3. SYSTEM OVERVIEW and INTEGRATION -- HARDWARE

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2001-Mar 01: Initial release under configuration control
2001-May 09: Updated text based on latest block diagrams; updated digitizer specifications
2002-May 29: Updated text based on latest Bins & Module designs, updated gain and phase specs
2004-June 30: Updated the Acceptance Test Plan and the module descriptions
2004-Nov 01: Updated the digitizer and synthesizer specifications, and the module list
2004-Nov 29: Added an introduction
2004-Dec 06: Removed computing sections and corrected FE section

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. Each of the brown EVLA project blocks will be discussed in more detail in this section. The goal of the EVLA project is to increase the overall system bandwidth by a factor of 80 and to increase the sensitivity and spatial resolution of the present VLA. One of the tasks required to accomplish this goal is to replace the current waveguide system with a fiber optic system. The fiber optic system will transmit phased Local Oscillator (LO) signals to each of the antennas and digitized raw astronomy data from the antennas to the new high performance correlator. The EVLA project will require new feeds, receivers, synthesizers, reference generators, down/up converters, samplers, and a fiber optic system

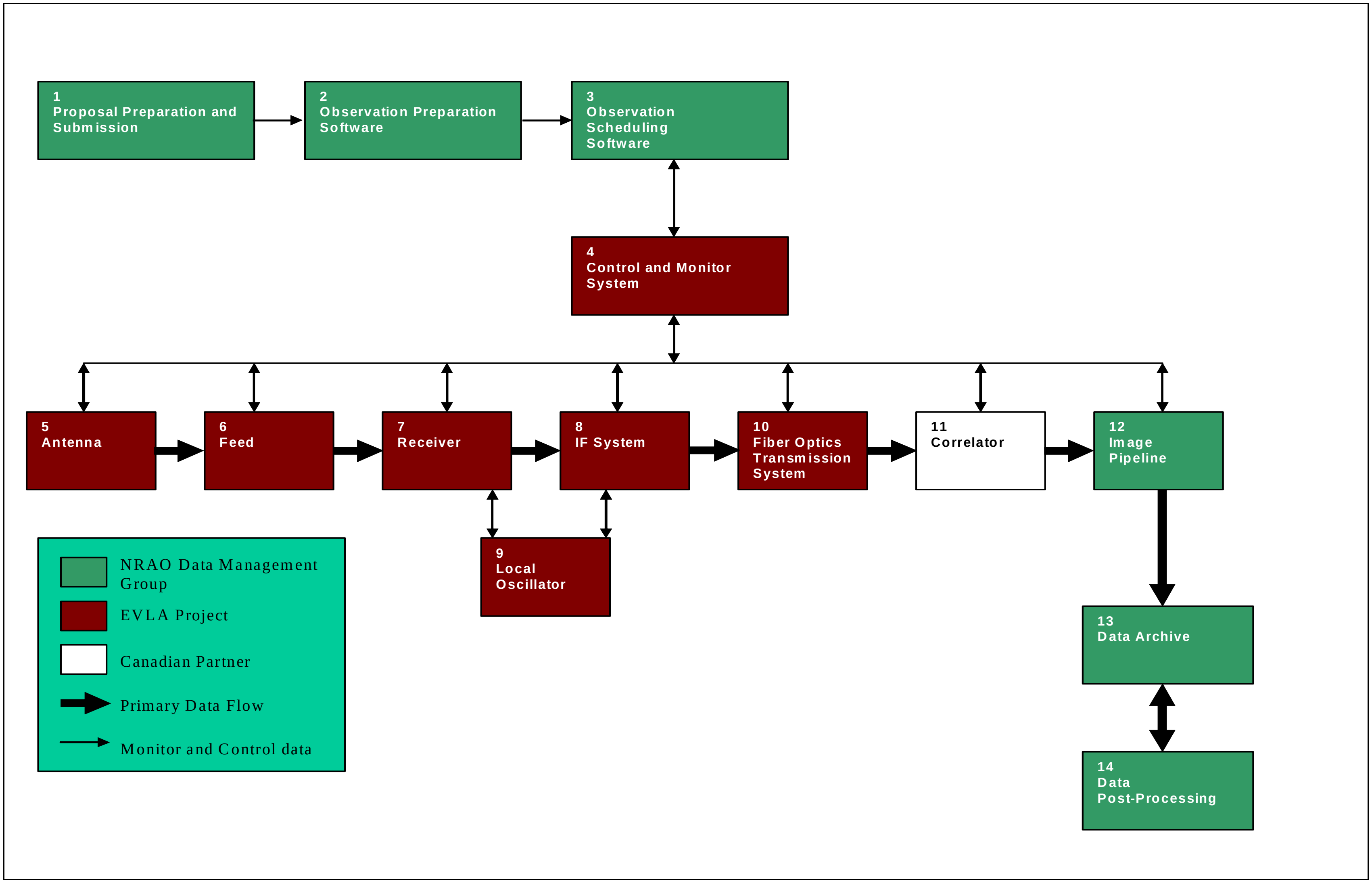

Figure 3-1 Principal EVLA Subsystems

3.1.1 Antennas

The EVLA reuses 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. The present antennas operate from 1 to 50 GHz with gaps between the bands. Adjustable dish panels can be manually fine tuned to enhance performance of high frequency bands.

