

3 SYSTEM INTEGRATION

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Revision History

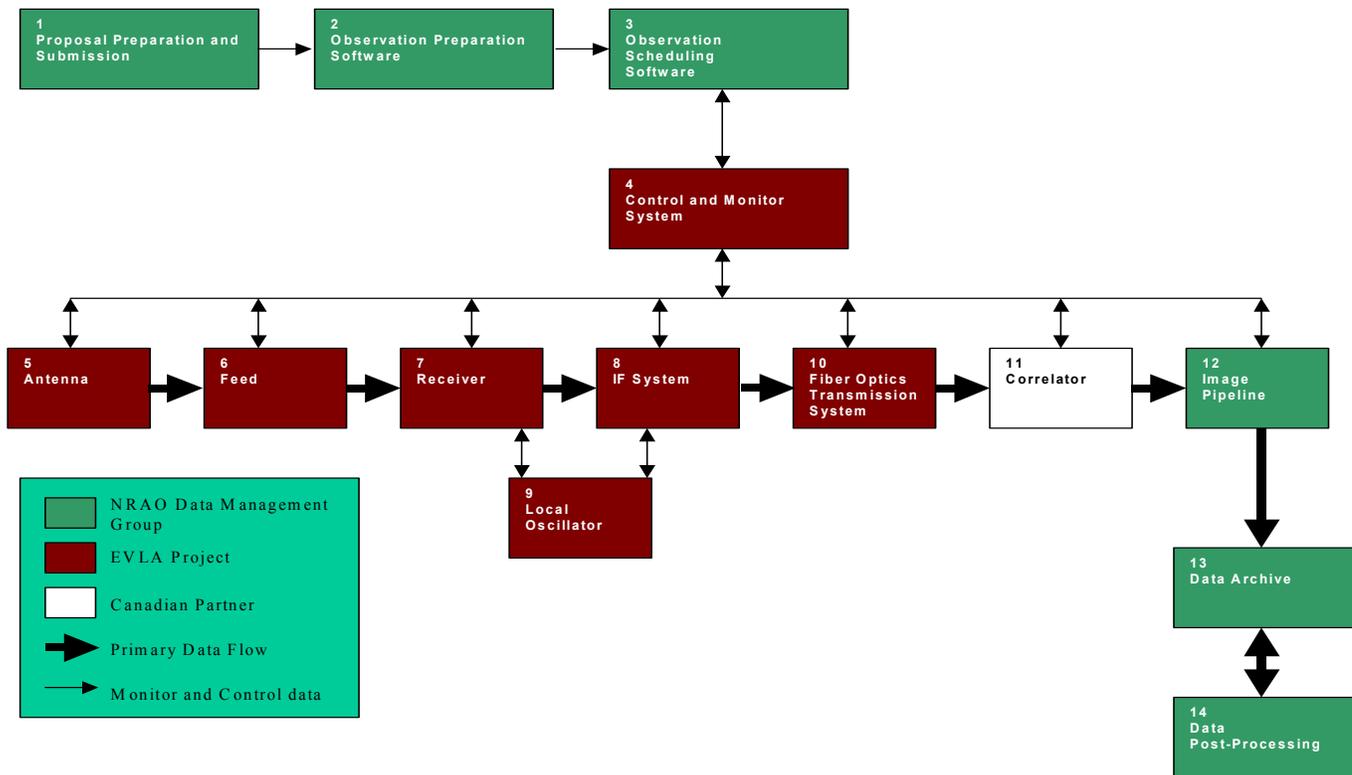
- 2001-Mar 01: Initial release under configuration control
- 2001-May 09: Updated text based on latest block Diagrams, updated digitizer specifications
- 2001-May 29: Updated text based on latest Bins & Module designs, updated gain and phase specs

Summary

3.1 Introduction

In this chapter we present a summary of the performance, engineering and test specifications for the EVLA project. Figure 3-1 shows the principal subsystems of the EVLA.

Figure 3-1 Principal EVLA Subsystems



3.2 Specifications and Requirements

3.2.1 Antennas

The EVLA re-utilizes the existing twenty-eight E-Systems 25-meter parabolic antennas that make up the current VLA system. Modifications are made as necessary to support the new feeds, front ends, electronics and fiber optics systems.

3.2.2 Frequency and Polarization Coverage / Receiver Specifications

The EVLA system is designed for complete frequency coverage between 1 and 50GHz. Both Left and Right Hand Circular Polarizations are available over this entire frequency range. In addition, the EVLA system continues to support the existing 74 MHz and P-Band capabilities of the VLA. The following table shows the operational frequency bands along with the T_{sys} , Efficiency, and polarizations of each band.

