EVLA Project Book, Chapter 5.

5 RECEIVERS

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5.0 System Definition and Overview

The VLA antennas currently support six cryogenically-cooled receivers at the Cassegrain focus, covering portions of the following frequency bands: L, C, X, U, K, and in most cases, Q. See 3.2.1 for a definition of frequency bands. The receivers are mounted to a stationary feed ring in the vertex room, which is immediately below the main panel. A rotating sub-reflector steers the beam to the desired receiver. Two additional frequency bands are to be added as part of the EVLA project, S and Ka. In addition, K band frequency coverage is being increased by improvements to the lock-range of the 1st local oscillator (LO). The end result is that eight receivers will provide continuous coverage from 1 to 50 GHz.

Later in the EVLA project access to the prime focus may be provided by adding an additional degree of freedom to the sub-reflector motion. If so, dipoles for observing at frequencies below 400 MHz will be moved to the prime focus from their current position at the image of the prime focus in front of the subreflector. A cooled receiver (50K) may be provided for frequencies 400 MHz to 1000 MHz. For the frequency band 1 GHz – 1.2 GHz, a cryogenically–cooled receiver is planned for the prime focus.

This EVLA Project Book section is concerned with the microwave receiving system from the input of the feed horn for each band, to the 1st IF output at 8 – 12 GHz. The following list details the frequency coverage of each of the 8 centimeter-wave receivers included in the EVLA Phase 1 plan, and the proposed system temperatures:

TABLE TBD: EVLA RECEIVER FREQUENCY RANGES AND OPERATING TEMPERATURES

BAND	FRQ RANGE (GHz)	REQ Tsys(2) (K)	CURRENT Tsys(3) (K)	CURRENT Trx(4) (K)	REQ Tsys(5) (K)
L	1 – 2(1)	26	35	14.7	10.9
S	2 – 4	29	31	21.7	20.3
C	4 – 8	31	40	15.5	12.0
X	8 – 12	34	35	24.5	23.8
Ku	12 – 18	39	59	28.2	18.6
K	18 – 26	54	65	27.0	22.4
Ka	26 – 40	45	NA	NA	NA
Q	40 – 50	66	80	67.8	55.9

NOTES:
(1) 1200 – 1735 MHz nominal, response fall-off from 1000 – 1200 MHz @ <= TBD dB/decade.
(2) From VLA Expansion Project, Phase I, The Ultra sensitive Array, Table 3.1.
(3) LXKQ bands: From VLA Observational Status Summary, Table 4. SCU bands: Average of functioning VLBA sites from VLBA pointing gains table file @ "/home/jansky/POINTING/gains.table"

(4) Average of "SOIDA" test data of a sample of receivers, 3 points per band (center & edges), all weighted equally.
(5) Calculated from the simple ratio of (REQ Tsys/CURRENT Tsys) * CURRENT Trx. This is the "top-down" projection of what the EVLA receiver temperature would have to be if all other items (feed system, antenna) were to retain their current noise contributions.

The receivers for each of these bands will consist of some or all the following components:

1. A wideband, corrugated feed horn;
2. Polarization-energy separation components—Phase-shifters, EM-mode transitions, ortho-mode transducers;
3. Calibration noise injection components—Microwave noise sources, wideband amplifiers, calibration couplers;
4. Cryogenically-cooled, Low Noise Amplifiers (LNA) components—LNAs, isolators, filters;
5. Post-LNA amplification components—Room temperature microwave amplifiers, isolators, filters;
6. 1st IF Conversion components—RF splitters, mixers, isolators, filters;
7. 1st IF LO amplification and frequency conversion components—Microwave frequency multipliers, isolators, filters;
8. Receiver control and monitoring system components—Card cage, temperature/vacuum control printed circuit boards (PCB), LNA bias control PCBs, sensor conditioning/readback PCBs;
9. Dewar cryogenics—Refrigerators, vacuum control valves.

5.0.1 Feed horn

Each receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the feed horn for each band may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.0.2 Polarization

5.0.2.0 Introduction

Each receiver will include NRAO custom-designed, very-wide-bandwidth waveguide components designed to separate the right and left hand polarized incoming microwave energy. The Polarizer components provide two linear electric fields to the receiver that represent the magnitude and phase of the circular left and right field vectors E_L and E_R. The Polarizer may consist of a single part as in the case of a wave-guide septum type polarizer, or it may consist of two or more part as in the case of as phase-shifter and Orthomode Transducer (OMT) combination. A detailed description of the polarization components for each band may be found in each receiver section of this chapter, and in the "Feeds" chapter of this EVLA Project Book document.

The requirements in this section are traceable to the EVLA Proposal and the Supplemental Information for the NSF document. Additional requirement details are expected in the form of Science Requirements and System Engineering Requirements.

5.0.2.1 Overview

The 1-50 GHz frequency coverage is possible by dividing the 50 GHz bandwidth into discrete bands. The factors considered when selecting the bandwidths for each band include:
(1) Available technology,
(2) The number of receivers/feeds, and
(3) The performance of the receiver/feed/antenna at the band edges.

The number of bands proposed is eight. These bands are identified in Table 1 along with the principal performance requirements for each band. It is possible that the frequency range defined in Table 1 for each band may vary by a few hundred megahertz due to component tolerance for commercial and custom parts.

Table 1 Principal Performance Requirements by Band

Band Designation	Frequency Range (GHz)	Bandwidth Ratio	System Temperature (K)	Total System Efficiency
L	1.0 – 2.0	2.0	26	0.50
S	2.0 – 4.0	2.0	29	0.62
C	4.0 – 8.0	2.0	31	0.60
X	8.0 – 12.0	1.5	34	0.56
U	12.0 – 18.0	1.5	39	0.54
K	18.0 – 26.5	1.5	54	0.51
Ka	26.5 – 40.0	1.5	45	0.39
Q	40.0 – 50.0	1.25	66*	0.34

* At low frequency end of the band

System Temperature budgets (TBD, per band) will allocate noise temperature requirements to antenna and receiver components. The noise temperature requirements allocated to polarizers will define the insertion loss and return loss specifications for these components. Likewise, a System Efficiency budget (TBD, per band) will define the beam squint, and return loss of the feed-polarizer combination.

5.0.2.2 Polarization

All feeds and polarizers will provide dual circular polarization, and they will be designed to minimize cross-polarization.

5.0.2.3 Polarization Purity

Polarization purity will be less than 5% for each of the eight bands except at the band edges. This requirement will be used to specify the ellipticity/axial ratio, and cross-polarization isolation.

5.0.2.4 Mechanical/Physical (not a traceable requirement)

The maximum weight and size of the polarizers shall be considered.

5.0.2.5 Specifications

All specifications will flow directly from the requirements above, or they will be derived from the requirements above. For the later case, each derived specification will be traceable to one or more requirements.

5.0.2.6 General

General specifications are those that pertain to all polarizers. As the design and development process proceeds general specifications may be tailored for specific polarizers.

(a) Polarizers will be specified or designed for each of the following bands:
- 1.0-2.0 GHz
- 2.0-4.0 GHz
- 4.0-8.0 GHz
- 8.0-12.0 GHz
- 12.0-18.0 GHz
- 18.0-26.5 GHz

- 26.5-40.0 GHz
- 40.0-50.0 GHz

(b) All polarizers will be located within the dewar and operated at 15 K to minimize effects of losses in these components.
(c) All polarizers will be optimized to provide the maximum possible on-axis G/T performance
(d) Environmental
- Operational Temperature Range - 15 K
- UV protection – N/A
- Humidity – TBD

(e) TBD

5.0.3 Calibration
Each receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Receiver calibration characterization data will be generated during the receiver test and characterization process, and will be provided to EVLA Operations for on-line, system calibration.

A detailed description of the calibration components for each band may be found in each receiver section of this chapter.

5.0.4 Cryogenically-cooled Amplifiers
Each receiver will include NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers for each polarization. These NRAO amplifiers are designed to operate through multiple thermal cycles from room temperature (nominally 290 deg K) to the working temperature of 15 deg K by careful matching of the thermal characteristics and coefficients of expansion of the materials used, and by externalizing the FET biasing control circuitry.

A detailed description of the LNA components for each band may be found in each receiver section of this chapter.

5.0.5 Room Temperature RF Amplifiers
The receivers for Ku, K, Ka, and Q bands will include additional room temperature amplification components designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers, though not as stringent as those of the LNAs, do include wide bandwidth, a moderately-low noise figure, and a moderately-high 1 dB compression point.

A detailed description of the room temperature amplifier components for each band may be found in each receiver section of this chapter.

5.0.6 1st IF Conversion
Each receiver will include the mixer, filter, and isolator components required to convert the received ("sky") frequency RF energy to within the 1st IF frequency of 8 – 12 GHz. The receivers for the 4 highest bands (Ku, K, Ka, and Q bands) will be designed to accept 2, independently tunable local oscillator (LO) signals and the incoming RF energy for each polarization, and generate two, 4 GHz-wide 1st IF outputs for the RCP energy, and two, 4 GHz-wide 1st IF outputs for the LCP energy.

The receivers for the bands above the 1st IF frequency of 8 – 12 GHz (Ku, K, Ka, and Q bands) shall include the down-conversion circuitry on the receiver. The receivers for the bands below the 1st IF frequency of 8 – 12 GHz (C, S, and L bands) will share the down-conversion circuitry in a set of common modules, 1 for each signal channel.

The X-band receiver frequency coverage will exactly overlap the 1st IF frequency of 8 – 12 GHz, and therefore will not require a 1st IF converter.

A detailed description of the 1st IF Conversion components for each band may be found in each receiver section of this chapter.

5.0.7 LO Conditioning

The receivers for Ku, K, Ka, and Q bands will include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators.