3.1.2 Feeds

The continuous frequency coverage, required by the project, will be obtained by sub-dividing the 50 GHz range into discrete bands. The following factors were considered when selecting the bandwidths for each band: (1) available technology, (2) the number of receivers/feeds, and (3) performance of the receiver/feed/antenna at the band edges. The present number of bands proposed is eight. These bands are identified in Table 3.1 along with the proposed bandwidth per band. For comparison, Table 3.1 also includes the Bandwidth Ratio.

Table 3.1 - Frequency Coverage and Bandwidth

Band Designation	EVLA Frequency Range (GHz)	EVLA Bandwidth Ratio
L	1.0 – 2.0	2.0
S	2.0 – 4.0	2.0
C	4.0 – 8.0	2.0
X	8.0 – 12.0	1.5
U	12.0 – 18.0	1.5
K	18.0 – 26.5	1.5
Ka	26.5 – 40.0	1.5
Q	40.0 – 50.0	1.25

The existing K and Q band feeds can be used for EVLA without modification. Both existing feeds were designed and are tested for operation over the EVLA range. It is the tunable range of the existing VLA LO/IF subsystem that limits current performance.

3.1.3 Receivers

The EVLA requirement to provide continuous frequency coverage from 1 to 50 GHz requires low noise receiving systems be installed to provide the maximum G/T performance. The VLA currently supports six cryogenic receivers with gaps in coverage between existing bands. Continuous frequency coverage will be achieved by adding two new receivers (S- and Ka- Bands) and by expanding the frequency range of the others.

To interface with the new EVLA LO/IF subsystem, the existing K-band and Q-band receivers will require a modifications to block convert the entire RF band down to an IF of 8-18 GHz. New S and Ka band receivers and feeds will be designed to meet EVLA requirements. The remaining bands, (L, C, X, and U) will require substantial receiver modifications. Figure 3.2 shows the basic receiver configuration.

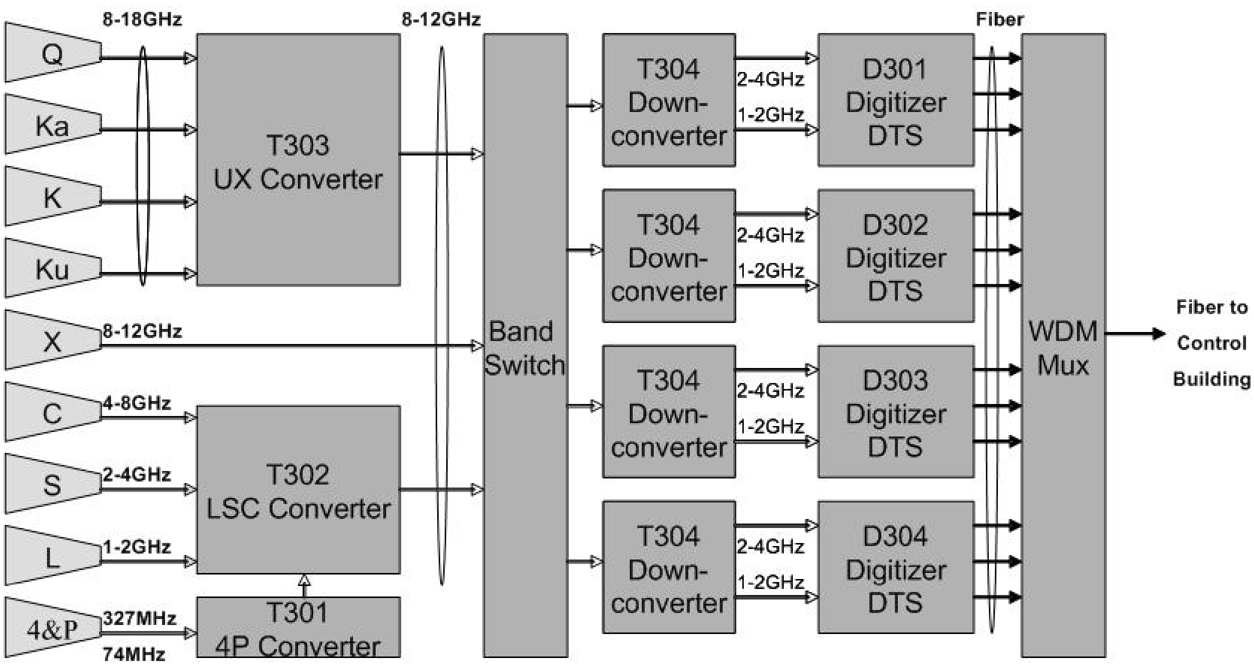

Figure 3.2 Receiver Configuration

3.1.4 Local Oscillator

The Central EVLA LO system generates, from the primary reference (maser), all of the local oscillator signals needed by each antenna and the correlator, figure 3.3. These references are generated by either direct multiplication, direct division, or by phase locked synthesizers. Currently, the reference 5 MHz supplied by the hydrogen maser is used to lock a 128 MHz synthesizer. This synthesizer's output is then directly multiplied to 512 MHz, which is used as the antenna's primary reference. The 128 MHz is divided to 5.12 MHz, 19.2 Hz, 128 Hz, and 0.1 Hz. The 5.12 MHz is the clock for the round trip phase system, the 128 Hz is the beat frequency used by the round trip phase system, 19.2 Hz is the heart beat timing signal used for maintaining communications and for noise calibration, and the 0.1 Hz signal is the reset signal sent to align the phase of the antenna reference signals.

