EVLA Project Book, Chapter 5.

5 RECEIVERS

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Revision History

2001-July-01: Initial release.
2001-Oct-01: System definition & detail added.
2002-May-17: Consolidated.
2003-Aug-18: Expanded Solar Mode information & receiver details.
2004-Nov-15: Update table, card cage & front-end text. Add L&S-Band HP gain block, interim C-Band polarizer & gain slope.
2004-Dec-06: Add receiver & gain equalizer block diagrams. Minor corrections to table & text. Add headroom spec discussion.
2006-Mar-24: Minor updates, remove gain equalizer section (now in LO/IF Chapter)
2007 Aug-27: Minor updates, new information added to sections dealing with OMT development and EVLA X-Band receiver

5.0 Receiver Parameters (Summary)

TABLE 5-1 : EVLA RECEIVER PARAMETERS

Frequency (GHz)	1.2 - 2[1]	2 – 4	4 – 8	8 – 12	12 – 18	18 – 26.5	26.5 – 40	40 - 50
Band[2]	"L"	"S"	"C"	"X"	"Ku"	"K"	"Ka"	"Q"
Tsys (°K)	26	26	26	30	37	59	53	74 - 116
Tsky[3] (°K)	12	12	10	10	12	25	13	26 - 68
Trcvr[4] (°K)	14	15	16	20	25	34	40	48
Feed Type[5]	Compact	Compact	Compact	Conical	Conical	Conical	Conical	Conical
Efficiency[6]	0.45	0.62	0.60	0.56	0.54	0.51	0.39	0.34
Location[7]	-84.1°	101.6°	165.2°	-156.3°	47.6°	25.9°	-16.9°	4.5°
Polarizer Type[8]	QR, Hyb.	QR, Hyb.	QR, Hyb.	note[9]	PS,W-B	PS,W-B	PS,W-B	SS
LO Frequency (GHz)	NA	NA	NA	NA	NA	15–18	14.7-16.3	16.7-20
LO Multiplier[10] (GHz)	NA	NA	NA	NA	NA	X 2	X 3	X 3
Frequency Output	1 – 2	2 – 4	4 – 8	8 – 12	8 – 18	8 – 16.5	8 – 18	8 - 18
Output Power[11] (dBm)	-33	-34	-31	-32	-35	-36	-34	-38
Est. Headroom[12] (dB)	35	36	31	30	28	21	23	15
Output to Module[13]	T302	T302	T302	T304	T303	T303	T303	T303
Refrigerator Model[14]	1020 ?	350	350	22 ?	350	350	350	22
Details: 5.1.7.	1	2	3	4	5	6	7	8

[1] 1 GHz is the nominal low end of this band, but full performance is specified only above 1.2 GHz.
[2] These 60-year-old radar band designations are very obsolete, but handy.
[3] Antenna & atmosphere contribution to Tsys when pointed at zenith in dry winter weather. Includes 3°K cosmic background.
[4] Averaged across full band, assumes LNA noise temperature of 1°K/GHz below 8 GHz, and 0,5°K/GHz above 8 GHz.
[5] All feeds are corrugated horns.
[6] Total system efficiency as specified in the EVLA Requirements.
[7] As seen from apex. Direction is counterclockwise around the feed circle with 0° at right side of elevation axis.
[8] All dual circular polarization. "QR, Hyb" means a quad-ridge OMT followed by a 90° hybrid. "PS, W-B" means a waveguide Phase Shifter followed by Wollack's implementation of a Bøifot class IIb OMT. "SS" means a Sloping Septum polarizer.
[9] Type will be decided following design studies. See 5.1.7.4
[10] The frequencies in the row above will be multiplied by this factor in the receiver.
[11] Total power contained in the output band specified, observing "cold sky".
[12] With respect to the 1% compression point when on "cold sky". Values are from receiver noise model simulation. See 5.1.5.1
[13] RF/IF output signal from receiver feeds the designated frequency converter module: T302 = LSC Converter, T303 = UX Converter, T304 = Baseband Converter
[14] CTI Incorporated model numbers.

5.1 General:

This section will cover those items common to all the receivers. Individual receivers will be discussed in the sections indicated in the "Details" row of table 5-1.

5.1.1 Cryogenics:

The new EVLA receiver upgrades will all be designed around the CTI Model 350 refrigerator. The CTI Model 350 refrigerator was chosen over the CTI model 22 refrigerator for load and temperature stability, long-term maintenance cost and over all reliability. Two stages of cooling are provided by the Model 350 refrigerators - the 1st stage at 50°K provides cooling for the thermal radiation shielding and the 2nd stage at 15°K for the low-noise amplifiers. The heart of the cryogenic system is the piston type compressor that supplies helium gas to the refrigerator through a set of stainless steel rigid and flexible helium lines. Three components – a refrigerator, compressor and helium lines make up what is commonly known as a closed-loop system. The compressor helium pressure (typically 280/80 and as high as 300/100 psi) is monitored by pressure transducers. Due to the number of receivers/refrigerators added by the EVLA Project, a third helium compressor is required to meet the additional helium demand. The Cryo Group has built 30 new compressors, one for each antenna plus two spare units.

Because of the large size and mass of the new EVLA L-Band receiver, a high capacity refrigerator may be required. The CTI Model 1020 fridge freed up from the old VLA A-Rack dewar may be used instead of a 350.

5.1.1.1 Vacuum:

Vacuum pumps are required to evacuate the receivers (i.e., the dewar or vacuum chamber) to 0.5 Torr in order for the cryogenic refrigerator to perform to its maximum efficiency. Receiver pump-down time is determined by vacuum pump rating, dewar volume and vacuum manifold size. Two vacuum pumps are required for the EVLA receivers. The existing 7 scfm pump on each antenna is supplemented by a new 14 scfm unit. The higher scfm pump will accommodate the additional new S and Ka-Band EVLA front-ends. The vacuum manifold is fabricated out of 1¼" stainless steel seamless tubing. The vacuum integrity is maintained by incorporating a vacuum rated solenoid valve between the vacuum manifold and the dewar. The pressure in the manifold and the dewar is monitored by vacuum thermocouples.

