THE NEXT STEP FOR THE VLA;

A SYSTEM OVERVIEW AND TECHNOLOGIES FOR THE EVLA

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ABSTRACT

The Expanded Very Large Array (EVLA) Project will provide an order-of-magnitude improvement in most of the observational capabilities of the VLA. Continuous frequency coverage over the range 1-50 GHz will be provided by 8 cryogenically cooled receivers. Up to 8 GHz of IF bandwidth per polarization will be provided for processing. The IF data will be transmitted from the antennas to the central correlator on wide-bandwidth digital fiber optic data links providing a data rate of 96 Gbps per antenna. A new correlator capable of processing 8 GHz of bandwidth per polarization will provide 16384 spectral channels across this bandwidth.

INTRODUCTION

The VLA [1] is a synthesis array radiotelescope consisting of twenty-seven 25m diameter reflector antennas. The antennas can be moved on railway tracks along the arms of a Y shaped array, where the arms of the Y are up to 21 km in length. The VLA was originally built in the late 1970's and, for the most part, the original electronic systems are still in use. A new project, called the Expanded VLA (EVLA) Project, has now begun to replace the existing electronic systems with modern technology, whilst keeping the original antennas, in order to obtain an order-of-magnitude improvement in most of the key observational capabilities of the instrument. The major goals of the project are to provide continuous frequency coverage from 1-50 GHz with high G/T and with up to 8 GHz of IF bandwidth for each of two polarizations. A new correlator will allow this wide bandwith to be processed for all 4 polarization products with good spectral resolution. These goals require a number of modern wide-bandwidth technologies to be used for the EVLA. Details concerning the EVLA Project can be found in an on-line document [2].

LOW-NOISE FRONT ENDS

The frequency range 1-50 GHz will be covered in the eight EVLA receiver bands shown in Table 1 which also shows the goals for system temperatures and system (aperture x correlator) efficiencies. The system temperatures are based on an assumption of good weather and, in general, are mid-band estimates with values at the band edges predicted to be a few tens of percent higher. For the 45 GHz band, values are given for the bottom and top parts of the band because of increased atmospheric absorption and decreased reflector performance in the upper part of the band.

The wide-bandwidth feeds for these bands will be profiled corrugated horns [3] for the 1.5, 3.0 and 6.0 GHz bands and conical corrugated horns [4] for the higher frequency bands. All feeds and receivers on the VLA are located on a circle around the axis of the primary reflector near its vertex. An offset Cassegrain geometry is used so that the secondary

Table 1. Performance goals for the EVLA receiver bands.

Band Center Frequency (GHz)	Frequency Range (GHz)	System Temperature (K)	Total System Efficiency	Maximum IF Bandwidth (GHz)
1.5	1.0-2.0	20	.55	2x1
3.0	2.0-4.0	25	.60	2x2
6.0	4.0-8.0	31	.65	2x4
10	8.0-12.0	34	.65	2x4
15	12.0-18.0	35	.65	2x6
22	18.0-26.5	52	.60	2x8
33	26.5-40.0	56	.55	2x8
45	40.0-50.0	76-104	.50-.45	2x8

