First Light for the Long Wavelength Demonstrator Array (LWDA)

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LWDA Overview

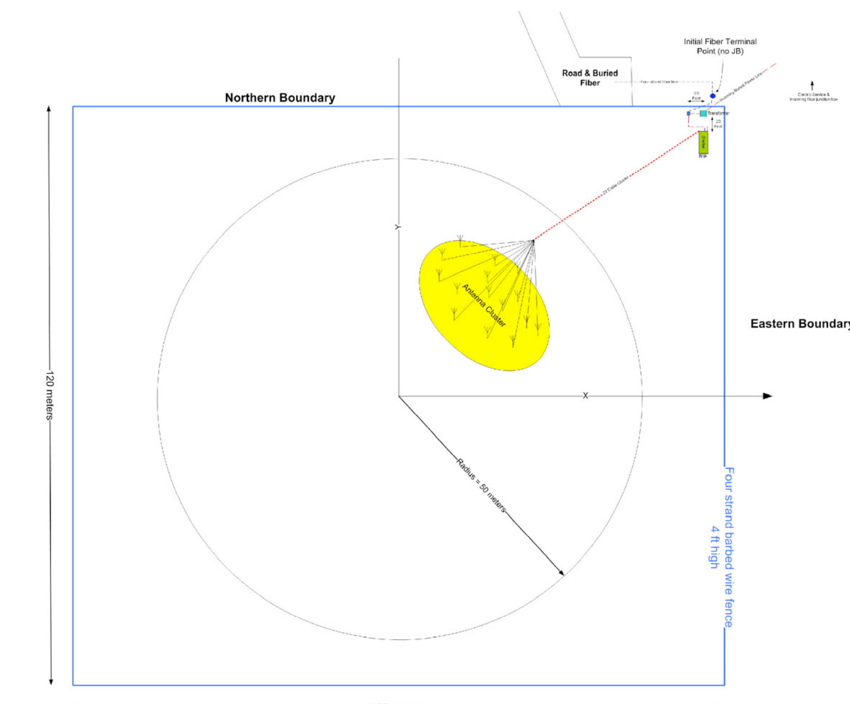
The LWDA is a 16-element array, located near the VLA site in New Mexico, that operates in the frequency range 60–80 MHz. The antennas receive dual linear polarizations. The electronics provide the capabilities for digital delay beamforming with two fully-independent beams of 1.6 MHz bandwidth, as well as all-sky monitoring.

The LWDA was developed by the Naval Research Laboratory (NRL) and the University of Texas Applied Research Laboratories (ARL:UT) as an initial phase of the Long Wavelength Array (LWA) project. The LWA will be a large low-frequency interferometric array consisting of about 52 stations of 256 dipoles each, covering the frequency range 20–80 MHz. The LWA is being developed by the Southwest Consortium and the stations will be spread around New Mexico and possibly parts of Texas with a maximum baseline of 400 km. More information on the LWA project is available at <http://lwa.unm.edu>. The LWDA benefits the LWA project by fielding prototype hardware, providing real experience with site preparation, RFI monitoring and mitigation, software development, environmental concerns, as well as some initial science capability.

LWDA construction was completed and first light images were obtained on October 23, 2006. The LWDA will be operated for the next couple of years as the first full 256-element LWA station is designed and built.