A detailed description of the LO conditioning components for each band may be found in each receiver section of this chapter.

5.0.8 Monitor and Control

Each receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the following receiver parameters:

Dewar 15 deg K stage Temperature
Dewar 50 deg K stage Temperature
Dewar 300 deg K stage Temperature
Dewar vacuum
Vacuum line vacuum
Refrigerator AC current
Heater AC current
RCP LNA FET bias voltages—Each stage
LCP LNA FET bias voltages—Each stage
RCP LNA FET bias currents—Each stage
LCP LNA FET bias currents —Each stage
RCP output total power
LCP output total power
RCP output switched power
LCP output switched power

The command and monitor interface between the antenna control unit (ACU) and the existing 6 cryogenically-cooled receivers is currently provided by two F14 modules located in the F-rack. Each F14 is designed to support a maximum of 3 receivers. Rather than build a third F14 module with its attendant obsolescence problems to support the additional 2 receivers, an entirely new control module will be designed and built and the existing F14 discontinued from use. The new electronic system will include all the current control and monitor functions of the F14 as listed in VLA Technical Report 68:
(List)

The following new control and monitor functions will be provided, to include "canned" tests to be operated by an embedded microprocessor:

(List)

The new control and monitor electronic system will support all 8 cryogenically-cooled receivers located at the feed ring with provisions to support an additional cryogenically-cooled 1 GHz – 1.2 GHz receiver to be located at the prime focus, 1 or more cooled receivers for 400 MHz – 1000 MHz also at the prime focus, and un-cooled dipoles for frequencies below 400 MHz. It will interface with the EVLA Monitor and Control bus to provide status information to the on-line computer and to relay control from the on-line computer to the receivers. In addition, a computer port will be provided to permit local connection of a laptop computer for diagnostic purposes. A control and status panel will be provided to provide the following functions:
(List)

The digital electronics used in the on-receiver monitor and control cards, and in the off-receiver systems interface cards are anticipated to have clocks and high frequency components that may have the tendency to radiated within the RF or IF frequencies of the EVLA receivers. Proper circuit board design techniques, shielding, and careful selection of operating clock frequencies shall be used in order to suppress any such radio frequency interference (RFI) to below the harmful levels specified in ITU-R-RA769. Where such levels are unattainable, internally generated RFI shall be suppressed to below the level of the external RFI environment within a particular band or sub-band.

Modules in the electronic system will provide unique identification numbers (ID) to the Maintenance Management System via the Monitor and Control bus. The numbers will be provided by TBD and be in a format as specified in Chapter TBD on Monitor and Control.

Existing receivers for a given antenna will continue to be supported by the F14 electronics until that antenna receives the EVLA upgrade. The EVLA upgrade will include installation of the new Monitor and Control bus and the new receiver monitor and control electronics system. Since the new receivers may not all be available for the upgrade, the new electronics must be designed to work with the old receivers. New features provided for in the electronics system may not be available until the new receivers are installed. Additional transition issues:
(List)

A detailed description of the calibration components for each band may be found in each receiver section of this chapter.

5.0.9 Cryogenics
Each receiver will include the refrigerator and vacuum components required to maintain thermally stable, 15 and 50 degree stages within the receiver dewar. The VLA receiver dewar for frequencies above 1 GHz must be cryogenically-cooled. The cooling system uses a helium compressor and a cryogenic pump or refrigerator on each dewar. Helium is compressed to 300 psi at the compressor and delivered to the refrigerator. The refrigerator cools amplifiers in the dewar to 15K using a 2-stage gas expansion and heat transfer cycle. The helium is returned to the compressor at 75 psi in a closed loop system.

Three types of cryogenic pumps are in use, all manufactured by CTI:
Model 1020 (flow, other specs)
Model 350
Model 22
The net addition of three dewars for the EVLA requires additional compressor capacity. The VLA helium compressor system currently consists of two 3 HP Copeland compressor motors rated at 48 SCFM. The VLA receiver system is split between the two helium compressors. System A supplies helium to the original C and U band receiver dewar at 28 scfm and the new K-Band receiver dewar at 17 scfm. Compressor B system supplies helium to the L-Band dewar at 17 scfm and the Q and X band receiver dewar at 9 scfm each.

The compressor currently in use is a

Copeland Corporation Model ERAF-031E-TAC
CFH 382.2 Med. Temp Refrigerant
18100 BTUH
3 Horse Power
208 volt 3 Phase

For the EVLA, Ka and S band receiver dewars will be added, and the C and U band receivers will each have its own dewar for a net gain of 4 dewars. Since the existing helium compressor capability is not adequate to provide the additional flow, the compressor motors must be upgraded to a higher displacement to avoid adding a third compressor.

The Cryogenic Group is testing a higher displacement compressor motor manufactured by Copeland Corporation. The overall dimensions on the new compressor motor are the same as the existing unit, which avoids modification to the compressor cabinets. The new motor uses a larger piston to increase the flow rating from 382.2 CFH to 520.5 CFH for medium temperature refrigerant:

Copeland Corporation Model 3RAA-031-TAC
CFH 520.5 Med. Temp Refrigerant
22300 BTUH
3 Horse Power
208 volts, 3 Phase

The new higher-displacement motor tested satisfactorily with a load of three CTI model 350 refrigerators and one CTI model 22 refrigerator, but during the transition, one of the compressors must also support the original CTI 1020 refrigerator currently used for the original C and U band receiver dewar. High return pressures and high cryogenic temperature on the 1020 refrigerator are of some concern. The final plan calls for the following configuration:

System A: L, K, S bands each with a CTI model 350 refrigerator and X band with a CTI model 22 refrigerator.
System B: C, U, Ka bands each with a CTI model 350 refrigerator and Q band with a CTI model 22 refrigerator.
System C: If a dewar is added to the prime focus for the band 1 GHz to 1.2 GHz, a smaller third compressor will be added to the apex. Cooling to 50 K may be desirable if dewars are added for the frequency band 600 MHz to 1000 MHz at prime focus, in which case single stage refrigerators will be required.

The closed loop helium system requires stainless steel tubing to connect the high pressure and return lines between the compressor and dewars. The following line plumbing work will be required for the EVLA:

TBD list

Pressure sensors are proposed as follows:

Dynisco Transducer Model G850-100-5C
0-500 psig
28 VDC

EVLA Vacuum Pump and Manifold.

Vacuum pumps are required to evacuate the dewars to 5X10-1 Torr for the cooling cycle to work. Receiver pump down time is dependent on receiver chamber size, contaminates, vacuum hose length and ID, but is on the order of 10 minutes in most cases. Two vacuum pumps are currently being used on the VLA antennas. The original vacuum pump (Sargent Welch) was installed in the early days of the VLA, while the second pump (Alcatel) was installed during the Voyage encounter. The Sargent Welch unit tends to trip the circuit breaker during cold start after a power outage because of high pump currents, where the Alcatel unit does not. The Sargent Welch Model 8805 vacuum pump is mounted on the A-rack and is dedicated to the C/U band receiver. The vacuum manifold consists of a 3/4" vacuum hose and a solenoid valve. The Model 8805 uses a 1/3 HP motor and is rated for 5 CFM.

The Alcatel Pump Model 2008A is mounted on the F-Rack and is dedicated to the L, X, Q and K-band receivers. The unit uses a manifold consisting of a 3/4" vacuum hose and solenoid valves, the same as the Sargent Welch. The Model 2008A uses a 1/2 HP motor and is rated for 9 CFM.

As part of the EVLA, the Cryogenics Group proposes replacing the existing Sergeant Welch vacuum pump with an Alcatel pump for reliability and to reduce receiver pump down time. The final configuration will be dependent on receiver and feed orientation.

Vacuum system A:
Vacuum system B:

Vacuum lines to accommodate the new dewars are required as follows:

> 1 1/2" SS Tubing with SS welded flanges to adapt to prefabricated 1 1/2" SS elbows, tees and 1 1/2 X 3/4" reducers.

Vacuum sensors are proposed on the vacuum pump as follows:

> Hasting DV-6m Tube

A detailed description of the cryogenic components for each band may be found in each receiver section of this chapter.

5.0.10 Maintenance issues

High reliability must be emphasized, even if peak performance is slightly compromised because of the replication of 28 receivers and the difficulty of access especially during the A configuration. The MTBF of receivers currently is TBD. It is anticipated the new receivers will be at least as reliable as the current ones. The weakest link for the receiver is TBD, and to compensate, TBD Provisions for handling: TBD (handles, containers, installation). ID numbers. Receivers will be interchangeable between antennas. Commonality of parts between receiver dewars will save construction cost; common parts are planned to be TBD. Typically, RF levels can be adjusted by TBD. Alignment of the receiver and feed horn with the beam is provided by TBD and can be verified by TBD.

5.0.11 Testing

Equipment, images, intercepts, intermodulation, insertion loss, saturation,

5.0.12 Prototyping, construction plans.

5.1 The EVLA L-band Receiver System (1-2 GHz)

5.1.0 Summary (L Band)

The EVLA L-band receiver development project is an upgrade to the existing VLA L-band front end system. It includes the expansion of the system frequency coverage from the current 1340 to 1730 MHz to a full 1 – 2 GHz, and the expansion of the instantaneous bandwidth from the current 2 x 50 MHz x 2 polarizations, to 1 x 1 GHz x 2 polarizations. To accomplish these 2 prime goals the current feed horn and polarizer sections will have to be redesigned for the wider bandwidth, the current LNAs and other dewar RF devices will have to be replaced with wider bandwidth devices. Previous tests have indicated that the waveguide phase-shifter section may be replaced with a commercially-available hybrid phase-shifter device, located within the dewar. These same tests, however, indicated that the waveguide phase-shifter is not the current limiting factor in VLA L-band frequency coverage. Frequency conversion from the L-band "sky frequency" to the 8 – 12 GHz, EVLA 1st IF frequency shall be performed by a separate up-converter module shared with the S and C band receivers.

