# The Expanded Very Large Array Low Band Upgrade

*Tracy E. Clarke*[1], *Rick A. Perley*[2], *Namir E. Kassim*[3], *Brian C. Hicks*[4], *Frazer N. Owen*[5], *Steve Durand*[6], *Chuck Kutz*[7], *Marian Pospieszalski*[8], *Kurt W. Weiler*[9], *Tom L. Wilson*[10]

[1]Naval Research Laboratory, Remote Sensing Division, Code 7213, 4555 Overlook Ave SW, Washington, DC 20375-5320 USA tracy.clarke@nrl.navy.mil

[2]National Radio Astronomy Observatory Array Operations Center, P.O. Box O, 1003 Lopezville Road, Socorro, NM 87801 USA rperley@nrao.edu

[3]Naval Research Laboratory, namir.kassim@nrl.navy.mil

[4]Naval Research Laboratory, brian.hicks@nrl.navy.mil

[5]National Radio Astronomy Observatory Array Operations Center, fowen@nrao.edu

[6]National Radio Astronomy Observatory Array Operations Center, sdurand@nrao.edu

[7]National Radio Astronomy Observatory Array Operations Center, ckutz@nrao.edu

[8]National Radio Astronomy Observatory Technology Center, 180 Boxwood Estate Road, Charlottesville, VA 22903 USA mpospies@nrao.edu

[9]Naval Research Laboratory, kurt.weiler@nrl.navy.mil

[10]Naval Research Laboratory, tom.wilson@nrl.navy.mil

## Abstract

The EVLA upgrade will enable full frequency coverage between 1 and 50 GHz. The legacy 74 and 330 MHz low frequency receivers have been largely decommissioned by compatibility issues with the new EVLA digital electronics. We describe an EVLA Low Band initiative to replace the existing narrow band receivers with a new low-noise, broadband system covering 66 to 470 MHz. The bandwidth at 74 MHz will increase by more than an order of magnitude while the 330 MHz bandwidth increases by a factor of 6. The initial deployment of the system will use the current, limited bandwidth feeds.

## 1. Introduction

The relatively narrow-band “legacy” 74 and 330 MHz systems on the National Radio Astronomy Observatory (NRAO) Very Large Array (VLA) have served as both scientific and technical pathfinders for high angular resolution, low frequency radio astronomy [1]. Important scientific achievements include wide-field imaging and discovery of transient phenomena at the Galactic center, characterization of unique Galactic and extragalactic absorption mechanisms, identification of steep-spectrum galaxy cluster halo and relic sources, and a sky survey that can serve as initial calibration grid for the emerging class of much larger instruments including LOFAR, LWA, MWA, and eventually SKA [2-8]. Technical developments stimulated by these systems include wide-field imaging, radio frequency interference excision, and ionospheric calibration and characterization [9-11], all of which continue to be improved at the GMRT and other currently operational low frequency observatories.

The transition of the VLA to the digital electronics of the Expanded Very Large Array (EVLA) resulted in the temporary loss of low frequency capabilities. Building on a strong history of collaboration in developing the legacy low frequency VLA systems, the Naval Research Laboratory and the NRAO are working together to bring low frequencies back to the EVLA, with the eventual goal of a flexible, broad-band system that can access the range from ~50-470 MHz. The first step is development of a single, new, low-noise broadband receiver for the EVLA that can initially function with the existing 74 and 330 MHz feeds and replace the original narrow band receivers. In this paper we describe the design of the new receivers and our plans to deploy and test them on the EVLA.

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

## 2. The New EVLA Low-Band Receivers

The new low-band receiver design will aggregate four independent channels into one linear dual-polarized signal path. Telemetry and a high-stability noise source for calibration will be shared between these independent but co-located receiver chains, allowing each channel to be designed to address the Galactic background level in its particular bandpass. This will permit the system to utilize legacy antenna feeds for 74 and 330 MHz (4-band and P-band, respectively) while serving as an easily extensible platform capable of supporting the next generation of wide-bandwidth low-frequency antenna feeds. We intend to achieve a significant improvement in sensitivity by producing a system with a significantly lower noise temperature than the previous generation of low-frequency receivers.