Each pump is connected to a vacuum manifold, which serves 4 receivers. A ¾" vacuum hose is used to connect to the manifold. Each receiver controls a solenoid that can open the line between the vacuum manifold and the dewar. Each receiver can issue a "pump request" signal to the vacuum pump on its manifold. When no receivers are being pumped, a solenoid on the manifold is opened to atmosphere. The resulting pressure on the receiver's solenoid causes it to seat more firmly and reduces any tendency to leak. Control logic in the receiver controls the sequencing of pumps, solenoids, heaters, and refrigerators.

5.1.2 Noise calibration:

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

5.1.3 Monitor & Control:

Each receiver has a set of ancillary electronics attached, traditionally called the “card cage”. This circuitry controls the state of the receiver, provides bias to the Low-Noise Amplifiers, and provides preliminary signal conditioning for the monitor outputs. It accepts commands from, and provides data to, the Monitor & Control system (M&C) via the Module Interface Board (MIB). The M&C system circuitry is designed for ease of production with modern components. The M&C system reports the following parameters:

Dewar Temperature: 15°K, 50°K stations and case (ambient) temperature.
Vacuum Pressure: dewar & manifold.
LNA FET biases: gate and drain voltages and currents for each stage of each low noise amplifier.
Noise source parameters: voltage, current, and attenuator setting (if required).
Switch positions and gains for normal or solar observing.
Optional RCP, LCP IF & LO total power detectors (for diagnostic purposes).
Card Cage power supply rails.
Receiver ID: Band, Serial Number and Revision Level.

The M&C system can command the following actions:
Cool-down, Warm-up, Pump dewar, etc.
Set configuration for normal or solar observing.

The EVLA card cage contains two newly designed boards. The LNA bias card is designed to provide the gate and drain bias for up to 8 amplifier stages, which readily accommodates the 3 or 4 stages required by the LNAs in each polarization channel. The control card provides the interface to the various temperature and pressure sensors, implements the state machine control required for sequencing the pump request, dewar vacuum solenoid and cryogenic fridge during the autonomous cool-down of the receiver, and supplies the interface to the M&C interface F317 module for receiving control commands and returning monitored status information. In order to avoid potential glitches in RF gain due to pickup on the LNA bias lines from the toggling of digital signal lines within the card cage, the M&C system will only be allowed to actively access the card cage when astronomical data are not being taken.

A new diode protection card is used on the EVLA receivers. This card is mounted directly to the 32-pin hermetic connector and protects the LNAs from over-voltage conditions or transient spikes. It also contains a serial EPROM from which the M&C system can obtain the receiver’s ID information (i.e., frequency band, serial number & revision number). Unlike the old VLA receivers where this information was hardwired inside the card cage, this scheme -allows the card cage to be universal. It can be swapped between receivers without requiring any modifications.

5.1.4 Solar Observing:

To provide the maximum range of solar observation with minimum cost and degradation of normal observation, a “coupler-fed” receiver configuration has been adopted. In this scheme, a separate signal path is provided for observing the sun. A directional coupler before the Low Noise Amplifier (LNA) extracts a portion of the input signal and feeds it to a room-temperature amplifier which has a much higher dynamic range than the LNAs. This amplifier is termed “High Noise Amplifier”. A switch selects the output of either the LNA or the HNA for transmission to the rest of the receiver system.

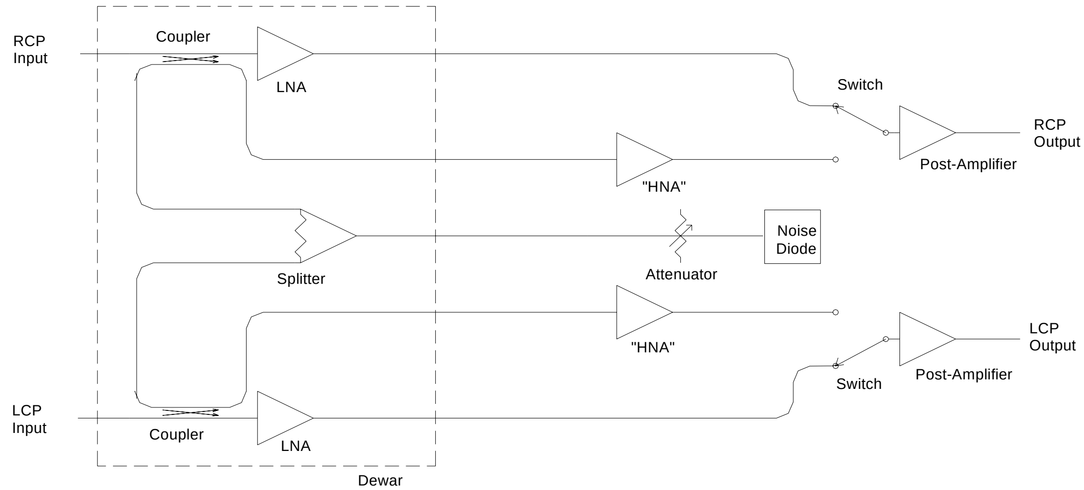

Figure 5-1 : Coupler-Fed Scheme for Solar Observing

This scheme has minimal impact on normal observing since the coupler required is already in the receiver for noise calibration injection. Instead of the usual termination, the coupler's fourth port is connected to the input of the HNA by a length of transmission line.

