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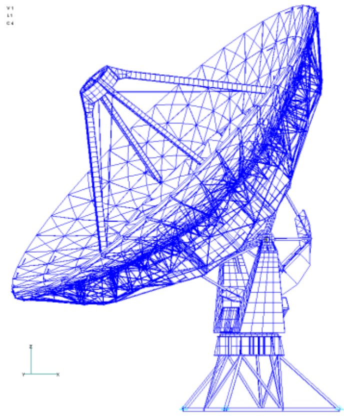
SOCORRO, NEW MEXICO



EVLA TECHNICAL REPORT #175

LOW BAND RECEIVER PERFORMANCE

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S.DURAND, P.HARDEN

Upgraded low band receivers, figure 1, were installed in the VLA antennas in 2013. This memo describes the performance specifications and the performance obtained.

NRL has an important history of support and use of NRAO's 74 MHz and 330 MHz narrow-band "legacy" systems on the VLA. These systems have been used successfully for research in areas of Navy interest including astrophysics, ionospheric physics, and related technical areas such as ionospheric calibration and modeling, RFI mitigation, and wide-field imaging. These legacy systems have also attracted a rich variety of astronomical investigations from the international community of VLA users.

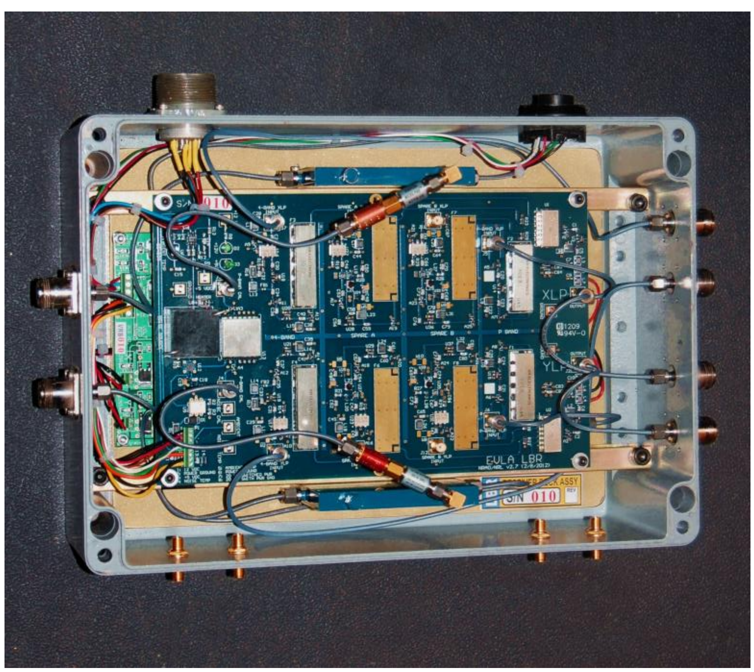

Figure 1 Photo of an Upgraded Low Band Receiver

The Low Band Receiver has four input channels and a single output channel per IF (two per receiver). The receivers are mounted in the antenna apex, Figure 2. The P-band and 4-Band dipoles are mounted below the antenna apex and the output cables are routed to their respective amplifier sections.