VLA Band	Freq	Freq. Range	T_{sys} (K)	Eff	Polarization
4	74 MHz	73.5-74.5 MHz	1000-10000		RHCP/LHCP
P	327 MHz	300-340 MHz	150-180		RHCP/LHCP
L	1.5 GHz	1.2 – 2.0 GHz	26	0.50	RHCP/LHCP
S	3.0 GHz	2.0 – 4.0 GHz	29	0.62	RHCP/LHCP
C	6.0 GHz	4.0 – 8.0 GHz	31	0.60	RHCP/LHCP
X	10.0 GHz	8.0 – 12.0 GHz	34	0.56	RHCP/LHCP
U	15.0 GHz	12.0 – 18.0 GHz	39	0.54	RHCP/LHCP
K	22.0 GHz	18.0 – 26.5 GHz	54	0.51	RHCP/LHCP
Ka	33.0 GHz	26.5 – 40.0 GHz	45	0.39	RHCP/LHCP
Q	43.0 GHz	40.0 – 50.0 GHz	66	0.34	RHCP/LHCP

3.2.3 System Temperatures

The spreadsheet on the following page shows calculations for estimated system temperatures.

Figure 3-2 Systems temperatures

System Temperature Calculations

ν_g	BAND	Unvarying					Galactic and 3 ^o bb (corrected for absorption)					Atmospheric Emission			T _{sys} (corrected for atmospheric absorption)		
		T _{amp}	T _{loss}	T _{cal}	T _{spill}	T _o	T _{gal}	T _{bb}	T _{bg}	τ	T _{bg} e ^{-τ}	T _{atm}	1-e ^{-τ}	T _{atm} (1-e ^{-τ})	Σ_T	e ^{τ}	T _{sys}
0.075	U6					50	1200	3	1203	0.008	1193	280	0.008	1242	5	1.008	1252
0.150	U5					50	200	3	203	0.008	201	280	0.008	2	253	1.008	255
0.240	U4					50	65	3	68	0.008	67	280	0.008	2	134	1.008	135
0.370	U3					40	25	3	28	0.008	28	280	0.008	2		1.008	70
0.550	U2					30	9	3	12	0.008	12	280	0.008	2		1.008	46
0.825	U1					20	3	3	6	0.008	6	280	0.008	2		1.008	28
1.000	L	2		2	11	20	1	3	4	0.008	5	280	0.008	2	28	1.008	27
1.450	L	2		2	11	20	0	3	3	0.008	4	280	0.008	2	28	1.008	26
3.000	S	3		2	8	23	0	3	3	0.009	3	280	0.009	3	29	1.009	29
6.000	C	5		2	6	25	0	3	3	0.010	3	280	0.010	3	31	1.010	31
10.000	X	8		2	5	28	0	3	3	0.012	3	280	0.012	3	34	1.012	34
15.000	Ku	10		3	5	30	0	3	3	0.017	3	280	0.017	5	38	1.017	39
22.000	K	10		4	4	30	0	3	3	0.065	3	280	0.063	18	51	1.067	54
34.000	Ka	14		3	4	35	0	3	3	0.020	3	280	0.020	6	44	1.020	45
45.000	Q	18		4	4	40	0	3	3	0.070	3	280	0.068	19	62	1.070	66
49.000	Q	18		4	4	40	0	3	3	0.250	3	280	0.221	62	105	1.250	131
80.000	W	32		8	3	60	0	3	3	0.200	2	280	0.181	51	113	1.220	138

T_{amp} = Amplifier Temperature

T_{loss} = Loss from Polarizer, Horn, Waveguide, Etc..

T_{cal} = Injected Cal Signal

T_{spill} = Ground Radiation Scattered into Feed

Assumptions:

- > Elevation = 90°
- > Coldest Part of Galaxy
- > Driest Typical Atmosphere
- > Winter Temperatures

$$T_{\text{sys}} = T_o + T_{\text{bg}}e^{-\tau \sec z} + T_{\text{atm}}(1 - e^{-\tau \sec z})e^{\tau \sec z}$$

3.2.4 Tuning Capabilities / LO-IF System Specifications

The EVLA system has the ability to tune two different frequency/polarization pairs anywhere within one, or two, frequency bands, with each pair providing up to 4 GHz of bandwidth in each polarization – a maximum total bandwidth of 16 GHz. In addition, the Local Oscillator system has the flexibility to function with both the new EVLA front ends and the existing VLA front ends.

Sky Frequencies and Sub-Bands

Sky Frequency Band:	(1.0)1.2-2	2-4	4-8	8-12	12-18	18-26	26-40	40-50
Feed:	L	S	C	X	Ku	K	Ka	Q
Delta F:	1	2	4	4	6	8	14	10
Max Bandwidth of Sub Band:	1	2	4	4	4	4	4	4
Number of Sub-Bands:	2	2	2	2	2	2	2	2

(All Frequencies in GHz)

Four independently tuneable 2nd LO synthesizers are used allowing greater tuning flexibility.

4-Band and P-Band capabilities continue to exist in the EVLA. These capabilities are the same as the current VLA bands except they can utilize the 8 bit samplers. These bands are upconverted to L-Band and processed thru the same IF chain. They can be used independently, together or in conjunction with any other frequency band.