The Antenna EVLA LO system receives the reference 512 MHz from the fiber. This reference also contains a 0.1 Hz signal that is recovered and used to reset the antenna phases. The 512 MHz is divided down to 128 MHz and is multiplied up to 1024 MHz, 2048 MHz, and 4096 MHz. The multiplied signals are used for the IF converter modules and the data transmission system. The 128 MHz is further divided in an FPGA to 19.2 Hz and 9.6 Hz to provide timing for the module interface boards and the cal switching, respectively. The 512 MHz and the 128 MHz are used as references for the microwave synthesizers. There are a total of six synthesizers and their outputs are used by the IF converter modules and the front ends.

The 512 MHz is returned back to the central system through an optical splitter. This 512 MHz is used for the round trip phase measurement system.

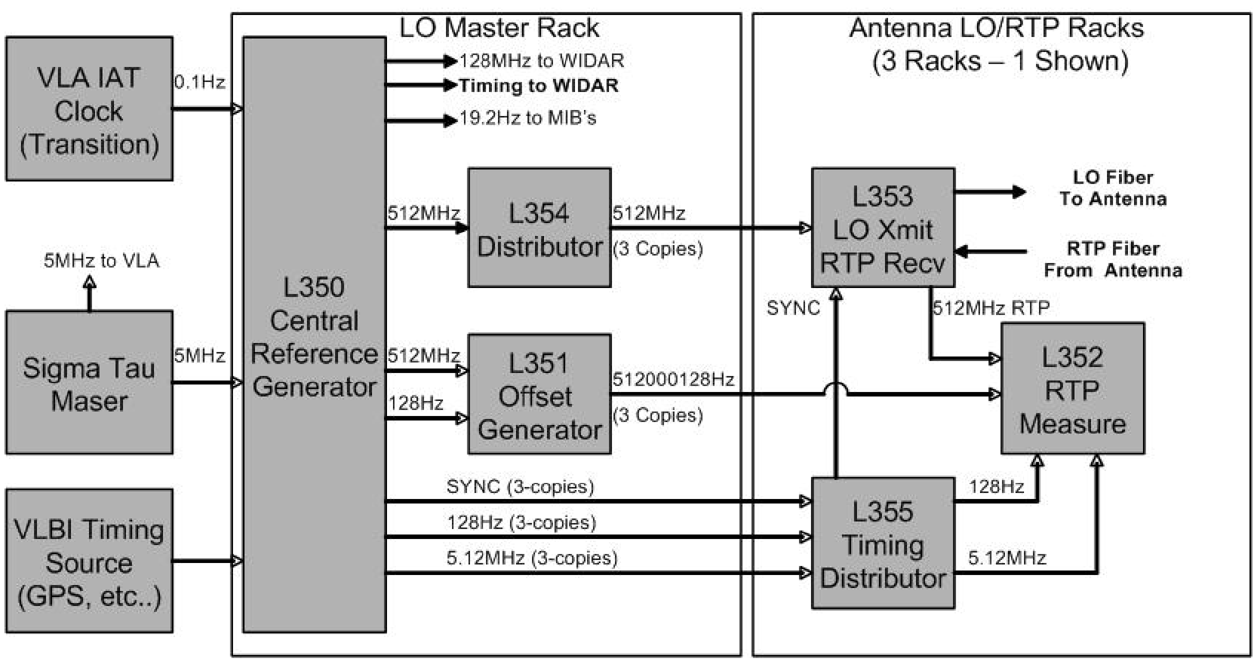

Figure 3-3. Central EVLA LO System

3.1.5 IF Systems

In each EVLA antenna there are seven converter modules (four different designs), figure 3.4. The high frequency front ends use a block down convert scheme to place the first IF in the 8 to 18 GHz range. Each of these block-converted IFs are then switched into the UX converter module where the X-band portion is fed straight through or the Ku-band portion is down converted to X-band.

In the lower frequency front ends, the IFs are up-converted. The 74MHz and P-band front ends are up-converted to L-band with the 4P converter. The L-band, S-band, C-Band, and converted 4P band IFs are switched into the LSC converter where they are up-converted to X-band. The X-band IFs are switched into the baseband converter. There are four base band converters in each antenna one per IF. The baseband converter down converts the IF to either L-band or S-band depending on which samplers is to be used.

