The Proposed VLA VHF Extension
Field and Lab Test Results, Design Updates, and Deployment Plans

• Enables timely (key) research in cosmology
  – raises profile of VLA/EVLA
  – puts VLA on par or ahead of other low-ν facilities
    – LOFAR (science data from core in 07)
    – PAST (science data in 07 - but polz. cal. constrained)
    – MWA (proposal pending; science data possible in 08)
  – expands EVLA low-ν capability

• Enables general user (legacy) science

• Brings together two active observatories
  – Hardware built by SAO receiver lab

$\lambda_{92}$ cm

$\lambda_{153}$ cm

$\lambda_{400}$ cm

(removed for 153cm ops on key science)
Status

• 3 element 195 MHz subarray in routine use
• Impact on VLA L and P-band: small
• RFI characterized; coordination effort begun
• Production RX designed
  – General user science band included
• No showstoppers yet regarding sensitivity
  – But addressing unknowns of high-dynamic range, high-sensitivity imaging in an intense RFI environment requires
    • production RXs
    • » 3 antennas
    • coordination with broadcasters
195 MHz Imaging

![Graph showing 195 MHz Imaging data with coordinates and flux levels.]

Peak flux = 8.1697E+01 JY/BEAM
Levels = 1.520E-02 * (3, 6, 12, 24, 48, 96, 192, 384, 768, 1536)
Timeline

• Aug 04 - Dec 04  Planning/Initial Feasibility
• Dec 04 - Feb 05  Prototype construction
• Mar 05 - Jun 05  Field testing on site
  – Jul 05 - Sep 05  Remote field testing, follow-up
• 27 Jul 05  NRAO design/logistics review
• Aug 05 - Nov 05  Hardware Production
• Oct 05 - Nov 05  Deployment (4 RX/wk)
• Dec 05  First science time/proof of concept
Field Test Activities

- **1.5m performance**
  - Total power G/T
  - Cross power G/T
  - Holography
  - Cross polarization
- **L-band / P-band performance impact**
  - Tsys (L)
  - G/T (L, P)
  - Beamwidth (P)
- **RFI characterization**
  - Mitigation planning
  - Coordination investigation
- **Assessment of key and legacy science feasiblity**
# VLA Prototype Performance

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>Goal</th>
<th>Anticipated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Beam</strong></td>
<td>4.3°</td>
<td>√</td>
<td>--</td>
</tr>
<tr>
<td><strong>Beam sidelobes</strong></td>
<td>~10 % @ λ/D</td>
<td>a few %</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td><strong>T&lt;sub&gt;sys&lt;/sub&gt; / ε</strong></td>
<td>600-800 K (†)</td>
<td>400-500 K</td>
<td>~500-700 K (††)</td>
</tr>
<tr>
<td><strong>Receiver X-polz</strong></td>
<td>10-40%</td>
<td>10%</td>
<td>match P-bnd</td>
</tr>
<tr>
<td><strong>Line RMS/450°h</strong></td>
<td>~6-8 mK@15′</td>
<td>a few mK</td>
<td>~ 4-5 mK(§)</td>
</tr>
<tr>
<td><strong>Impact: λ20cm</strong></td>
<td>0 ± 1%</td>
<td>≤ 1%</td>
<td>0±1%</td>
</tr>
<tr>
<td><strong>Impact: λ92cm</strong></td>
<td>0 - 10%</td>
<td>&lt; 5%</td>
<td>0%</td>
</tr>
</tbody>
</table>

† Corresponds to ε~ 30%; T<sub>sys</sub> ~200 K (195 MHz). Wb obtains ε~ 30%; Tsys~400 K (150± MHz). †† Contingent on deployment options TBD. § Depends on correlator mode, observing strategy, RFI; see later discussion.
195 MHz Holography

Antenna 8 RR Beam Pattern: Amplitude

-10 dB

Contours: 0, -3, -6, -10, -13, -16, -20, -30, -40, -50 dB relative to the peak
## RX Design Changes

