ngVLA Electronics Memo No. 14

The MSIP Qualification Electronics Design and Hardware

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Objective

The objective of the Qualification Electronics is to provide a full electronics suite to evaluate the prototype antenna performance. This includes all signal path hardware from the feed to the correlator and all associated support systems needed for the electronics. This will include the helium, cooling, network, power, M&C and mechanical interface sub-systems. This overview is a conceptual design to demonstrate what electronics are required to support a dual band system for antenna testing and validation.

Introduction

The MSIP (Mid-Scale Innovation Program) antenna will (initially) support just two bands to complete antenna performance validation. The vendor chosen to build this antenna is ***mtex*** and the NRAO team will work closely with ***mtex*** for performance validation. The intended receivers for the prototype antenna qualification will be the EVLA X-band and Q-band currently used in the VLA antennas. (Mangum, 01/11/2022) To properly use the intended receivers, supporting electronics will also be needed for LO references, down-conversion, M&C, digitizing, DC power, etc. [After the antenna evaluation is complete, a suite of ngVLA receivers and electronics will likely be installed for prototype ngVLA testing.]

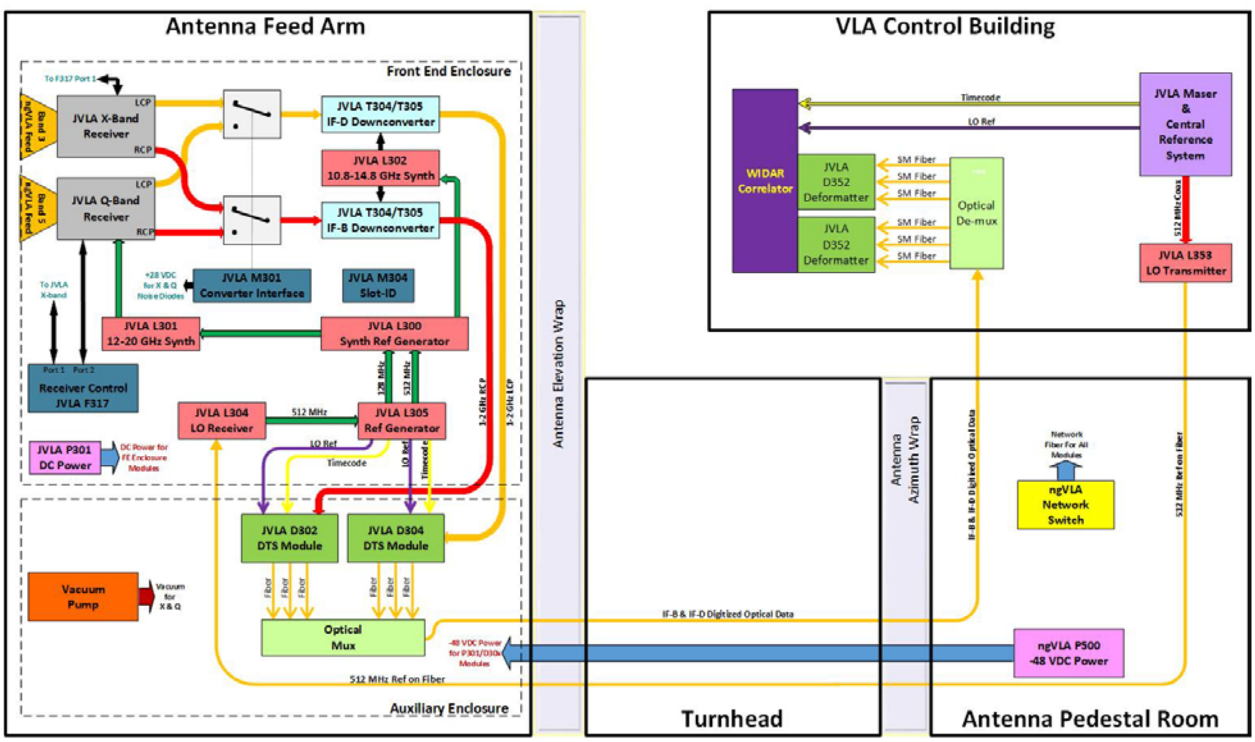
Both receivers will be used with scaled, ngVLA style feeds (EMSS designed) to fit the top plates of each receiver. This will allow lower frequency (8-12 GHz) initial radiometric alignments and pointing tests easily interfaced with current VLA pointing tests. The use of the Q-band receiver will permit shorter wavelength testing for various aperture efficiency, stability, etc. testing.

