The EVLA Project

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EVLA Project Goals

- **Fundamental Goal:** By building on the existing infrastructure, multiply ten-fold the VLA’s observational capabilities.
- **Full frequency coverage from 1 to 50 GHz.**
  - 8 frequency bands with cryogenic receivers.
  - Two independent simultaneously available frequency pairs, with no tuning restrictions.
- **1 $\mu$Jy point-source continuum sensitivity** (most bands)
- **New correlator with 8 GHz/polarization capability**
  - 16384 minimum channels/baseline, with full polarization.
  - Full recirculation capability for expanded frequency resolution.
  - 128 independently digitally tunable frequency slots.
- **Noise-limited full-beam imaging in all Stokes parameters**
- **Completion by 2012.**
A key EVLA requirement is continuous frequency coverage from 1 to 50 GHz. This will be met with 8 frequency bands:
- Two existing (K, Q)
- Four replaced (L, C, X, U)
- Two new (S, A)
Existing meter-wavelength bands (P, 4) retained with no changes.
Blue areas show existing coverage.
Green areas show new coverage.
Two independent frequency tunings can be placed *anywhere* in the selected band (or bands).
Sensitivity Improvement: $1-\sigma$, 12 hours

**Continuum Sensitivity**

- R.M.S. Noise in MicroJy
- Frequency in GHz

**Spectral Line Sensitivity**

- R.M.S. Noise in MilliJy
- Frequency in GHz

Red: Current VLA, Black: EVLA Goals
The EVLA’s performance is vastly better than the VLA’s:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VLA</th>
<th>EVLA</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point Source Sensitivity (1-σ, 12 hours)</td>
<td>10 μJy</td>
<td>1 μJy</td>
<td>10</td>
</tr>
<tr>
<td>Maximum BW in each polarization</td>
<td>0.1 GHz</td>
<td>8 GHz</td>
<td>80</td>
</tr>
<tr>
<td># of frequency channels at max. bandwidth</td>
<td>16</td>
<td>16,384</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum number of frequency channels</td>
<td>512</td>
<td>4,194,304</td>
<td>8192</td>
</tr>
<tr>
<td>Coarsest frequency resolution</td>
<td>50 MHz</td>
<td>2 MHz</td>
<td>25</td>
</tr>
<tr>
<td>Finest frequency resolution</td>
<td>381 Hz</td>
<td>0.12 Hz</td>
<td>3180</td>
</tr>
<tr>
<td>(Log) Frequency Coverage (1 – 50 GHz)</td>
<td>22%</td>
<td>100%</td>
<td>5</td>
</tr>
</tbody>
</table>

The total cost for this >10-fold improvement is ~$94M – about 1/3 the cost of the VLA.
What is the EVLA Not Doing?

• Expanding to provide 10 times the current best resolution (the New Mexico Array).
  – Lost: A ~few Kelvin brightness sensitivity at milliarcsecond resolution capability provided by the full EVLA.

• A super-compact configuration, for low surface brightness imaging (the ‘E’ configuration).
  – This ~$6M component could easily and quickly be done as a standalone project. (Lost: 10 $\mu$K brightness sensitivity on 12 arcsecond scale at 34 GHz).

• A sub-1 GHz facility. The VLA’s optics system makes it very difficult to implement an efficient wide-band low-frequency capability.
  – All proposed methods to do this require extensive design and development – for which we have no budget.
## The Eight Cassegrain Frequency Bands