The four linearly polarized feed inputs to the receiver are designated as 'P-band', '4-band', 'Spare A' and 'Spare B' (Figure 1). The two 'spare' channels will offer calibrated receive chains with high linearity (IP3=29 dBm) and a low noise initial gain stage (51K) for future expansion.

By employing low-cost commercial MMIC amplifiers for coverage below 150 MHz, it has been possible to concentrate resources on the development of a state-of-the-art ambient-temperature amplifier for the P-band channel. It is anticipated that this configuration will establish the receiver noise temperature of the P-band section to be less than 88K without the need for cryogenics. The sky noise at 330 MHz is about 35 K. This is a significant improvement over the legacy receiver. The EVLA system utilizes a synchronized noise calibration system that requires a noise source be injected prior to the first stage amplifier of each receiver channel. This configuration allows the continuous calculation of system temperature.

The new system will be located at the apex of each EVLA dish and will accept both passive and active feeds. Wide-bandwidth bias-T networks will optionally provide power to future feeds incorporating active-balun technology. Inexpensive lumped-element filters will be used to define the bandpass of each receiver section prior to combination into a single output pair. Presently in the EVLA system the 4-band and P-band channels are nominally defined to operate between 66-82 MHz and 230-470 MHz, respectively (Figure 2). These bandpass definitions will be verified during early commissioning observations. The bandpass of the two 'spare' channels will eventually be defined by the installation of filters.

Linear polarization was chosen to avoid the frequency dependent phase errors associated with the quadrature hybrids historically used to convert orthogonal linear feeds into right and left circular polarizations.