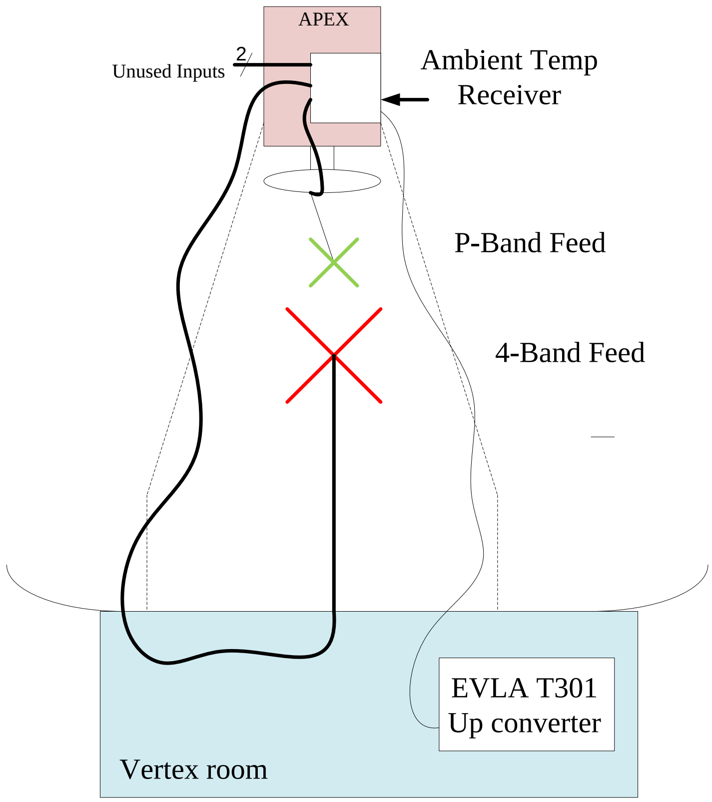

Figure 2, Single Receiver, ambient environment

Each signal is amplified, filtered and combined prior to the final output amplifier section of the receiver, figure 3. The receiver is deigned to operate at ambient temperatures and employs a temperature controlled noise source. Only two channels per IF are presently used allowing two additional channels for future growth.