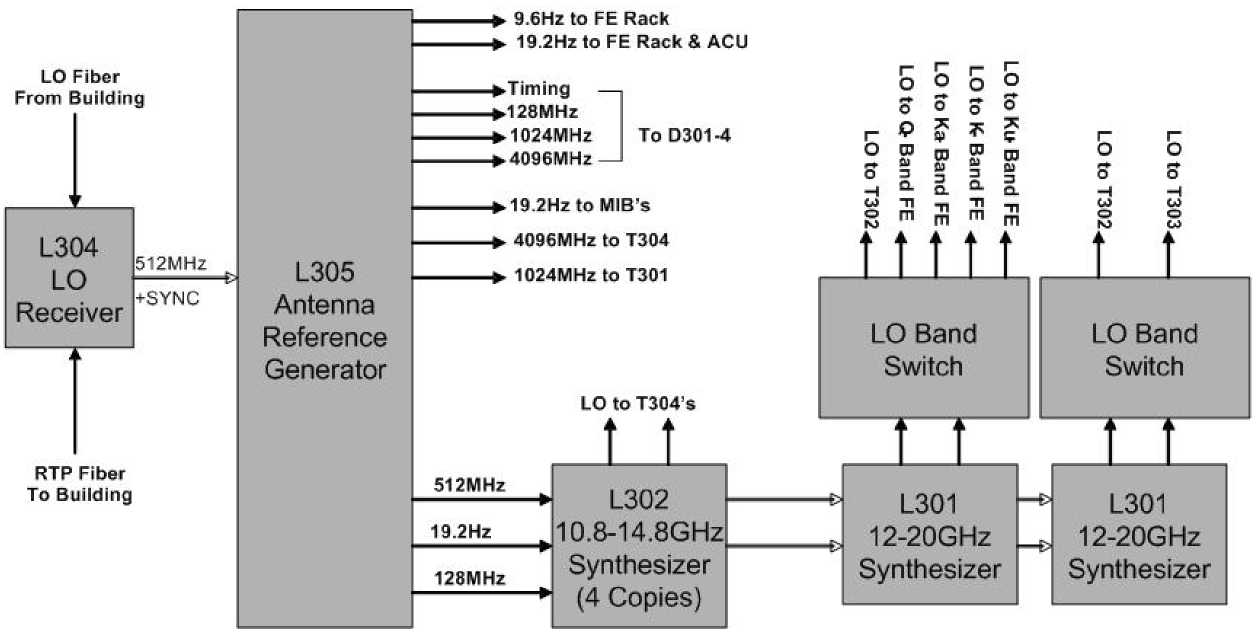

Figure 3.4 Converter Configuration

3.1.6 Fiber Optics Transmission Systems

The EVLA makes extensive use of fiber optic technologies for the IF data transmission, the local oscillator and reference distribution, and all monitor/control functions. The block diagram for the Data Transmission System is shown in figure 3.5.

A set of twelve fibers runs to each pad location throughout the EVLA. The cables are set in a star configuration with all fibers originating at the control building and ending each antenna pad. The fibers from the main distribution frame in the control building are grouped together into trunks and are terminated at each pad. The main distribution frame is a commercial product that will be filled to 50% capacity at the end of the project.