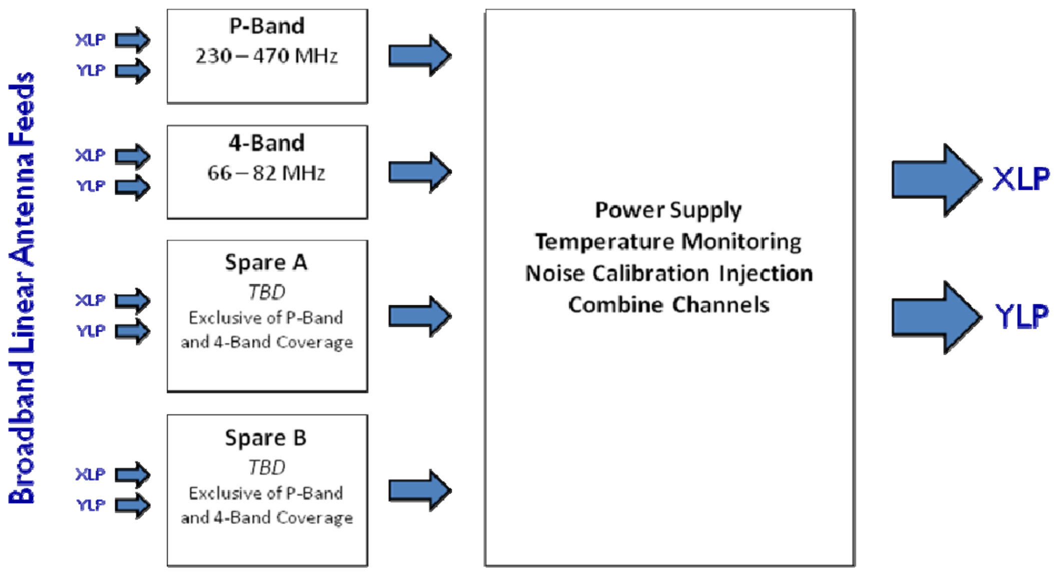


Figure 1 - EVLA Low Band Receiver Structure

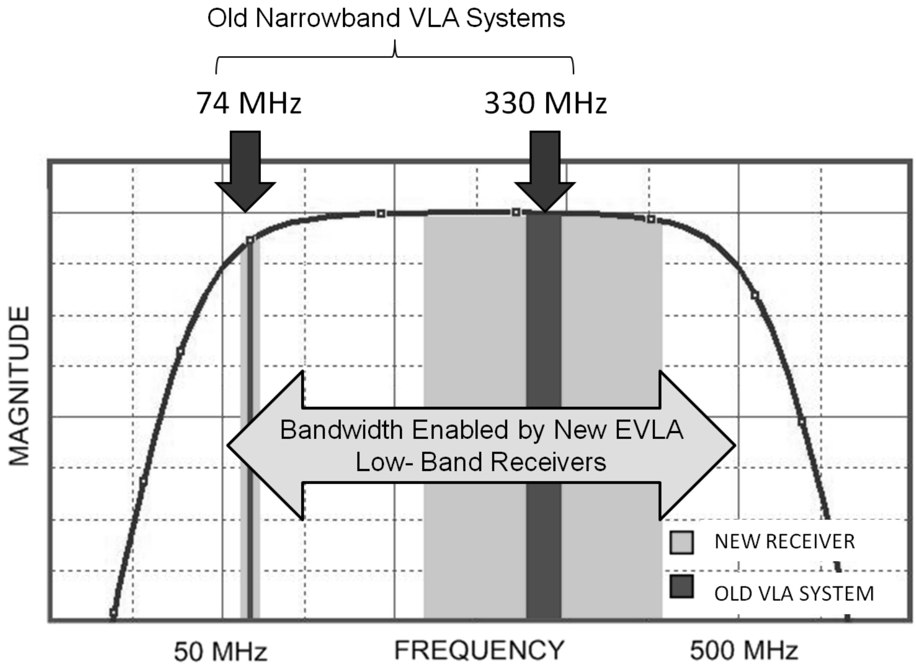

Figure 2 - Increased Bandwidth of new EVLA Low Band system.

## 4. Deployment and Commissioning plans

The initial low band receivers will be installed and tested at the EVLA in mid 2011 during the hybrid BnA configuration. Following the initial testing and performance review, the final EVLA low band system installation is anticipated to be completed by the end of 2011. The first peer reviewed scientific observing using the new system will likely be undertaken during the second observing trimester in 2012.

Commissioning of the low band system will commence as broadband receivers are installed on the EVLA. The full bandpass that will be available on the system is not currently known due mainly to uncertainties in the response of the narrow band feeds. Initial testing of the system will include both narrowband and broadband commissioning activities in order to clearly define the system performance, investigate the radio frequency interference environment, and determine the maximum bandpass available for the 74 and 300 MHz channels.

## 5. Summary

We have described ongoing plans to restore low-frequency ($\nu < 1$ GHz) capabilities to the EVLA. The drastic improvements of the new system over the legacy VLA system are made possible by a combination of lower receiver noise temperature, broader bandwidth and the expanded capabilities of the EVLA WIDAR correlator. The scientific productivity of this system will be further enhanced by recent improvements in techniques of RFI mitigation [12, 13] as well as ionospheric calibration [10-11, 14-15]. The VLA legacy systems have attracted a rich variety of astronomical investigations from the international community of low frequency users, and we look forward to their return commencing in 2012 when the new EVLA system becomes operational.

## 6. Acknowledgments

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. Basic research in radio astronomy at the Naval Research Laboratory is supported by 6.1 base funding.

## 7. References


1. N. E. Kassim, T. J. W. Lazio, W. C. Erickson, R. A. Perley, W. D. Cotton, E. W. Greisen, A. S. Cohen, B. Hicks, H. R. Schmitt, and D. Katz, "The 74 MHz System on the Very Large Array," *Astrophysical Journal Supplement Series,* **V172**, October 2007, pp. 686-719.

