

Results of the Variable Frequency Drive Experiment on EVLA Cryogenic Receivers



Study for the Green Antenna

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Atacama Large Millimeter/submillimeter Array

Karl G. Jansky Very Large Array

Robert C. Byrd Green Bank Telescope

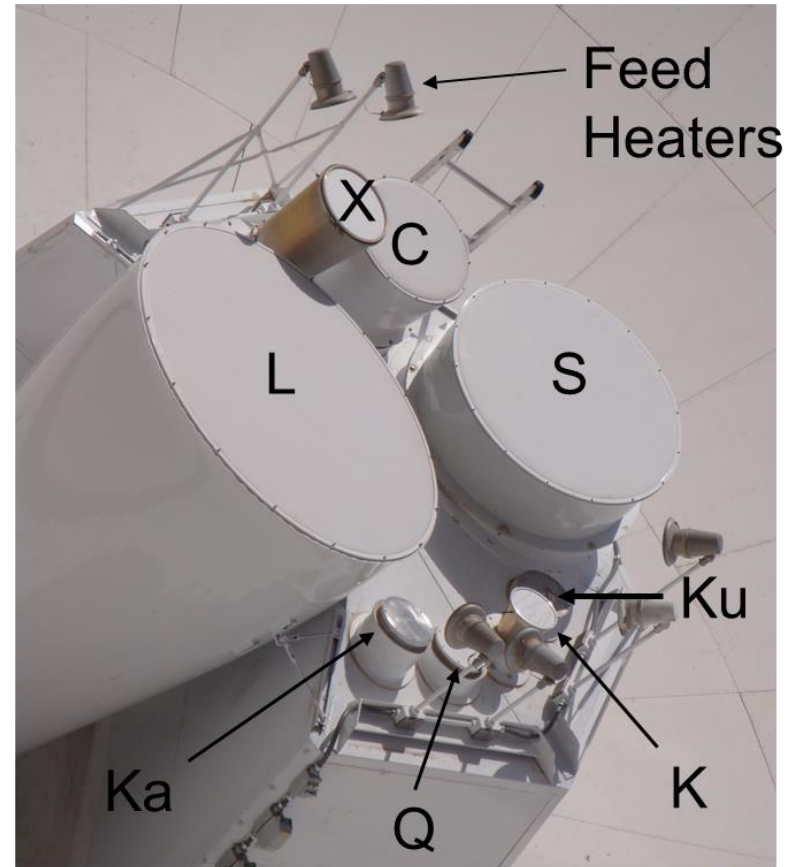
Very Long Baseline Array



Full frequency coverage with outstanding performance

- There are eight cassegrain focus systems, and one prime focus system.

Band (GHz)		SEFD (Jy) (27 antennas)
.05 -- .45	P	~60
1-2	L	13
2-4	S	9.5
4-8	C	8.5
8-12	X	8.1
12-18	Ku	8.1
18-26.5	K	13
26.5-40	Ka	22
40-50	Q	45