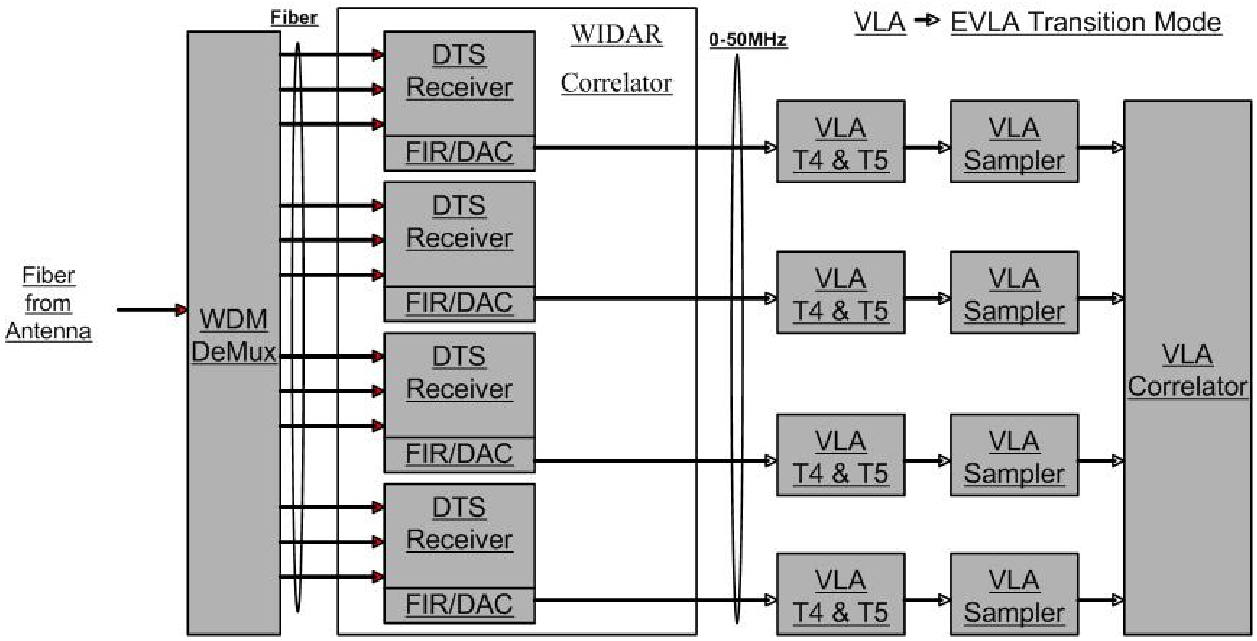

Figure 3.5 Data Transmission System Block Diagram

3.1.7 Control and Monitor System

The antenna monitor and control subsystem (AMCS) will consist of processors located throughout the system from the control building to within the EVLA antennas themselves. Processors residing in the control building will have no limits on size and complexity and will take the form of either VME/Compact-PCI single crates or high reliability desktop machines. Processors located within the antennas will be small micro-controller type processor boards with small amounts of RAM and low clock speeds to help reduce RFI. These micro-controllers will interface the components of the antenna to the rest of the monitor and control system; they are referred to as module interface boards (MIBs).

The antenna monitor and control subsystem (AMCS) is that portion of the EVLA monitor and control system responsible for operating the array of antennas including both the new VLA antennas as they come online and the existing VLA antennas during the transition phase. All AMCS processors, including the MIBs within the antennas, will be networked using Ethernet over fiber-optic cable.

3.2 Specifications and Requirements

The top-level technical requirements are provided in detail in Chapter 2 section 2. The following sections present hardware configurations.

3.2.1 Antennas Specifications

The present VLA antennas will not need major modifications to meet the scientific goals. The standard overhaul maintenance will be performed as each VLA antenna is converted to an EVLA antenna. 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 50 GHz. 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. Table 3.1 below shows the operational frequency bands along with the Tsys, efficiency, and polarizations of each band.

Table 3.1. Operational Frequency Bands

VLA Band	Frequency	Frequency Range	Tsys (K) *	Efficiency **	Polarization
4	74 MHz	73.5-74.5 MHz	1000-10000	0.20	RHCP/LHCP
P	327 MHz	300 - 340 MHz	150-180	0.40	RHCP/LHCP
L	1.5 GHz	1.2 – 2.0 GHz	27	0.50	RHCP/LHCP
S	3.0 GHz	2.0 – 4.0 GHz	27	0.62	RHCP/LHCP
C	6.0 GHz	4.0 – 8.0 GHz	27	0.60	RHCP/LHCP
X	10.0 GHz	8.0 – 12.0 GHz	31	0.56	RHCP/LHCP
U	15.0 GHz	12.0 – 18.0 GHz	38	0.54	RHCP/LHCP
K	22.0 GHz	18.0 – 26.5 GHz	61	0.51	RHCP/LHCP
Ka	33.0 GHz	26.5 – 40.0 GHz	55	0.39	RHCP/LHCP
Q	43.0 GHz	40.0 – 50.0 GHz	70	0.34	RHCP/LHCP

* At zenith, cool dry weather, referenced above the atmosphere

** At mid band

3.2.3 System Temperatures

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

Table 3-2. System Temperatures

		Unvarying				Galactic and 3°bb (corrected for absorption)					Atmospheric Emission			System Temperature		
υ_g	BAND	T_{rec}	T_{cal}	T_{spill}	T_o	T_{gal}	T_{bb}	T_{bg}	τ	$T_{bg}e^{-\tau}$	T_{atm}	$1-e^{-\tau}$	$T_{atm}(1-e^{-\tau})$	T_{sys}	e^{τ}	T'_{sys}
1.450	L	14	1	8	23	0	3	3	0.008	3	280	0.004	1	27	1.008	27
3.000	S	14	1	8	23	0	3	3	0.009	3	280	0.004	1	27	1.009	27
6.000	C	16	1	6	23	0	3	3	0.010	3	280	0.005	1	27	1.010	27
10.000	X	20	1	5	26	0	3	3	0.012	3	280	0.008	2	31	1.012	31
15.000	Ku	25	1	5	31	0	3	3	0.017	3	280	0.015	4	38	1.017	39
22.000	K	34	2	4	40	0	3	3	0.065	3	280	0.063	18	61	1.067	65
34.000	Ka	40	2	4	46	0	3	3	0.020	3	280	0.020	6	55	1.020	56
45.000	Q	42	2	4	48	0	3	3	0.070	3	280	0.068	19	70	1.070	75
49.000	Q	42	2	4	48	0	3	3	0.250	2	280	0.221	62	112	1.250	140

T_{rec} = Receiver Temperature

T_{cal} = Injected Cal Signal

T_{spill} = Ground Spillover Power

$T_{bg} = T_{bb} + T_{gal}$

$T'_{sys} = [T_o + T_{bg}e^{-\tau secz} + T_{atm}(1-e^{-\tau secz})]\, e^{\tau secz}$

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

Assumptions:

> Elevation = 90°

> Coldest Part of Galaxy

> Driest Typical Atmosphere

> Winter Temperatures

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. Table 3.3 gives the bands and bandwidths.

Table 3.3 Sky Frequencies

Sky Frequencies and Sub-Bands (All Frequencies in GHz)

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

Four independently tunable second LO synthesizers are used, allowing greater tuning flexibility.

