The Long Wavelength Array (LWA)

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The Long Wavelength Array (LWA)

20-80 MHz tuning range (at least)
Baselines up to 400 km for resolution [8,2]" @ [20,80] MHz
52 “stations” - mJy-class sensitivity
Each station is an array of dipole-like elements in 100 m diameter aperture for FOV = [8,2]°
Access to both GC & important northern regions
Important astrophysical & ionospheric science
LWA Science

Astrophysics

Cosmology
High redshift radio galaxies, containing the earliest black holes
Evolution of dark matter & dark energy by differentiating relaxed & merging clusters

Acceleration, Propagation & Turbulence in the Interstellar Medium
Origin, spectrum & distribution of Galactic cosmic rays
Supernova remnants & Galactic evolution
Pulsars

Solar Science & Space Weather
Radio heliography of solar bursts & coronal mass ejections
Solar radar

Ionospheric Physics

Unprecedented continuous spatial & temporal imaging of the ionosphere

Potential to test and improve global ionospheric models

Exploration of the Transient Universe
New coherent sources (More GCRT J1745-3009s?)
GRB Prompt Emission
Magnetar Flares
Extra-Solar Jupiters: Detect magnetic field; conditions for life?
Poorly explored parameter space…new sources
LWA Heritage

Clark Lake TPT
10-120 MHz

ETA 29-47 MHz
High Dynamic Range Direct Sampling
RFI Mitigation

VLA 74 MHz
High-Resolution Imaging, Ionospheric Calibration

LWDA 60-80 MHz
Low Self-RFI Design (to EVLA stds)

LWA 20-80 MHz

Large FOV Experience

Cas A
Cyg A
Galactic plane
Calibratibility & Collecting Area

Each station needs to contribute sufficient collecting area to ensure calibratibility of array.

Estimates of # of dual-pol antenna elements required per station, extrapolating from VLA 74 MHz experience

$N_a = 256$ (baseline)

Tough call!
Sparse Pseudorandom Station Geometry

• Every element digitized to allow unconstrained pointing of beams
• Cost $\propto N_a$, so prefer to minimize $N_a$
• Using 256 stands results in spacings 3 x Nyquist at 80 MHz
• Therefore, array has to be pseudorandom to mitigate against aliasing

• Have to depend on elements & front end noise temp. for broadbanding
• Alternative scheme using large numbers of closely-spaced electrically-short elements (broadbanded using mutual coupling) also being considered.
# LWA Phased Deployment

<table>
<thead>
<tr>
<th></th>
<th>LWA-1(+)</th>
<th>LWIA</th>
<th>LWA</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freq Range</strong></td>
<td>[20, 80] MHz</td>
<td></td>
<td></td>
<td>[10, 88] MHz ext.</td>
</tr>
<tr>
<td><strong>No. of Stations</strong></td>
<td>1 (+2 small)</td>
<td>16</td>
<td>52</td>
<td>min: 100 m (core)</td>
</tr>
<tr>
<td><strong>Max Baseline</strong></td>
<td>(TBD)</td>
<td>200 km</td>
<td>400 km</td>
<td></td>
</tr>
<tr>
<td><strong>Image Resolution</strong></td>
<td>(TBD)</td>
<td>[15, 4]'</td>
<td>[8, 2]''</td>
<td></td>
</tr>
<tr>
<td><strong>T\textsubscript{sys}</strong></td>
<td>G.N.D.*</td>
<td></td>
<td></td>
<td>9000 K @ 38 MHz</td>
</tr>
<tr>
<td><strong>Sensitivity/beam</strong></td>
<td>[40, 25] mJy</td>
<td>[3, 2] mJy</td>
<td>[0.8, 0.5] mJy</td>
<td>2 pol, 1 h, 8 MHz</td>
</tr>
<tr>
<td><strong>sky coverage</strong></td>
<td>$\theta &lt; 74^\circ$</td>
<td></td>
<td></td>
<td>includes GC</td>
</tr>
<tr>
<td><strong>FOV size</strong></td>
<td>[8, 2]°</td>
<td></td>
<td></td>
<td>zenith pointing</td>
</tr>
<tr>
<td><strong>Simult. beams</strong></td>
<td>3</td>
<td></td>
<td></td>
<td>ortho. circ. pols.</td>
</tr>
<tr>
<td><strong>Time resolution</strong></td>
<td>1 ms (5 ns)</td>
<td></td>
<td></td>
<td>(raw sample mode)</td>
</tr>
<tr>
<td><strong>Freq resolution</strong></td>
<td>100 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>data rate</strong></td>
<td>576 Mb/s</td>
<td>9.3 Gb/s</td>
<td>30 Gb/s</td>
<td>sum of stations</td>
</tr>
</tbody>
</table>

*G.N.D.* = Galactic noise-dominated by at least 6 dB, preferably 10 dB
Antennas & Front Ends

Antenna Candidates

“Big Blade”

Front End Candidates

NRL “Gen1”
T = 250 K
G = 24 dB
P_{1dB} = -5 dBm (in)

NRL/NRAO “Gen2”
T = 120 K
G = 32 dB
P_{1dB} = -14 dBm (in)

Cas A Fringes

Galactic Noise-Dominated T_{sys}
LWA Station Electronics Architecture

- AB x2
- RF
- A/D-DR
- Beam 1
- Beam 2
- Beam 3
- Transient Buffer
- Diagnostics
- All-sky observing
- Triggered Events
- User-Provided Backends
- 3 independently-pointed beams, each selected from 1 of the 2 tunings
- Orthogonal circular polarizations

Front Ends
Long Coax
Gain & Filter, 20-80 MHz
256 MSPS x 8-bit; Channelization
2 indep. tunings, 8 MHz / 100 Hz channels
User-Provided Backends
Direct Sampling Receivers
Interconnect Matrix
Data Aggregation & Comm.
TBS
other
RFI is ALWAYS in the way.

Easy to deal with as long as:
- Receivers stay linear,
- $\Delta t < 1$ ms,
- $\Delta \nu < 1$ kHz.

Concerns:
- ATSC (digital TV) – could loose portions of 54-72 MHz & 76-88 MHz at some sites (74 MHz is protected)
- BPL – no problems observed (yet)

Development Plan

2006 Summer: Initial funding
2007 Spring: Funding distributed
2007 Sep: “Kickoff” Meeting
2007 Late Fall: System Rqmts. Rev. (SRR)
2008 Winter: LWA1+ PDR
2008 Fall: LWA1+ CDR
2009: LWA1+ IOC
2011: LWIA (16 stations over 200 km)
2013: LWA core (i.e., short baselines)
2015: 52 stations incl. 400 km baseline(s)

US$ 3.7M
~US$ 6M
~US$ 33M
Long Wavelength Array

Exploration of the meter-wavelength sky & the Earth’s ionosphere with arcsecond resolution and milliJansky-class sensitivity