Implementation Status of the Ultra-Wideband Receiver Package For The North American Array

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- Collaborators:

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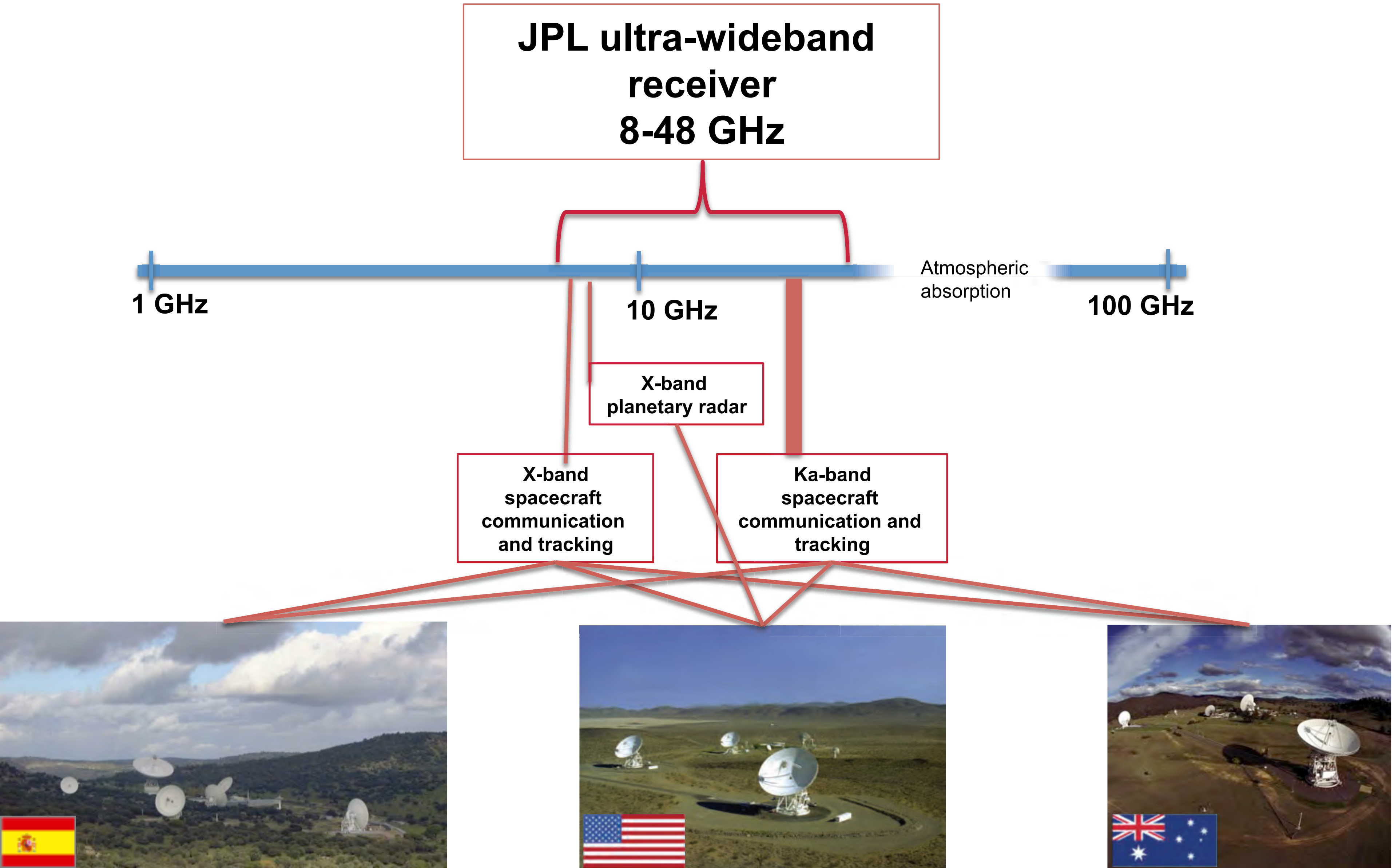
Outline

1. Overview
2. System Requirements
3. Development Status
   a. Feed horn
   b. Low-noise amplifier
   c. Cryogenic package
4. Summary

1. Overview


JPL ultra-wideband receiver
8-48 GHz
1 GHz
10 GHz
Atmospheric absorption
100 GHz
X-band planetary radar
X-band spacecraft communication and tracking
Ka-band spacecraft communication and tracking