4-Band and P-Band capabilities continue to exist in the EVLA as they are in the VLA, except they will use the 8 bit samplers. These bands are up converted to L-Band and processed through 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 direct digital synthesizers in the 10.8-14.8 GHz synthesizers.

3.2.4.1 Local Oscillator Specifications

12-20 GHz Synthesizer:

Tuning: F=N*512 +/-128MHz, 23<N<40

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

10.8-14.8 GHz Synthesizer:

Tuning: 10.8-14.8GHz 48 bit resolution

LO Source for Main Downconverters

4096 MHz LO

Tuning: Fixed 4096 MHz

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

Detailed designs and specifications of all LO synthesizers are described in detail in Chapter 6 of the EVLA Project Book.

These specifications for the LO stability, a repeat of the specifications given in Chapter 2, Section 2.2.3.3, 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 are evenly divided as follows: one-third to the front end, one-third to the T304 downconverter, and one-third to the 4P, LSC and UX converters combination. This specification applies after correction using round trip phase and phase rotation (fringe tracking).

A) Short Term:
   The rms phase jitter over any 1 second interval is to be less than 500 fs.

B) Long Term:
   The slope of the phase over any 30 minute interval is to be less than 200 fs/minute. The peak-to-peak fluctuations of the phase about this slope are to be less than 1400 fs.

C) Phase Shift with pointing change:
   Less than 700 fs between any two directions accessible with the antennas

   Less than 70 fs per degree of antenna motion for slews of less than ten degrees.

Phase noise is defined as phase instability above an offset of 1 Hz from 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 Baseband Downconverter Stage

All receiving bands in the EVLA are converted to X-Band, defined as the baseband, 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 fixed LO.

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 of 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 are 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 Gsps 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 Gsps commercial A/D converter. This sampler will be used for S, L, P, and 4 bands.

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 1 GHz, 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 will use wideband digitizers developed for the ALMA project to be used in normal operation of C, X, Ku, K, Ka, and Q frequency bands. These digitizers have the following specifications:

Sampling rate:	4.096Gsps (good up to 5 Gsps)	
Bit resolution:	3 bits	
Quantization levels:	8 levels	
Aperture time:	<50 ps	
Jitter:	~2 ps	
Threshold indecision region:	3-4 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	
	Vin < -1.5x	000
where x = RMS voltage at comparator		
	-1.5x < Vin < x	001
	-x < Vin < -0.5x	011
	-0.5x < Vin < 0	010
	0 < Vin < 0.5x	110
	0.5x < Vin < x	111
	x < Vin < 1.5x	101
	Vin > 1.5x	100
Output de-multiplexing:	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.

3.2.5.2 Narrow Band Digitizer Specifications

Sampling rate:	2.048 Gsps
Bit resolution:	8 bits
Quantization levels:	256
Aperture time:	<160 ps
Jitter:	<160 ps
Threshold indecision region:	TBD (a few mv?)
Analog bandwidth:	>2 GHz
Sampling bands:	Baseband 0-1GHz, Passband: 1-2 GHz
Output de-multiplexing:	1:8
Output data word width/rate:	64(8x8) bits / 256 MHz
Output logic levels:	Low Voltage Differential Signaling (LVDS)

The EVLA system is currently using the upper 8 bits of a commercial 10-bit, 2 Gsps device from ATMEL TS83102G0B.

3.2.6 External RFI

The EVLA system is being designed to operate in the presence of ever increasing levels of radio frequency interference (RFI). The design of the WIDAR correlator, as well as the use of three and eight bit quantization in the digitizers plays a major role in the systems immunity to external RFI. A further discussion of RFI is located in Section 3.7.

3.2.7 Suppression and Mitigation of 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. The levels are specified in EVLA Memo #46, RFI Emission Goals for EVLA Electronics, Rick Perley, 10/15/02.

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 is being built in Canada for the EVLA project. The correlator specifications are given in Section 2.3 and Table 8.1 in Chapter 8.

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

3.3.3 CEB LO/IF Electronics
CEB_block_diagram

3.3.4 Correlator
Please refer to Figure 8-2

3.3.5 Monitor Control System
Please refer to Figure 9-1 in Chapter 9

3.3.6 Computing System

3.4 Acceptance Testing
Acceptance tests are structured to be used by the Electronics and Engineering Services Divisions. The purpose is to provide a set of tests that determine if an antenna is ready to be turned over to Operations. Since the topology of the antennas is not going to change and all of electronic modules have passed individual modules tests, the acceptance test focuses on system performance. The following is a list of acceptance tests that when successfully completed indicate an EVLA antenna is ready to be turned over to the Socorro Operations Division.

3.4.1Receiver Noise Diode Test

Digitize the analog signal out of the receiver while the noise diode is being switched at 9.6 Hz. Transmit the signal over the digital link and recreate the signal at the output of the T-5. Arrange the LO settings so the same signal is sent to each of the four DTS modules. This test determines any artifacts of the conversion and filtering process. The bit-error-rate of all 12 links is also measured during this test. Each receiver will be tested for approximately one minute.

Noise calibration: Each receiver is provided with an injected noise signal equivalent to approximately 5% of the nominal system temperature for that band. This noise can be commanded on or off by the monitor and control system (M&C). During normal observing, it is controlled by a 9.6 Hz square wave with 50% duty cycle. The noise for both LCP and RCP on any receiver is generated by a single source on that receiver.