Note that for normal observing, the source signal is fed directly into the LNA, while the noise calibration is injected through the (typically 30-dB) coupled line. For the HNA case, the situation is reversed: the source signal is coupled in 30-dB down, while the noise calibration is fed in directly to the HNA. This scheme allows for both low and high noise calibration levels to be injected into the appropriate signal path from a single noise diode without additional amplification. A settable attenuator will be required to adjust the noise calibration level across the very wide range of input powers envisioned.

For source temperatures at the lower end of the solar range, the receiver temperature may not be negligible, and the assumption that all antennas have the same system temperature will not be valid. For this reason, each solar receiver will need its own solar noise calibration system. Since this consists mainly of the substitution of a controllable attenuator for a fixed one, the cost per receiver is small.

The number of receiver bands that will incorporate the Solar Observing mode has yet to be determined. The new L-Band receivers will definitely have this capability added and one other band may also be outfitted (perhaps S or C-Band) depending on the state of the EVLA contingency funds. All the other new EVLA receiver bands will be designed so that the coupler-fed scheme may be added at a later date with minimal changes. One prototype receiver in each band will have the Solar Mode configuration evaluated. The K and Q-Band receivers will be excluded since these existing receivers would require substantial modifications to the dewar and microwave plumbing.

See EVLA Memo 72 for more details. A simplified block diagram illustrating the coupler-fed scheme is shown in Figure 5-1.

5.1.5 Polarizers:

Circular polarizers are required to separate the astronomical signal into its left and right orthogonal components. No single polarizer design can perform this function adequately in each of the 8 bands which will be used to cover the 1 – 50 GHz EVLA frequency range. Several different types of circular polarizers will be employed:

5.1.5.1 L, S & C-Band (1-8 GHz) : These 3 bands will use a quad-ridge orthomode junction (OMT) and a 90° hybrid. The OMTs for 1-2 GHz and 4-8 GHz have been designed and prototypes have been fabricated and are undergoing evaluation. The OMTs for the 2-4 GHz will be scaled from the 1-2 GHz design.

5.1.5.2 X-Band (8-12 GHz) : The EVLA X-Band receiver will not re-use the commercial sloping-septum circular polarizer currently employed in the old VLA receiver as it is too narrow-band. However, the 1.5:1 bandwidth ratio required is not so wide as to necessitate an octave wide polarizer. A quad-ridge OMT design may be difficult to fabricate at these frequencies because of the small size of the coaxial probes. A scaled version of the polarizer currently used in the VLA/EVLA K-Band receiver is a possible option, however the size of the Srikanth phase-shifter and Wollack OMT combination would be approximately 29 inches and would make for an unwieldy dewar size. The solution to this OMT problem will explored in a 2-pronged attack. One track has the CDL developing an all-waveguide OMT solution. The second track has an engineer at Green Bank working on a planar OMT prototype. We will select the design that best meets our performance and physical constraints.

5.1.5.3 Ku, K & Ka-Band (12-40 GHz) : These 3 bands will use a corrugated waveguide phase-shifter designed by Srikanth, followed by Wollack's design of a Bøifot type IIb OMT. This design has been successfully used at K-Band on the VLA and will be retained on the EVLA. The polarizers required for both the Ku & Ka-Band receivers will be scaled from the K-Band design. The new Ka-Band receiver designed for the GBT is already using the 26.5-40 GHz phase-shifter and OMT designs and similar units have already been fabricated for the EVLA Ka-Band front-end.

5.1.5.4 Q-Band (40-50 GHz) : This band will retain the Atlantic Microwave sloping septum polarizer currently used on the VLA.

5.1.5 Front-End Requirements and Specifications:

The majority of the top level EVLA requirements and specifications for the front-ends are listed in Section 2.2 of the Project Book.

5.1.5.1 Headroom

In order to avoid the adverse affects of non-linearities which may arise in amplifiers, mixers or diode attenuators that are driven into compression, the design of the EVLA front-ends and IF modules attempts to ensure that the standard operating point (i.e., observing "cold" sky) is well below the saturation point of any active device. This is a delicate balance since the signal must also be well above the noise floor of the various amplifiers in the RF/IF chain to ensure the overall system temperature is not degraded. The headroom spec for the EVLA is to have all active components operating at least 20 dB below the 1% compression point (which corresponds to being about 32 dB below the 1 dB compression point) when the receiver is looking at cold sky. As can be seen from Table 5-1, the noise model simulation for the various receiver bands suggest that the 20 dB spec will be met in all bands except for Q-Band.

The major impact of insufficient headroom will only become a major limitation in the presence of strong RF interference, where unwanted harmonics and intermodulation products generated in the amplifiers and mixers may cause spurious signals to arise. It is expected that the 20 dB headroom spec will provide adequate dynamic range to mitigate the effects of both existing and future RFI. Several astronomical tests have been carried out on the VLA to explore the affects of strong CW signals on closure and imaging (see EVLA Memo 82 and 110.

5.1.6 Front-End Testing:

The following parameters are measured and archived in an easily-retrievable digital form before the receiver is installed:

Across the band:

- Receiver temperature
- Noise calibration values
- Gain
- Output power
- 1 dB compression point (only on prototype receiver).

Frequency-independent:

- Cool-down from ambient, plot vs. time.
- Normal cold-stage temperatures and other cryogenic data as required.
- Current for each supply voltage.
- Complete set of monitor data.

Also recorded:

- Serial numbers and locations (e.g., RCP or LCP) of important components

All archived data will record the date and the name of the person testing the receiver and the equipment used. Note that the T_{Rx} for the highest frequency receivers are measured in two different ways. The K, Ka & Q-Band receivers all have block converter mixers which do a wideband translation of the RF down to an 8-18 GHz IF. To properly measure performance of the RF, IF and LO components of the receiver, the radiometer sensitivities are measured by stepping the 1st LO while holding the IF frequency constant (this evaluates the effects of the LO chain on sensitivity). The second method is the so-called block converter mode where the 1st LO is held constant and the 2nd LO is stepped across the 8-18 GHz IF (this evaluates the effects of the IF match on sensitivity).