An additional 4096 MHz fixed LO and conversion is provided for the narrowband path in each downconverter channel when using the higher resolution, lower bandwidth samplers. This LO is also used during the transition period. During the transition the existing VLA Correlator requires Fringe rotation and in the final system, the WIDAR EVLA Correlator requires frequency offsets. These functions, along with the finer tuning steps, are provided by the Fine Tuning Synthesizers in both the 12-20 GHz and 10.8-14.8 GHz synthesizers

3.2.4.1 Local Oscillator Specifications

12-20 GHz Synthesizer:

Tuning: 5 MHz Steps +/- $F_{FINE\ TUNING\ SYNTHESIZER}$

LO Source for Q/Ka/K-Band Front Ends, LSC Converter and UX Converter

10.8-14.8 GHz Synthesizer:

Tuning: 5 MHz +/- $F_{FINE\ TUNING\ SYNTHESIZER}$

LO Source for Main Downconverters

4096 MHz Synthesizer

Tuning: 4096 MHz +/- 12 MHz in 1 Hz steps

LO Source for Narrow band path of Main Downconverters – used for transition

Fine Tuning Synthesizer:

Direct Digital Synthesizer, F_{CENTER} and F_{RANGE} TBD

Tuning: < 1 uHz steps (48 bits)

Detailed designs and specifications of all LO synthesizers are described in detail in Chapter 6.

3.2.4.1.1 LO Phase Stability

These specifications do not include phase instability induced by the antenna structure or the atmosphere. These specifications do include any instability induced in the front end by the LO system. These specifications have been divided as follows: one-third to the front end, one-third to the T304 downconverter, and one-third to the 4P, LSC and UX converter combination.

Short term: Less than 0.5 ps rms for times under 1 second.
(this equates to 5% coherence loss at 100 GHz)

Long term: Slope <200 fs/min for time scales longer than 30 minutes.
(roughly 1/4 turn at 40 GHz)

Peak-to-peak phase deviations over 30 minutes less than 1.4 ps after removal of any linear slope (20 degrees at 40 GHz).

Phase shift with pointing change:

Less than 0.7 ps over the whole sky (10 deg at 40 GHz).
Less than 0.07 ps per degree of slew for short slews at elevations
below 60 degrees (1 deg of phase at 40 GHz).

This specification applies after correction using any round trip and/or pulse cal data that might be available.

Phase noise is defined as phase instability above an offset of 1 Hz of the frequency of concern. Phase drift is defined as the phase instability below an offset 1 Hz from the frequency of concern.

3.2.4.2 Downconverter Stage

All receiving bands in the EVLA are converted to X-Band by some combination of their respective front ends and/or up to three up-converter modules - one 4/P-Band to L-Band, one L/S/C-Band to X-Band and the last Ku-Band to X-Band.

In each antenna there are four main IF downconverter modules, each driven by an independent LO synthesizer. Each has a single 4 GHz wide X-Band input that is split into two IFs. These IFs are each up to 2 GHz wide and are in the passband from 2 to 4 GHz. A second passband is provided for low bandwidth signals to feed higher resolution digitizers. This path has an additional conversion fed by a 4096 +/- 12 MHz synthesizer

The two IF outputs from each of the four downconverters are harmonic sampled by a pair of 3-bit 4 Gsps digitizers. Alternatively, a single IF from each downconverter is digitized by an 8-bit 2 Gsps digitizer. It is also possible to use a mixture 3-bit and 8-bit digitizers – the only limitation being that each downconverter can drive only one type of digitizer at a time.

The input and output noise power spectral distribution is nominally flat over the passband. The down converter module provides for total power measurement of each split IF as well as the total IF. Internal

filters and external filter connections are provided to either narrow the desired passband or notch out undesired areas within the passband.

3.2.4.3 Gain Flatness and Passband Ripple

The overall gain flatness of the EVLA FE/LO/IF system is specified as 5dB over any 2 GHz bandwidth with a design goal of 3dB over any 2 GHz bandwidth. These specifications have been divided as follows: one-third to the front end, one-third to the T304 downconverter, and one-third to the 4P, LSC and UX converter combination.

Passband ripple is specified to be a maximum of 0.2dB for ripple with a period less than 2 MHz.

3.2.5 Digitizers

The EVLA system digitizes data in the antenna vertex room. Data is sampled by high speed Analog to Digital (A/D) converters. Two sets of converters are available to users. The first is a wide bandwidth device with lower bit resolution that is used for most observing modes of the EVLA. Current plans call for the use of the 4 Gbps 3-bit devices currently being developed for ALMA. The second is a narrower bandwidth device with higher bit resolution that is used for observing in bands with higher levels of Radio Frequency Interference (RFI). Current plans call for the use of an 8-bit 2 giga-sample per second device made up of one or two commercial A/D converters.

During the transition period, this narrow bandwidth 8-bit digitizer is also used to provide compatibility between antennas with the new electronics and the existing VLA Correlator. The IF signal is filtered to a bandwidth of 1GHz, digitized, and transmitted to the CEB over fiber as a digital signal. In the CEB, the data is filtered using digital FIR filters, decimated, spectrally inverted (in the digital domain) if required, then converted back to analog using a D/A converter. This analog signal is then fed into the VLA Correlator using the existing VLA Baseband electronics and samplers.