<table>
<thead>
<tr>
<th>Component</th>
<th>Change</th>
<th>Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-hybrid</td>
<td>Move to before LNA; broader band, lower loss component</td>
<td>Purity of polarization; isolation of LNA from mismatches</td>
</tr>
<tr>
<td>LNA</td>
<td>Operating point</td>
<td>Higher gain, lower $T_{RX}$</td>
</tr>
<tr>
<td>Noise diode injection</td>
<td>Move to after LNA; off for science observations</td>
<td>Stability; low $T_{RX}$; preclude leakage into P-band receiver</td>
</tr>
<tr>
<td>Lumped-element balun</td>
<td>Replace coaxial balun</td>
<td>Low insertion loss, broad bandwidth</td>
</tr>
<tr>
<td>Bandpass filter</td>
<td>Use 8-pole custom filter</td>
<td>Exclusion of TV carriers</td>
</tr>
<tr>
<td>High-Q crystal notch filters</td>
<td>Inclusion</td>
<td>Exclusion of TV carriers to enable operation of ALCs and to avoid ringing in spectra</td>
</tr>
<tr>
<td>Dipole shorting switch</td>
<td>Inclusion</td>
<td>P-band performance.</td>
</tr>
<tr>
<td>Connection to superflex</td>
<td>3 dB pad at 2-band RX out</td>
<td>Damp 3 MHz bandpass ripple in 1.5m AND P-band output</td>
</tr>
<tr>
<td>2-band / P-band power and cal on/off control (PROPOSED)</td>
<td>S/W control of power and cal signal to 2-band and P-band (PROPOSED)</td>
<td>Noninterference assured. 2-band off for P-band obs. P-band off for 2-band obs. Control power at A-rack input</td>
</tr>
</tbody>
</table>
Layout of Production RX

- VLA 1.5 meter receiver
- LNA gain 24 dB 25 K
- Amp gain 30 dB nf 2.8 dB
- Combiner
- BPF
- Notch filters
- Noise diode
- 9.6 Hz calibration signal
- Temperature controller
- Dipole
- Balun 1.1 dB loss
- Shorting control
- Quad Hybrid 2 dB loss
- LNA gain 24 dB 25 K
- Amp gain 30 dB nf 2.8 dB

Quad Hybrid response
- Amplitude balance: 3 dB
- Phase balance 2 degrees

Bandpass filter response
- 3 dB BW 184 MHz to 198 MHz
- 30 dB at 180 MHz and 202 MHz

Notch filter frequencies
- 3 dB 10 kHz BW, -20 dB notch
  199.25 MHz, 197.75 MHz, 193.25 MHz
  192.31 MHz, 187.25 MHz, 186.31 MHz
  185.75 MHz, 179.75 MHz

Power and Cal control
- To Receiver Electronics
  - Cal to 1.5 m
  - Cal to P band
  - +15V to 1.5 m and dipole shorting relay
  - +15V to P band
- From Vertex Room
  - 9.6 Hz Cal
  - +15V
- DPDT relay
- VLA control bit
Production RX Performance

Production Receiver Characteristics

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Total: 184-198 MHz @ -3 dB set by bandpass filter [Q-hybrid: 160-230 MHz Feed: 193 MHz optimized, Δν/ν ~ 5-8%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>84 dB with pads and ground isolation betw. stages</td>
</tr>
<tr>
<td>Notches</td>
<td>TV 7(v), TV8(a), TV9(v), TV10(v,a) TV11(v), DTV9(c), DTV10(c)†</td>
</tr>
<tr>
<td>Power out</td>
<td>-67 dBm over 14 MHz at input to A-rack</td>
</tr>
<tr>
<td>Supply</td>
<td>15 VDC @ &lt;1A; 15/28 V for cal.</td>
</tr>
</tbody>
</table>