5.1.1 Introduction

5.1.2 Specifications and Requirements

5.1.2.1 Frequency Coverage

The EVLA L-band receiver 3 dB minimum frequency coverage shall be from 1200 – 1730 MHz. Gain linearity within that range will be < +/- 1.5 dB. Roll-off between 1000 and 1200 MHz shall be <= TBD dB/decade.

5.1.2.2 Instantaneous Bandwidth

The EVLA L-band receiver instantaneous bandwidth will include the full, 1 – 2 GHz frequency coverage for both polarization channels.

5.1.2.3 Receiver Temperature

The EVLA L-band receiver noise temperature shall be less than 10.9 K across the full frequency coverage specified.

5.1.2.4 Instantaneous Dynamic Range

The EVLA L-band receiver system shall provide a linear, instantaneous dynamic range of TBD dB. The 1 dB compression point of the receiver shall be TBD dBm.

5.1.2.5.0 LO Input

Phase-synchronized local oscillator references shall be provided to the 4, P, L, and S band up-converter modules used by the L-band receiving system to convert the input frequency of the receiver to the 1^{st} intermediate frequency (IF) band of 8 – 12 GHz.

5.1.2.5.1 LO Input Frequencies

The local oscillator used to convert the L-band signals to the 1st IF frequency of 11 – 10 GHz, shall be a fixed CW tone at 12 GHz.

5.1.2.5.2 LO Input Purity

The 12 GHz local oscillator used to convert the L-band signals to the 1st IF frequency of 11 – 10 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.1.2.5.3 LO Input Power Levels

The 12 GHz local oscillator used to convert the L-band signals to the 1st IF frequency of 11 – 10 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.1.2.6 RF Output Power
The EVLA L-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm. Measurement shall be taken through a 1500/1000 MHz bandpass filter.

5.1.2.7 AC Input Power
150 VAC RMS AC power is required to power the EVLA L-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA L-band receiver CTI-350 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.1.2.8 DC Input Power
The EVLA L-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA L-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.1.2.9 Total Power Dissipation
The total power dissipation of the EVLA L-band receiver shall be <= TBD W.

5.1.2.10.0 Cryogenics
As with the VLA receivers, the EVLA L-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.1.2.10.1 Refrigerator
As with the VLA receivers, A CTI-350 refrigerator will be used to cool the EVLA L-Band dewar. The CTI-350 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.1.2.10.2 Compressor
Compressed helium will be provided by compressor TBD.

5.1.2.11 Feed horn
The EVLA L-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the L-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.1.2.12 Polarization

The EVLA L-band receiver will include NRAO custom-designed, very-wide-bandwidth waveguide components designed to separate the right and left hand polarized incoming microwave energy.

The planned L-Band design uses a compact corrugated horn, which is connected to the OMT via a pressure window and perhaps a circular wave-guide adaptor to interface the horn to the receiver. The OMT can be thought of as a polarization filter that can separate orthogonal polarizations (Boifot, 396). The two output ports then both contain information about left and right circular polarizations. The two output ports of the OMT are connected by coaxial cable to the two inputs of a hybrid. The hybrid is a four port directional couple – sometime called a sum/difference hybrid. The two coaxial outputs have electric fields that are proportional to the magnitude and phase of the circular left and right field vectors E_L and E_R that were incident on the OMT. A block diagram of this design is provided in Figure 1.

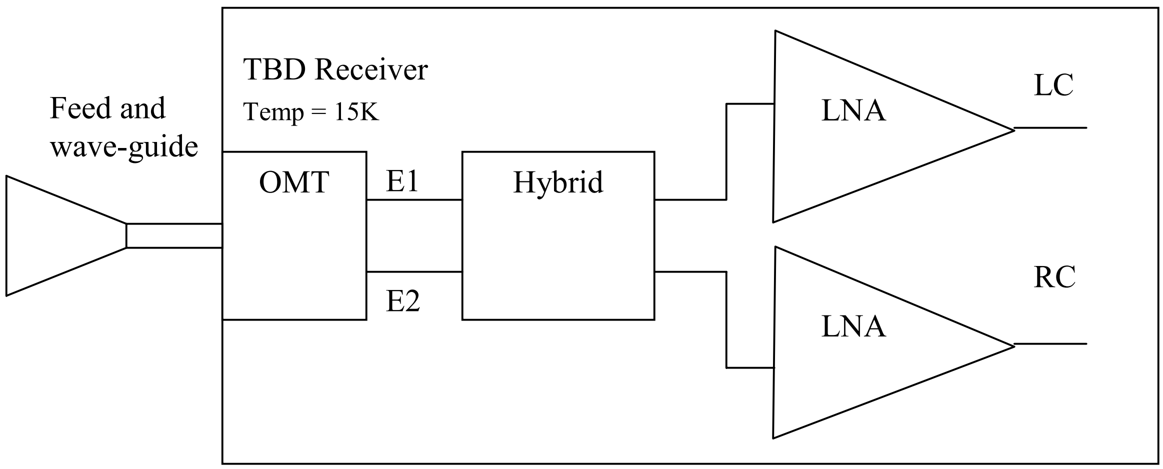

FIG. 1 – Block Diagram: L, S, and C Band Polarizer Components

This design approach is planned for S and C Bands as well. The advantage to this design is that it reduces the distance from the feed aperture to the bottom of the receiver by removing the long length phase shifter that precedes the OMT as in the VLA L-Band design. This is especially important for the EVLA L-Band horn where the length of the 1-2 GHz feed is substantially longer than it's counter part narrow band horns used in either the VLA or VLBA. Another advantage for all three bands is that no components are at ambient temperature except the feed horn and the wave-guide used to interface the horns to the receivers. Beyond 8 GHz this design is limited to manufacturability issues. At these wavelengths the ridge separation and the coax transition become difficult to manufacture. Above 8 GHz other designs are planned as will be explained in detail below.

TBD Table TBD – L-Band OMT Specifications

5 **Item**	**Nomenclature**
Type	Quadridge
Frequency Range	1.0 –2.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD – L-Band Hybrid Specifications

6 **Item**	**Nomenclature**
Type	90 deg.

Frequency Range	1.0 –2.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.1.2.13 Calibration
The EVLA L-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all L-band receivers across the entire EVLA array.

5.1.2.14 Cryogenically-cooled Amplifiers
The EVLA L-band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.1.2.15 Room Temperature RF Amplifiers
The EVLA L-band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.1.2.16 1st IF Conversion
The EVLA L-band receiver shall include only those components required to amplify and calibrate the received 1 – 2 GHz RF energy. Frequency conversion shall be accomplished by 2 external rack-mounted up-converter modules, 1 for each GHz-wide polarization channel. These up-converter modules shall be shared with 4, P, S, and C bands, with the input receiver being selected via electromechanical band switches. The up-converter modules shall be designed to accept 1, independently tunable local oscillator (LO) signal and the GHz-wide incoming L-band RF energy for each polarization, and generate a single, 1 GHz-wide 1st IF output for the RCP channel, and a single, 1 GHz-wide 1st IF output for the LCP channel.

5.1.2.17 LO Conditioning
The EVLA L-band receivers will include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.1.2.18 Monitor and Control
The EVLA L-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA L-band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.1.3 Test Results
5.1.4 References

5.2 The EVLA S-band Receiver System (2-4 GHz)
5.2.0 Summary (S Band)
The current VLA system does not include an S-band receiver system. However, the VLBA system does include a 2130 – 2350 MHz, cryogenically-cooled receiver system at each antenna. It is anticipated that, with the modification of the bandwidth-limited feed horn and dewar components, the EVLA S-band system design will be able to significantly leverage off of the current VLBA design. A new feed horn will have to be designed to cover the full 2 – 4 GHz frequency range, and properly illuminate the smaller, VLA sub-reflector. The VLBA, wave guide phase shifter may be replaced with a hybrid phase-shifting device, such as has been tested on the VLA antenna 24 L-band receiver. Frequency conversion from the S-band "sky frequency" to the 8 – 12 GHz, EVLA 1st IF frequency shall be performed by a separate up-converter module shared with the L and C band receivers.

5.2.1 Introduction

5.2.2 Specifications and Requirements

5.2.2.1 Frequency Coverage
The EVLA S-band receiver 3 dB frequency coverage shall be identical to its instantaneous bandwidth of 2 – 4 GHz. Gain linearity within that range will be < +/- 1.5 dB.

5.2.2.2 Instantaneous Bandwidth
The EVLA S-band receiver instantaneous bandwidth will include the full, 2 – 4 GHz frequency coverage for both polarization channels.

5.2.2.3 Receiver Temperature
The EVLA S-band receiver noise temperature shall be less than 20.3 K across the full frequency coverage specified.

5.2.2.4 Instantaneous Dynamic Range
The EVLA S-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.2.2.5 LO Input
Phase-synchronized local oscillator references shall be provided to the 4, P, L, and S band up-converter modules used by the S-band receiving system to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.2.2.5.1 LO Input Frequencies
The local oscillator used to convert the S-band signals to the 1st IF frequency of 10 – 8 GHz, shall be a fixed CW tone at 12 GHz.

5.2.2.5.2 LO Input Purity
The 12 GHz local oscillator used to convert the S-band signals to the 1st IF frequency of 10 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.2.2.5.3 LO Input Power Levels
The 12 GHz local oscillator used to convert the S-band signals to the 1st IF frequency of 10 – 8 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.2.2.6 RF Output Power
The EVLA S-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.2.2.7 AC Input Power
150 VAC RMS AC power is required to power the EVLA S-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA S-band receiver CTI-350 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.2.2.8 DC Input Power
The EVLA S-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA S-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.2.2.9 Total Power Dissipation
The total power dissipation of the EVLA S-band receiver shall be <= TBD W.