3.2.5.1 Wideband Digitizer Specifications

The EVLA system has wideband digitizers to be used in normal operation of most frequency bands. These digitizers have the following specifications:

Sampling rate:	4.096Gbps (good up to 5 Gbps)	
Bit resolution:	3 bits	
Quantization levels:	8 levels	
Aperture time:	<50 ps	
Jitter:	~2 ps	
Threshold indecision region:	a few mv	
Analog bandwidth:	2-4 GHz.	+0, -0.5 dB
Analog input level:	0 dBm	
Sampling bands:	Passband: 2-4 GHz	
Clock input:	4 GHz Sinewave, 0dBm	
Output coding:	3 bit Grey code	
	$V_{in} < -1.5x$	000
	$-1.5x < V_{in} < x$	001
	$-x < V_{in} < -0.5x$	011
	$-0.5x < V_{in} < 0$	010
	$0 < V_{in} < 0.5x$	110
	$0.5x < V_{in} < x$	111
	$x < V_{in} < 1.5x$	101

where x = voltage at comparator

	$V_{in} > 1.5x$	100
Output demultiplexing:	1:16	
Output data word width/rate:	48(16x3)bits / 256 MHz	
Output logic:	Low Voltage Differential Signaling (LVDS)	
Power supply:	+2.5 VDC, 2 Watts (approx)	

The EVLA system is currently planning to use the 3-bit samplers being designed for the ALMA project. The specifications above are the current published goals for the ALMA devices.

3.2.5.2 Narrow Band Digitizer Specifications

Sampling Rate:	2.048 Gsps
Bit resolution:	8 bits
Quantization Levels:	256
Aperture Time:	TBD (~50 ps ?)
Jitter:	TBD (a few ps ?)
Threshold Indecision Region:	TBD (a few mv?)
Analog Bandwidth:	>2 GHz
Sampling Bands:	Baseband 0-1GHz, Passband: 1-2 GHz
Output Demultiplexing:	1:8
Output Data Word Width/Rate:	64(8x8) bits / 256 MHz
Output Logic Levels:	Low Voltage Differential Signaling (LVDS) or PECL

The EVLA system is being designed for the sampler specified above but currently, the best device available is a 1.5 Gsps, 8-bit device from Maxim. Two of these devices running at 1.024 Gsps can be multiplexed to form a single unit running at 2.048 Gsps. Tests and simulations are being run to test the validity of this idea.

3.2.6 External RFI

The EVLA system is being designed to operate in the presence of ever increasing levels of Radio Frequency Interference. The design of the Widar Correlator, as well as the use of three and eight bit quantization in the digitizers plays a major roll in the systems immunity to external RFI. A Further discussion of RFI is located in section 3.8

3.2.7 Self Generated RFI

The EVLA system is also susceptible to RFI generated on site and within the EVLA's own systems. Sources of this RFI include:

- High speed digital electronics in the antenna pedestal and vertex rooms
- The LO/Reference systems in the EVLA antennas and central building
- High speed computers and networks covering the entire VLA site
- High speed digital electronics in the existing and new correlators
- Electronics systems in the ALMA test interferometer
- Site 2-way radio communications.

All of these systems must be built and tested to minimize RFI emission levels.

3.2.8 Monitor and Control

The Monitor and Control (M&C) system of the EVLA is based entirely on a TCP/IP based Ethernet. Fiber based Gigabit Ethernet is being used for the antenna field and major computer systems. A combination of fiber and shielded twisted pair based 100 megabit Ethernet is used in the antenna electronics systems and between some computing systems in the CEB.

3.2.9 Correlator

The WIDAR Correlator being built in Canada for the EVLA is designed to the following specifications:

- In wideband mode, provide 16384 spectral channels across 16Ghz of total Bandwidth (consisting of 8 x 2 GHz analog bands) on every baseline. The number of bands used and number of spectral channels per band is flexible.
- In narrowband modes (e.g. many programmable 8 MHz bands), provide up to 0.25 million spectral channels per baseline. Mixed narrowband and wideband modes are possible.
- Provide 1 Hz spectral resolution in narrowband radar mode.
- Simultaneous, fully digital, phased-VLA operation for VLBI.
- Spectral dynamic range > 105 even in the presence of powerful narrowband signals.
- Digital Filters to eliminate costly narrowband analog filters from the antenna electronics
- Multiple sub array-capabilities
- 32 station capability (installed racks for 40, expandable to 256)
- Pulsars: fast (<100 us) phase binning, >1000 bins

3.2.10 Computing Systems

In order to provide facilities expected of a modern astronomical instrument, there will be completely new computer systems. An "end-to-end" implementation philosophy will track observations from proposal to archive. At the completion of an observation, the archive will include proposal cover sheets, telescope schedules, observation status information, the observed data, an automatically generated "reference image," and information entered during the data reduction.

3.2.10.1 Computer System Requirements

More sophisticated scheduling algorithms will be needed to allocate observations based on prevailing weather and interference conditions. Observations will be initiated and tracked by a modern Monitor and Control (M&C) system. In particular, the M&C system will have the task of configuring the correlator and directing the output into a data pipeline.

In order to produce images and spectra from observations as soon as they are taken, the correlated data will be passed through an image pipeline. The pipeline will calibrate and image the data using canned procedures. The procedures will contain heuristic methods driven by the goal-oriented descriptions of the observation supplied by the observer. A data archive will be an integral part of the pipeline.