The areas to define include:

1. Hardware needed and availability
    a. The EVLA signal path modules will be used for simplest integration of the ***mtex*** antenna with the existing VLA systems and network.
    b. New sub-systems will be needed for the EVLA electronics support such as HVAC, glycol cooling system, helium compressor and distribution, AC and DC power.
    c. These new sub-systems will match ngVLA implementation and interfaces as closely as possible to allow easy integration for ngVLA prototyping.

2. LO tuning plan
    a. A simplified tuning plan eliminates modules to save volume in the FE enclosure.
    b. All RF switches are eliminated except for one. An X-Q selection switch will be needed.
3. Signal processing plan
    a. The existing fiber infrastructure used for ALMA testing will be repurposed for MSIP.
    b. The use of EVLA digitizer modules simplifies the interface to WIDAR.
    c. The WIDAR Station Rack (S008) will be outfitted with Deformatter/Station cards to accommodate a 29th antenna for ease of testing.
4. DC power requirements
    a. A new P500 -48 VDC power supply for MSIP and ngVLA will be selected
    b. The P301 DC power supply module for the EVLA electronics will be modified with a larger DC-DC converter for the +17.5 VDC
5. Physical placement and cooling
    a. The EVLA hardware will be installed in enclosures as similar to the ngVLA prototypes as possible, but will be different internally.
    b. The simplified tuning plan eliminates modules which reduces the volume in the enclosure. (Mass is well below 522 kg maximum)
    c. These modules will require cooling air instead of glycol cooling plates. The ngVLA glycol cooling interface will be available, but using an exchanger and fans instead of cold plates.

ngVLA MSIP Antenna X/Q Test Electronics Block Diagram



1 Hardware Needed and Availability

The Qualification Electronics system will require several modules for the RF and digitized signal paths to provide references, clocks, monitor and control, DC power, etc. These modules will provide all necessary external stimuli to the signal path hardware and will match the existing VLA software/firmware as closely as possible. This will allow a more seamless integration of the test antenna into the VLA observing and testing scripts as well as monitor and control of all hardware.

A. Pedestal Room:
1. A -48 VDC power source (preferably the ngVLA P500) for distribution in the pedestal room, the Auxiliary and the FE enclosures.
2. Battery backup allowing >15 minutes DC power reserve
3. A network switch for all M&C communication between the antenna hardware and the control building
4. HVAC cold air supply to rack
5. Pedestal room rack

B. Auxiliary Enclosure
1. D302 and D304 modules
2. Optical Mux module
3. Passive splitters for 128 MHz, 2048 MHz and (possibly for 3-bit) 4096 MHz clocks
4. Vacuum pump for X & Q receivers
5. Glycol heat exchanger and fans

C. Front End (FE) enclosure:
1. F306 X-band VLA style receiver (with card cage and ngVLA type feed)
2. F310 Q-band VLA style receiver (with card cage and ngVLA type feed)
3. T304/T305 IF-B modules
4. T304/T305 IF-D modules
5. L301-1 synthesizer (1st LO)
6. L302-1 synthesizer (2nd LO)
7. L300 Synthesizer Reference Generator to deliver 128 MHz comb, 512 MHz comb and possibly 2048 MHz to the DTS modules
8. L304 in pedestal to receive the optical 512 MHz reference and convert it to 512 MHz RF
9. L305 to recover and clean up the 512 MHz RF and distribute 128 MHz and timing signals
10. F317 Front End Controller module for M&C of both receivers
11. M301 Converter Interface (or some reduced function emulator) for X/Q band switching and 28 VDC generation for noise diode switching
12. P301 DC power supply module
13. M304 slot-id module
14. Optical to electrical converter box for 10 Hz
15. Glycol heat exchanger and fans

