Focal Plane Array Discussion

NRAO, Charlottesville

May 29 – 30, 2003

Participants:

Richard Bradley (NRAO)  Walter Brisken (NRAO)
German Cortez (NAIC)   Peter Dewdney (DRAO)
Rick Fisher (NRAO)     Peter Napier (NRAO)
Daniel Schaubert (UMass)  Bruce Veidt (DRAO)
Focal Plane Array Discussion

Agenda for Thursday, May 29

10:15     Coffee/Tea
10:30     Introduction
10:35     GBT array feed (Bradley, Fisher)
11:35     Arecibo multi-beam feed (Cortez)
12:35     Lunch
14:00     EVLA focal plane options (Napier, Dewdney)
15:00     DRAO LAR feed (Veidt, Dewdney)
16:00     Coffee/Tea
16:20     Array feeds (Schaubert)
17:50     End of session wrapup
18:00     Adjourn for dinner
VLA Optics

<table>
<thead>
<tr>
<th>Point</th>
<th>Coordinates (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Feed</td>
<td>0.975, 1.676</td>
</tr>
<tr>
<td>B. Intersection of subreflector and primary axis</td>
<td>0.0, 8.479</td>
</tr>
<tr>
<td>C. Edge of primary</td>
<td>12.5, 4.325</td>
</tr>
<tr>
<td>D. Inner edge of paneled primary</td>
<td>2.0, 0.112</td>
</tr>
<tr>
<td>E. Base of strut</td>
<td>7.550, 1.594</td>
</tr>
<tr>
<td>F. Top of modeled strut</td>
<td>1.391, 9.217</td>
</tr>
<tr>
<td>G. Prime focus</td>
<td>0.0, 9.0</td>
</tr>
<tr>
<td>H. Vertex of primary</td>
<td>0.0, 0.0</td>
</tr>
</tbody>
</table>
VLA Subreflector
VLA Low Frequency Problems

- Cassegrain focus best for $\lambda \leq 21\, \text{cm} \ (\nu \geq 1\, \text{GHz})$

- Best fit prime focus is behind subreflector

- No simple wideband prime-focus feeds with appropriate illumination
Possible Solutions

- **Rotating subreflector mount** *(baseline plan)*
  + Room for several feeds  - High cost
  + Exposes true prime focus

- **Deployable off-axis feed(s)**
  + No change to subreflector  - Suboptimal performance
  - Large array(s) required

- **Deployable out-of-focus feed(s)**
  + No change to subreflector  - Suboptimal performance
  - Large array(s) required

- **Feed behind 1m hole in subreflector**
  + Access to prime focus  - Degrades other beams
  - Room for only one feed
  - Major change to design

- **New array of low frequency antennas**
  + Optimized for low freqs  - High cost
  + Simultaneous observations
Vivaldi Array Advantages

- Control over illumination
- Very wide bandwidths
- Potential for multiple beams
- Can be used out of focus / off axis
FRRM
(Focus Rotation Rotation Mount)
FRRM (cont.)

Possible concept (1)

- **Feed 1** 700 to 1200 MHz horn with cooler receiver

- **Feed 2** 410 to 700 MHz horn

- **Feed 3** 240 to 410 MHz horn
FRRM (cont.)

Possible concept (2)

- **Feed 1** 800 to 1200 MHz horn with cooling receiver

- **Feed 2** 240 to 800 MHz focal plane array
FRRM (cont.)

The following figures show the optimized illumination for a 9 × 9 Vivaldi array centered on prime focus. The elements are 12 cm across; the entire array is 108 cm square. In this contour is a factor of 1.5 lower than the next highest. The dark circle is the edge of the 25 m primary. The inner circle is the extent of the unpaneled area.
7x7, 12 cm elements illumination

- **250 MHz**
  - $G=35.40\,\text{dBi}$
  - $T_{\text{sys}}=153.2\,\text{K}$
  - $A/T=2.591$
  - $\eta=0.683$

- **600 MHz**
  - $G=43.14\,\text{dBi}$
  - $T_{\text{sys}}=66.4\,\text{K}$
  - $A/T=6.169$
  - $\eta=0.703$

- **1532 K**
  - $G=39.48\,\text{dBi}$
  - $T_{\text{sys}}=84.9\,\text{K}$
  - $A/T=4.676$
  - $\eta=0.683$

- **61.3 K**
  - $G=45.64\,\text{dBi}$
  - $T_{\text{sys}}=61.3\,\text{K}$
  - $A/T=6.677$
  - $\eta=0.901$
Offset feed array (cont.)