5.1.7 Receiver Details:

5.1.7.1 L-Band (1-2 GHz):

The EVLA requirement for the L-Band specifies optimum performance over the 1.2 – 2 GHz range with usable performance down to 1 GHz. The L-Band feed has been designed to meet this requirement. The S & C-Band feeds, and the L, S & C-Band receivers, will be designed for operation over a full 2:1 bandwidth. A new compact corrugated horn will replace the current lens-corrected L-Band horn. It is 13.5 feet long and 63 inches in aperture. It takes up nearly 90° of the feed circle and weighs about 625 lbs. The ring-loaded section, the mounting flange section, and the radome section are machined from solid aluminum. The remaining corrugations will be formed by stacking “rings” and “bands” and coating the exterior with epoxy-fiberglass, as was done for the VLBA L-Band feeds.

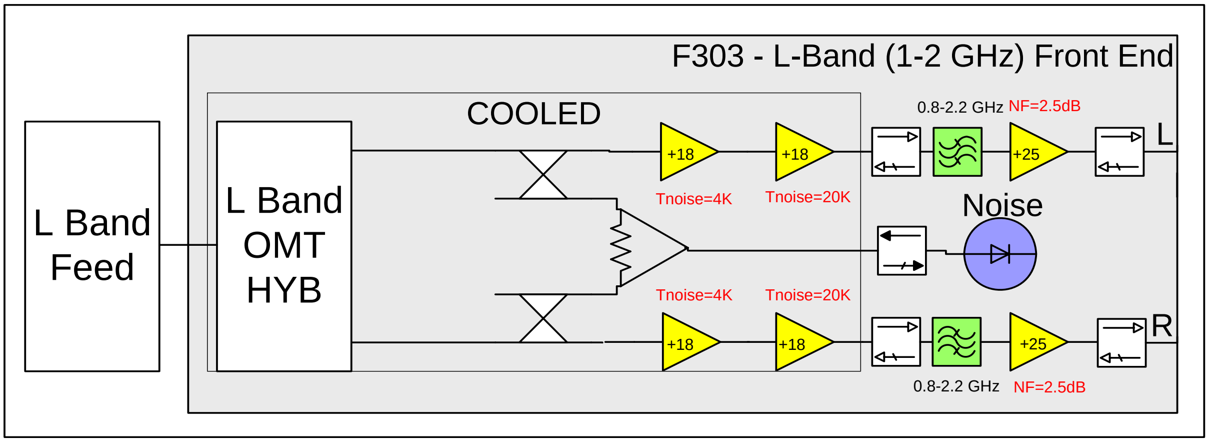

Figure 5-2: EVLA L-Band (1 - 2 GHz) Receiver

A new octave-band quad-ridge OMT has been designed for the L-Band front-end. This design will be scaled up in frequency for use at S & C-Band. Commercial 3-dB, 90° hybrids will be employed for resolving the left- and right-hand circular polarization.

The cooled Low-Noise Amplifiers (LNAs) are based on new-generation designs from NRAO's Central Development Laboratory (CDL). Amplifiers with excellent input impedance matching are necessary to meet the polarization purity specification. Since wideband cryogenic isolators are unavailable at L-Band, the CDL has developed a balanced amplifier design with an input return loss of better than 15 dB. The LNAs will be built as "gain blocks" with ~18 dB gain. Two cascaded gain blocks will be used per channel (for a total of 4 amplifiers in each dewar). The first gain block will use custom InP transistors to achieve a noise temperature of about 4°K. The second gain block will use commercial HFETs to achieve a 1 dB compression point in excess of +13 dBm but with a higher noise temperature closer to 20°K. This configuration provides the best compromise between low-noise and dynamic range. It ensures that the cryogenic amps won't saturate before the warm post-amps from the effects of the RFI currently envisioned at the VLA site. The scheme allows a switched filter bank to be added later in the room temperature portion of the signal path if necessary. This configuration also allows possibility of adding cooled filters between the cooled gain blocks at a future date to mitigate the effects of exceptionally strong RFI should it ever arise.

The LNAs provide about 35 dB of gain. External to the dewar, room temperature amplifiers provide about 25 dB more gain. This portion of the RF chain is relatively straightforward and consists of commercial isolators, filters and amplifiers.

As the new OMT design is too big to fit easily within the existing VLA L-Band dewar, an entirely new cryogenic package and receiver layout will be required. A heavily modified VLA L-Band dewar was used to evaluate the cryogenic performance of the wideband OMT in the lab and on the atenna. As new EVLA L-Band receivers are installed on the array, the old VLA L-Band dewars will be reused in the new EVLA S-Band receiver.

The new EVLA L-Band prototype receiver will be ready for test in early 2008. The production receivers will be build at a rate that exceeds the antenna upgrade schedule (i.e., about 5 per year). On the first dozen or so EVLA antennas, L-band capability will be maintained by mounting old L-Band receivers modified with balanced amplifiers and hybrid couplers to the newly installed feeds with a simple adapter ring. These "interim" receivers provide satisfactory performance over the 1.2-2 GHz band.