D. Antenna Turnhead
1. Glycol cooled helium compressor for receivers in the FE enclosure
2. Helium buffer tanks and control system (possibly)

EVLA module availability

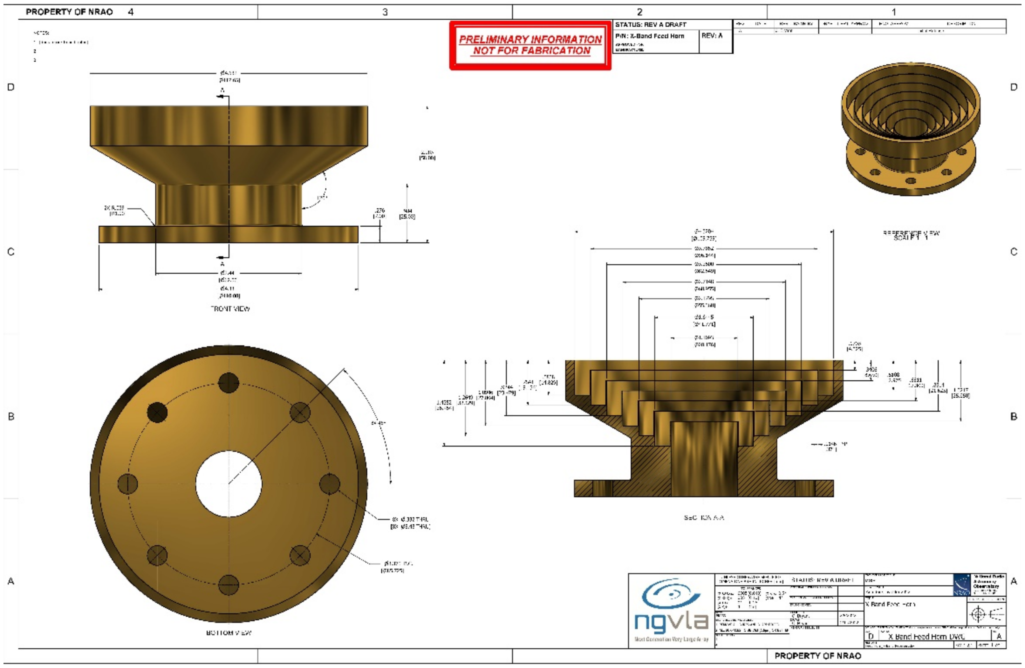
EVLA Module	Quantity Needed	Availability
Network Switch	1	Several available
D302	1	3
D304	1	3
Optical Mux	1	2
Vacuum Pump	1	1
P301	1	5
L304	1	3
L305	1	3
F317	1	5
O/E Converter 10 Hz	1	3
M301	1	3
F306 (X-band)	1	2
F310 (Q-band)	1	2
L300	1	3
L301	1	5
L302	1	5
T304	2	5
T305	2	7
Connectors, cables, hoses, He lines, etc	TBD	
L353	1	2
D352	2	2
Station Boards	2	2