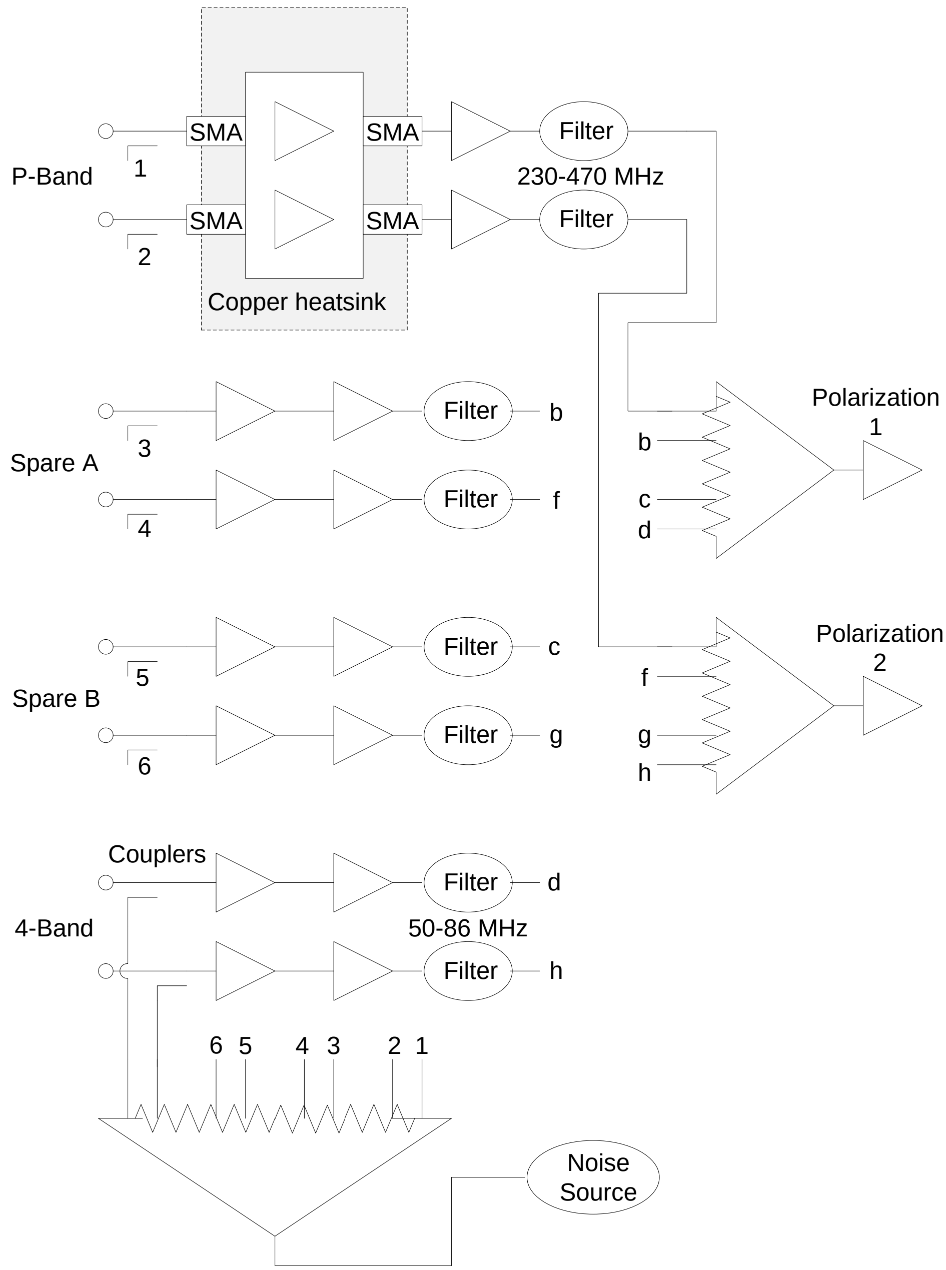

Figure 3 Summed output of 4-Band and P-Band

The specifications for the Low Band receiver are shown in table 1. Each of the receiver input channels have different filters and LNAs. Input #1 is designed for 4-Band. Input Channel 4 is designed for P-Band. The receiver has an input passband in both 4-Band and P-band which is wider than the LO/IF system of the EVLA antenna. The restricted bandpasses are shown in parentheses in table 1. The output of the Low Band Receiver is the sum of the four input channels and has a passband of 50MHz - 1024 MHz.

Table 1, Low Band Receiver Specifications

Input 1 - 4-band	50-86 MHz (EVLA 68-86 MHz)
Input 2 –	Spare
Input 3 –	Spare (120-175MHz)
Input 4 - P-band	230-470 MHz (EVLA 230-436 MHz)
Total Output power	-55dBm (50MHz to 1024 MHz)
RF Signal Combiner	Post LNA 4-way combiner
Polarization	Dual Linear
Filter requirements	
(-1 dB points)	50-86 MHz, 230-470 MHz
Out of band rejection	>35dB
Feed Cross Polarization	> 20dB, 1-1024 MHz
Receiver Channel Isolation	> 50dB, 1-1024 MHz
Receiver Located	Apex
Physical size	9"x 13"x 4.5"
Weather tight enclosure	Modified legacy P-band enclosure
Power requirements	17.5 +/-2Vdc - < 2 Amps (Isolated)
Total Power Gain Stability	< 2% Change in output power/10C/30 minutes
Noise Diode Thermal stability	< 0.5% change in output power /30 minutes, Oven controlled
Noise Diode Temperature	Analog output proportional to temperature in °C
Monitor points (Vertex Room)	Power supply voltage and current
Operating temperature	-20 to 50 °C
Power-up to Operational	< 30 minutes
ESD protection	installed on power and signal lines
P-Band Noise source injection	Matched cables from source to LNA input
Output level	-44 dBm +/-1 dB (4-Band and P-Band combined)
Circuit board RF connectors	SMA
Receiver enclosure connectors	SMA
Dual receiver operation	Low band (4&P) and either X or Ku

F320/F14 Interface Specification

Noise diode temperature	Analog voltage proportional to temperature
Noise diode temperature in alarm	Alarm threshold and flag in MIB
17.5-voltage	Analog voltage proportional to Voltage
17.5-current	Analog voltage proportional to Current
20 Hz signal on/off Optical	-10 dBm Optical digital signal
20 Hz signal on/off Copper	Switched 28Vdc, jumper selectable
F318 Monitoring	power supply voltages
F318 Monitoring	internal temperatures