5.1.7.2 S-Band (2-4 GHz):

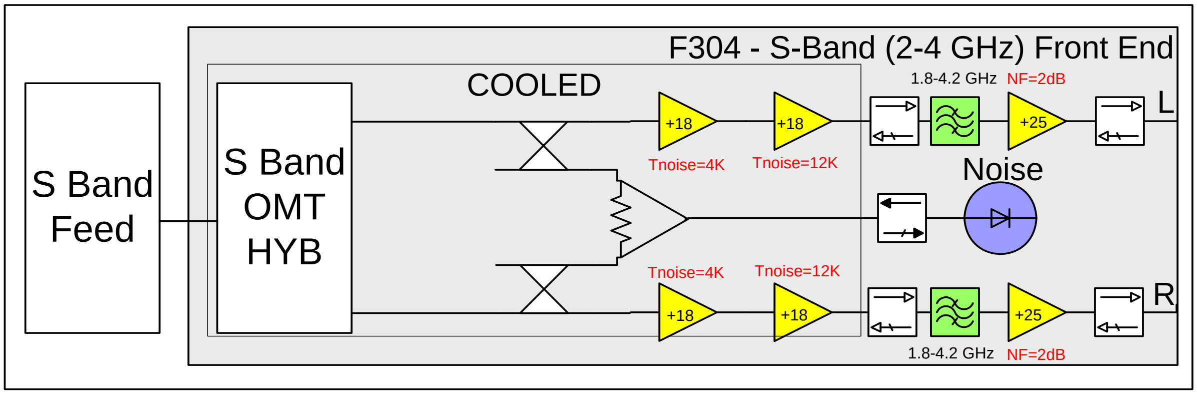

Figure 5-3: EVLA S-Band (2 - 4 GHz) Receiver

The S-Band feed is a scaled version of the EVLA C-Band feed. It was designed and fabricated using the band and ring technique used on the L-Band feed. The polarizer (a combination of a quad-ridge OMT and a 90° hybrid) will be scaled from the L-Band design. The receiver will use newly designed 2-stage balanced amplifiers from CDL which provide good input matching and high dynamic range in the presence of RFI.

The prototype S-Band receiver will be constructed in early 2008 with production scheduled to begin later that year. The current plan calls for the existing VLA L-Band dewar to be reused in the EVLA S-Band receiver. To that end, the old dewar will modified slightly to accommodate the new 2-4 GHz OMT (which should be somewhat smaller in size than the old L-Band OMT).

5.1.7.3 C-Band (4-8 GHz):

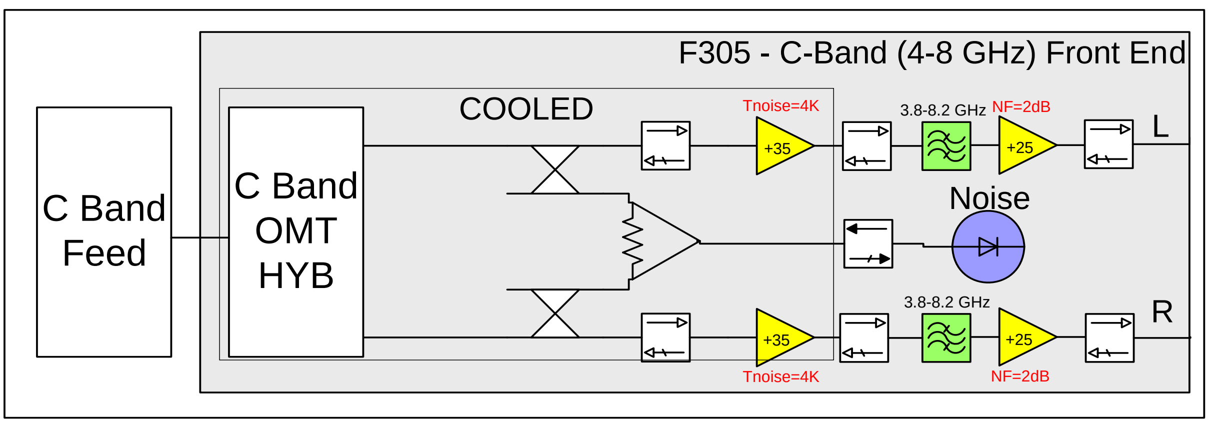

Figure 5-4: EVLA C-Band (4 - 8 GHz) Receiver

The C-Band feed is machined using centrifugal cast sections. The polarizer will consist of a quad-ridge OMT, scaled in frequency from the L-Band design, followed by a commercial 90°hybrid coupler. Since the OMT design will not be ready for the first dozen or so EVLA modified antennas, these “interim” receivers will use commercial sloping-septum polarizers, similar to the units used in the VLBA C-Band receivers.

The receiver uses cryogenic isolators and LNAs from CDL. Their existing 3-13 GHz design has been modified to achieve optimized performance across the 4-8 GHz regime. Since receivers at this frequency and higher can be packaged in small, 10” diameter dewars, the packaging of the C-Band receiver and the future X, Ku & Ka-Band systems will use the same layout and components as much as practicable.

The first EVLA-compliant wideband C-Band receiver should be complete by early 2008. The production receivers will then be built at a rate that meets or exceeds the antenna upgrade schedule (i.e., about 5 per year). This is essential since the existing VLA C-Band receiver can no longer be used after the upgrade of an antenna has begun. It should be noted that while the interim receivers has the same 4.5-5.0 GHz polarizer that the old VLA A-Rack receiver uses, that have the wideband 4-8 GHz LNA's and warm RF signal chain that the final EVLA configuration requires. They have been found to have acceptable sensitivity, albeit with poor polarization characteristics, over most of the 4-8 GHz range. This new C-Band capability is now being actively exploited with special EVLA-only antenna sub-arrays.