2. System Requirements

System Requirements

- Continuous coverage for 8-48 GHz
- T_{rx} < 30 K,
  T_{sys} of 34 K @ 10 GHz and 45 K @ 30 GHz required
- Dual polarization

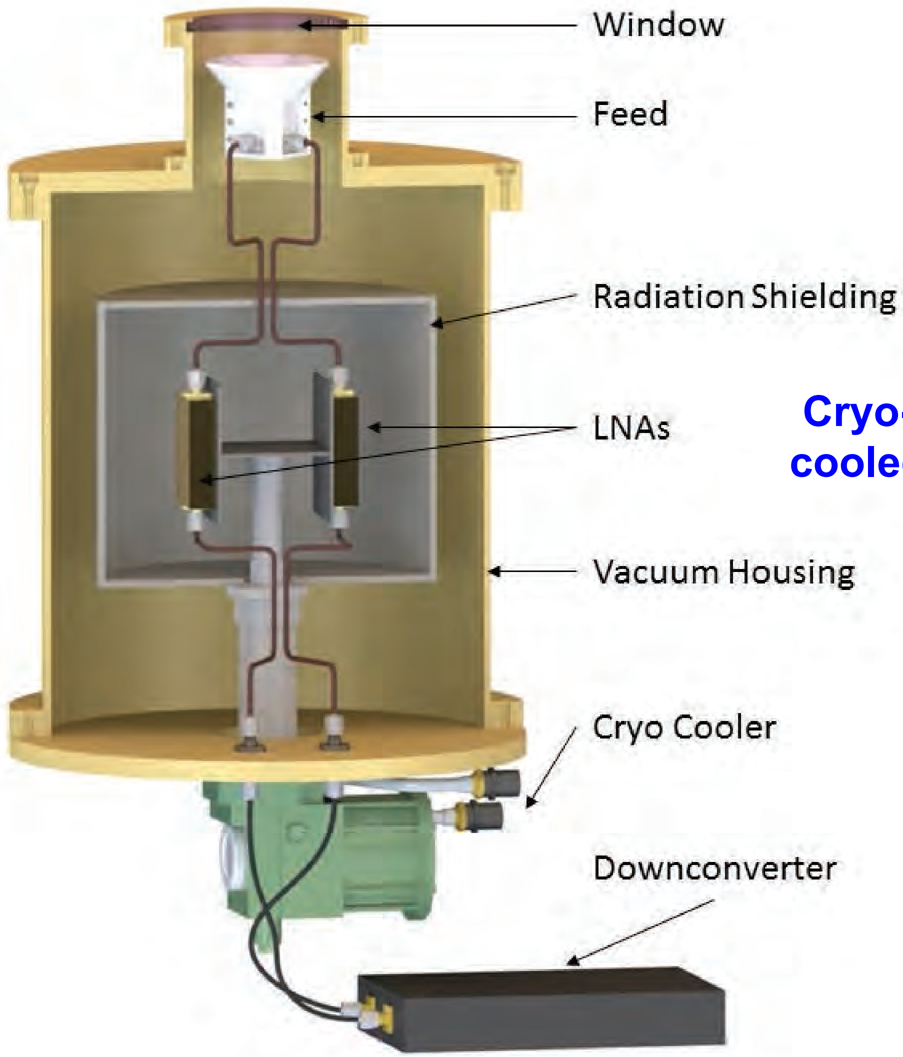
Design considerations

- Easy to manufacture
- Easy to service
- Compact cryogenic package
- Low Cost

Assumptions

- Baseline antenna is offset Gregorian (e.g. MeerKAT antenna) scaled to 18 m diameter with f/D = 0.55
- Optimize for 10 GHz

2. System Requirements



Cryo-cooled

Ultra-wideband receiver package is composed of:

- **Quad Ridge Feed Horn (QRFH)**
- **Low-noise amplifier**
- **Down-conversion stage**