Purpose:

This test verifies the function of the 8 bit digitizers, the formatters, the optical link, the output of the digital-to-analog converter on the DTS de-formatter module and the T-5 operation. The same LCP and RCP signal is presented to each of the four samplers so a comparison can be made.

Requirements:

A complete set of receivers
A complete LO system
9.6 Hz clock signal
Installed fiber cable wrap and vertex room fiber termination box
A complete set of D30X modules in the antenna with MIB control, 8-bit samplers
EDFA installed in the CEB
Four DTS deformatter boards in CEB
T-4 and T-5 modules

Technique:

The M&C will be used to configure the antenna and then perform each test. After 30 seconds, the M&C will capture and upload the digital data from the deformatter. This data will then be processed and provided as a plot for each IF.

During the test, the output of the T-5 will be monitored with a spectrum analyzer and oscilloscope to determine the bandpass shape, correct switched power and total output power levels being sent to the VLA correlator.

The M&C will flag and print any monitor data that is out-of-range during the test. This will include monitor data from all modules on the antenna and related modules in the control building.

The M&C will test all eight receivers in sequence and print the data at the conclusion of the test.

3.4.2 Cable Wrap Optical Round Trip Phase

This test requires very little from the antenna as no power or active modules are required. The passive optical coupler located in the L304 module is all that is required to complete the loop in the antenna. Most of the modules under test are located in the CEB.

Purpose:
This test verifies that the LO optical link which provides the main LO of 512 MHz to the antenna is functioning.

Requirements:
EVLA digital phase detector system
L304 modules in the vertex room of the antenna
All control room 512 MHz modules present and working (L350, L352, L353)
The 1024 MHz and 128 MHz need to be phase locked
Installed fiber cable wrap and vertex room fiber termination box
Monitor data from L352

Technique:
Connect a spectrum analyzer to the output of the L304 module and determine the levels of the sidebands around the 512 MHz.

3.4.3 Check Round Trip Phase Stability with Antenna Moving

Purpose:
This is a test of round trip stability with the antenna moving and verification of the performance of the round trip phase hardware. This test is designed to detect any effect of antenna motion on the phase difference between the round trip fibers. The resolution of the test is estimated to be not better than 0.5 ps.

Requirements:
A round trip fiber loops to the antenna
All control room 512 MHz modules
Installed fiber cable wrap and vertex room fiber termination box
Monitor data from L352
Computer control of antenna in AZ/EL coordinates
Software for application of RT phase to correlator data
Fully functional LO/IF system

Technique:
Using the EVLA monitor and control system (M&C), monitor the round trip phase as the antenna is moved in both directions

Results:
Phase sensitivity to antenna motion

3.4.4 Power System Test 48Vdc

RFI, temperatures, full current, battery back-up, output noise

Purpose:

The 48 Vdc power supply will be tested prior to the Receiver Noise Diode Test. The test includes testing the battery backup operation, voltage quality under full load, and emergency shut down.

Requirements:

Functional 48Vdc power supply in the pedestal room
Installed cable wrap

3.4.5 Front-End Bench Test Data

The Front End group will provide the Socorro Operations Division with laboratory test results for each receiver. This data will be presented in both as tables and graphs. The following data shall be provided:

Across the band: (frequency independent)
Receiver temperature
Noise calibration values
Gain
Output power
1 dB compression
Serial numbers
Locations of important components in the receiver

Frequency-independent data:
Cold-stage temperatures vs. time during cool down
Cold-stage temperatures during bench test
Typical current for each supply voltage

The following monitor data will be recorded by the M&C system:
Dewar Temperature: 15K, 50K stations and case temperature
Dewar and Manifold Vacuum
LNA FET biases voltages and currents for each stage of each LNA
Noise source parameters: voltage, current, and attenuator setting
Switch positions and gains for normal or solar observing
Receiver ID: Band, serial number, and revision level

The Monitor and Control system can command the following actions:
Cool-down, warm-up, pump dewar.
Set configuration for normal or solar observing.

3.4.6 MCB Rack Ethernet Switch and Thermal Tests

The Ethernet switch is provided with on board diagnostics. This tool will be accessed and the data will be provided to Operations. This data will include: traffic level versus bandwidth available, framing errors, and enclosure temperature.

Purpose:

Verify the performance of the MCB system using on-board Ethernet diagnostics.

Requirements:

Functional Ethernet switch and UPS
MCB patch panel configuration
Complete set of EVLA modules operating in the antenna

3.4.7 Hz Drift Test 19.6

Purpose:

Verify that the reset pulse is processed correctly. Rate of drift in nano-seconds per 10 seconds will be provided.

Requirements:

Fully functional LO system

Technique:

While monitoring the output of the T5 in the control building, disable the L305 re-sync pulse that is normally sent to the antenna every 10 seconds. Using an oscilloscope to monitor the switched power, the signal at the T5 should drift with respect to the VLA 9.6 Hz signal at a rate of approximately 200ns every 10-second cycle. After re-enabling the re-sync pulse, the two signals should lock with no discernible cumulative drift.