The requirements for proposal handling, data analysis, and archiving are being developed by the Data Management End-to-End (E2E) group. These are being developed in the E2E project book. See, for example, the requirements sections in:

<http://www.nrao.edu/e2e/documents/e2eprojectbook.pdf>

The scientific requirements of the monitor and control system can be found in Benson, J. & Owen, F., "Scientific Requirements for the EVLA Real-Time System," EVLA Memo 15, 2000.

http://www.aoc.nrao.edu/doc/vla/EVLA/Memos/Sci_Req.ps

M&C requirements for the use by operations and electronics are being separately developed. The initial operational requirements may be found at:

<http://www.aoc.nrao.edu/vla/EVLA/Computing/WorkingDocs/index.shtml>

3.2.10.2 Monitor and Control

The M&C System will provide a complete and well-integrated tool suite to test, control, monitor, maintain, and calibrate the instrument. It will provide facilities for use by observers, by operations staff, and by scientific, computing, and engineering support personnel. It will be a distributed computing architecture. It will be possible to monitor and control all hardware from a remote location via an authorized, secure network connection. Where possible, the system will use commercial, off-the-shelf (COTS) equipment. The main network infrastructure will be TCP/IP over Ethernet, using single mode fiber to the antennas. It is extremely desirable to reduce the radio frequency interference (RFI) in the antennas themselves, so fiber will also be used there if cost permits.

3.2.10.3 Data Processing

AIPS++ will provide the software necessary to reduce all data from the EVLA. AIPS++ already contains a complete suite of applications for reduction of radio aperture synthesis data, including editing, calibration, image, image enhancement, and displays of image and all intermediate products. This will be the environment in which development of new processing techniques will be done, including, for example, bandwidth synthesis.

A detailed analysis of the scope and nature of data processing that will be needed by deployment of the full EVLA shows that there will be a spectrum of data processing needs. With reasonable predictions for the growth in the computer industry (e.g., Moore's Law continuing to the end of the project in 2009 - see [1] and references therein), we expect to be able to process the data from the most demanding observations with the EVLA using a moderately parallel cluster for reasonable costs. Many more typical observations will be entirely processable using a desktop computer.

The numerically intensive parts of AIPS++ are able to take advantage of parallel and distributed computing environments in order to support the data processing requirements of the EVLA. A collaboration between NCSA and

NRAO has led to AIPS++ parallel codes for the most demanding parts of synthesis data reduction: spectral line imaging, wide-field imaging, and mosaicing.

3.2.10.4 Image Pipeline

In order to produce images and spectra from observations as soon as they are taken, the correlated data will be passed through an image pipeline. The procedures will contain heuristic methods driven by the descriptions of the observation supplied by the observer. The heuristic methods will make use of the status information about all EVLA components to provide a "reference image" from the data. For many observations, this will be sufficient for use by the observer, or at the very least will serve as a starting point for subsequent additional processing by the observer. The pipeline will be implemented using the

extensive scripting and synthesis data reduction capabilities of the AIPS++ package. The development of pipeline processing is also being developed for other NRAO telescopes.

3.2.10.5 Data Archive

In the majority of cases, the reference image produced by the pipeline and stored in the archive will constitute a scientific result that does not require further data reduction.

After an observation has been stored in the archive, it will be possible to retrieve the data to apply data post-processing tools to the data in the archive to produce additional scientific results. It will be possible to treat the data in the archive as if it were being provided by the telescope in real-time. All data that affect the production of scientific data products are to be archived along with the visibilities. The analysis of EVLA computing needs estimates that typically the average data rate from the EVLA will be from 50 to 100 Terabytes per year. Although this is very large by today's standards, we expect that at the end of construction, the cost of such storage will be in the range \$50k to \$100k per year. It is likely that the data will be stored in a heterogeneous array of computers, rather than on a single, large computer. The design and implementation of the archive will be leveraged on other efforts presently in place (e.g., HST, IPAC, Sloan) and in development (the National Virtual Observatory) in the wider astronomical community. If appropriate, the archive will be out-sourced to an organization that already serves large databases to the community. The archive will enable EVLA results to be used (after the usual proprietary period) in the National Virtual Observatory initiative, thus enhancing the scientific impact of the array. This work is also being developed for other NRAO telescopes.

3.2.10.6 Software Practices

The AIPS++ group, which will provide the underpinning for the pipeline data processing, has good professional practices that we will use as a model for all software developed for the EVLA. These include peer review of newly submitted code, a test procedure for each class submitted to the libraries, weekly discussions, weekly targets and reports for all engineers, periodic and fixed release dates, etc.

Software will be developed and requirements refined periodically based on operational experience.

3.2.10.7 Standards

When the overall requirements are complete, we will decide on the necessary platforms, tools, and standards to implement the software. This will not be until after the computing PDRs.

3.2.10.8 Data Requirements

Special attention must be paid to the data integrity throughout the system. The data must be adequately sampled and keyed so that assembling a complete data stream (observing request parameters, observed parameters, correlation fragments, etc.) is available without undue complexity and delay, especially for pipeline processing and archiving.

3.3 System Block Diagrams

The following Block Diagrams are available on-line as PDF and MS-Visio files.