CRYO System Issue

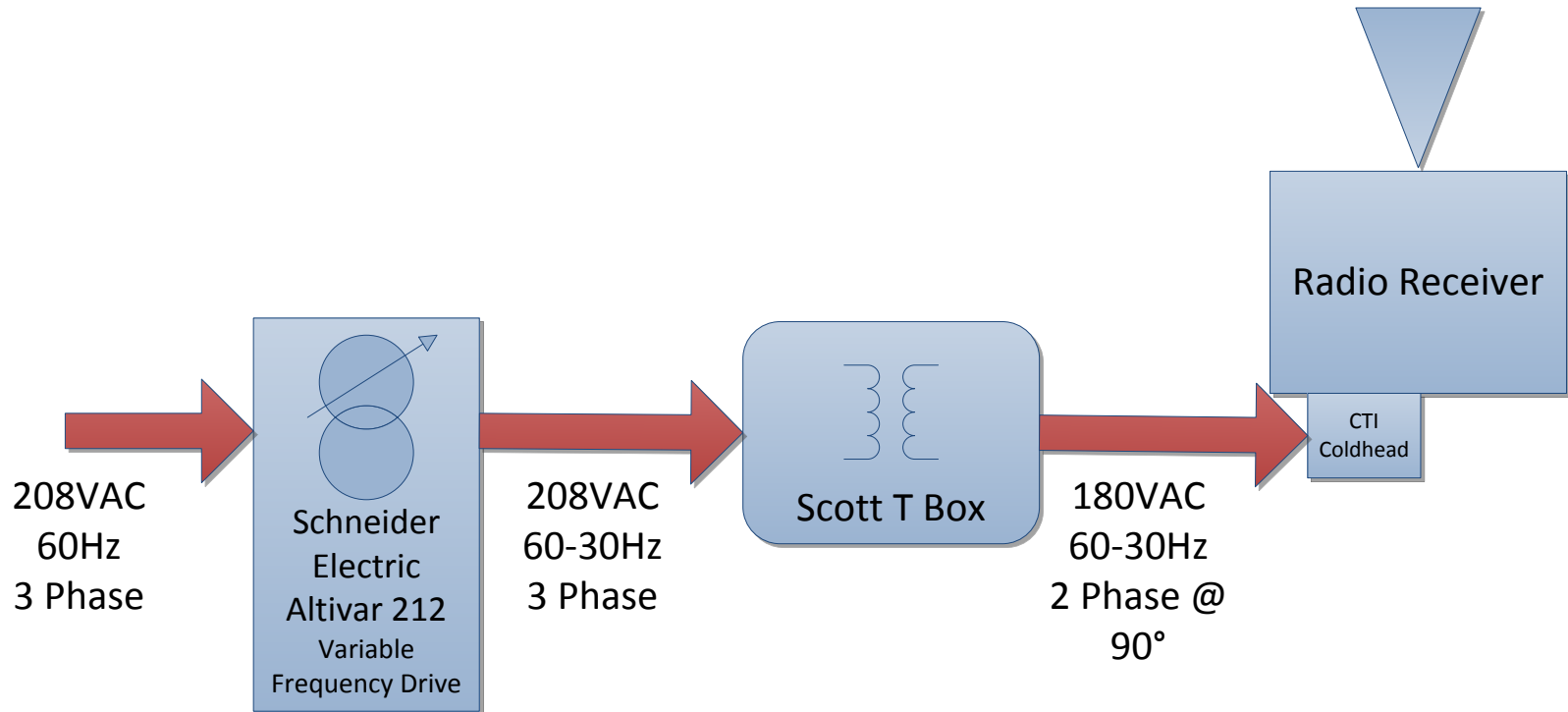
- One CTI refrigerator per receiver band - Eight separate CTI refrigerators,
-
- Three Helium Compressor
 - Helium flow required by 8 receivers: **112 scfm**
 - Each Helium compressor delivers: **48 scfm**
 - Minimum number of compressors required: **3**
- Circuit **1** : K, S, Ku – **2** : Q, X, C - **3** : Ka, L
- Refrigerators and compressors run at maximum capacity *24/7*
- **Electric Bill = ~\$300K per year**
- **Maintenance 5 staff and \$50K M&S per year**

Variable Frequency Drive Experiment: A two-step process

- **Step One:**
 - On a randomly-selected receiver of each type, measure the 50K and 15K cold stage temperatures as the AC input frequency is lowered stepwise from 60 Hz to 30 Hz.
 - After each change, the temperatures are allowed to fully stabilize before the data is recorded.
- **Step Two:**
 - Install **M**ulti **L**ayer **I**nsulation (MLI) around the 50K radiation shield, and re-cool the receiver.
 - Repeat the testing in Step One.
 - L and S band receivers not retested: these already have MLI installed