5.1.7.4 X-Band (8-12 GHz):

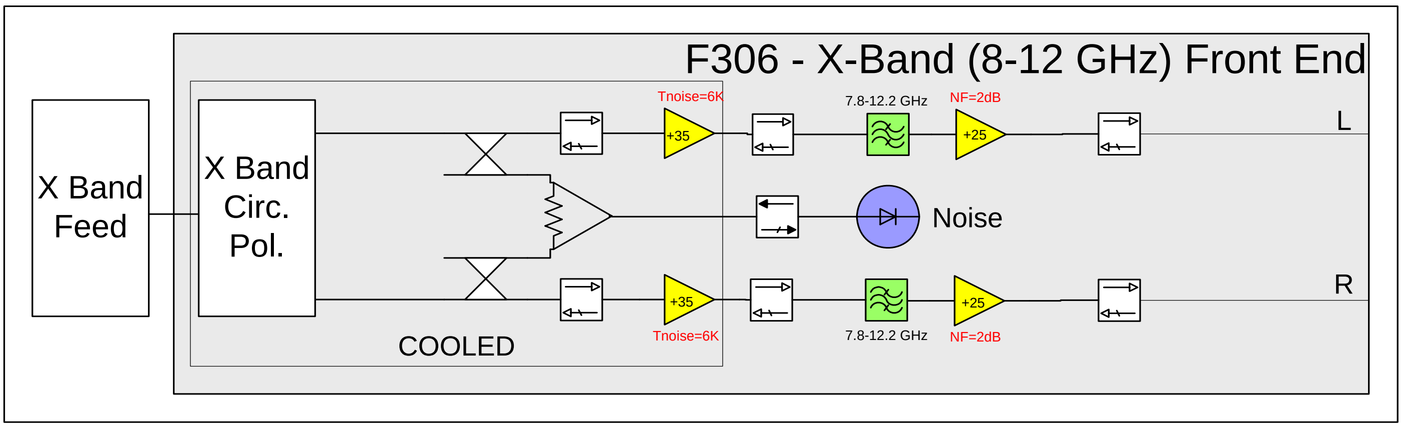

Figure 5-5: EVLA X-Band (8 - 12 GHz) Receiver

The X-Band receiver will be the last to begin production (currently scheduled for 2010). Until then the current VLA X-Band systems will be retained, limiting coverage to 8.0 – 8.8 GHz. The existing feed and receiver will be remounted in the EVLA antenna feed circle. Two prototypes of the new machined feed have been built and tested on the Green Band antenna range with successful results. Antenna 24 has been outfitted with one of the new feeds. Eventually the old X-Band feed will be replaced by the new wide-band design on all the antennas.

The EVLA X-Band receiver will not re-use the commercial sloping-septum polarizer of the old receivers, as it is too narrow-band. The 1.5:1 bandwidth ratio required is not so wide as to limit us to a quad-ridge OMT design. This scheme may be too difficult to fabricate at these frequencies because of the small size of the coaxial probes. However, if a QR-OMT could be fabricated, rather than use a 90 degree hybrid after the OMT to generate the circularly polarized channels, a cooled waveguide dielectric phase-shifter may be worth investigating. Another OMT option is to use a scaled version of the polarizer currently used in the EVLA K-Band receiver. Unfortunately the size of the Srikanth phase-shifter and Wollack OMT combination would be approximately 29 inches in length and would make for an unwieldy sized dewar nearly twice as long as that used in the current K-Band which is already our longest receiver. We might consider a planar OMT design, similar to that developed at the Radio Astronomy Lab at Berkeley, where the opposing probes feed two microstrip 180 degree hybrid couplers which then get combined in a 90 degree coupler. This would provide a very compact design but may be too lossy. The use of high-temperature superconducting circuits to minimize the insertion loss might be beneficial. Another all-waveguide solution would be to use a Mitsubishi-style ultra-thin OMT with turnstile junction. These and other polarizer options need to be explored and simulated before a final decision can be made.

The design of a new OMT needed to achieve a wideband X-Band receiver may be impacted by the 48 scfm compressor constraints on the EVLA antennas. If the OMT is not the same size or smaller than the sloping septum polarizer in the existing narrow band 8.0-8.8 GHz receiver, it will not fit inside the current dewar. This means a bigger dewar would be required. If the new dewar becomes too large to be adequately cooled by the current Model 22 refrigerator, then a new Model 350 fridge would be needed. Unfortunately the capacity of the 3 compressors on the antenna may not be able to accommodate another 350. Adding a 4th compressor would cost about $250K in parts and manpower. It might be possible to use the new EVLA compressor to cool the X, K & Ka-Band receivers, all of which would have 350 fridges (which would need a total of 51 scfm). To do so would require the new compressor to be modified to squeeze some extra cooling capacity out of it. However, there are serious concerns about the long term effect caused by using a smaller venturi to increase the pressure in the compressor. To do so will also increase the current draw in the motor, which means an increase in heat loading on the windings and thus a greater risk of compressor failure in future years. Modifying all 30 or so of the new EVLA compressors would cost about $30K. However, the long term impact of the potentially increased failure rate is unknown. Ideally it would be best to avoid either of these scenarios.

The OMT problem is being actively addressed by a 2-pronged attack. One track has Srikanth at the CDL developing an all-waveguide OMT solution. The second track has Stennes at Green Bank working on a planar OMT prototype. A planar OMT design would be guaranteed to fit inside the current X-Band dewar, although such a design may be found to be too lossy. An all-waveguide OMT design is unlikely to fit within the existing X-Band dewar footprint, however, we may be able to use a new, bigger dewar that a Model 22 would still be capable of adequately cooling.

The receiver will use LNAs from CDL based on their current 8-18 GHz design.

A new module, the F320, will interface the existing X-Band receiver and any other interim receivers to the new Monitor & Control system. This module will be phased out as new receivers come on line.

Around the middle of 2009 we will select the OMT design that best meets our performance and physical constraints. Production would begin in early 2010.