5.2.2.10.0 Cryogenics
The EVLA S-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.2.2.10.1 Refrigerator
A CTI-350 refrigerator will be used to cool the EVLA S-Band dewar. The CTI-350 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.2.2.10.2 Compressor
Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.2.2.11 Feed horn

The EVLA S-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the S-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.2.2.12 Polarization

The S-Band design is conceptually the same as L-Band

TBD Table TBD – S-Band OMT Specifications

7 **Item**	**Nomenclature**
Type	Quadridge
Frequency Range	2.0 –4.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD – S-Band Hybrid Specifications

8 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	2.0 –4.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.2.2.13 Calibration

The EVLA S-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all S-band receivers across the entire EVLA array.

5.2.2.14 Cryogenically-cooled Amplifiers

The EVLA S-band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.2.2.15 Room Temperature RF Amplifiers

The EVLA S-band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.2.2.16 1st IF Conversion

The EVLA S-band receiver shall include only those components required to amplify and calibrate the received 2 – 4 GHz RF energy. Frequency conversion shall be accomplished by 2 external rack-mounted up-converter modules, 1 for each GHz-wide polarization channel. These up-converter modules shall be shared with 4, P, L, and C bands, with the input receiver being selected via electromechanical band switches. The up-converter modules shall be designed to accept 1, independently tunable local oscillator (LO) signal and the GHz-wide incoming S-band RF energy for each polarization, and generate a single, 2 GHz-wide 1st IF output for the RCP channel, and a single, 2 GHz-wide 1st IF output for the LCP channel.

5.2.2.17 LO Conditioning

The EVLA S-band receiver will include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.2.2.18 Monitor and Control

The EVLA S-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA S-band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.2.3 Test Results
5.2.4 References

5.3 The EVLA C-band Receiver System (4-8 GHz)
5.3.0 Summary (C Band)

The current VLA C-band system is an early design which includes a significant length of room temperature waveguide running from the feed-ring feed horn down to the multi-band A-rack dewar located within the vertex room. The long length of room-temperature waveguide and the early LNA designs used in this system combine to keep the average Tsys in excess of 40 degrees K. However, the VLBA system does include a 4500 – 5140 MHz, cryogenically-cooled receiver system at each antenna. It is anticipated that, with the modification of the bandwidth-limited feed horn and dewar components, the EVLA C-band system design will be able to significantly leverage off of the current VLBA design. A new feed horn will have to be designed to cover the full 4 – 8 GHz frequency range, and properly illuminate the smaller, VLA sub-reflector. A new, in-dewar OMT will have to be designed to cover the full-octave EVLA C-band frequency coverage. The phase-shifting component may change from being a wave guide system to a wide-band hybrid phase shifter located in the dewar after the OMT. Frequency conversion from the C-band "sky frequency" to the 8 – 12 GHz, EVLA 1st IF frequency shall be performed by a separate up-converter module shared with the L and S band receivers.

5.3.1 Introduction

5.3.2 Specifications and Requirements

5.3.2.1 Frequency Coverage

EVLA C-band 3 dB frequency coverage shall be identical to its instantaneous bandwidth of 4 – 8 GHz. Gain linearity within that range will be < +/- 1.5 dB

5.3.2.2 Instantaneous Bandwidth

EVLA C-band instantaneous bandwidth will include the full, 4 – 8 GHz frequency coverage for both polarization channels.

5.3.2.3 Receiver Temperature

The EVLA C-band receiver noise temperature shall be less than 12.0 K across the full frequency coverage specified.

5.3.2.4 Instantaneous Dynamic Range

The EVLA C-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.3.2.5.0 LO Input

Phase-synchronized local oscillator references shall be provided to the 4, P, L, and S band up-converter modules used by the C-band receiving system to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.3.2.5.1 LO Input Frequencies

The local oscillator used to convert the C-band signals to the 1st IF frequency of 10 – 8 GHz, shall be a fixed CW tone at 16 GHz.

5.3.2.5.2 LO Input Purity

The 16 GHz local oscillator used to convert the C-band signals to the 1st IF frequency of 12 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.3.2.5.3 LO Input Power Levels

The 16 GHz local oscillator used to convert the C-band signals to the 1st IF frequency of 12 – 8 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.3.2.6 RF Output Power

The EVLA C-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.3.2.7 AC Input Power

150 VAC RMS AC power is required to power the EVLA C-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA C-band receiver CTI-350 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.3.2.8 DC Input Power

The EVLA C-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA C-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.3.2.9 Total Power Dissipation

The total power dissipation of the EVLA C-band receiver shall be <= TBD W.

5.3.2.10.0 Cryogenics

The EVLA C-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.3.2.10.1 Refrigerator

A CTI-350 refrigerator will be used to cool the EVLA C-Band dewar. The CTI-350 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.3.2.10.2 Compressor

Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna “elevation platform”.

5.3.2.11 Feed horn

The EVLA C-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the C-band feed may be found in the “Antenna” and “Feeds” chapters of this EVLA Project Book document.

5.3.2.12 Polarization

The C-Band design is conceptually the same as L-Band.

TBD Table TBD – C-Band OMT Specifications

9 Item	Nomenclature
Type	Quadridge
Frequency Range	4.0 –8.0 GHz

Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD – C-Band Hybrid Specifications

10 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	4.0 –8.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.3.2.13 Calibration

The EVLA C-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing “cold sky”, and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all C-band receivers across the entire EVLA array.

5.3.2.14 Cryogenically-cooled Amplifiers

The EVLA C-band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.3.2.15 Room Temperature RF Amplifiers

The EVLA C-band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.3.2.16 1st IF Conversion

The EVLA C-band receiver shall include only those components required to amplify and calibrate the received 4 – 8 GHz RF energy. Frequency conversion shall be accomplished by 2 external rack-mounted up-converter modules, 1 for each GHz-wide polarization channel. These up-converter modules shall be shared with 4, P, S, and L bands, with the input receiver being selected via electromechanical band switches. The up-converter modules shall be designed to accept 1, independently tunable local oscillator (LO) signal and the GHz-wide incoming C-band RF energy for each polarization, and generate a single, 4 GHz-wide 1st IF output for the RCP channel, and a single, 4 GHz-wide 1st IF output for the LCP channel.

5.3.2.17 LO Conditioning

The EVLA C-band shall not include the frequency up-conversion function on the receiver. Frequency conversion shall be accomplished by 2 external rack-mounted up-converter modules, 1 for each GHz-wide polarization channel. The frequency up-converter modules shall include components designed to generate the optimum LO power level for injection into up-converter mixer stages of the module. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.3.2.18 Monitor and Control

The EVLA C-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA C-band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.3.3 Test Results

5.3.4 References

5.4 The EVLA X-band Receiver System (8-12 GHz)

5.4.0 Summary (X Band)

The EVLA X-band receiver development project is an upgrade to the existing VLA X-band front end system. It includes the expansion of the system frequency coverage from the current 8000 to 8800 MHz to a full 8 – 12 GHz, and the expansion of the instantaneous bandwidth from the current 2 x 50 MHz x 2 polarizations, to 1 x 4 GHz x 2 polarizations. To accomplish these 2 prime goals the current feed horn and polarizer sections will have to be redesigned for the wider bandwidth, and the current LNAs and other dewar RF devices will have to be replaced with wider bandwidth devices. A new, in-dewar polarizer will have to be designed to cover the full WR-90 waveguide band of the EVLA X-band frequency coverage. A NRAO designed polarizer system used on the current, new VLA K-band receivers is believed to be scalable down to the planned, EVLA X-band of 8 – 12 GHz. At this time is assumed that the X-band outputs of the EVLA X-band receiver front end will be passed-on to the 8 – 12 GHz EVLA 1st IF section without conversion.

5.4.1 Introduction

5.4.2 Specifications and Requirements

5.4.2.1 Frequency Coverage

The EVLA X-band receiver 3 dB frequency coverage shall be identical to its instantaneous bandwidth of 8 – 12 GHz. Gain linearity within that range will be < +/- 1.5 dB.

5.4.2.2 Instantaneous Bandwidth

The EVLA X-band receiver instantaneous bandwidth will include the full, 8 – 12 GHz frequency coverage for both polarization channels.

5.4.2.3 Receiver Temperature

The EVLA X-band receiver noise temperature shall be less than 23.8 K across the full frequency coverage specified.

5.4.2.4 Instantaneous Dynamic Range

The EVLA X-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.4.2.5 LO Input

The X-band outputs of the EVLA X-band receiver front end will be passed-on to the 8 – 12 GHz EVLA 1st IF section without conversion.

5.4.2.5.1 LO Input Frequencies

Not Applicable.

5.4.2.5.2 LO Input Purity

Not Applicable.

5.4.2.5.3 LO Input Power Levels

Not Applicable.

5.4.2.6 RF Output Power

The EVLA X-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.4.2.7 AC Input Power

150 VAC RMS AC power is required to power the EVLA X-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA X-band receiver CTI-22 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.4.2.8 DC Input Power

The EVLA X-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA X-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.4.2.9 Total Power Dissipation

The total power dissipation of the EVLA X-band receiver shall be <= TBD W.