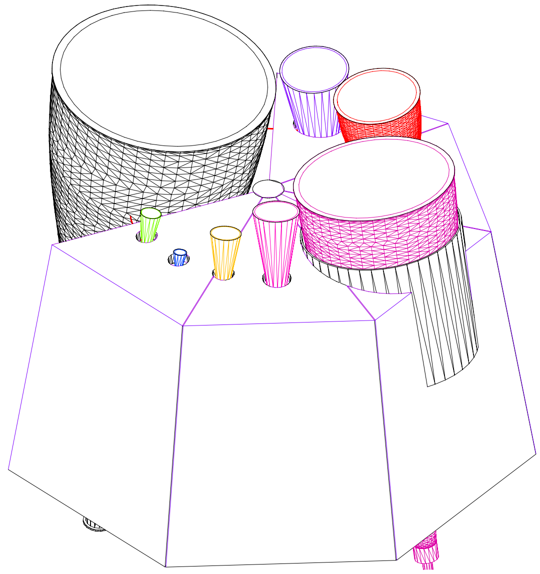

Fig. 1. Arrangement of EVLA feeds

focus lies on this circle and changes in observing band are made by rotating the subreflector to locate the secondary focus on the desired feed. Fig. 1 shows the EVLA feed arrangement. Each receiver band is contained in its own 15 K cryogenic dewar. The low-noise amplifiers for the 1.5 GHz and 3.0 GHz bands are Gallium Arsenide FET amplifiers and for the higher frequency bands they are Indium Phosphide FET amplifiers. All amplifiers are designed and built by the NRAO Central Development Laboratory [5]. All receivers are circularly polarized. For the 1.5, 3.0 and 6.0 GHz bands left and right circular polarizations are obtained using a quad-ridged orthomode transducer (OMT) [6] followed by a quadrature hybrid. The design of such an OMT for 2:1 bandwidth ratio that is free of undesired bandpass features caused by trapped modes is challenging and has not yet been completed. For the 10, 15, 22 and 33 GHz bands the circular polarizations are obtained using a corrugated waveguide phase shifter [7] followed by a symmetrical side port OMT [8]. For the 45 GHz band, the circular polarizations are provided by a sloping septum polarizer [9].

BROADBAND IF SYSTEM

The intermediate frequency (IF) outputs from all receivers are in the band 8-12 GHz. Two independently tunable IF's are provided for each polarization. These IF's are down converted to 2 GHz bandwidth basebands contained in the band 2-4 GHz. The bandwidth available from each receiver is shown in the last column of Table 1 where the factor 2 indicates that basebands are provided for both right and left circular polarizations. The 2-4 GHz baseband is bandpass sampled by a 4 Gsample/sec, 3 bits/sample digitizer that is currently under development for the Atacama Large Millimeter Array (ALMA) Project [10]. For the 1.5 GHz receiver, where RFI is a problem, more digitization resolution is required. For this band only 1 GHz of baseband bandwidth is available and it is sampled with a 2 Gsample/sec, 8 bits/sample digitizer using commercially available digitizer technology.

For the highest frequency bands, where a total of 16 GHz of bandwidth is available, the total data rate is 96 Gb/sec. This data will be transmitted from the antenna to the correlator, over distances of up to 21 km, on a single fiber using twelve 10 Gb/sec digital fiber optic links based on OC-192 WDM technology.

WIDEBAND CORRELATOR

The EVLA wideband correlator [11], to be designed and constructed by the Herzberg Institute of Astrophysics in Canada, can process a total of 16 GHz of IF bandwidth arranged as eight 2 GHz bandwidth basebands. All 4 Stokes polarization parameters are provided. The correlator is an "XF" correlator in which correlation as a fuction of time lag between antennas is performed before Fourier transform to the frequency domain. Sufficient lags are provided to produce 16384 spectral channels over 8 GHz of bandwidth, with more channels being available in smaller bandwidths through the use of recirculation. The 2 GHz bandwidth basebands are divided into sixteen 125 MHz wide sub-bands using finite impulse response (FIR) filters. These sub-bands are processed using a new correlator chip, currently under development, which will be a gate array containing 2048 complex lags arranged as sixteen 128 complex-lag correlators, operating at a maximum data rate of 256 Msamples/s. The correlator, which is capable of processing 1,2,3,4 or 8 bit data, will initially be configured as a 32 station correlator but will be easily expandable to 40 or 48 stations.

SCHEDULE

All parts of the EVLA system are currently undergoing detailed design and prototyping with a goal of installing a prototype system on a single VLA antenna for testing in the second quarter of 2003. Installation of the new systems on remaining antennas will begin in the second quarter of 2004 at the rate of 7 antennas per year. Installation of the new correlator will begin in 2006 with a goal of beginning observations with a subset of the correlator in 2007, and completing the correlator in 2009. The new EVLA systems are designed to be compatible with the existing electronics system so that routine observing can continue during the transition years.

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