

E-pln; 1.5 & 6.0 GHz

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Near-Field
E- & H-Planes

Near Field; 1.5 GHz

Near Field; 1.0 GHz

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Compare Near- & Far-Fields

H plane; 1.0 GHz; Far Fld.: gated

E plane; 1.0 GHz; Far Fld.: gated

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Compare Near- & Far-Fields

H plane; 1.4 GHz; Far Fld.: gated

E plane; 1.4 GHz; Far Fld.: gated

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Compare Near- & Far-Fields

H plane; 1.8 GHz; Far Fld.: No gating

E plane; 1.8 GHz; Far Fld.: No gating

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Theory & Measured
1.0 GHz

Amplitude (dB)

Angle (degrees)

Far field; 1.0 GHz; H-pln
Theory
Measrd

Far field; 1.0 GHz; E-pln
Theory
Measrd

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Theory & Measured

1.5 GHz

[Graphs showing far field radiation patterns for 1.5 GHz, comparing theory and measurement for H-pln and E-pln polarizations.]

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Theory & Measured
2.0 GHz

Far field; 2.0 GHz; H-pln

Far field; 2.0 GHz; E-pln

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Co- & X-Polarized Field Patterns - Measured

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Co- & X-Polarized Field Patterns - Measured

45 Deg. Far-field; 1.9 GHz

45 Deg. Far-field; 2.0 GHz

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Measured Return Loss

Wave Guide calib.; With & w/o Escolam 10

**S11 (dB)**

Freq. (GHz)
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

\[ \Delta \Theta = \frac{\lambda}{\rho_{\text{max}}} \quad \Delta \phi = \frac{\Delta \Theta}{\sin \Theta_{\text{max}}} \]

<table>
<thead>
<tr>
<th>Freq. (GHz)</th>
<th>( \Delta \theta )</th>
<th>( \Delta \phi )</th>
<th>Number of Points (sub)</th>
<th>Actual Used</th>
<th>Number of Points (main)</th>
<th>Actual Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>5</td>
<td>720</td>
<td>1800</td>
<td>5,040</td>
<td>12,600</td>
</tr>
<tr>
<td>10</td>
<td>0.2</td>
<td>1.0</td>
<td>18,000</td>
<td></td>
<td>126,000</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.05</td>
<td>0.30</td>
<td>240,000</td>
<td></td>
<td>1,680,000</td>
<td></td>
</tr>
</tbody>
</table>
Feed As Installed
On the Antenna

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Comparison of 75" OD and 62" OD Feeds

Efficiency vs Frequency (GHz)

- 75" OD
- 62" OD
Calculated Antenna Beam (Ideal Case)

1.4 GHz; Symm. plane; Eff. 0.539

2.0 GHz; Symm. plane; Eff. 0.648
Calculated Antenna Beam at 1.4 GHz

1.4 GHz; Symm. plane; 0.539, 0.430, 0.453

Gain (dB)

Angle (degrees)

-5 -4 -3 -2 -1 0 1 2 3 4 5

At focus
sub 0.0
sub-0.75

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Calculated Subreflector Beam at 1.4 GHz

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Calculated Antenna Beam at 2.0 GHz

2.0 GHz; Symm. plane; 0.648, 0.407, 0.537

Gain (dB) vs Angle (degrees)

-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3

at focus
sub0.0
sub-1.75

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Calculated Subreflector Beam at 2.0 GHz

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Focus Curve

Focus curve: L-Band

Efficiency

Subreflector position (ins)

-3 -2.5 -2 -1.5 -1 -0.5 0

0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6

1.4 GHz
2.0 GHz
Comparison of 75" OD and 62" OD Feeds

Efficiency vs. Frequency (GHz)

- 75" OD
- 62" OD

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# L-Band Feed Summary

<table>
<thead>
<tr>
<th>Freq. (GHz)</th>
<th>Taper at 9.3° (dB)</th>
<th>X-pol (dB)</th>
<th>P.C. below Aperture (ins)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>-6.1</td>
<td>-5.7</td>
<td>-29</td>
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<td>-6.0</td>
<td>-29</td>
</tr>
<tr>
<td>1.2</td>
<td>-8.2</td>
<td>-8.0</td>
<td>-26</td>
</tr>
<tr>
<td>1.4</td>
<td>-10.6</td>
<td>-10.0</td>
<td>-26</td>
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<td>-11.4</td>
<td>-29</td>
</tr>
<tr>
<td>1.8</td>
<td>-10.2</td>
<td>-10.0</td>
<td>-27</td>
</tr>
<tr>
<td>2.0</td>
<td>-10.6</td>
<td>-10.0</td>
<td>-34</td>
</tr>
</tbody>
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