5.4.2.10.0 Cryogenics

As with the VLA receivers, the EVLA X-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.4.2.10.1 Refrigerator

As with the VLA receivers, A CTI-22 refrigerator will be used to cool the EVLA X-Band dewar. The CTI-22 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.4.2.10.2 Compressor

Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.4.2.11 Feed horn

The EVLA X-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the X-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.4.2.12 Polarization

The polarizer design planned for X-Band is a scaled version of a proven design currently used in the VLA K-Band receivers. The design has proven performance with a bandwidth ration of 1.5:1. The design consists of a phase-shifter used to translate the left and right circular polarization into an orthogonal linear pair. The phase-shifter is followed by a Boifot Junction OMT.

This design approach is planned for X, Ku, and Ka Bands as well. The advantage to the Boifot Junction OMT is its inherent wide bandwidth capability (Boifot, 397). The E-plane side-arm design also provides a relatively compact design. The X-Band OMT is expected to be approximately 18 in. long. Below 8.0 GHz this design becomes excessively large in length and width. Above 40 GHz another design is planned as will be explained in detail below.

TBD Table TBD – X-Band OMT Specifications

11 **Item**	**Nomenclature**
Type	Boifot Junction
Frequency Range	8.0 –12.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD – X-Band Phase-Shifter

12 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	8.0 –12.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD

Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.4.2.13 Calibration
The EVLA X-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all X-band receivers across the entire EVLA array.

5.4.2.14 Cryogenically-cooled Amplifiers
The EVLA X-band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.4.2.15 Room Temperature RF Amplifiers
The EVLA X-band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.4.2.16 1st IF Conversion
The EVLA X-band receiver band coverage exactly overlaps the 8 – 12 GHz 1st IF frequency band. As a result, the full 4 GHz-wide RCP and LCP channels are passed-on for conversion to the 2 – 4 GHz 2nd IF frequency band.

5.4.2.17 LO Conditioning
Not applicable.

5.4.2.18 Monitor and Control
The EVLA X-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA X-band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:

- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.4.3 Test Results
5.4.4 References

5.5 The EVLA Ku-band Receiver System (12-18 GHz)
5.5.0 Summary (Ku Band)
The current VLA Ku-band system is an early design that includes a significant length of room temperature waveguide running from the feed-ring feed horn down to the multi-band "A-rack dewar" located within the vertex room. The long length of room-temperature waveguide and the early LNA designs used in this system combine to keep the average Tsys well in excess of 110 degrees K. However, the VLBA system does include a 12000 – 15400 MHz, cryogenically-cooled receiver system at each antenna. It is anticipated that, with the modification of the bandwidth-limited feed horn and dewar components, the EVLA Ku-band system design will be able to significantly leverage off of the current VLBA design. A new feed horn will have to be designed to cover the full 12 – 18 GHz frequency range, and properly illuminate the smaller, VLA sub-reflector. A new, in-dewar, wave guide septum OMT will have to be designed to cover the full WR-62 waveguide band of the EVLA Ku-band frequency coverage. A NRAO designed polarizer system used on the current-build, VLA K-band receivers is believed to be scalable down to the planned, EVLA Ku-band of 12 – 18 GHz Frequency conversion from the Ku-band "sky frequency" to the 8 – 12 GHz, EVLA 1st IF frequency will be included on the receiver. On-receiver frequency conversion is already the norm on the current VLA K and Q band receivers.

5.5.1 Introduction
5.5.2 Specifications and Requirements
5.5.2.1 Frequency Coverage
EVLA Ku-band 3 dB frequency coverage shall cover the frequency range of 12 – 18 GHz in 2 bands. Gain linearity within that range will be < +/- 1.5 dB.

5.5.2.2 Instantaneous Bandwidth
EVLA Ku-band instantaneous bandwidth will include 2, independently tunable 4 GHz-wide polarization pairs.

5.5.2.3 Receiver Temperature
The EVLA Ku-band receiver noise temperature shall be less than 18.6 K across the full frequency coverage specified.

5.5.2.4 Instantaneous Dynamic Range
The EVLA Ku-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.5.2.5.0 LO Input
Phase-synchronized local oscillator references shall be provided to the ELVA Ku-band receiver which shall be used in the receiver down converter section to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.5.2.5.1 LO Input frequencies
The local oscillator used to convert the Ku-band signals to the 1st IF frequency of 12 – 8 GHz, shall be fixed CW tones at 12 and 13 GHz.

5.5.2.5.2 LO Input Purity
The 12 GHz local oscillator used to convert the Ku-band signals to the 1st IF frequency of 12 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.5.2.5.3 LO Input Power Levels

The 12 and 13 GHz local oscillator tones used to convert the Ku-band signals to the 1st IF frequency of 12 – 8 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.5.2.6 RF Output Power

The EVLA Ku-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.5.2.7 AC Input Power

150 VAC RMS AC power is required to power the EVLA Ku -band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA Ku -band receiver CTI-350 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.5.2.8 DC Input Power

The EVLA Ku-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

The EVLA Ku -band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.5.2.9 Total Power Dissipation

The total power dissipation of the EVLA Ku -band receiver shall be <= TBD W.

5.5.2.10.0 Cryogenics

As with the VLA receivers, the EVLA Ku -band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.5.2.10.1 Refrigerator

A CTI-350 refrigerator will be used to cool the EVLA Ku -Band dewar. The CTI-350 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.5.2.10.2 Compressor

Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.5.2.11 Feed horn

The EVLA Ku-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the Ku-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.5.2.12 Polarization
The Ku-Band design is conceptually the same as X-Band.

TBD Table TBD – Ku-Band OMT Specifications

13 Item	Nomenclature
Type	Boifot Junction
Frequency Range	12.0 –18.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD – Ku-Band Phase-Shifter

14 Item	Nomenclature
Type	90 deg.
Frequency Range	12.0 –18.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.5.2.13 Calibration
The EVLA Ku -band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing “cold sky”, and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all Ku-band receivers across the entire EVLA array.

5.5.2.14 Cryogenically-cooled Amplifiers
The EVLA Ku -band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.5.2.15 Room Temperature RF Amplifiers
The EVLA Ku -band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.5.2.16 1st IF Conversion
The EVLA Ku-band receiver will include the mixer, filter, and isolator components required to convert the received 12 – 18 GHz RF energy to within the 1st IF frequency of 8 – 12 GHz. The on-receiver converter shall be designed to

accept 2, independently tunable local oscillator (LO) signals and the incoming RF energy for each polarization, and generate two, 4 GHz-wide 1st IF outputs for the RCP channel, and two, 4 GHz-wide 1st IF outputs for the LCP channel.

5.5.2.17 LO Conditioning

The EVLA Ku-band receiver shall include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.5.2.18 Monitor and Control

The EVLA Ku -band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA Ku -band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:

- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.5.3 Test Results

5.5.4 References

5.6 The EVLA K-band Receiver System (18-26 GHz)

5.6.0 Summary (K Band)

The existing VLA, F109 K-band receiver has the capability to tune across the entire, planned EVLA K-band range of 18 – 26 GHz, however, a number of components in the IF section will have to be changed-out to provide the proposed, 4 GHz-wide instantaneous IF channels. In addition, the number of IF outputs will be increased from the current 2 x 50 MHz x 2 polarizations, to 2 x 4 GHz x 2 polarizations, with each of the two polarization pairs being independently tunable.

5.6.1 Introduction

5.6.2.0 Specifications and Requirements

5.6.2.1 Frequency Coverage

EVLA K-band 3 dB frequency coverage shall cover the frequency range of 18 – 26 GHz in 4 bands. Gain linearity within that range will be < +/- 1.5 dB.

5.6.2.2 Instantaneous Bandwidth

EVLA K-band instantaneous bandwidth will include 2, independently tunable 4 GHz-wide polarization pairs.

5.6.2.3 Receiver Temperature
The EVLA K-band receiver noise temperature shall be less than 22.4 K across the full frequency coverage specified.

5.6.2.4 Instantaneous Dynamic Range
The EVLA K-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.6.2.5.0 LO Input
Phase-synchronized local oscillator references shall be provided to the ELVA K-band receiver that shall be used in the receiver down converter section to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.6.2.5.1 LO Input Frequencies
The local oscillator used to convert the K-band signals to the 1st IF frequency of 12 – 8 GHz, shall be 4 fixed CW tones at 15, 16, 17, and 18 GHz.

5.6.2.5.2 LO Input Purity
The 4 local oscillator tones used to convert the K-band signals to the 1st IF frequency of 12 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.6.2.5.3 LO Input Power Levels
The 4 local oscillator tones used to convert the K-band signals to the 1st IF frequency of 12 – 180 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.6.2.6 RF Output Power
The EVLA K-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.6.2.7 AC Input Power
150 VAC RMS AC power is required to power the EVLA K-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA K-band receiver CTI-22 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.6.2.8 DC Input Power
The EVLA K-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

The EVLA K-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.6.2.9 Total Power Dissipation
The total power dissipation of the EVLA K-band receiver shall be <= TBD W.

5.6.2.10.0 Cryogenics
As with the VLA receivers, the EVLA K-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.6.2.10.1 Refrigerator
As with the VLA receivers, A CTI-22 refrigerator will be used to cool the EVLA K -Band dewar. The CTI-22 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.6.2.10.2 Compressor
Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.6.2.11 Feed horn
The EVLA K-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The current VLA K-band feed horn meets all EVLA K-band requirements, and will therefore be unchanged during the EVLA K-band receiver conversion. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the K-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.6.2.12 Polarization
The K-Band design is conceptually the same as described above for X-Band; However, the VLA K-Band design serves as the model for all phase-shifter/Boifot Junction OMT combinations used for EVLA.

TBD Table TBD – K-Band OMT Specifications

15 **Item**	**Nomenclature**
Type	Boifot Junction
Frequency Range	18.0 –26.5 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD– K-Band Phase-Shifter

16 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	18.0 –26.5 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.6.2.13 Calibration

The EVLA K-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all K-band receivers across the entire EVLA array.