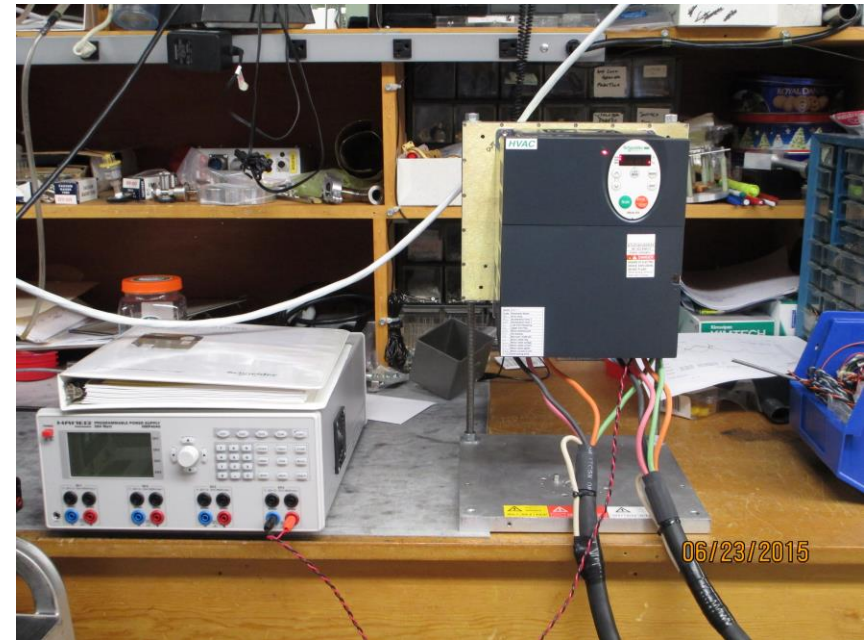


Laboratory Experimental Setup

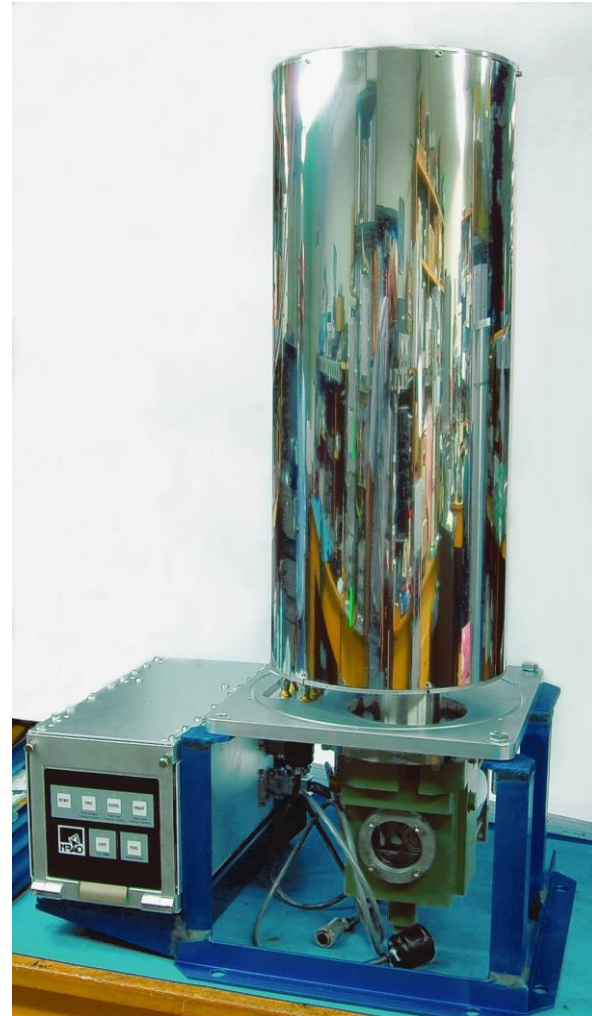


Test VFD Drive Unit and Scott -T Box

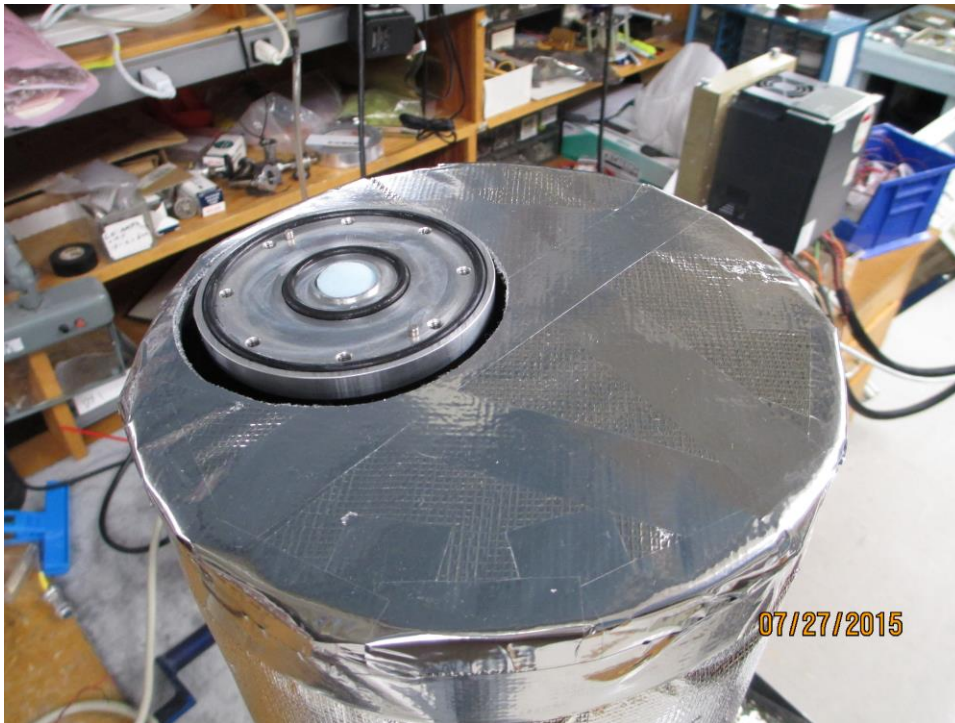
- Test VFD:
 - 3-phase 208VAC 60Hz input
 - 2-phase 180VAC 30-60 Hz output, independently controlled
 - Output current & phase monitoring, fault detection
 - RFI-tight enclosure, for operation on a VLA antenna