Table 1

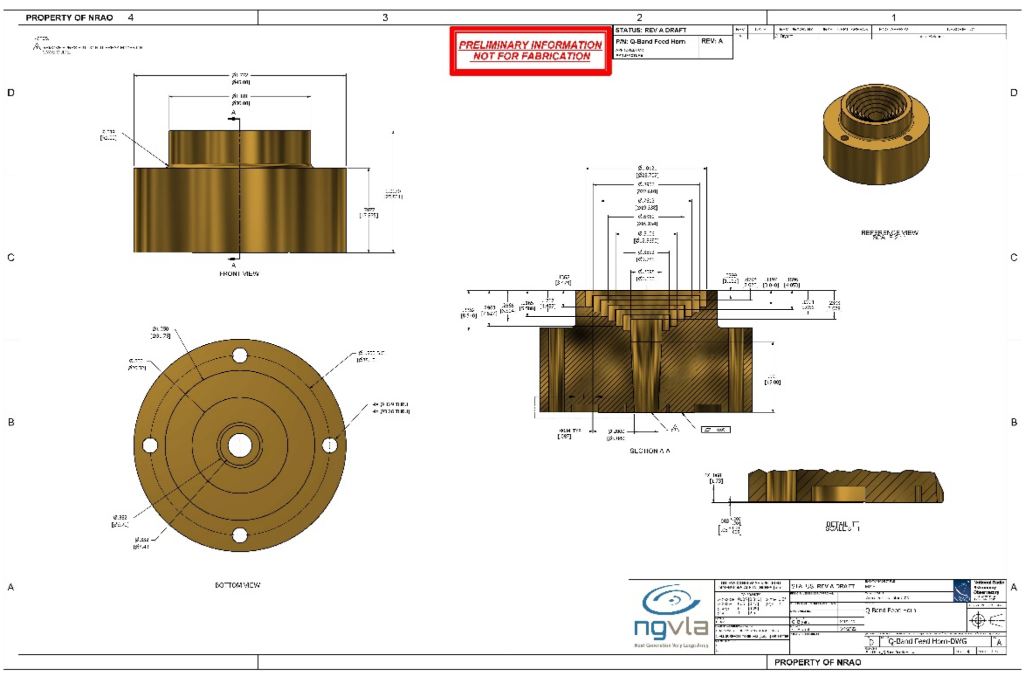
New Hardware Required

New Module	Quantity Needed	Availability
P500 (ngVLA)	1	Receiving quotes
ngVLA style X feed	1	Built and awaiting test
ngVLA style Q feed	1	Built and awaiting test
ngVLA trunk fiber cables	7	Requesting quotes

Table 2



ngVLA Style X-band Feed



ngVLA Style Q-band Feed

2 LO Tuning Plan

A preferred default condition (from the hardware standpoint) would be to provide some limited tuning ability where the second L301 synthesizer, the entire T303 and all but one RF switch is eliminated from the FE enclosure electronics. By providing an 8-12 GHz bandpass directly to the two T304 modules (LCP and RCP), we would be able to simplify the hardware and provide coarse tuning only with a single L301 and no second conversion stage. This concept has been reviewed by the antenna testing group and has been chosen to reduce module count and hardware volume in the Front End enclosure. (See ***Table 3***.)

L301 Freq (MHz)	x3	Q-band Sky (MHz)	IF to T304 (MHz)
19328	57984	49984 - 45984	8000 - 12000
19072	57216	49216 - 45216	8000 – 12000
18816	56448	48448 - 44448	8000 – 12000
18560	55680	47680 - 43680	8000 – 12000
18304	54912	46912 - 42912	8000 – 12000
18048	54144	46144 - 42144	8000 – 12000
17792	53376	45376 - 41376	8000 – 12000
17536	52608	44608 - 40608	8000 – 12000
17280	51840	43840 - 40000	8000 - 11840

Table 3

The hardware required for MSIP tuning would include:

1. L301 Synthesizer to the Q-band receiver (X-band does not require LO)
2. L302 Synthesizer to provide fine tuning for the T304 converter module
3. L300 Synthesizer Reference Generator to provide comb lines and clock signals
4. L304 LO Reference Receiver to convert 512 MHz optical signal from building to 512 MHz RF
5. L305 Reference Generator and Distribution to clean up (PLL) 512 MHz and distribute LO and timing

3 Signal Processing Plan

The X-band will output 8-12 GHz (RF) directly and the Q-band will provide 8-12 GHz (RF) using the L301 conversion tuning scheme as shown in ***Table 3.*** An RF switch will route either the X or Q-band LCP and RCP signals to the T304s. The outputs of the T304 IF Converter modules (1-2 GHz) will then feed (via low loss coaxial cable) directly into the DTS modules (D302 and D304). Due to space constraints, the D302 and the D304 will be mounted in the Auxiliary Enclosure while the rest of the signal path hardware will be mounted in the Front End Enclosure. Low-loss coaxial cables up to 8m long will need to be used, but the low frequency and available gain/attenuation in the system should easily compensate for any signal loss.