The present output is the sum of the 4-band and P-Band signals. Figure 4 shows a cartoon of the receiver output frequency response with an overlay of the frequency response of the legacy dipoles. The stop band rejection is designed to be more than 30 dB. Figure 5 shows a laboratory measurement of the receiver output with a -65 dBm broadband noise source input. The passband shapes of the 4-band and P-band RF filters are clearly shown. Figure 6 shows the output waveform of the receiver in the array with a legacy 4-band and P-band dipole attached. RFI signal are present in the P-band bandpass.

One of the design criteria for the LBR was to make the 74MHz output power to be about the same as the P-band power. However, in practice, when the 74 MHz dipoles were deployed, this added about 10-12 dB of power to 74 MHz over the P-band power (more than expected). This causes the T304/T305 down Converters to apply attenuation before the samplers, reducing P-band power by an unwanted 10-12 dB. The ALC was being driven by the 74 MHz power. The receivers were modified and the 74 MHz gains were lowered by 10-12 dB to equalize the 74 MHz and P-band powers with dipoles connected. A summary of the modeled performance at 125 and 175 MHz bandwidths are given in table 2.

Table 2, Summary of Modeled System Performance

	125 MHz (Ambient temp =20C)		**175 MHz (Ambient temp =20C)**		
Component	**T (K)**	**ΔT (K)**	**T (K)**	**ΔT (K)**	**Comments**
Dipole	300	6.988	300	6.988	This table indicates the estimated temperature for each stage of the receiver component chain and its resulting ΔT contribution to the receiver temperature
Connector	300	1.252	300	1.482	
Coax	300	16.390	300	16.402	
Connector	300	1.324	300	1.568	
Feed Thru	300	1.329	300	1.576	
Coax	300	15.424	300	15.459	
Coupler IL	300	21.982	300	22.032	
Coupler Branch (K)	300	3.000	300	3.000	
LNA noise (K)	300	60.7	300	60.7	
Coax	300	0.0269	300	0.0269	
Attenuator	300	1.78420	300	1.17716	
Post Amp Noise (K)	300	2.964	300	2.360	
T-receiver (K)		132		133	

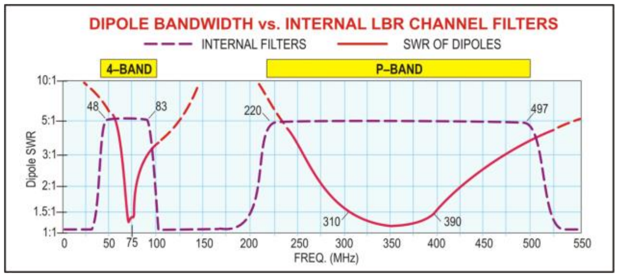

Figure 4 Summed output of 4-Band and P-Band

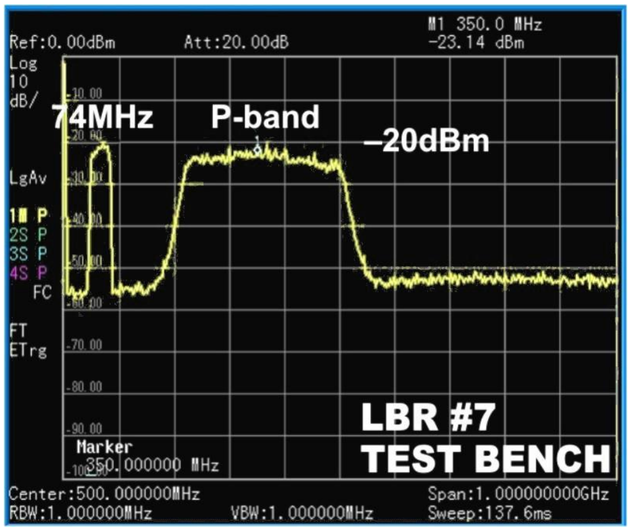

Figure 5 Test bench**:** Original 4- and P-band noise powers in the lab, 74 MHz set to same total power as P-band. Noise source input -65 dBm.