EVLA Ku-band Receiver Construction



An EVLA Ku-band receiver retrofitted with MLI on the radiation shield

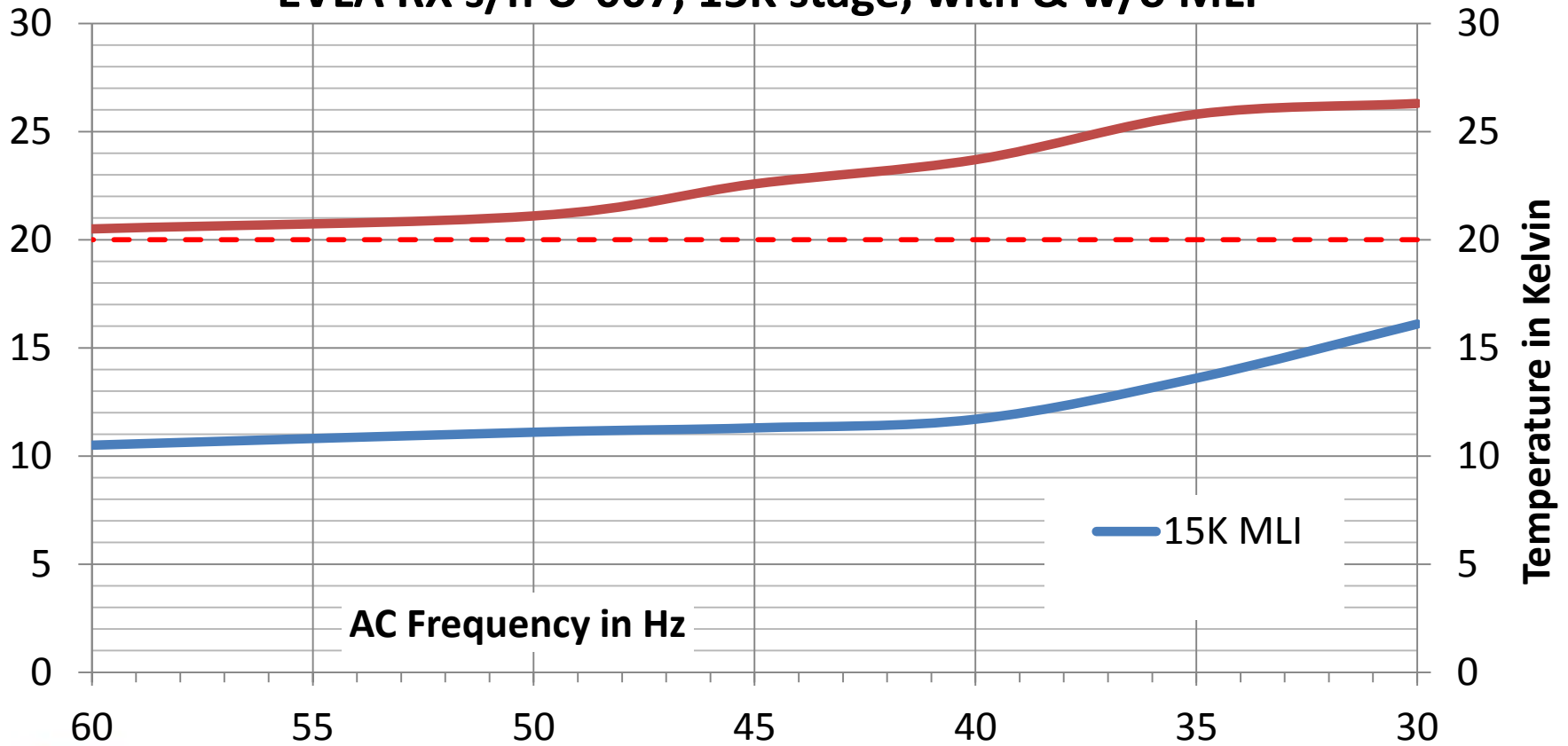