5.1.7.5 Ku-Band (12-18 GHz):

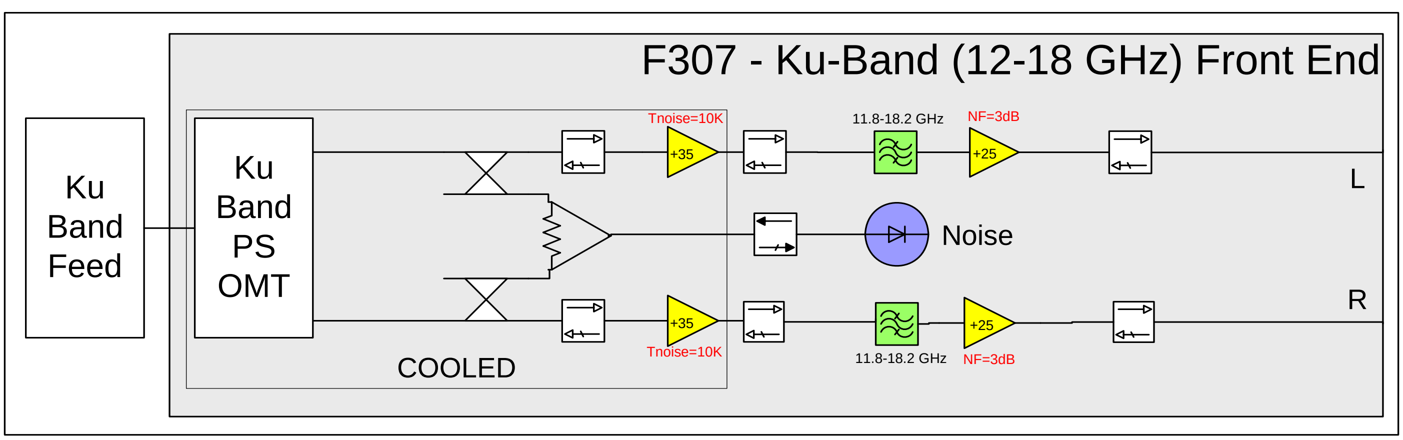

Figure 5-6: EVLA Ku-Band 12 - 18 GHz) Receiver

The design of the new Ku-Band receiver will, to a large extent, be scaled down in frequency from the K-Band receiver. It will require a newly designed linear-taper wide-band corrugated horn feed. Two prototypes are currently being machined. The circular polarizer will be based on the Srikanth phase-shifter and Wollack OMT combination, similar to the K-and Ka-Band polarizers. The receiver will use LNAs from CDL based on their current 8-18 GHz design.

The prototype Ku-Band receiver will be constructed in 2008 with production scheduled to begin in 2010. As is the case with C-Band, the existing Ku-Band receivers can no longer be used after an antenna upgrade has begun. In this case, no interim receivers will be provided. The total number of Ku-Band receivers on the array may drop to a mere handful before the new design enters mass-production.

5.7.1.6 K-Band (18-26.5 GHz):

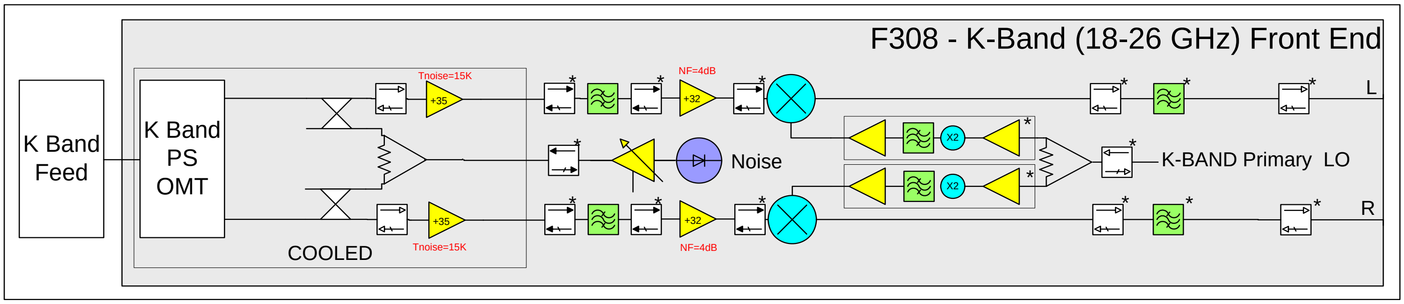

Figure 5-7: EVLA K-Band (18 - 26 GHz) Receiver

The EVLA K-Band receiver is an upgraded version of the existing VLA system. It retains the current full-bandwidth feed horn, with modifications, including a new ring load section and a new thicker top plate, to improve the feed-receiver interface both electrically and mechanically.

Early-generation GAsFET LNAs will be replaced with newer, lower-noise MAP-style versions. Upgrading many of the existing MAP LNAs with Cryo-3 devices in the first stage will also be carried out at the CDL to improve the receiver temperature by nearly 5°K. The most significant changes to the receiver are the implementation of the Block Converter scheme, which converts the entire 18-26.5 GHz RF band down to an 8-16.5 GHz IF (requiring replacement of the current mixers), and the addition of a commercial frequency doubler to enable high-side LO injection. New isolators are added and components replaced as required to improve gain flatness and "headroom".

The existing receiver bias, control, and monitoring circuitry (the "card cage") is replaced by more modern and more capable circuits.

The K-Band receiver modifications will be done at a rate that matches the antenna upgrade schedule (i.e., about 5 per year).