5.6.2.14 Cryogenically-cooled Amplifiers

The EVLA K-band receiver will include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.6.2.15 Room Temperature RF Amplifiers

The EVLA K-band receiver will include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.6.2.16 1st IF Conversion

The EVLA K-band receiver will include the mixer, filter, and isolator components required to convert the received 18 – 26 GHz RF energy to within the 1st IF frequency of 8 – 12 GHz. The on-receiver converter shall be designed to accept 2, independently tunable local oscillator (LO) signals and the incoming RF energy for each polarization, and generate two, 4 GHz-wide 1st IF outputs for the RCP channel, and two, 4 GHz-wide 1st IF outputs for the LCP channel. The current F209, VLA K-band receiver outputs only a single 1st IF channel for each polarization, so components will be added to the existing receivers to accept a 2nd, independent LO input, and output the 2nd pair of 4 GHz-wide 1st IF channels.

5.6.2.17 LO Conditioning

The EVLA K-band receiver shall include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.6.2.18 Monitor and Control

The EVLA K-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA K-band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:

Vacuum pump
Vacuum solenoid
Cryogenic refrigerator
Dewar heaters

5.6.3 Test Results

5.6.4 References

5.7 The EVLA K-band Completion Receiver System (18-26.5 GHz)

5.7.0 Summary (K-Band Completion)

The K-band completion project will fill-out the current VLA, 28 antenna array by building an additional 7 (5 + 2 spares), 18 – 26.5 GHz receivers of the current F109 design. Some internal mixer and IF components will be re-specified to allow a more easy transition to the EVLA 4 GHz IF design.

5.7.1 Introduction

5.7.2 Specifications and Requirements

5.7.2.1 Frequency Coverage

The VLA K-band receiver 3 dB frequency coverage capability includes the full EVLA K-band receiver frequency range of 18 – 26 GHz, but is currently limited by the lock-range of the current F3, 1st LO module. The current F3 locks at 35 different frequencies from 16 – 20 GHz, limiting the K-band receiver frequency coverage to between 20.4875 and 25.0425 GHz. Gain linearity within that range is < +/- 1.5 dB.

5.7.2.2 Instantaneous Bandwidth

VLA K-band receiver instantaneous bandwidth includes a single 50 MHz-wide polarization pair, which may be tuned anywhere within the frequency coverage of the receiver, as limited by the F3 LO locking capabilities.

5.7.2.3 Receiver Temperature

The VLA K-band receiver noise temperature is currently less than 27.0 K across the full frequency coverage specified.

5.7.2.4 Instantaneous Dynamic Range

The instantaneous dynamic range of the current VLA F209 K-band receiver is TBD. The receiver 1 dB compression point = TBD dB. The instantaneous dynamic range of the EVLA K-band receivers shall match or exceed the current F210 receiver.

5.7.2.5.0 LO Input

The local oscillator used to convert the EVLA K-band completion receiver signals to the VLA 1st IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F3 module.

5.7.2.5.1 LO Input Frequencies

The local oscillator used to convert the K-band completion receiver signals to the 1st IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F3 module. The F3 module locks at 35 different frequencies from 16 – 20 GHz.

5.7.2.5.2 LO Input Purity

The local oscillator used to convert the K-band completion receiver signals to the 1st IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F3 module.

5.7.2.5.3 LO Input Power Levels
The local oscillator used to convert the K-band completion receiver signals to the 1st IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F3 module.

5.7.2.6 RF Output Power
The VLA K-band receiver front-end RF output total noise power is currently –40 +/- 3 dBm.

5.7.2.7 AC Input Power
150 VAC RMS AC power is required to power the VLA K-band receiver dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the VLA K-band receiver CTI-22 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.7.2.8 DC Input Power
The VLA K-band receiver requires the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

VLA K-band receiver generates all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power is converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.7.2.9 Total Power Dissipation
The total power dissipation of the VLA K-band receiver is <= TBD W.

5.7.2.10.0 Cryogenics
The VLA K-band receivers use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.7.2.10.1 Refrigerator
A CTI-22 refrigerator is used to cool the VLA K-band receiver dewar. The CTI-22 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.7.2.10.2 Compressor
Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.7.2.11 Feed horn
The VLA K-band receiver includes a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The current VLA K-band feed horn meets all EVLA K-band requirements, and will therefore be unchanged during the EVLA K-band receiver conversion. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the K-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.7.2.12 Polarization

The K-Band design is conceptually the same as described above for X-Band; However, the VLA K-Band design serves as the model for all phase-shifter/Boifot Junction OMT combinations used for EVLA.

TBD Table TBD – K-Band OMT Specifications

17 **Item**	**Nomenclature**
Type	Boifot Junction
Frequency Range	18.0 –26.5 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD– K-Band Phase-Shifter

18 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	18.0 –26.5 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.7.2.13 Calibration

The VLA K-band receiver includes components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Only low noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky. Calibration pulse control is provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all K-band receivers across the entire VLA array.

5.7.2.14 Cryogenically-cooled Amplifiers

The current VLA K-band receiver includes 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.7.2.15 Room Temperature RF Amplifiers

The current VLA K-band receiver includes additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.7.2.16 1st IF Conversion

The current VLA K-band receiver design currently includes the mixer, filter, and isolator components required to convert the received 18 – 26.5 GHz RF energy to within the current 1st IF frequency of 4.5 – 5.0 GHz. The receiver is designed to accept 1 local oscillator (LO) signal and the incoming RF energy for each polarization, and generate one, 50 MHz-wide 1st IF output for the RCP channel, and one, 50 MHz-wide 1st IF output for the LCP channel. The EVLA K-band completion receivers are being built using the Miteq TB0440LW1 mixer, rather than the previous TB0426LW1 mixer. The TB0440LW1 is specified to accept an LO or RF input from 4-40 GHz, vs. the more limited 4-26 GHz input frequency range of the Miteq TB0426LW1. The expanded output frequency range of the Miteq TB0440LW1 mixer of 0.5-20 GHz covers both the current VLA as well as the EVLA 1st IF frequency range, and should allow a seamless transition to the EVLA IF.

5.7.2.17 LO Conditioning

The current VLA K-band receiver design includes components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.7.2.18 Monitor and Control

The current VLA K-band receiver includes a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability are provided for the monitoring and control of a subset of the receiver parameters itemized in section 5.0.8. The VLA K-band receiver card cage consists of the following control, monitor, and regulation boards, and is compatible with the current VLA receiver control system:

- Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
- Slot 2: Unused, spare.
- Slot 3: Monitor Card: TBD
- Slot 4: RCP LNA bias control
- Slot 5: LCP LNA bias control
- Slot 6: Sensor interface card: Signal conditioning for the following monitored parameters:
  - Dewar 15 deg K stage Temperature
  - Dewar 50 deg K stage Temperature
  - Dewar 300 deg K stage Temperature
  - Dewar vacuum
  - Vacuum line vacuum
  - Refrigerator AC current
  - Heater AC current
  - RCP LNA FET bias voltages—1st stage + composite
  - LCP LNA FET bias voltages—1st stage + composite
- Slot 7: Control card: Control logic and drive for the following receiver control functions:
  - Vacuum pump
  - Vacuum solenoid
  - Cryogenic refrigerator
  - Dewar heaters

5.7.3 Test Results

5.7.4 References

5.8 The EVLA Ka-band Receiver System (26-40 GHz)

5.8.0 Summary (Ka Band)

The current VLA system does not include a Ka-band receiver system. However, the VLA does include 18 –26.5 GHz K-band and a 40 – 50 GHz Q-band receivers. It is anticipated that the EVLA Ka-band system design will be able to significantly leverage off of the current VLA K and Q band designs. A new feed horn will have to be designed to cover the full 26.5 – 40 GHz frequency range, and properly illuminate the VLA sub-reflector. A prototype wave guide septum OMT device scaled from the production K-band devices has been tested in NRAO Charlottesville, with promising results. It is believed that all the current K-band feed components (feed horn, circular to square transition, 45 degree transition, phase shifter, and wave guide septum OMT) may be scaled down to Ka band without major redesign. The Ka-band design shall include 2, 4 GHz-wide polarization pairs, with each of the two polarization pairs being independently tunable. Frequency conversion from the Ka-band "sky frequency" to the 8 – 12 GHz, EVLA 1st IF frequency will be included on the receiver. On-receiver frequency conversion is already the norm on the current VLA K and Q band receivers.

5.8.1 Introduction

5.8.2 Specifications and Requirements

5.8.2.1 Frequency Coverage

EVLA Ka-band 3 dB frequency coverage shall cover the frequency range of 28 – 40 GHz in 5 bands. Gain linearity within that range will be < +/- 1.5 dB.

5.8.2.2 Instantaneous Bandwidth

EVLA Ka-band instantaneous bandwidth will include 2, independently tunable, 4 GHz-wide, polarization pairs.

5.8.2.3 Receiver Temperature

The EVLA Ka-band receiver noise temperature shall be less than TBD K across the full frequency coverage specified.

5.8.2.4 Instantaneous Dynamic Range

The EVLA Ka-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.8.2.5.0 LO Input

Phase-synchronized local oscillator references shall be provided to the ELVA Ka-band receiver that shall be used in the receiver down converter section to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.8.2.5.1 LO Input Frequencies

The 5 local oscillator tones used to convert the Ka-band signals to the 1st IF frequency of 12 – 8 GHz, shall be fixed CW tones at 12, 13, 14, 15, and 16 GHz.