Ku-Band Receiver with Dewar (PI – Denis Urbain)



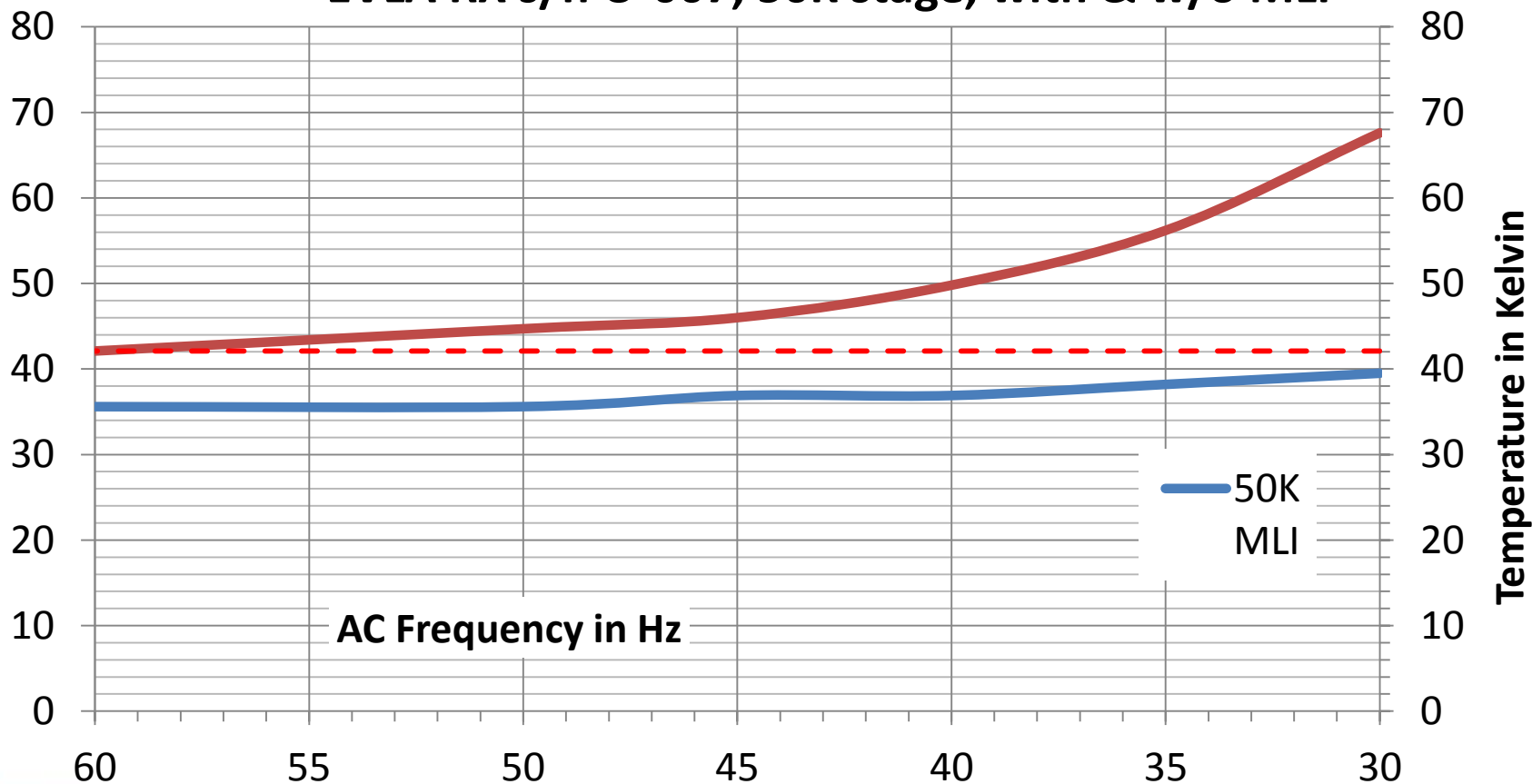
Ku-band RX 15K Stage Temperatures (with and w/o MLI)