3.3.1 Antenna System Diagram

To be included in a future edition

3.3.2 Antenna RF/LO/IF Electronics

[antenna block diagram 11.5.01](#)

3.3.3 CEB LO/IF Electronics

[CEB block diagram 11-5-01](#)

3.3.4 Correlator

Please refer to Figure 8-2

3.3.5 Monitor Control System

Please refer to Figure 3-1

3.3.6 Computing System

Please refer to Figure 3-1

3.4 Acceptance Testing

3.4.1 Test Definition

TBD

3.4.2 Test Procedure Development

TBD

3.4.3 System Testing

TBD

3.4.4 Test Result Documentation & Reporting

TBD

3.5 Hardware Development

With the exception of the Correlator, the vast majority of the EVLA electronics hardware is being developed in the labs at the NRAO Array Operation Center in Socorro, New Mexico. The NRAO/AOC labs are set up to:

- Construct prototypes for all EVLA hardware.
- Manufacture low-volume production components.
- Repair and maintain EVLA components for the life of the system.

To accomplish this, substantial investments are being made in Computer Aided Design / Computer Assisted Engineering (CAD/CAE) software, modern analog and digital test equipment, surface mount soldering equipment and the personnel training.

Manufacture of bare printed circuit boards and larger volume production components is outsourced to contractors in the United States, Canada and Mexico.

3.5.1 Test and Laboratory Equipment

Due to the greatly enhanced requirements of the EVLA electronics, advanced test and laboratory equipment is required for the development and maintenance of the EVLA hardware over the life of the system. The following table shows the equipment required for the EVLA.

Equipment	Systems	Purchase/Existing
High Speed Digital Scope (2.5GHz)	DTS, LO/IF, Digitizers, Correlator	E (Pie Town Link)
Digital Scopes (min 500 MHz BW)	DTS, LO/IF, Front Ends, Systems, M&C	P
Optical Spectrum Analyzer	DTS, LO/IF	E (Pie Town Link)
Microwave Spectrum Analyzers (x)	LO/IF, RFI, Digitizers, Front Ends	P
Vector Network Analyzer	LO/IF, Front Ends, DTS, RFI	P
OC192 Communication Analyzer	DTS	E (ALMA)
High Speed Logic Analyzer	DTS, Digitizers, M&C	E (ALMA)
Phase Noise Test Set	LO/IF	E (VLA/VLBA)
Signal Generators (x)	LO/IF, Front Ends, DTS	

3.5.2 Engineering Design and Test Software

Design, development and testing of EVLA hardware is being performed largely using commercially available software packages. These include (but are not limited to):

Microsoft Visio 2002 or AutoCad 2000i (or later) for Block diagrams and other system documentation.

Protel 99SE (or later) or OrCad v9.1 (or later) for schematic and PCB design,

Xilinx Foundation-Classic or Foundation-ISE v 4.1 (or later) for FPGA and CPLD development.

AutoCad 2000i (or later) or AutoCad Inventor v5 (or later) for mechanical designs.

LabView 6.0i (or later) for bench testing and integration, as well as for test fixtures to be used for maintenance over the life of the EVLA system.

3.5.3 Hardware Design Standards

3.5.3.1 Units and measurements:

All units and measurements in the EVLA systems are imperial to maintain compatibility with existing VLA standards

3.5.3.2 EVLA Electronics Rack, Bin, Module, and Connector Numbering System

A numbering system based on the existing VLA system is used to identify EVLA racks, bins, modules and connectors. This numbering system is defined in EVLA specification number A23010N0001.

3.5.3.3 EVLA Module Names and Numbers

T301	4P Converter	Converts 4/P band to L-band
T302	LCS Converter	Converts L, S and C band to X-Band (incl 4 and P IF)
T303	UX Converter	Converts Ku Band to X-Band (incl K, Ka and Q IF) Bypasses X-Band IF
T304	Downconverter	Converts X-Band to Sampler Inputs
L301	12-20 GHz Synthesizer	LO source for K, Ka and Q Front Ends LO source for UX Converter LO source for LCS Converters
L302	10.8-14.8 GHz Synthesizer	LO Source for Downconverters
L303	4096 MHz Synthesizer	Fine Tuning LO for Downconverters
L304	LO/Reference Receiver	Receives LO/Ref signals from LO Fiber
L305	Reference Generator/Dist	Generates and distributes Reference and Timing Signals
P301	LO/IF Power Supply	48 VDC Input Supply for LO/IF Bins
P302	48 VDC Power Supply	120VAC to 48 VDC Power Supply
P303	FE / UX Power Supply	Front End and UX Converter Power Supply
D301	Sampler/DTS	Samplers
D302		IF Data Transmission Formatters
D303		Fiber Optic Transmitter
D304		
M301*	Switch Controller	Controls LO/IF Switches
M302*	Utility Module	General Purpose M&C Module
F301*	Front End M&C Module	Front End M&C Module

* These modules not yet shown on Block Diagram

3.5.3.4 Expanded VLA Drafting Numbering System

The Expanded VLA Drafting number in system is outlined in EVLA specification number A23010N0002. The numbering system(s) described in this document is used for all work in the NRAO Electronics Division, Computing Division and Central Development Lab (CDL). In addition, it is used for all NRC/DRAO based EVLA work.