†(a) audio, (v) video, (c) digital carriers

Anticipated Antenna Performance

<table>
<thead>
<tr>
<th>Primary beam</th>
<th>~ 4.3° half power full width; 10 dB 1st sidelobe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross pol.</td>
<td>Comparable to P-band</td>
</tr>
<tr>
<td>SEFD</td>
<td>2400 – 4000 Jy (16 cm dipole spacing)</td>
</tr>
<tr>
<td></td>
<td>2000 – 3300 Jy (10 cm dipole spacing) †</td>
</tr>
</tbody>
</table>

† 2400-4000 Jy reflects 10% reduction in $T_{sys}$ enabled by improvements in receiver design. 2000-3300 Jy reflects further 15% improvement anticipated when short stand-offs are employed between 1.5m and 0.92m dipoles. Later slides treat this proposed configuration in greater detail.
Sensitivity and EOR Science

• Original RMS estimate [expect ~ 23mK \times f(\text{HI}) ]
  - 3.1 mK in 300^h@85% / 1.6 MHz line / 2200-2400 Jy / 26 antennas / dual pol. / 0.2\lambda

• New RMS estimate
  - RFI excision \Rightarrow use mode 4 (1.56 MHz/24.4 kHz or 781 kHz/12.2 kHz)
  - BW loss/off-src subtraction: 1.4\times (1.56 MHz) 2.0\times (781 kHz)
  - SEFD: 1.1-1.7\times (15.6 cm dipole spacing) 0.9-1.3\times (10 cm spacing)
  - Drop lowest \text{z} target: 0.82\times (450^h)

• Total Penalty (15.6 cm spcg) 1.3-2.0\times (1.56 MHz)
  1.8-2.8\times (781 kHz)

Total Penalty (10 cm spcg) 1.0-1.5\times (1.56 MHz)
  1.5-2.1\times (781 kHz)

• Short of detection, likely 3\sigma upper limit on f(\text{HI}) anticipated
  - \sim 0.5 for average SEFD (10 cm/1.56 MHz)
Impact on L and P-bands

• L-band
  – $T_{SYS}$ measured w/ dipole on/off on 2 days
    • Difference consistent with zero $\pm 1$K at zenith ($T_{SYS} \sim 30$K)
  – G/T measured w/ dipole on/off on 2 days
    • Ratio for dipole on/off $\sim 0 \pm 1\%$ (CasA)

• P-band (ABSENT LOAD TESTS, HARD TO MEASURE)
  – Shorted 1.5m dipole (PREFERRED OPTION)
    • Improvement in G/T@327 MHz $\sim 7 \pm 5\%$ (multiple beam cuts)
    • Some +ve bias possible due to 1.5m ND leakage in P-band
    • Finite element model predicts $< 0.1$ dB effect
  – Loaded 1.5m dipole (LESS HEAVILY STUDIED IN THE FIELD)
    • G/T for the test antenna is in the midrange of antennas
    • Finite element model predicts $< 0.1$ dB effect
Proposed Change to Feed Assembly

- Critical item for discussion with NRAO
- Dipole gain are sensitive to their separation
  - Affects forward gain and impedance at balun input
  - Current spacing, Δ=15.6 cm
- Gain at 1.5m can be improved ~10% for
  - 10 cm spacing
  - P-band remaining λ/4 from the subreflector
  - Reduction in spill-over also possible (of order 10K effect)

<table>
<thead>
<tr>
<th>Distance (cm)</th>
<th>185 MHz (dB)</th>
<th>195 MHz (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.6</td>
<td>7.41</td>
<td>7.33</td>
</tr>
<tr>
<td>10.0</td>
<td>7.74</td>
<td>7.78</td>
</tr>
<tr>
<td>8.00</td>
<td>7.39</td>
<td>7.90</td>
</tr>
<tr>
<td>5.00</td>
<td>7.28</td>
<td>8.02</td>
</tr>
</tbody>
</table>

1.5m relative gains. Calculation assumes balun input matched at 195 MHz for all spacings since it can be customized during manufacture.