3.4.8 RFI Leakage in the Antenna

Purpose:

Determine if the antenna is producing excessive RFI. Data will show any detected internally generated emissions.

Requirements:

Functional EVLA antenna

Technique:

Monitor the radiation levels inside the vertex room while a program similar to the Receiver Noise Diode Test (#1 in this document) is run. Normal emissions levels from shielded EVLA modules are too small to measure.

3.4.9 LO Reference Signal Quality

The LO is obtained from the master oscillator located in the Electronics Building. A 512 MHz signal is transmitted over a dedicated single mode fiber at 1310 nm. The L304 receives the optical signal, converts it to electrical (RF) and sends it to the L305. The L305 uses this signal to phase lock a low noise VCXO whose output becomes the antenna master LO reference. A portion of the optical LO 512 MHz signal is sent back to the control building where it is converted to an electrical (RF) signal in the L353 module and sent to the L352 module. The L352 then makes the round trip phase calculation.

Purpose:
Determine phase stability of the 512 MHz LO after a round trip to the antenna.

Requirements:
All control room 512 MHz modules
Fiber cable wrap and vertex room fiber termination box installed
L304 module in the antenna
Monitor data from L305

Technique:
Using the maser-referenced 512 MHz, measure the phase noise at the output of the L353 module. This signal is used to determine the round trip phase of the LO system.

3.5 Hardware Development
With the exception of the WIDAR 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 personnel training.

Manufacture of bare printed circuit boards and large 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 chart 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 (EVLA)
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 (EVLA)
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	
Receiver Test Rack	Front end	P

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 too):

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

Protel 99SE (or later), PadsPCB 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	Base Band Converter Analog	Converts X-Band to 1-2 and 2-4 GHz digitizer Inputs
T305	Base Band Converter Digital	Digital control and total power digitizers for T304
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
L304	LO/Reference Receiver	Receives 512 MHz LO & timing from LO fiber
L305	Antenna Reference Generator	Generates and distributes reference and timing signals in antenna
L350	Central Reference Generator	Generates and distributes reference and timing signals in control building
L351	Master Offset Generator	Generates reference signals for round trip phase measurement
L352	Round Trip Phase	Measures LO round trip phase to each antenna
L353	LO Transmitter / RTP Receiver	Transmits 512MHz LO to antenna, Receives 512 MHz return signal

L354	LO Reference Driver	Distributes LO signals in control building racks
L355	Timing Distribution	Distributes digital timing signals in control building racks
P301	LO/IF Power Supply	DC/DC converter for LO/IF bins
P302	FE / UX Power Supply	DC/DC converter for front ends and UX converter
P350	LO Power Supply	DC/DC converter for LO master racks
P351	LO/RTP Power Supply	DC/DC converter for LO Transmitter and RTP modules
D301	Sampler/DTS	3 and 8 bit digitizers
D302		IF data transmission formatters
D303		Fiber optic transmitters
D304		
M301	Switch Controller	Controls LO/IF Switches and T301-3 downconverters
M302	Utility Module	General purpose M&C module
M304	Module ID	Provides network addressing information to modules
F317	Front End M&C Module	Front end M&C module
F320	Front End Transition Module	Provides interface between existing VLA front ends and EVLA system

3.5.3.4 EVLA Drafting Numbering System

The EVLA 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:	5 G
Vibration:	TBD G

* Modules must remain at a fixed position within 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:	5 G
Vibration:	TBD G

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:	5 G
Vibration:	TBD G

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:	5 G
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 and bin 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, custom machined 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 reliability and performance concerns, all blind mate connectors have been eliminated from the EVLA system.

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 an 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.

The Ethernet networking hardware used for the monitor control bus (MCB) in the antenna vertex room requires special shielding. A custom designed rack with an integrated fiber optic patch panel has been designed for this purpose.

3.5.6 CEB Racks, Bins and Modules

The EVLA LO system uses a modified version of the VLA rack and bin 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, custom machined 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 reliability and performance concerns, all blind mate connectors have been eliminated from the EVLA system.

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

3.6 System Power Supplies

3.6.1 Antenna Electronics Systems

Antenna vertex room, pedestal room and apex electronics are powered from N+1 redundant 48VDC 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 by the addition of 48VDC 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.

3.6.2 CEB Electronics Systems

LO/IF electronics in the central electronics building are powered from N+1 redundant 48VDC 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 by the addition of 48VDC gel cell type batteries. Commercial equipment in the LO/IF racks, such as computers, networking equipment and test equipment, will 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 telecommunications industry components and are readily available as turn-key systems from a number of sources.

3.6.4 Computing and Network Hardware

All computing and networking hardware is operated from the site AC power and uses battery backed Un-interruptible Power Supplies (UPS).

3.7 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.

3.7.1 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 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 55dB 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.

3.7.2 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 designed 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:	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

3.7.3 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:	RF Shielded Chamber specified at 100dB shielding up to 10 GHz.
Front End:	300 MHz -12 GHz amplifiers.
Signal Path:	Operational up to 18 GHz
Receiver:	HP70001A spectrum analyzer operational up to 22 GHz with narrowest RBW = 10 Hz.