The NRAO Engineering Services division is continuing the use of their current numbering system, originally defined by the VLA antenna vendor.

3.5.4 Hardware Environmental Requirements

3.5.4.1 Antenna Vertex Room Electronics

These specifications are for survivability. Individual modules or components may have tighter requirements to maintain certain operational specifications (gain, phase stability, etc..). These additional requirements are listed with the applicable equipment

Operating Temperature: 0 to +50 C
Storage Temperature: -20 to +70 C
Humidity: 0 to 95% non-condensing
Altitude: 7200 ft AMSL
Operational Orientation: Any position *
Storage Orientation: Any Position
Shock: TBD G
Vibration: TBD G
ESD Protection ?

* Modules may have to remain at a fixed position relative to the rack/bin for cooling purposes.

3.5.4.2 Antenna Pedestal Room Electronics

These specifications are for survivability. Individual modules or components may have tighter requirements to maintain certain operational specifications (gain, phase stability, etc..). These additional requirements are listed with the applicable equipment

Operating Temperature: 0 to +50 C
Storage Temperature: -20 to +70 C
Humidity: 0 to 95% non-condensing
Altitude: 7200 ft AMSL
Operational Orientation: Upright
Storage Orientation: Any Position
Shock: TBD G
Vibration: TBD G
ESD Protection ?

3.5.4.3 Antenna Apex Electronics

These specifications are for survivability. Individual modules or components may have tighter requirements to maintain certain operational specifications (gain, phase stability, etc..). These additional requirements are listed with the applicable equipment

Operating Temperature: -20 to +70 C

Storage Temperature: -20 to +70 C

Humidity: 0 to 100% condensing
Altitude: 7200 ft AMSL
Operational Orientation: Any position
Storage Orientation: Any Position
Shock: TBD G
Vibration: TBD G
ESD Protection ?

3.5.4.1 Control Building Electronics

These specifications are for survivability. Individual modules or components may have tighter requirements to maintain certain operational specifications (gain, phase stability, etc..). These additional requirements are listed with the applicable equipment

Operating Temperature:	0 to +50 C
Storage Temperature:	-20 to +70 C
Humidity:	0 to 70% non-condensing
Altitude:	7200 ft AMSL
Operational Orientation:	Upright
Storage Orientation:	Any Position
Shock:	N/A
Vibration:	N/A

3.5.5 Antenna Racks, Bins and Modules

The EVLA LO/IF system uses a modified version of the VLA antenna rack, bin and module specifications. This allows reuse of racks and some system components, particularly during the transition period. It also allows for the cannibalization of some existing system hardware to reuse costly, machined custom hardware. The specifications and designs of this hardware are modified as necessary to meet RFI/EMC and cooling requirements of the new EVLA electronics system. The connectors are being updated to eliminate obsolete, hard-to-find or excessively expensive components.

Due to high RFI risk and high heat dissipation, the digitizers and IF data transmission systems use a completely new packaging concept. This packaging consists of a RFI shielded, air cooled module design that houses the 3-bit digitizers, 8-bit digitizers, and data transmission system (DTS) hardware for a single polarization pair. Four of these modules are installed in a specially designed, small, RFI shielded rack installed in the vertex room of each antenna

The Ethernet networking hardware used for the Monitor Control Bus (MCB) in the antenna vertex room also requires special shielding. The rack design for this hardware is either a rack similar to that described for the digitizers and DTS hardware or a shielded commercial rack.

3.5.6 CEB Racks, Bins and Modules

The EVLA LO system uses a modified version of the VLA rack, bin and module specifications for the LO systems in the Central Electronics Building. This is done to allow reuse of racks and some system components, particularly during the transition period. It also allows for the cannibalization of some existing system hardware to reuse costly, machined custom hardware.

The specifications and designs of this hardware are modified as necessary to meet RFI/EMC and cooling requirements of the new EVLA electronics system. The connectors are being updated to eliminate obsolete, hard-to-find or excessively expensive components.

The fiber optic systems will be using commercial off the shelf hardware for cable splicing, routing and patch panels.

The correlator and computing systems are using completely new hardware.

3.6 System Software Development

3.6.1 Software Design Standards

To be included in a future edition

3.6.2 Computing Platform(s)

To be included in a future edition

3.6.3 Computer/Network Security

To be included in a future edition

3.7 System Power Supplies

3.7.1 Antenna Electronics Systems

Antenna Vertex room, Pedestal Room and Apex electronics are powered from N+1 redundant 48 Volt DC power supplies. Final voltage regulation occurs at the module or bin level. Final regulators can be linear type devices, switching (PWM) type devices, or a combination of the two depending on RFI and thermal requirements. As an option, backup power is provided for by the addition of 48 Volt DC Gel Cell type batteries. Commercial equipment such as computers, networking equipment and test equipment can be powered from 120VAC commercial power. Computers, network routers, voice communication equipment and any alarm/safety related equipment is provided with battery backup for (TBD) minutes of operation in the event of a power failure.