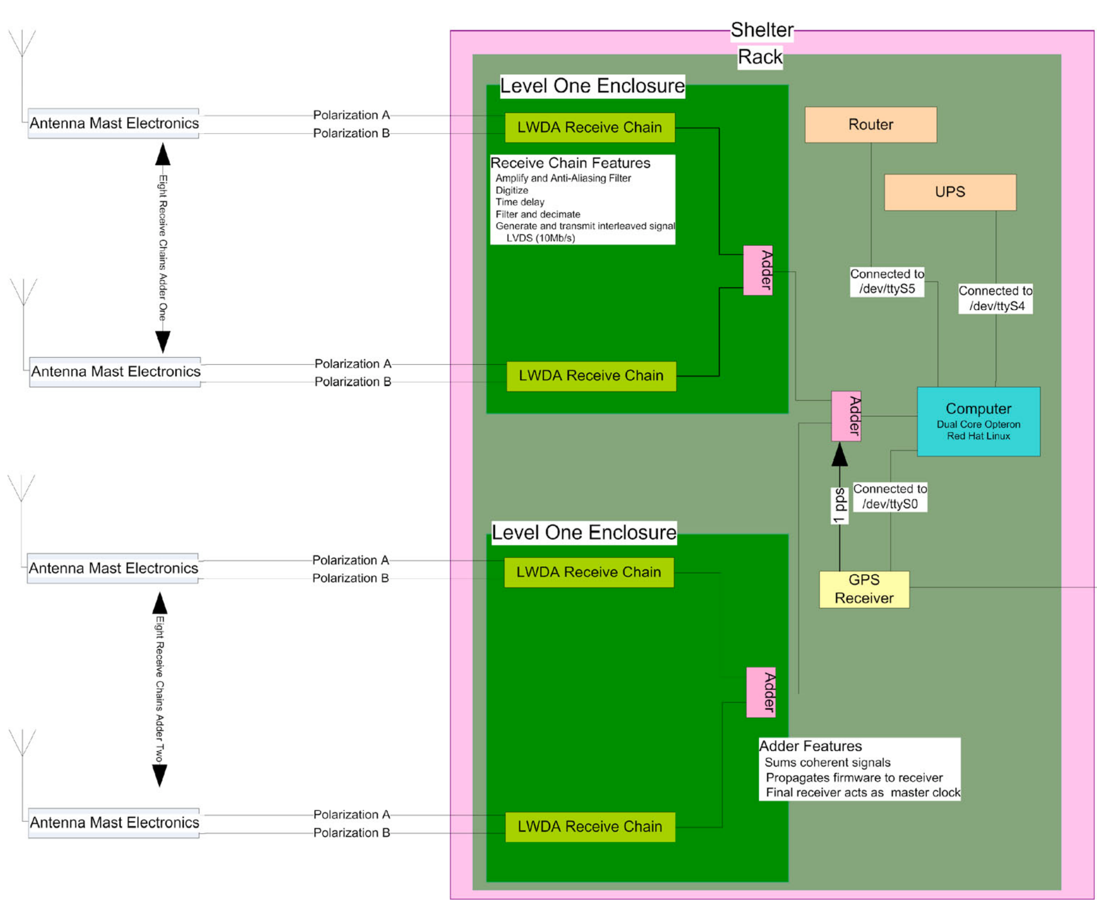
View of the 16 antennas on the LWDA site on the Plains of San Agustin in New Mexico with a 25-m VLA dish in the background.

Station Configuration



The LWDA antenna locations were chosen as a subset of a larger planned configuration. The full configuration, for 256 antennas, is a pseudo-random array, optimized for sidelobe reduction (see LWA Memo #14). The 256 antennas are distributed over a circular area 50m in radius. The 16 antennas of the LWDA are shown in the figure above, and are located in the north-east quadrant of the full array.