The test plan is to use the 8-bit digitizers only. Implementing the 3-bit digitizer is possible in the hardware, but would have limited tunability and require some non-standard code on the system software side. In order to simplify the MSIP to VLA interface, 8-bit mode only makes most sense. The D30x modules will require 128 MHz and 2048 MHz clocks as well as the fiber timecode. The 128 MHz and fiber timecode will come from the L305 located in the Front End Enclosure and the 2048 MHz clock will be run from the L300 also located in the FE enclosure.

No power supply module will be required in this enclosure as the D30x modules run directly off the distributed -48 VDC power.

The six 10 Gb/s optical outputs (three from each D30x) will be multiplexed in the auxiliary enclosure and delivered to the deformatter card in the correlator via a single-mode fiber that runs from the antenna test pad to the VLA control building. This single fiber will be de-multiplexed and the three fibers for each IF will be run into to appropriate deformatter cards. The VLA Correlator Group is working on outfitting Station Rack S008 to receive and process two IF's (only) including deformatters, station boards, timing, etc. This work will allow the MSIP antenna to be used at any time without affecting the rest of the VLA and simplify inclusion of the MSIP antenna into VLA pointing runs.

4 DC Power Requirements

The antenna electronics and cooling systems will require -48 VDC. A telecom style 208 VAC to -48 VDC power supply and battery backup (to provide a minimum of 15 minutes of runtime) will be located in the pedestal room of the ***mtex*** antenna. The -48 VDC will be distributed on the antenna to the Auxiliary Enclosure and the Front End Enclosure.

The D302 and D304 modules in the Auxiliary Enclosure are powered directly by the -48 VDC. There will also be 48 VDC cooling fans in the enclosure.

-48 VDC will be supplied to the P301 module in the Front End Enclosure. The P301 will supply DC voltages to all modules in the enclosure through three distribution boards. The voltages required in the Front End Enclosure are:

1. +7.5 VDC @ 14.6 A
2. -7.5 VDC @ 0.7 A
3. +17.5 VDC @ 9.7 A ***This requires a VICOR 500W Maxi DC-DC converter***
4. -17.5 VDC @ 2.4 A

To supply the necessary current for the +17.5 VDC distribution (10A), the P301 will need to be upgraded. The P301 is designed to be upgradeable by installing a larger capacity DC-DC converter. The upgrade is simple and allows a single power supply to provide DC power to all EVLA modules.

The X and Q-band receivers have noise diodes used in the calibration and testing process which use +28 VDC. The P301 does not supply this voltage, but the M301 has a +32 VDC rectifier which can be trimmed down for +28 VDC since it will not be used for RF switching. (There will be one coaxial RF switch to select between X-band or Q-band receiver outputs.)