3.7.2 CEB Electronics Systems

LO/IF electronics in the Central Electronics building are powered from N+1 redundant 48 Volt DC power supplies. Final voltage regulation occurs at the module or bin level. Final regulators can be linear type devices, switching (PWM) type devices, or a combination of the two depending on RFI and thermal requirements. As an option, backup power is provided for by the addition of 48 Volt DC Gel Cell type batteries. Commercial equipment in the LO/IF racks such as computers, networking equipment and test equipment can be powered from 120VAC commercial power.

The Hydrogen MASER and other critical time standard devices are to have battery backup for (TBD) minutes of operation in the event of a power failure.

3.7.3 Correlator

The correlator and digital IF fiber optic receiver systems are powered by a high capacity 48VDC battery system that is continuously fed from the site AC power. This is currently planned to be a packaged system from a commercial vendor. These are common in the telecommunications industry and are readily available as turn-key systems from a number of sources.

3.7.4 Computing and Network Hardware

All computing and networking hardware is operated from the site AC power and utilizes battery backed Uninterruptible Power Supplies (UPS).

3.8 RFI

One of the primary EVLA design criteria is to be able to observe in a hostile environment of radio frequency interference (RFI). The wide bandwidths and frequency tuning range of the EVLA greatly increase our exposure to radio frequency interference (RFI). The centimeter wavelength bands are being increasingly

filled by wireless communication: cell phones, pagers, aeronautical navigation and traffic control, satellite broadcast, and many other services. Terrain shielding, which for decades helped isolate radio observatories from RFI, is becoming less relevant as interference from broadcast and communication satellites, balloons, and airplanes increases. A modern broadband radio astronomy system needs to have greater sensitivity and bandwidth to do the new science, but also has to work amidst a growing forest of strong and potentially debilitating artificial signals. The new receivers and transmission system are designed with particular attention to the extra demands imposed by these signals.

3.8.1 Design Goals

Our goal is to design a system that can function with strong man-made signals in the receiver passband and not corrupt visibility measurements due to spurious intermodulation products. To provide the necessary dynamic range to enable handling of strong signals (both man-made and natural, in both the spatial and frequency domains), the entire signal transmission system must be designed with extremely linear response. This goal is accomplished by a layered approach, each layer avoiding or removing RFI which can cause nonlinearities in the subsequent electronics. This is essential for utilization of the full bandwidth brought from the antennas, and for avoidance of signal compression due to finite dynamic range, which can give rise to nonlinearities and spurious signals. At the top layer, this is accomplished by using the minimal amount of amplifier gain and careful design for linear response. Signals are then digitized in the antenna with either 3 or 8-bit digitizers, the latter providing a narrower bandwidth, higher dynamic range signal path for improved RFI immunity.

The next layer of RFI mitigation consists of a digital Finite Impulse Response (FIR) filter. This filter is reconfigurable in software by loading tap weights into the filter memory. The FIR filter can be used to place rejection notches or bandpass edges where needed and can be dynamically reconfigured to adjust to a changing RFI environment.

The final layer of RFI excision is in the digital correlator itself. The up to 8-bit sampling of the DRAO WIDAR correlator design provides outstanding immunity to strong RFI -- spectral dynamic ranges in excess of 55 dB are anticipated. The new correlator is designed with high tolerance to strong interfering signals, and has a sufficiently large number of high-resolution frequency channels to permit detailed removal of data contaminated by narrow-band interfering signals.

In addition, total power measurements are available at several places in the system in order to monitor RFI.

3.8.2 Environmental Monitoring System

The purpose of the RFI EMS is to measure the characteristics of externally generated RF signals which are incident on the VLA, and which the EVLA electronics has to tolerate. These characteristics include frequency, power, modulation, time on and off, and direction of incidence. The EMS is to provide calibrated power levels in terms of Power Flux Density (PFD) per various resolution bandwidths, and ultimately operate over 300 MHz-50 GHz.

The current system includes:

Antennae: 1-8 GHz omnidirectional
1-18 GHz directional horn on rotator

Front End: 3 MHz -10 GHz

Signal Path: Operational up to 18 GHz

Receiver: Surplus HP70001A spectrum analyzer operational up to 22 GHz, with narrowest RBW = 10 Hz.

Tower: Antennae and Front End mounted on 54 foot tower at the VLA

3.8.3 System Hardware Emission Testing Facilities

The purpose of the RFI EMC facility is to measure the characteristics of radiated RF signals from electronics equipment designed for the EVLA. The chamber and associated test equipment is to ultimately operate over the 300 MHz- 50 GHz range and measure total power of emissions.

The current system includes:

Facility: Surplus RF Shielded Chamber stored at Green Bank specified at 100 dB shielding up to 10 GHz.

Front End: 300 MHz-12 GHz amplifiers stored in IPG.

Signal Path: To be designed.

Receiver: Surplus HP70001A spectrum analyzer operational up to 22 GHz with narrowest RBW = 10 Hz.

3.9 References

1. Cornwell, T. J., "Computing for EVLA Calibration and Imaging," VLA Memo 24, 2001
2. Sahr, W. J., Hunt, G. C., & Cornwell, T. J., "The Expanded VLA Project", ADASS XI, to appear in ASP Conference Series, 2002