EVLA RX s/n U-007, 15K stage, with & w/o MLI



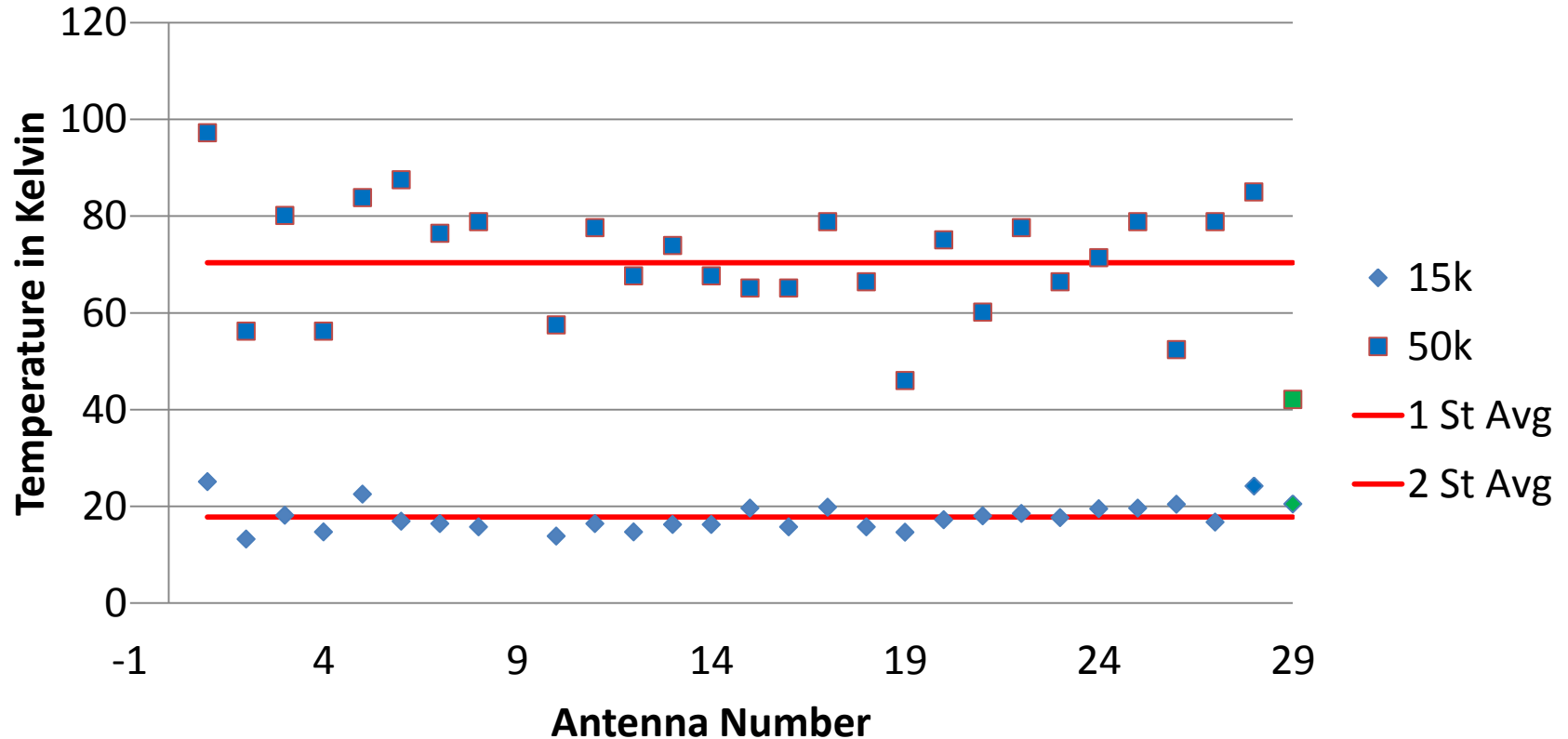
Ku-band RX 50K Stage Temperatures (with and w/o MLI)