2. M. E. Nord, T. J. W. Lazio, N. E. Kassim, S. D. Hyman, T. N. LaRosa, C. L. Brogan, N. Duric, "High-Resolution, Wide-Field Imaging of the Galactic Center Region at 330 MHz"*, Astronomical Journal,* **V128**, October 2004, pp. 1646-1670.

3. S. D. Hyman, T. J. W. Lazio, N. E. Kassim, P. S. Ray, C. B. Markwardt, and F. Yusef-Zadeh, "A powerful bursting source towards the Galactic Centre"*, Nature,* **V434**, March 2004, pp. 50-52.

4. T. J. W. Lazio, A. S. Cohen, N. E. Kassim, R. A. Perley, W. C. Erickson, C. L. Carilli, and P. C. Crane, "Cygnus A: A Long-Wavelength Resolution of the Hot Spots"*, Astrophysical Journal,* **V642**, May 2006, pp. L33-L36.

5. N. E. Kassim, R. A. Perley, K. S. Dwarakanath, W. C. Erickson, "Evidence for Thermal Absorption inside Cassiopeia A"*, Astrophysical Journal,* **V455**, December 1995, pp. L59-L62.

6. M. E. Nord, P. A. Henning, R. J. Rand, T. J. W. Lazio, and N. E. Kassim, "74 MHz Discrete HII Absorption Regions Toward the Inner Galaxy"*, Astronomical Journal,* **V132**, July 2006, pp. 242-252.

7. A. Cohen and T. Clarke, "An Ultra-Steep Spectrum Radio Relic in the Galaxy Cluster Abell 2443", *Astronomical Journal*, arXiv:1102.4606, in press.

8. A. S. Cohen, W. M. Lane, W. D. Cotton, N. E. Kassim, T. J. W. Lazio, R. A. Perley, J. J. Condon, and W. C. Erickson, "The VLA Low-Frequency Sky Survey"*, Astronomical Journal,* **V134**, September 2007, pp. 1245-1262.

9. W. M. Lane, A. S. Cohen, N. E. Kassim, T. J. W. Lazio, R. A. Perley, W. D. Cotton, and E. W. Greisen, "Postcorrelation radio frequency interference excision at low frequencies," *Radio Science,* **V40**, August 2005, RS5S05.

10. W. D. Cotton, J. J. Condon, R. A. Perley, N. E. Kassim, J. Lazio, A. Cohen, W. Lane, W. C. Erickson, "Beyond the isoplanatic patch in the VLA Low-frequency Sky Survey", *SPIE Proceedings: Ground-based Telescopes*, **V5489**, October 2004, pp. 180-189.

11. A. S. Cohen, and H. J. A. Röttgering, "Probing Fine-Scale Ionospheric Structure with the Very Large Array Radio Telscope, *Astronomical Journal,* **V138**, August 2009, pp. 439-447.

12. R. Athreya, "A New Approach to Mitigation of Radio Frequency Interference in Interferometric Data", *Astrophysical Journal*, **V696**, May 2009, pp. 885-890.

13. A. R. Offringa, A. G. de Bruyn, M. Biehl, S. Zaroubi, G. Bernardi, and V. N. Pandey, "Post-correlation radio frequency interference classification methods", *Monthly Notices of the Royal Astronomical Society,* **V405**, June 2010, pp. 155-167.

14. H. T. Intema, S. van der Tol, W. D. Cotton, A. S. Cohen, I. M. van Bemmel, and H. J. A. R{\"o}ttgering}, "Ionospheric calibration of low frequency radio interferometric observations using the peeling scheme. I. Method description and first results", *Astronomy and Astrophysics*, **V501**, July 2009, pp. 1185-1205.

15. L. V. E. Koopmans, "Ionospheric Power-spectrum Tomography in Radio Interferometry", *Astrophysical Journal*, V718, August 2010, pp. 963-971