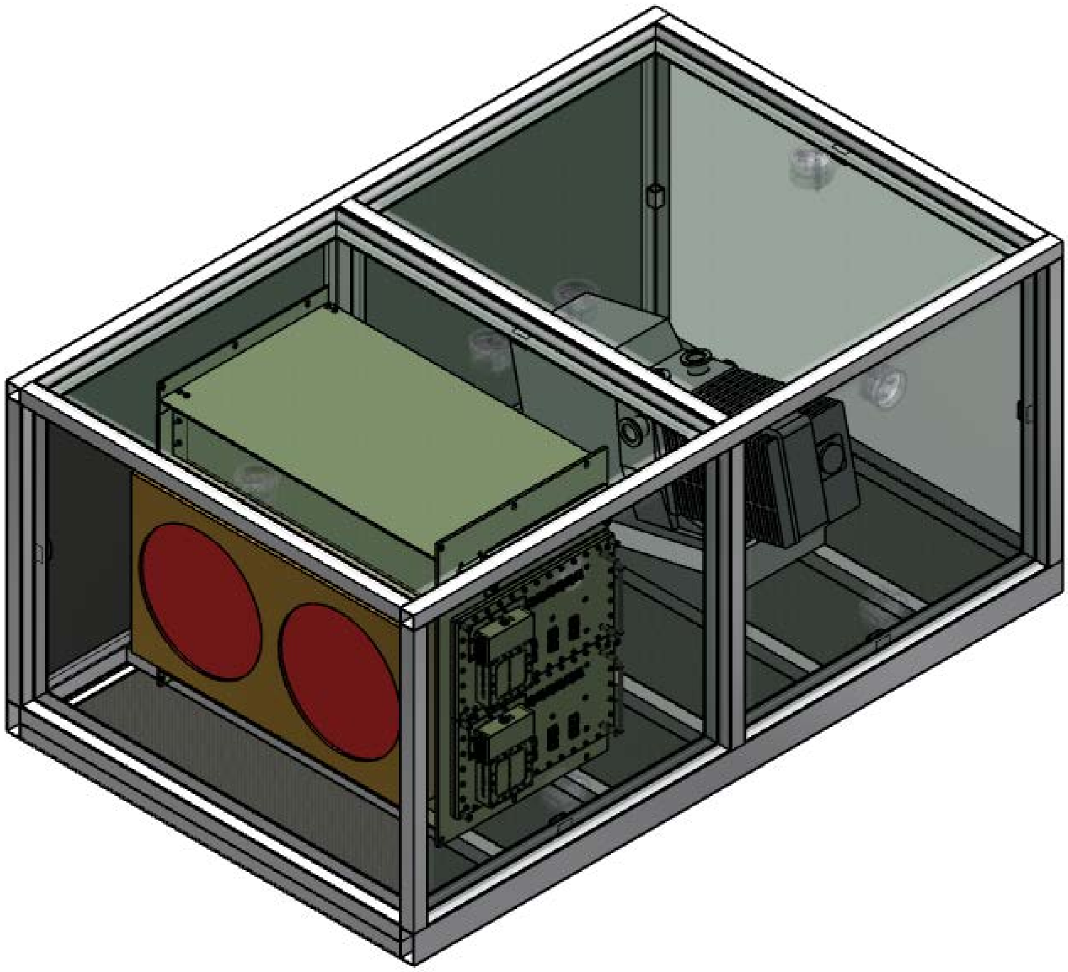
5 Physical Placement and Cooling

Table 3 shows the physical placement of the various electronics along with size, mass and heat load. Hardware will be located in one of three locations: The Pedestal Rack, the Front End Enclosure or the Auxiliary Enclosure.

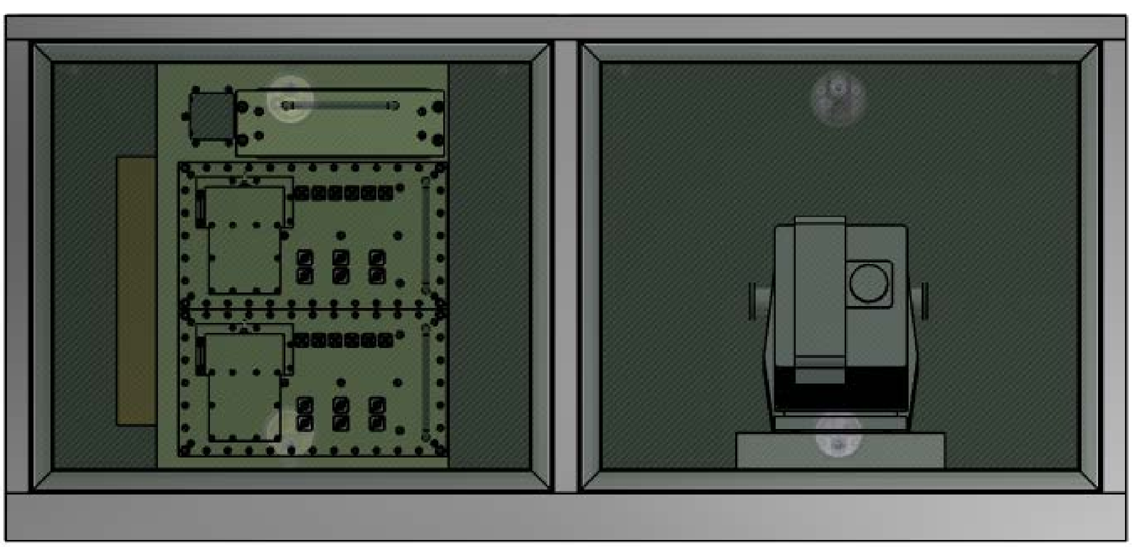
The Pedestal Rack will be cooled with a forced air system while the Front End and Auxiliary enclosures will be cooled using glycol coolant through a heat exchanger and high static pressure fans to force chilled air across the modules and through the enclosures.