EVLA RX s/n U-007, 50K stage, with & w/o MLI



Snapshot at Ku Band Rx temperatures

Ku Band Snapshot



Results of the Variable Speed Drive experiment with MLI - 15 degree stage

Receiver stage temperature in Kelvin	15K stage						Delta T15
	60Hz	50Hz	45Hz	40Hz	35Hz	30Hz	
L029 MLI	18.5	18.6	18.5	19	19.9	20.5	2
S008 MLI	11.5	12	12.2	12.6	14	14.9	3.4
C009	11.5	11.6	11.8	12.1	13.2	13.6	2.1
C009 MLI	11.1	11.2	11.3	11.4	12.3	12.7	1.6
X018	12.2	12.2	13.7	15.5	17.2	21.4	9
X018 MLI	11.3	11.5	11.9	12.1	13.3	13.8	2.5
Ku007	20.5	21.1	22.58	23.7	25.8	26.3	5.8
Ku007 MLI	10.5	11.1	11.3	11.7	13.6	16.1	5.6
K028	17.6	17.2	17.5	17.2	17.1	18.1	2
K028 MLI	17.1	17.2	17.3	17.5	17.7	18.2	2.1
Ka030	18.9	19.5	20.5	21.4	23.5	23.8	4.9
Ka030 MLI	18	18.1	18.6	19.2	22.4	24	6
Q003	14.9	15.7	16.3	17.5	19.8	40.8	25.9
Q003 MLI	13.1	13.5	13.8	14.9	15.7	20.8	7.7

Results of the Variable Speed Drive experiment with MLI - 50 degree stage

Receiver stage temperature in Kelvin	50K stage						
	60Hz	50Hz	45Hz	40Hz	35Hz	30Hz	Delta T50
L029 MLI	57.5	57.5	58.8	60.1	62.6	65.1	10
S008 MLI	52.4	51.1	52.4	53.7	56.2	61.3	10.2
C009	42.1	43.3	44.7	46	48.5	56.2	14.1
C009 MLI	36.9	36.9	38.2	39.5	42.1	44.7	7.8
X018	57.5	57.5	61.3	65.1	71.4	81.3	25
X018 MLI	43.4	43.4	44.7	46	48.5	52.4	12.7
Ku007	42.1	44.7	46	49.8	56.2	67.6	25.5
Ku007 MLI	35.6	35.6	36.9	36.9	38.2	39.5	3.9
K028	49.8	49.8	51.1	53.7	56.2	60.1	10.3
K028 MLI	46	47.2	48.5	49.8	51.1	55	9
Ka030	46	47.3	48.5	51.1	52.4	62.6	16.6
Ka030 MLI	38.2	39.5	42.1	43.4	42.1	46	7.8
Q003	66.4	70.1	75.1	80.1	87.5	116.3	49.9
Q003 MLI	43.4	46	51.1	56.2	61.3	76.4	33