<table>
<thead>
<tr>
<th>ν</th>
<th>1.5m loaded</th>
<th>1.5m shorted</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>305 MHz</td>
<td>7.35 dB</td>
<td>7.84 dB</td>
<td>0.49 dB</td>
</tr>
<tr>
<td>315</td>
<td>7.54</td>
<td>7.79</td>
<td>0.25</td>
</tr>
<tr>
<td>325 ††</td>
<td>7.50 ††</td>
<td>7.54</td>
<td>0.04</td>
</tr>
<tr>
<td>335</td>
<td>7.32</td>
<td>7.28</td>
<td>-0.04</td>
</tr>
<tr>
<td>345</td>
<td>7.05</td>
<td>6.89</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

P-band relative gains. Gains account for balun mismatch that increases as spacing departs from 15.6 cm. †† 7.55 dB @ 325 MHz w/o 1.5m dipole.
Varying Dipole Separation: Effect on P-band performance

Effect on 1.5m performance

- Finite element model calc.
- Reflection losses tracked
July 17 RFI Sweep

Cross Power 17-26 (uncal/unstable ALC) 05JUL17

-100
0
100
200
300
400
500
184 186 188 190 192 194 196 198 200 202 204
0
Frequency (MHz)

168.31 ± 0.01 [ch0 dti]
187.245 ± 0.015 [ch 0, not UNM]
DTV (UNM) 186-192 alloc.
HI line
197.25 ± 0.05 [ch 10, vla]
197.75 ± 0.02 [ch 0.5, vla internal]
HI lines
199.25 ± 0.05 [ch 11 vla, UNM]
200.00 ± 0.02 [vla internal]
200.18 ± 0.1
200.70 ± 0.05
200.80 ± 0.05
Immunity of Long Baselines to RFI

GMRT 230 MHz 0924-220 z=5.2
channel 20 (229.60MHz)

Correlated RFI

13 km
Deployment Logistics

- **Priority: minimize use of NRAO manpower**
  - Field testing relied principally on R. Smith, D. Mertely, and J. McClendon (to a lesser extent)
  - Heightened demand because of RFI impact on prototype
  - Demand greatly reduced over last 1-2 months

- **Deployment window October 10-December 5**
  - 4 RX/week on maint and s/w days (x Thanksgiving)
    - 15% contingency
  - Need 1 NRAO staff-equivalent
  - 2 SAO technical staff members available for barrel/manlift work
    - Install R and feed
    - DVM and RF reflection loss measurements.
  - 1-2 SAO staff members available for measurement/testing
  - 1 extra from SAO may be available for barrel work. TBD.
  - Carilli and Perley when available/practical
Deployment Logistics II

- **Test deployment of short stand-offs**
  - Clean swap of 1.5m feed assembly
  - Use cherry picker while barrel work ongoing at other antennas
    - ~1.5h of correlator time to establish baseline @ 0.92m and 1.5m
      - G/T and beamcuts
    - Swap feed assembly
    - ~1.5h of correlator time to establish shift @ 0.92m and 1.5m
      - G/T and beamcuts
  - Swap made after installation of receivers 1 & 2
  - Results available for NRAO consideration by the end of week 1
  - Deployment with long stand-offs through decision point in week 2
  - SAO will maintain necessary stock of assemblies for a “yes” or “no”
  - Removal of unnecessary feed assemblies (long or short) in parallel with later deployment work

- **Test time required**
  - 1h at the end of day 2; 6h at the end of week one (night)
  - 4-6h at the end of every other week (night)
  - Schedule may require some review as experience is gained
SAO Action Items Following Successful Review

• Procurement
  – Closely monitor deliver and production schedule
• Draft RFI coordination agreement in writing
  – Begin coordination with DTV10 (KCHF) for testing at VLA
• Assess RFI subtraction using correlator data
• Review deployment logistics
  – Discussion of short stand-offs
  – Assess SAO and likely NRAO manpower
  – Draft step by step schedule of weekly activities
    • Establish contingencies
    • Assure realism
• Assess EVLA availability for 2005/06 tracks
  – 3 kW power supplies, P-band module readiness, shorting bit wiring
  – Evaluate UV coverage if down 5 antennas