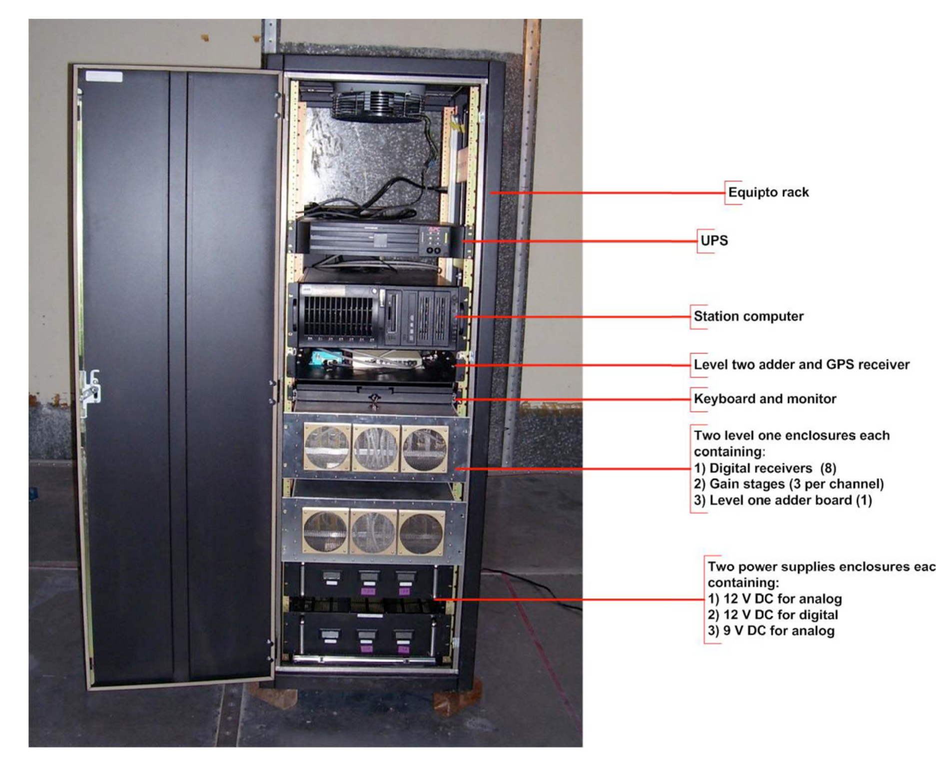
System Architecture



Antenna

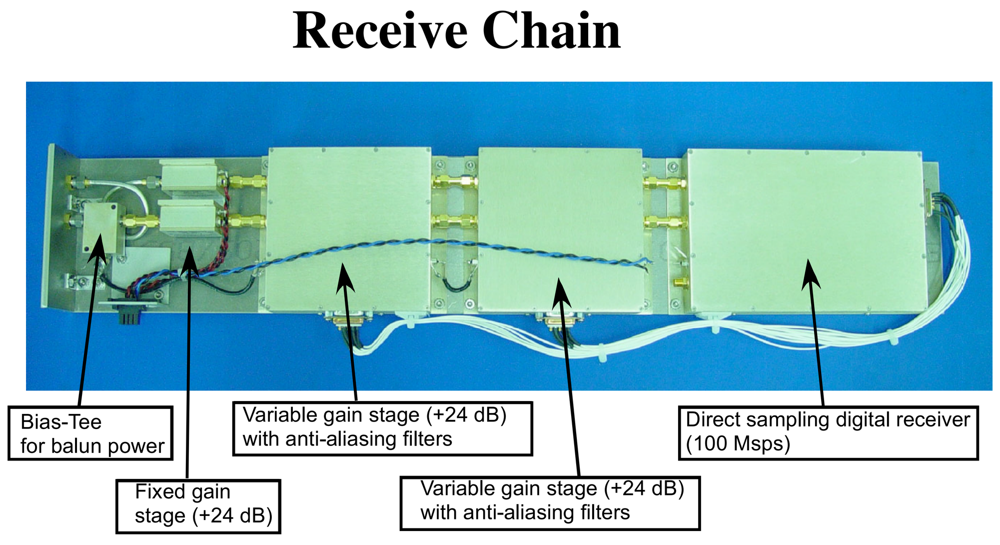
The antenna element is designed to receive signals in the 60–80 MHz band such that the system is significantly sky noise dominated over that band, in dual orthogonal linear polarizations. The antenna is designed to be fairly compact as well as easy and inexpensive to construct (~$530 each in quantity). The antenna and mount are designed to withstand 100 mile/hour peak wind loading, and have a design lifetime of more than 10 years.