Retrofit the EVLA receivers with MLI blankets

- Purchase raw material from manufacturer (JEHIER , RUAG)
 - Example: RUAG Coolcat 2 NW 1.5m x 3m about ~\$500
RUAG Coolcat 2 NW 1.5m x 100m about ~\$6400
- Purchase pre-cut blanket kits direct from manufacturer
 - More expensive but faster and easier installation, plus reusable
- Install the kits when the antenna goes for service or a receiver needs repair or upgrade
 - 180 receivers need to have MLI installed
 - The Dewar must be opened to wrap the radiation shield with the MLI blanket (one day per receiver of work)
- **It will take about 3 years to retrofit the whole array**

Observations and Conclusions

- All EVLA receivers even the Q-band can be run at reduced speed.
- Adding MLI lowered the temperature of both stages, and reduced temperature variation with the refrigerator speed.
- With MLI on all receivers, refrigerator speed can be reduced to 40 Hz, with no increase on the 15K stage temperature.
- Larger reductions (down to 30 Hz) are possible on some of the receivers.
- A VFD system can support of a “Standby” mode of operation , where receivers not actively in use run at a slower speed (30 Hz or less). Temperatures will be only slightly warmer than normal, so recovery time is in minutes, when taken out of Standby.

Helium Compressor Capacity w/VFD

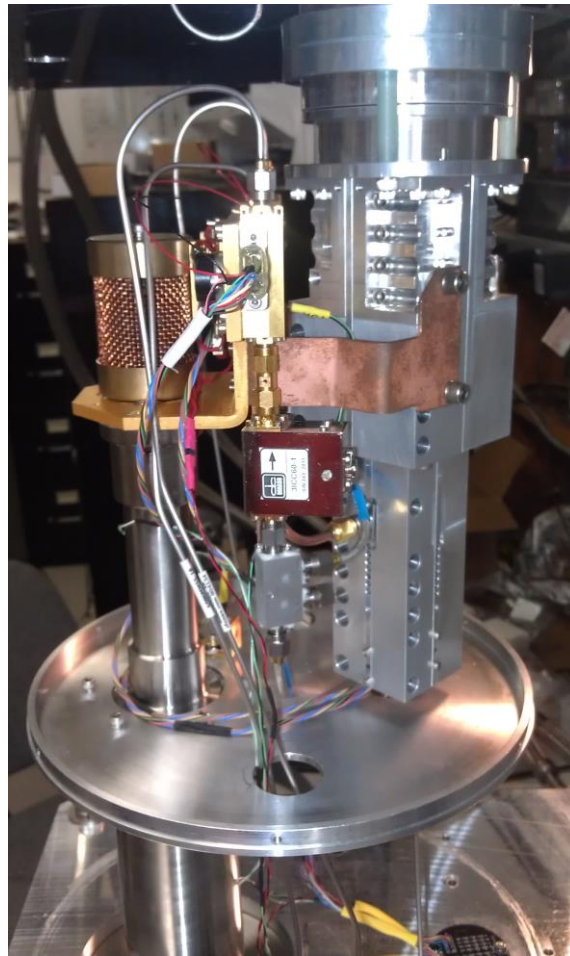
- Current System Requirements, w/o VFD
 - Helium flow required by 8 receivers: **112 scfm**
 - Each Helium compressor delivers: **48 scfm**
 - Minimum number of compressors required: **3**
- Estimated System Requirements, using VFD
 - Example A: 8 receivers running at 40Hz
Total Helium flow required: **74.6 scfm**
 - Example B: 7 receivers in Standby, one operational (full speed)
Total Helium flow required: **60.5-70 scfm**
 - Minimum number of compressors required: **2**
 - **Power reduction ~33% during steady-state operation**
- Third compressor is only needed for initial startup, and can be used as an in-place redundant spare. Can be brought online automatically.
- Redundant spare virtually eliminates callouts, system downtime.



Proposed Follow-On Development Steps

- Design, fabricate and test a triple compressor system with a common supply/return manifolds for all 8 cryogenic receivers.
- Begin design/development of 8-channel VFD:
 - 3-phase 208VAC 60Hz input
 - 2-phase 180VAC 20-60 Hz output (x8), independently controlled
 - Output current & phase monitoring, fault detection
 - RFI-tight enclosure, for operation on a VLA antenna
 - Design/development of monitor and control interfaces for the compressors, VFD unit
- Perform the same study on the compressors
- Combined test of the above components, installation and test on the Green Antenna

Questions?





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