Figure 6 On Antenna: 4/P-band noise powers, 74 MHz -68 dBm; P-band -70 dBm **With dipoles**, showing noise power now equalized on both bands.

The measured receiver performance

Figure 6 is a P-band image of some of Frazer Owns' recent DDT data on an anonymous target, using 23 antennas, 32 MHz (centered on 354 MHz) and 3.5 hours of data. Flagging eliminated about 20 percent of this data. The central noise level is 0.75 mJy/beam, while the outskirts have 0.63 mJy/beam (uncorrected for primary beam). This reduction was done using Huib Intema's GMRT data reduction tools with minimal changes. The black circles mark 1.5 and 3 degree radii. Vertical large tick marks are 1 degree apart. There are about 550 sources detected with >6 sigma peaks when blindly running PyBDSM on the whole area.
The exposure calculator quotes 0.47 mJy/beam for the parameters above. This number is dominated by confusion noise (0.44 mJy/beam). Note that this observation is at sufficient negative DEC to elongate the synthesized beam, which will increase the confusion limit. If we believe the exposure calculator, it seems we're not too far off theoretical noise, definitely within a factor of 1.5

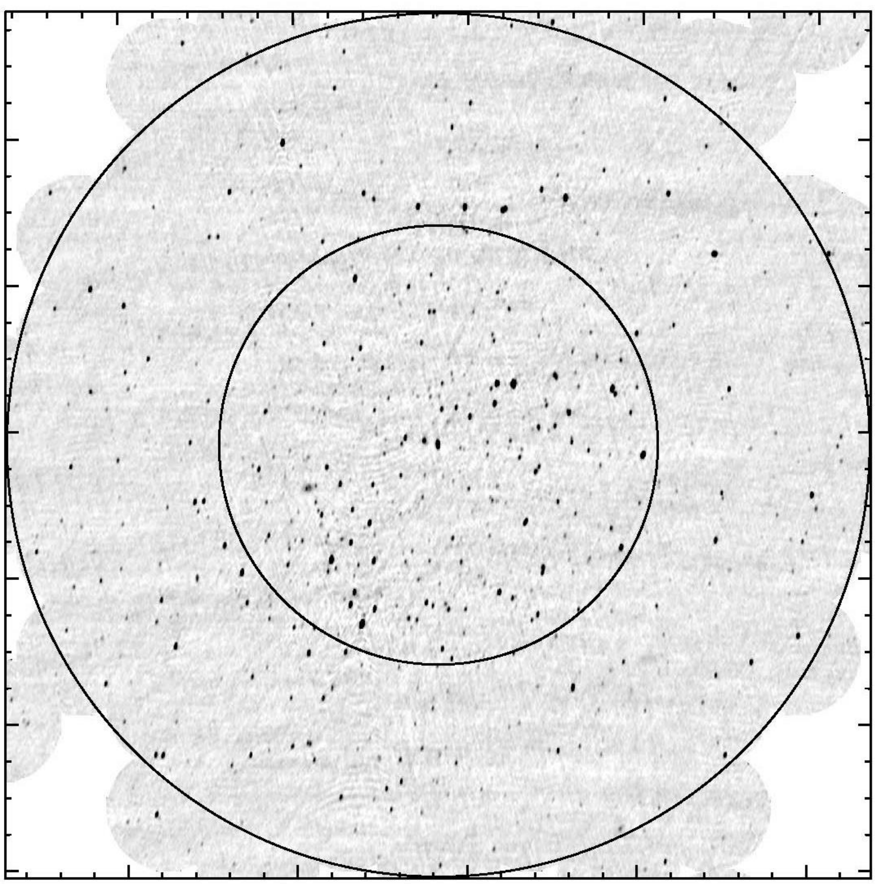

Figure 6 DDT data on an anonymous target,