5.7.1.7 Ka-Band (26.5-40 GHz):

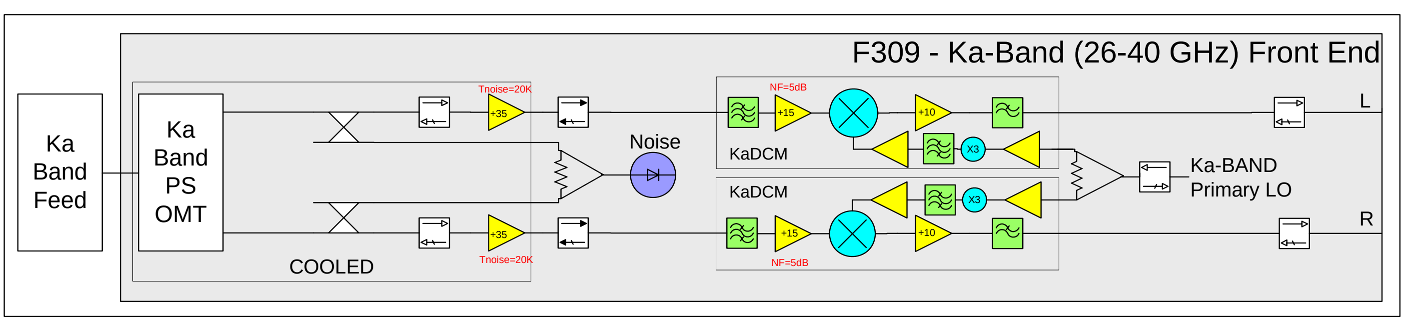

Figure 5-8: EVLA Ka-Band (26 - 40 GHz) Receiver

The design of the new Ka-Band receiver will, to a large extent, be scaled up in frequency the K-Band receiver. It will require a new feed and its circular polarizer will be based on the Srikanth phase-shifter and Wollack OMT combination. All of the feeds have been fabricated and the polarizer design has been tested at CDL and Green Bank with successful results.

The receiver will use MAP-style LNAs from CDL which are optimized for the 26.5-40 GHz band. The RF signal path out of the dewar will be in WR-28 waveguide. Waveguide vacuum windows and dewar penetrations preserved from the long ago decommissioned A-Rack paramps will be re-used. These old units were found to have a surprisingly flat and low-loss frequency response across the 26.5-40 GHz range. The calibration signal into the dewar will use a coaxial transmission line.
The receiver will include a block converter which will mix a 10 GHz wide band of the 26.5-40 GHz RF range down to 8-18 GHz. It will be based on a custom multifunction module using a number of custom and commercial MMIC designs. This single module will include an active tripler for the 14.7-16.3 GHz LO reference, as well as a 26.5-40 GHz RF post-amp with 15 dB of gain and a wideband block conversion mixer followed by a 10 dB IF post-amp. This configuration is optimized for headroom and sensitivity. Caltech was contracted to design and build two prototype units. NRAO will produce the production Block Converter modules in-house.

The first Ka-Band prototype receiver has been assembled and is undergoing evaluation tests in the lab. Production receivers will be done at a rate that will eventually match or exceed the approximate five-per-year antenna upgrade schedule.

5.1.7.8 Q-Band (40-50 GHz):

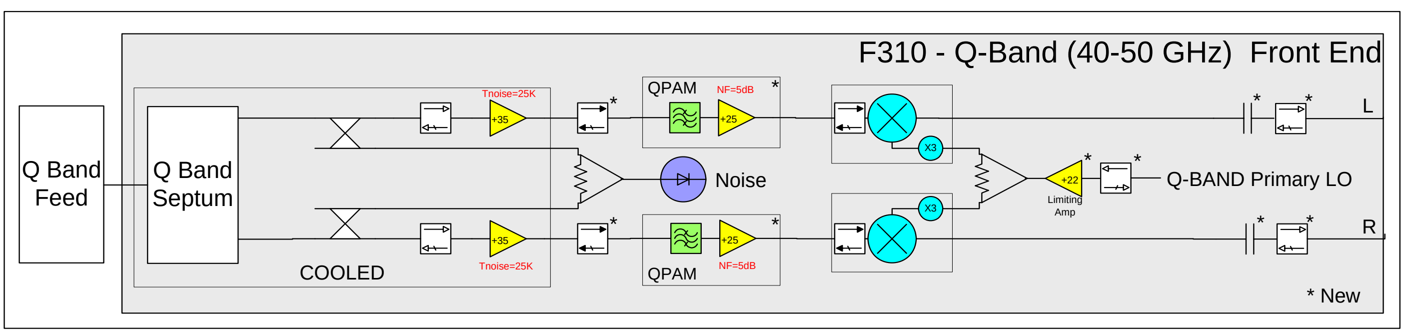

Figure 5-9: EVLA Q-Band (40 - 50 GHz) Receiver

The EVLA Q-Band receiver is an upgraded version of the existing VLA system. It retains the current feed horn and there are no changes to the RF signal path within the dewar.

All early generation 5-stage GAsFET LNA's will be replaced with newly designed amps with flatter gain across 40-50 GHz. A number of LNAs will also be upgraded with Cryo-3 devices in the first stage at the CDL. Outside the dewar, a warm 40-50 GHz post-amplifier is added ahead of the mixer in each channel. This improves the sensitivity of the receiver by about 5°K. This new RF amp is based on a custom MMIC design. Caltech was contracted to design and build two prototype units which have been successfully evaluated. NRAO is now producing the amplifier modules in-house.

Fortunately the Spacek mixers currently used in the receiver can accommodate the 40-50 GHz to 8-18 GHz Block Conversion scheme and are retained in the EVLA system. However, they fail to meet the 20 dB headroom specification by roughly 5 dB or more. Unless the RFI environment dramatically gets worse in the 40-50 GHz band, this will provide more than adequate dynamic range.

Other modifications include the addition of isolators and replacement of the old style Card Cage.
The Q-Band receiver modifications will be done at a rate that matches the antenna upgrade schedule (i.e., about 5 per year).