The following figures show the optimized beam pattern of a 9 × 9 array of 12cm Vivaldi elements. Each contour is 2 dB lower than the next highest. Note that the effects of scattering are not included here.
7x7, 12 cm elements beam

- **η_t=0.877**  η_b=0.798  η_s=0.975  250 MHz  
  Peak Sidelobe=3.2%

- **G=35.40 dBi**  T_sys=153.2K  A/T=2.591  η=0.683

- **η_t=0.899**  η_b=0.794  η_s=0.986  600 MHz  
  Peak Sidelobe=3.2%

- **G=43.14 dBmi**  T_sys=66.4K  A/T=6.169  η=0.703

- **η_t=0.901**  η_b=0.807  η_s=0.986  800 MHz  
  Peak Sidelobe=3.0%

- **G=45.64 dBmi**  T_sys=61.3K  A/T=6.677
FRRM (cont.)

Focal Plane Array Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>250 - 800 MHz</td>
</tr>
<tr>
<td>Element size</td>
<td>12 cm</td>
</tr>
<tr>
<td>Array size</td>
<td>$7 \times 7 - 9 \times 9$</td>
</tr>
<tr>
<td>Number of elements</td>
<td>112 - 180</td>
</tr>
<tr>
<td>Physical size</td>
<td>84 - 108 cm, square</td>
</tr>
<tr>
<td>Polarization</td>
<td>dual linear</td>
</tr>
<tr>
<td>Pattern taper</td>
<td>$\sim 6$dB at $67^\circ$</td>
</tr>
<tr>
<td>$T_{REC}$</td>
<td>25K</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>$&gt; 100$ MHz</td>
</tr>
<tr>
<td>Beams</td>
<td>2</td>
</tr>
</tbody>
</table>
Offset feed array
Offset feed array (cont.)

The following figure shows the focal plane radiation of VLA antenna pointing 7.2° off axis. Contours are drawn at 3dB in power. The plus shows the optic axis, the inner edge of the subreflector, the outer arc is the extent of the unpaneled area of the primary, and the dotted box is the tip of a 1.2 meter square focal plane array.
The following figures show the optimized illumination for an offset array pointing 7.2° from axis. Each component has a factor of 1.5 lower than the next highest. The excess illumination that occurs mainly at the higher frequencies is due to the element being too small – ray optics precludes the extremes of the array from contributing.
Offset feed array (cont.)

The following figures show the optimized beam pattern for the offset array pointing 7.2° from axis. Each contour is 2 dB lower than the next highest. An array larger than 1.5 m is required to produce a symmetric, high efficiency beam. It should be noted that the effects of strut scattering are not included here.
Offset feed array (cont.)

Focal Plane Array Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>300 - 1000 MHz</td>
</tr>
<tr>
<td>Element size</td>
<td>12 cm</td>
</tr>
<tr>
<td>Array size</td>
<td>10 × 10 - 12 × 12</td>
</tr>
<tr>
<td>Number of elements</td>
<td>220 - 312</td>
</tr>
<tr>
<td>Physical size</td>
<td>120 - 144 cm, square</td>
</tr>
<tr>
<td>Polarization</td>
<td>dual linear</td>
</tr>
<tr>
<td>Pattern taper</td>
<td>~ 6dB at 67°</td>
</tr>
<tr>
<td>$T_{REC}$</td>
<td>25K</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>&gt; 100 MHz</td>
</tr>
<tr>
<td>Beams</td>
<td>2</td>
</tr>
</tbody>
</table>
Out of focus array

Placing an array under the subreflector was studied. The array would necessarily be out of focus. In order to compare with other options, its size would need to be larger to achieve the more distributed radiation. The next two figures demonstrate this graphically. In black contours the z component of the Poynting vector, $S_z$, is shown. This has maximum at prime focus (coordinates $= 0.0m, 9.0m$). Total power collected by the array for a point source on axis is the integral of the power in the focal plane. For circular arrays, this integral is zero. The red contours show regions within which 50% of the power is collected. The red contours are for 75%, 87.5%, ... The blue solid line is the nominal subreflector position. The upper dashed line shows maximum vertical travel. For an array of 0.3m the minimum size of about 2.5m is required.
Approximate Timeline

Q1/06  Choose low freq. concept

Q4/06  Prototype

Q1/08  Begin installation

Q4/12  Installation complete
The UHF Array

- 16 or 20 new 30m antennas
- Operates from 74 MHz to 1.5 GHz
- Possibly scaled up ATA design
- No correlator upgrade required
- Uses existing infrastructure
- Simultaneous observation with E"