<table>
<thead>
<tr>
<th>Band (GHz)</th>
<th>System Temp (K)</th>
<th>Aperture Effic. (%)</th>
<th>IF BW (GHz)</th>
<th>Digitization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>28</td>
<td>.43</td>
<td>2x1</td>
<td>2 x 2GS/s x 8bits</td>
</tr>
<tr>
<td>2-4</td>
<td>25</td>
<td>.60</td>
<td>2x2</td>
<td>4 x 2 x 8</td>
</tr>
<tr>
<td>4-8</td>
<td>24</td>
<td>.60</td>
<td>2x4</td>
<td>4 x 4 x 3</td>
</tr>
<tr>
<td>8-12</td>
<td>34</td>
<td>.65</td>
<td>2x4</td>
<td>4 x 4 x 3</td>
</tr>
<tr>
<td>12-18</td>
<td>35</td>
<td>.65</td>
<td>2x6</td>
<td>6 x 4 x 3</td>
</tr>
<tr>
<td>18-26.5</td>
<td>45</td>
<td>.55</td>
<td>2x8</td>
<td>8 x 4 x 3</td>
</tr>
<tr>
<td>26.5-40</td>
<td>50</td>
<td>.45</td>
<td>2x8</td>
<td>8 x 4 x 3</td>
</tr>
<tr>
<td>40-50</td>
<td>60 - 95</td>
<td>.30</td>
<td>2x8</td>
<td>8 x 4 x 3</td>
</tr>
</tbody>
</table>

Blue = System tested and in place, or under installation.
Green = Prototypes to be tested in 2008.
Red = Deferred to end of project
All eight Cassegrain feeds are compact or linear taper corrugated horns with ring loaded mode converters.
Today’s EVLA Status

• 15 VLA antennas now converted to EVLA standards
• All of these are back in the array for regular observing.
  – All returned antennas can observe at the ‘old standard’ bands, except at U-band (15 GHz).
  – Temporary narrow-band receivers [L (1.3 – 1.8 GHz) and C (4.5 – 5.0 GHz)] are being retrofitted to their full-tuning capabilities: 1 – 2, and 4 – 8 GHz.
  – K (18 – 27 GHz) and Q (40 – 50 GHz) bands have full tuning capability now.
• The next retrofitted antenna should ‘fringe’ today, and be back in the array next week.
• The remaining 12 antennas will be upgraded at a rate of 6/year, completing in 2010.
• Nearly all technical issues resolved.
Full-Band Tuning Timescale

- The old correlator will be employed until the WIDAR correlator achieves full 27-antenna capability – mid 2009.
- Old correlator’s limitations remain:
  - 50 MHz BW
  - 16 to 512 channels
- Full band tuning available now, on schedule shown here.
EVLA and VLA Tsys at L-Band

This shows the great improvement in spillover performance of the new L-band (1 – 2 GHz) feed.
WIDAR Correlator

- Design and construction of correlator by the DRAO correlator group (Penticton, BC, Canada).
- All costs covered by Canadian NRC.
- WIDAR accepts 8 inputs, of up to 2 GHz BW each, normally configured as four input (R,L) pairs.
- Their design is an extraordinarily flexible machine allowing for up to 64 independently defined (in frequency and bandwidth) sub-band pairs within the input bandwidth.
- Each digitally-defined sub-band pair has 256 channels, to be distributed amongst 1, 2, or 4 polarization products.
- Recirculation provided for increased frequency resolution.
- Vast number of ways to share resources internally, trading inputs, or sub-band pairs, or polarization, for more channels.
- Full polarization, pulsar modes, phased array, VLBI-ready, extensive subarraying, etc.
- I have a (detailed) correlator document for those interested.
Correlator Resource Allocation Matrix

\[ \text{IQ} = 3 \]

Four Active Baseband Pairs
Initial Quantization = 3 bits

There are 64 independent sub-band pairs, each with its own center frequency, bandwidth, and polarization combination.

- Each sub-band pair has 256 spectral channels in this configuration.
- Each sub-band pair is independently tunable with BW = 128, 64, 32, … 0.03125 MHz.
Major Future Milestones

• Test 4-station prototype correlator on the sky  July – Oct. 2008
  – Four antenna test and verification system
  – Not available for science
• Testing of 10-station correlator:  Oct ’08 – Sept. 09
• Full Correlator Installation  Jan ’09 – Dec ’09
• VLA’s correlator turned off  Sept. 2009
  – New correlator capabilities will be much greater
  – About 5 VLA antennas will not be useable (temporarily)
• Resident Shared Risk Observing Begins  ~December 2009
• Last antenna retrofitted  Sept. 2010
• Last receiver installed  Sept. 2012