5.8.2.5.2 LO Input Purity

The 5 local oscillator tones used to convert the Ka-band signals to the 1st IF frequency of 12 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.8.2.5.3 LO Input Power Levels

The 5 local oscillator tones used to convert the Ka-band signals to the 1st IF frequency of 12 – 180 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.8.2.6 RF Output Power

The EVLA Ka-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.8.2.7 AC Input Power
150 VAC RMS AC power is required to power the EVLA Ka -band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA Ka -band receiver CTI-350 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.8.2.8 DC Input Power
The EVLA Ka -band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA Ka -band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.8.2.9 Total Power Dissipation
The total power dissipation of the EVLA Ka -band receiver shall be <= TBD W.

5.8.2.10.0 Cryogenics
The EVLA Ka -band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.8.2.10.1 Refrigerator
A CTI-350 refrigerator will be used to cool the EVLA Ka -Band dewar. The CTI-350 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.8.2.10.2 Compressor
Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.8.2.11 Feed horn
The EVLA Ka-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. It is anticipated that a scaled version of the current VLA K-band feed horn will meet all EVLA Ka-band requirements. The feed will be designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the Ka-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.8.2.12 Polarization
The Ka-Band design is conceptually the same as X-Band.

TBD Table TBD – Ka-Band OMT Specifications

19 Item	Nomenclature

Type	Boifot Junction
Frequency Range	26.5 – 40.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Cross-polarization Isolation	> xx dB TBD
Port Isolation	>xx dB TBD

Table TBD– Ka-Band Phase-Shifter

20 **Item**	**Nomenclature**
Type	90 deg.
Frequency Range	26.5 – 40.0 GHz
Insertion Loss	> xx dB TBD
Return Loss	> xx dB TBD
Isolation	> xx dB TBD
Amplitude Balance	< xx dB TBD
Phase Balance	< xx deg TBD

5.8.2.13 Calibration

The EVLA Ka -band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all Ka-band receivers across the entire EVLA array.

5.8.2.14 Cryogenically-cooled Amplifiers

The EVLA Ka -band receiver shall include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.8.2.15 Room Temperature RF Amplifiers

The EVLA Ka -band receiver shall include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.8.2.16 1st IF Conversion

The EVLA Ka-band receiver will include the mixer, filter, and isolator components required to convert the received 26 – 40 GHz RF energy to within the 1st IF frequency of 8 – 12 GHz. The on-receiver converter shall be designed to accept 2, independently tunable local oscillator (LO) signals and the incoming RF energy for each polarization, and generate two, 4 GHz-wide 1st IF outputs for the RCP channel, and two, 4 GHz-wide 1st IF outputs for the LCP channel.

5.8.2.17 LO Conditioning

The EVLA Ka-band shall include components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators. A detailed description of the LO conditioning components for each band may be found in each receiver section of this chapter.

5.8.2.18 Monitor and Control

The EVLA Ka -band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA Ka -band receiver card cage will consist of the following control, monitor, and regulation boards, and will be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.8.3 Test Results
5.8.4 References

5.9 The EVLA Q-band Receiver System (40-50 GHz)
5.9.0 Summary (Q Band)

The existing VLA, F110 Q-band receiver has the capability to tune across the entire, planned EVLA Q-band range of 40 – 50 GHz, however, a number of components in the IF section will have to be changed-out to provide the proposed, 4 GHz-wide instantaneous IF channels. In addition, the number of IF outputs will be increased from the current 2 x 50 MHz x 2 polarizations, to 2 x 4 GHz x 2 polarizations, with each of the two polarization pairs being independently tunable.

5.9.1 Introduction

5.9.2 Specifications and Requirements

5.9.2.1 Frequency Coverage

EVLA Q-band 3 dB frequency coverage shall cover the frequency range of 40 – 50 GHz in 4 bands. Gain linearity within that range will be < +/- 1.5 dB.

5.9.2.2 Instantaneous Bandwidth

EVLA Q-band instantaneous bandwidth will include 2, independently tunable, 4 GHz-wide, polarization pairs.

5.9.2.3 Receiver Temperature

The EVLA Q-band receiver noise temperature currently averages 55.9 K across the full frequency coverage specified.

5.9.2.4 Instantaneous Dynamic Range

The EVLA Q-band receiver linear, instantaneous dynamic range shall be => TBD dB. The receiver 1 dB compression point shall be => TBD dB.

5.9.2.5.0 LO Input

Phase-synchronized local oscillator references shall be provided to the ELVA Q-band receiver which shall be used in the receiver down converter section to convert the input frequency of the receiver to the 1st intermediate frequency (IF) band of 8 – 12 GHz.

5.9.2.5.1 LO Input Frequencies

The local oscillator used to convert the Q-band signals to the 1st IF frequency of 12 – 8 GHz, shall be fixed CW tones at 17, 18, 19, and 20 GHz.

5.9.2.5.2 LO Input Purity

The 4 local oscillator tones used to convert the Q-band signals to the 1st IF frequency of 12 – 8 GHz, shall have spectral purity parameter specifications >= those of the currently used L104, VLBA synthesizer module.

5.9.2.5.3 LO Input Power Levels

The 4 local oscillator tones used to convert the Q-band signals to the 1st IF frequency of 12 – 180 GHz, shall have a distributed, at-receiver input power level of >= 0 dBm.

5.9.2.6 RF Output Power

The EVLA Q-band receiver front-end RF output total noise power shall be –40 +/- 3 dBm.

5.9.2.7 AC Input Power

150 VAC RMS AC power is required to power the EVLA Q-band dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the EVLA Q-band receiver CTI-22 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.9.2.8 DC Input Power

The EVLA Q-band receiver shall require the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

As with the VLA receivers, the EVLA Q-band receivers shall generate all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power will be converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.9.2.9 Total Power Dissipation

The total power dissipation of the EVLA Q-band receiver shall be <= TBD W.

5.9.2.10.0 Cryogenics

The EVLA Q-band receivers shall use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.9.2.10.1 Refrigerator

As with the VLA receivers, A CTI-22 refrigerator will be used to cool the EVLA Q-Band dewar. The CTI-22 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.9.2.10.2 Compressor

Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna "elevation platform".

5.9.2.11 Feed horn

The EVLA Q-band receiver will include a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The current VLA Q-band feed horn meets all EVLA K-band requirements, and will therefore be unchanged during the EVLA Q-band receiver conversion. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the Q-band feed may be found in the "Antenna" and "Feeds" chapters of this EVLA Project Book document.

5.9.2.12 Polarization

The current VLA Q-Band design is planned to remain the same for EVLA. The polarizer in Q-Band is purchased from Atlantic Microwave. It is a, Septum style, single wave-guide component.

TBD Table TBD – Q-Band Polarizer Specifications (current spec's)

21 **Item**	**Nomenclature**
Type	Septum
Frequency Range	40.0 – 50.0 GHz
Insertion Loss	Not specified
VSWR	1.3:1 max (main and aux ports for both LCP and RCP)
Coupling (Both LCP and RCP ports)	Not specified (> 29 dB)
Ellipticity	1.0 dB max.
Directivity	15 dB min.
Port Isolation	>18 dB

5.9.2.13 Calibration

The EVLA Q-band receiver will include components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both low and high noise injection will be provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing "cold sky", and the high level injected noise power set to from 5% to 10% of the receiver total power output when observing the sun. Calibration pulse control shall be provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all Q-band receivers across the entire EVLA array.

5.9.2.14 Cryogenically-cooled Amplifiers
The EVLA Q-band receiver shall include 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.9.2.15 Room Temperature RF Amplifiers
The EVLA Q-band receiver shall include additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.9.2.16 1st IF Conversion
The EVLA Q-band receiver will include the mixer, filter, and isolator components required to convert the received 40 – 50 GHz RF energy to within the 1st IF frequency of 8 – 12 GHz. The on-receiver converter shall be designed to accept 2, independently tunable local oscillator (LO) signals and the incoming RF energy for each polarization, and generate two, 4 GHz-wide 1st IF outputs for the RCP channel, and two, 4 GHz-wide 1st IF outputs for the LCP channel. The current F210, VLA Q-band receiver outputs only a single 1st IF channel for each polarization, so components will be added to the existing receivers to accept a 2nd, independent LO input, and output the 2nd pair of 4 GHz-wide 1st IF channels.

5.9.2.17 LO Conditioning
The EVLA Q-band receiver shall include the same components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver as are used in the VLA, F210 Q-band receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators. A detailed description of the LO conditioning components for each band may be found in each receiver section of this chapter.

5.9.2.18 Monitor and Control
The EVLA Q-band receiver will include a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of the receiver parameters itemized in section 5.0.8. The EVLA Q-band receiver card cage shall consist of the following control, monitor, and regulation boards, and shall be designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.
Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the 15 monitored parameters specified in 5.0.8.
Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.9.3 Test Results
5.9.4 References

5.10 The EVLA Q-band Completion Receiver System (40-50 GHz)

5.10.0 Summary (Q-Band Completion)

The EVLA Q-band completion project will fill-out the current VLA, 28 antenna array by building an additional 5 (3, + 2 spares), 18 – 26.5 GHz receivers of the current F210 design. Some internal mixer and IF components will be re-specified to allow a more easy transition to the EVLA 4 GHz IF design.

5.10.1 Introduction

5.10.2 Specifications and Requirements

5.10.2.1 Frequency Coverage

VLA Q-band receiver 3 dB frequency coverage is equal to the EVLA Q-band receiver frequency range of 40 – 50 GHz in 4 bands. Gain linearity within that range is < +/- 1.5 dB.

5.10.2.2 Instantaneous Bandwidth

The VLA Q-band receiver includes a single, independently tunable 50 MHz-wide polarization pairs, which may be tuned anywhere within the frequency coverage of the receiver, as limited by the F3 and F12 LO locking capabilities.

5.10.2.3 Receiver Temperature

The VLA Q-band receiver noise temperature currently averages 55.9 K across the full frequency coverage specified.