Electronics Rack

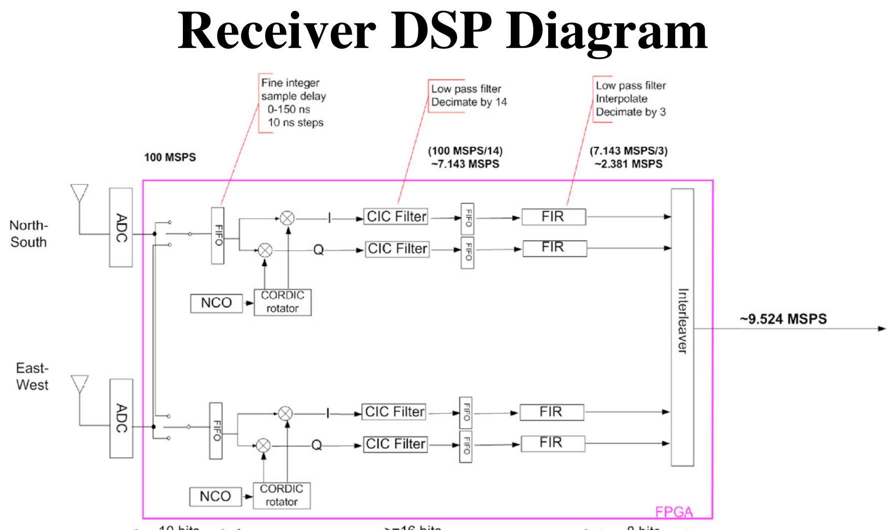


The LWDA equipment rack is shown above. The rack is an FCC compliant Equipto rack. The level one enclosures each contain eight receivers and one adder board. Power is supplied to each level one enclosure by three dedicated power supplies, contained within one power supply enclosure. The rack also contains a UPS and a network switch, used for communications with the external network.

Receive Chain



Receiver DSP Diagram



Digital Receiver Signal Processing

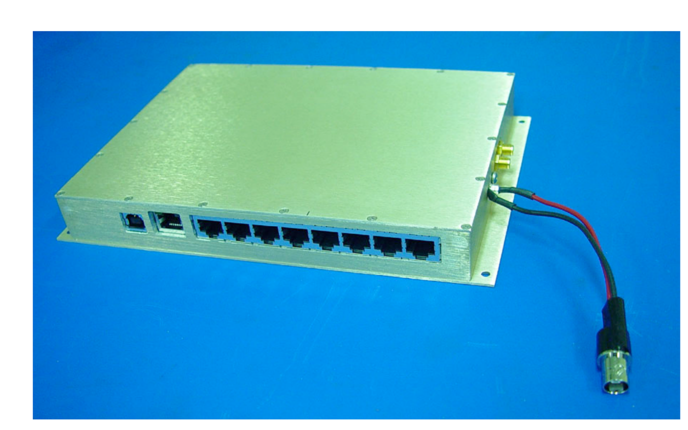
The receiver signal processing chain is reconfigurable on the fly. As a result, this section is subject to change depending on the current configuration of the array. However, as of the LWDA first light, the digital receiver signal DSP flow is as follows:

- The incoming RF data stream is digitized by a dual-channel 10-bit ADC at 100 Msps.
- The signal routing can then be controlled. We have two identical signal processing chains, but the parameters controlling these chains are independent, allowing two frequencies, two spatial beams, or two polarizations.
- After switching, the first stage of digital processing is a FIFO which provides an integer sample delay by up to 150ns in 10ns increments. Thus, geometric path delay and system time delays can be partially compensated for at this stage.
- The next stage of processing is a complex mixer, where the in-phase (I) and quadrature (Q) components are generated using a CORDIC rotator.
- The data are then low-pass filtered using a Cascaded Integrator Comb (CIC) filter and decimated by a factor of 14.
- There then follows another FIFO. This is termed the coarse sample delay, and it provides for sample delays in excess of 1 microsecond.
- A FIR filter defines the final 1.6 MHz bandpass and reduces the data rate by another factor of 3, after which the data are interleaved and passed to the adder board.

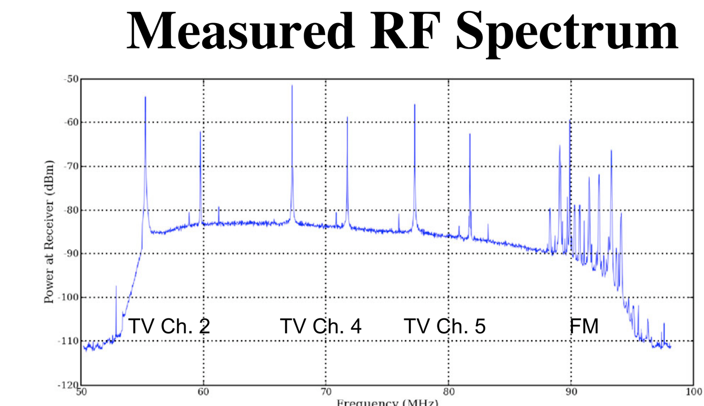
Beamformer

The beamformer, also known as the adder board, was designed to take the incoming digital signals from up to 8 LWDA receivers For these devices the beamformer board provides power management, remote FPGA configuration, clock synchronization, command/control signaling, and aggregation of collected data. The aggregated data is available to streaming over a USB2 port into a PC, and/or over a downstream LVDS port to a higher-level beamformer board.