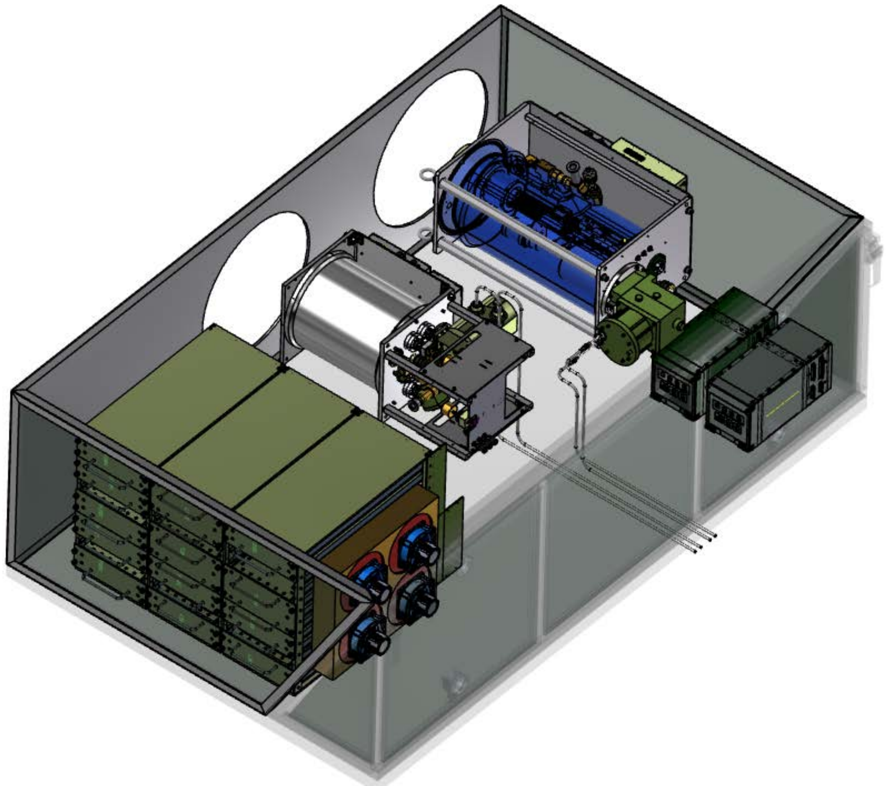
EVLA Module	MSIP Ant Location	Size (mm)	Mass (kg)	Thermal Load (watts)
P500	Pedestal rack	TBD	TBD	5500 (max)
Network Switch	Pedestal rack	445 x 406 x 42	6.0	150
D302	Aux enclosure	DTS module (in can)	11.79	100
D304	Aux enclosure	DTS module (in can)	11.79	100
Optical Mux	Aux enclosure	Double-wide	5.00	0
Vacuum Pump	Aux enclosure	483 x 164 x 240	30.00	1022 (max)
P301	FE enclosure	Double-wide	6.53	32
L304	FE enclosure	Double-wide	4.99	13
L305	FE enclosure	Triple-wide	6.80	34
F317	FE enclosure	Double-wide	6.44	12
10 Hz O/E Converter	FE enclosure	140 x 102 x 114	1.36	5
M301	FE enclosure	Double-wide	5.08	10
F306 (X-band)	FE enclosure	686 x 261 x 832	37.19	50
F310 (Q-band)	FE enclosure	540 x 254 x 737	28.12	50
L300	FE enclosure	Double-wide	5.72	15
L301	FE enclosure	Triple-wide (double with heatsink)	7.53	42
L302	FE enclosure	Triple-wide (double with heatsink)	7.53	50
T304	FE enclosure	Triple-wide	9.53	35 (combined)
T305	FE enclosure	Double-wide	4.72	
Connectors, cables, hoses, He lines, etc.	FE enclosure	TBD	TBD	
L353	Central LO rack	n/a	n/a	n/a
D352	WIDAR	n/a	n/a	n/a
Station Boards	WIDAR	n/a	n/a	n/a