5.10.2.4 Instantaneous Dynamic Range

The instantaneous dynamic range of the current VLA F210 Q-band receiver is TBD. The receiver 1 dB compression point = TBD dB. The instantaneous dynamic range of the EVLA Q-band receivers shall match or exceed the current F210 receiver.

5.10.2.5.0 LO Input

The local oscillator used to convert the Q-band completion receiver signals to the 1st IF frequency of 12 - 14 GHz will continue to be the current VLA F3 LO module. The local oscillator used to convert the Q-band completion 1st IF signals to the 2nd IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F12 module.

5.10.2.5.1 LO Input Frequencies

The local oscillator used to convert the Q-band completion receiver signals to the 1st IF frequency of 12 - 14 GHz will continue to be the current VLA F3 LO module. The local oscillator used to convert the Q-band completion 1st IF signals to the 2nd IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F12 module.

5.10.2.5.2 LO Input Purity

The local oscillator used to convert the Q-band completion receiver signals to the 1st IF frequency of 12 - 14 GHz shall continue to be the current VLA F3 LO module. The local oscillator used to convert the Q-band completion 1st IF signals to the 2nd IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F12 module.

5.10.2.5.3 LO Input Power Levels

The local oscillator used to convert the Q-band completion receiver signals to the 1st IF frequency of 12 - 14 GHz shall continue to be the current VLA F3 LO module. The local oscillator used to convert the Q-band completion 1st IF signals to the 2nd IF frequency of 4.5 – 5.0 GHz will continue to be the current VLA F12 module.

5.10.2.6 RF Output Power

The VLA Q-band receiver front-end RF output total noise power is currently –40 +/- 3 dBm.

5.10.2.7 AC Input Power

150 VAC RMS AC power is required to power the VLA Q-band receiver dewar warm-up heaters, and 150 VAC RMS shifted phase AC power is required to power the VLA Q-band receiver CTI-22 refrigerator unit. The current draw of these devices is as follows:

150 VAC @ TBD A
150 VAC, shifted phase @ TBD A

5.10.2.8 DC Input Power

The VLA Q-band receiver requires the following DC input power:

+15 VDC @ TBD A
- 15 VDC @ TBD A

The VLA Q-band receiver generates all other required, regulated DC voltages on-card from the +/- 15 VDC bus. The +/- 15 VDC power is converted from the 120 VAC, regulated, critical-power circuit via a remotely mounted, linear DC power supply.

5.10.2.9 Total Power Dissipation

The total power dissipation of the VLA Q-band receiver is <= TBD W.

5.10.2.10.0 Cryogenics

VLA Q-band receivers use an on-receiver cryogenic refrigerator to cool the dewar. Compressed helium for the refrigerator will be supplied from compressor line TBD, which is pressurized by one of two remotely mounted Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units.

5.10.2.10.1 Refrigerator

VLA Q-band receiver uses A CTI-22 refrigerator to cool dewar. The CTI-2 refrigerator requires TBD W of 2-phase, 150 VAC electrical power, and a TBD CFPM flow of compressed helium, at a TBD pressure.

5.10.2.10.2 Compressor

Compressed helium will be provided by 1 of the 2 upgraded, Copeland Corporation Model 3RAA-031-TAC, high capacity helium compressor units. The compressors are remotely-mounted on the VLA/EVLA antenna “elevation platform”.

5.10.2.11 Feed horn

The VLA Q-band receiver includes a NRAO custom-designed, very-wide-bandwidth, corrugated, conical feed horn. The current VLA Q-band feed horn meets all EVLA K-band requirements, and will therefore be unchanged during the EVLA Q-band receiver conversion. The feed is designed to capture the maximum amount of microwave RF energy reflected off of the cassegrain sub-reflector, without picking-up significant amounts of off-axis ground or antenna structure radiation. A detailed description of the Q-band feed may be found in the “Antenna” and “Feeds” chapters of this EVLA Project Book document.

5.10.2.12 Polarization

TBD Table TBD – Q-Band Polarizer Specifications (current spec’s)

22 **Item**	**Nomenclature**
Type	Septum
Frequency Range	40.0 – 50.0 GHz

Insertion Loss	Not specified
VSWR	1.3:1 max (main and aux ports for both LCP and RCP)
Coupling (Both LCP and RCP ports)	Not specified (> 29 dB)
Ellipticity	1.0 dB max.
Directivity	15 dB min.
Port Isolation	>18 dB

5.10.2.13 Calibration

The VLA Q-band receiver includes components designed to generate and inject fully characterized, synchronously-switched noise power across the entire receiver tuning range. Both only low noise injection is provided, with the low level injected noise power set to from 5% to 10% of the receiver total power output when observing “cold sky”, Calibration pulse control is provided via an external, 50% duty cycle, 19.2 Hz, 28 VDC square wave that is phase synchronized for all Q-band receivers across the entire VLA array.

5.10.2.14 Cryogenically-cooled Amplifiers

The VLA Q-band receiver includes 2 NRAO-manufactured, cryogenically-cooled, Indium Phosphide (InP), wide bandwidth, low noise amplifiers, 1 for each polarization. The specifications for these amplifiers follows:

TBD list

5.10.2.15 Room Temperature RF Amplifiers

The VLA Q-band receiver includes additional room temperature amplifiers designed to generate the optimum RF power level for injection into the 1st stage mixer. The specifications for these amplifiers follows:

TBD list

5.10.2.16 1st IF Conversion

The VLA Q-band receiver design currently includes the mixer, filter, and isolator components required to convert the received 40 – 50 GHz RF energy to within the current 1st IF frequency of 12 – 14 GHz. The receiver is designed to accept 1 local oscillator (LO) signal and the incoming RF energy for each polarization, and generate one, 50 MHz-wide 1st IF output for the RCP channel, and one, 50 MHz-wide 1st IF output for the LCP channel.

5.10.2.17 LO Conditioning

The VLA Q-band receiver includes components designed to generate the optimum LO power level for injection into the LO-up-converter and mixer stages of the receiver. These components include high 1 dB compression point amplifiers, filters, and fixed attenuators

5.10.2.18 Monitor and Control

The VLA Q-band receiver includes a card cage with PCBs designed to monitor and control the temperature, vacuum, and signal-flow characteristics of the receiver. Sensors and input-output (I/O) capability will be provided for the monitoring and control of a subset of the receiver parameters itemized in section 5.0.8. The VLA Q-band receiver card cage consists of the following control, monitor, and regulation boards, and is designed to be compatible with the current VLA receiver control system:

Slot 1: RF Card: RF/IF room temperature amplification, filtering, and isolation.
Slot 2: Unused, spare.

Slot 3: Monitor Card: TBD
Slot 4: RCP LNA bias control
Slot 5: LCP LNA bias control
Slot 6: Sensor interface card: Signal conditioning for the following monitored parameters:
- Dewar 15 deg K stage Temperature
- Dewar 50 deg K stage Temperature
- Dewar 300 deg K stage Temperature
- Dewar vacuum
- Vacuum line vacuum
- Refrigerator AC current
- Heater AC current
- RCP LNA FET bias voltages—1st stage + composite
- LCP LNA FET bias voltages—1st stage + composite

Slot 7: Control card: Control logic and drive for the following receiver control functions:
- Vacuum pump
- Vacuum solenoid
- Cryogenic refrigerator
- Dewar heaters

5.10.3 Test Results
5.10.4 References

5.11 Water Vapor Radiometer
5.11.0 Overview
Water vapor radiometers are being designed to measure the atmospheric water line at 22 GHz above each of the EVLA antennas. Fluctuations in the amount of water vapor above each antenna causes decorrelation of astronomical signals, which in principle can be improved by applying an antenna-based correction derived from the 22 GHz measurements. The phase fluctuations introduced by the water vapor are directly proportional to frequency, and so will affect the high frequency bands of the EVLA the most, especially in its most extended configurations.

5.11.1 Current design
The current design for the WVR splits the RF output from the K-band receiver and takes one of those outputs to a box, to be attached to on the underneath of the K-band receiver, containing the WVR electronics. Here the signal is amplified and divided into three channels covering the water line, and are detected using tunnel diode detectors. The rms sensitivity of each channel needs to be approximately 10 mK on timescales of ~3 to 3×10^3 seconds, a requirement determined from the atmospheric modeling predictions of Butler (1999, VLA Scientific Memo 177), and translates to a fractional gain stability of the whole system (including the K-band LNA and calibration noise diodes) of 1 part in 10^4 on those same timescales. Such gain stability requirements lead to very stringent temperature stability requirements for the electronics. The first stage of the temperature stability can be maintained by the HVAC, but subsequent stability requires the use of proportionally controlled thermo-electric coolers.

5.11.2 Monitor and control system
The monitor and control system will need to record data from each of the three WVR channels, and monitor the temperature at a number of locations inside and outside the WVR box. Corrections may be applied in real time to the astronomical data, although the information must also be saved in order to have the option of applying corrections off-line.

5.11.3 Maintenance issues:
Good gain stability and temperature stability are essential for the WVRs, and will have to be monitored regularly

for performance. The astronomical value of the WVRs will depend on the time of year and EVLA configuration, however, and will probably provide periods when maintenance can be carried out without much impact on the operation of the EVLA. In particular, in its current design with only three channels, the WVR will only be able to make corrections to astronomical data for path length fluctuations due to water vapor, and will not be sensitive to path length fluctuations due to liquid water in the atmosphere. This suggests it may be most useful during the spring and early summer, and in the EVLA's most extended configurations. It is therefore likely that maintenance can be carried out during the stable winter months and during the rainy season. The WVR electronics box will be designed so that it can be unmounted from a K-band receiver for maintenance without having to remove the K-band receiver from the feed ring itself.