Beamformer

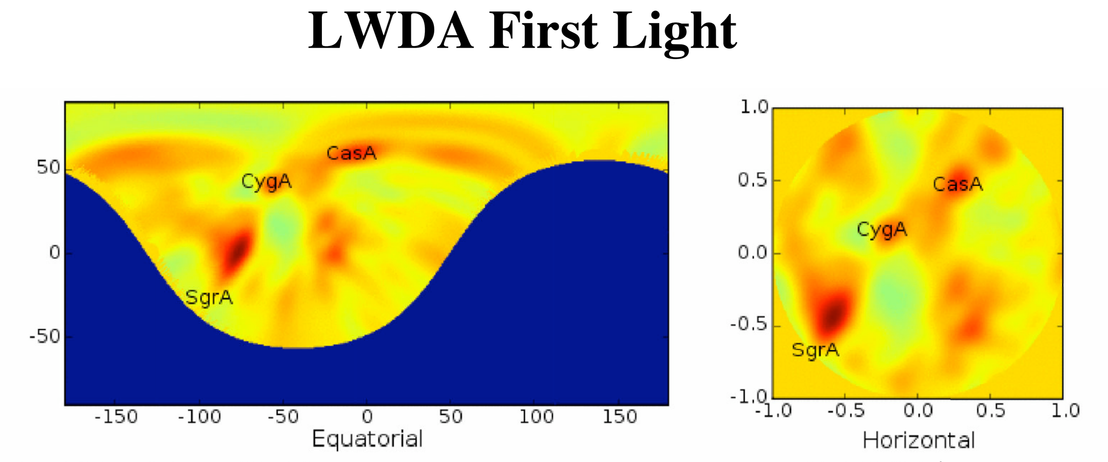


Measured RF Spectrum



Above is a typical spectrum measured in the field using the full receive chain, made by sweeping the 1.6 MHz bandwidth across the available tuning range. The 60–88 MHz bandpass is defined by the anti-aliasing filter in the second gain stage. TV channels 2, 4, 5 and the FM band are clearly visible; however, the spectrum between those carriers is quite clear of RFI and is strongly Galactic noise dominated.

LWDA First Light



A frame from the first light movie from the LWDA, showing the all sky imaging capability. The frames were created using a data acquisition mode that cycled through each of the 120 pairs of dipoles in the array and correlating the signals from each. Phase and gain calibrations, as measured during the array installation were applied to each of the visibilities. Then, the image was constructed by summing spatial sine waves with the appropriate amplitude and phase from each visibility. No deconvolution of the array sidelobe pattern (e.g. "cleaning") of the image has been performed. Emission from the bright sources Sgr A, Cas A, and Cyg A is clearly visible. Away from those sources, sidelobe confusion dominates the brightness and deconvolution will be required to determine the true dynamic range possible in these images.

LWDA Testing Plans

A number of tests and measurements using the LWDA are planned to validate the performance of the array and lead towards the full LWA.

Commissioning Tests
- DSP chain validation
- Sky noise dominance
- Beamforming tests
- Dipole and array pattern measurements
- Deep integrations to look for systematic effects
- Array phase calibrations
- Interferometric tests with an outlier dipole

Activities that support the design of the full LWA stations
- RFI surveys that can't be done with a simple spectrum analyzer
  - Impulsive RFI
  - Sources of very weak or infrequently "on" RFI that might limit LWA integration times
  - Long duration RFI surveys to look for changes
- Calibration accuracy and stability tests using astronomical sources
- Software development testbed

LWDA Science Plans

Although the LWDA is very small, some science observations are possible, and will help determine the feasibility of science observations with the first full LWA station.

Potential Science Observations:
- Low frequency spectra of bright pulsars
- Giant Pulse monitoring of the Crab Pulsar
- All-Sky Monitor mode for bright continuum transients
- Solar burst observations with high spectral and temporal resolution
- Gamma-ray burst prompt radio counterpart searches
- Blind searches for narrow, dispersed pulses
- Bistatic radar observations of the ionosphere
- Cas A/Cyg A flux ratio

References

A great deal of technical documentation for the LWDA and LWA projects is available as part of the LWA Memo Series online:
<http://www.ece.vt.edu/swe/lwa/>
The main LWA project site is:
<http://lwa.unm.edu>