Table 3

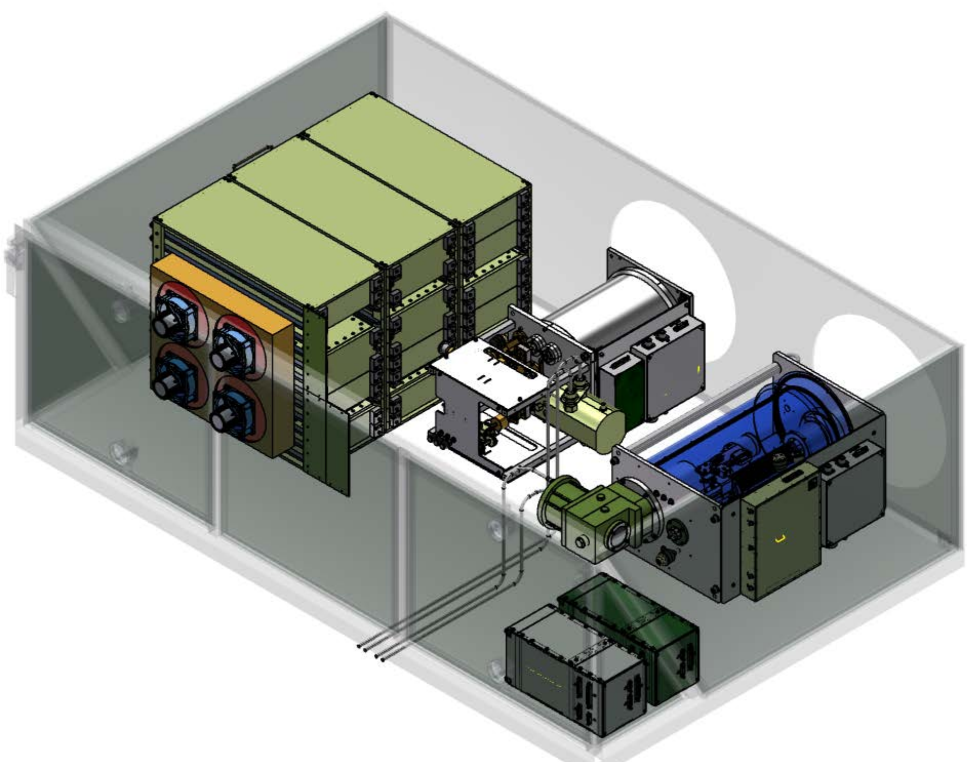


Auxiliary Enclosure





Front End Enclosure



Summary

The purpose of the Qualification Electronics is not to test new electronics, but to evaluate the performance of the ***mtex*** antenna. By using as many existing VLA modules as possible, we ensure easier integration of the ***mtex*** antenna with the rest of the VLA infrastructure. This includes both hardware and software. This also allows us to have a functional electronics suite for the antenna when it is assembled at the VLA site and ready to begin outfitting and testing at the end of 2023.

We will try to incorporate as many ngVLA prototype systems as possible (depending on design maturity), but we know several components of the system will be unique to MSIP such as:

1. The Front End and Auxiliary Enclosures will be similar in dimensions, but outfitted differently internally.
2. The X and Q-band feeds will be circularly polarized and physically scaled to work exclusively with the EVLA style receiver designs.
3. The glycol cooled helium compressor is a much simpler and less expensive unit than the prototype compressor needed for the full ngVLA receiver complement.
4. We may not have the helium buffer control system in the MSIP configuration, but after the antenna is qualified and ngVLA prototype hardware is installed.
5. We are planning on using the exact antenna fiber optic trunk cables as the ngVLA design, but the internal fibers (in each enclosure) will be different.
6. The network switch in the pedestal room will support the VLA infrastructure and likely a new switch will need to be installed for the ngVLA prototyping.
7. The P500 AC to DC power supply may not be the exact same model once true load calculations for the ngVLA hardware is determined.