→ Task plan is to construct and test this receiver package

Note: Notional layout shown, final layout will be more compact

3.a. Status - Feed Horn

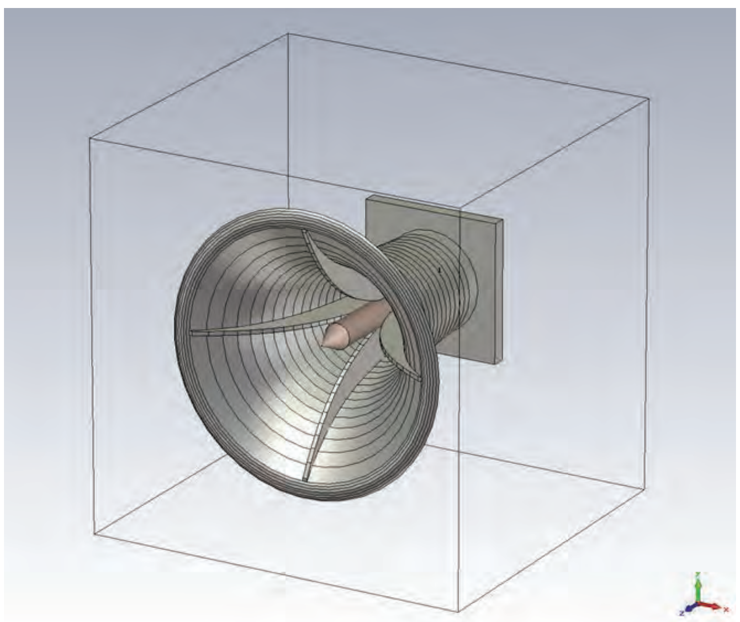
- Offset Gregorian paraboloid antenna assumed
- 8-48 GHz operation
- 0.55 focal ratio (similar to MeerKAT)
- Quad Ridge Feed Horn (QRFH)
  - Builds upon 6:1 design developed initially by A. Akgiray[1]
- Dielectric rod inserted to improve efficiency
  - Similar approach used by ATNF for Parkes Telescope ultra-wide band feed
  - Center radius of rod roughly determines coupling from horn to the rod vs. frequency, length determines pattern beam width (gain)

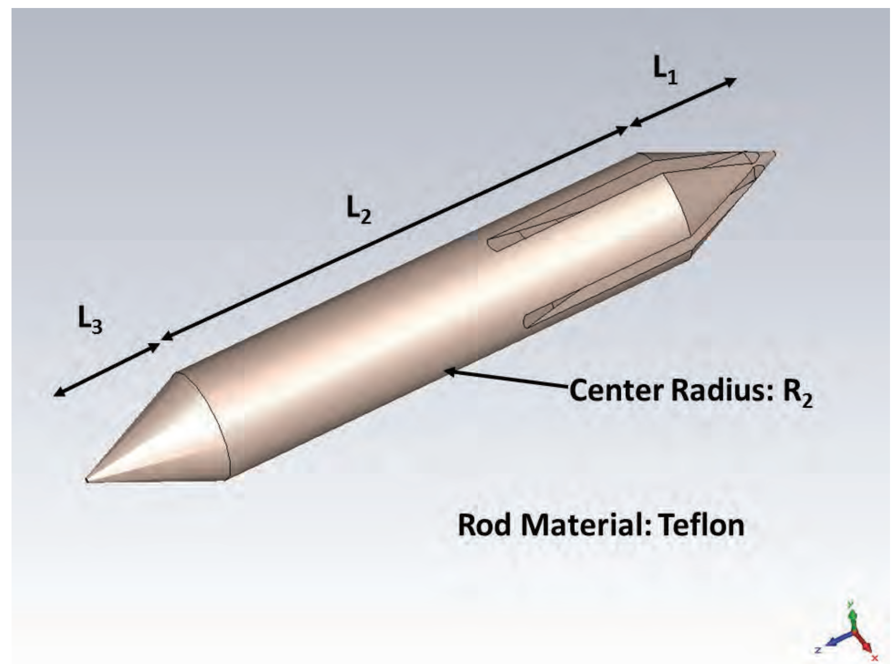
[1] Akgiray, A. H. (2013) Ph.D. Dissertation, California Institute of Technology

3.a. Status - Feed Horn

- Quad Ridge Feed Horn (QRFH) developed in collaboration with Sandy Weinreb's group
- Optimized for f/D = 0.55.

- Simple tapered Teflon rod is being modeled to demonstrate improvement in QRFH efficiency





Metal Only Horn with Dielectric Rod

3.a. Status - Feed Horn

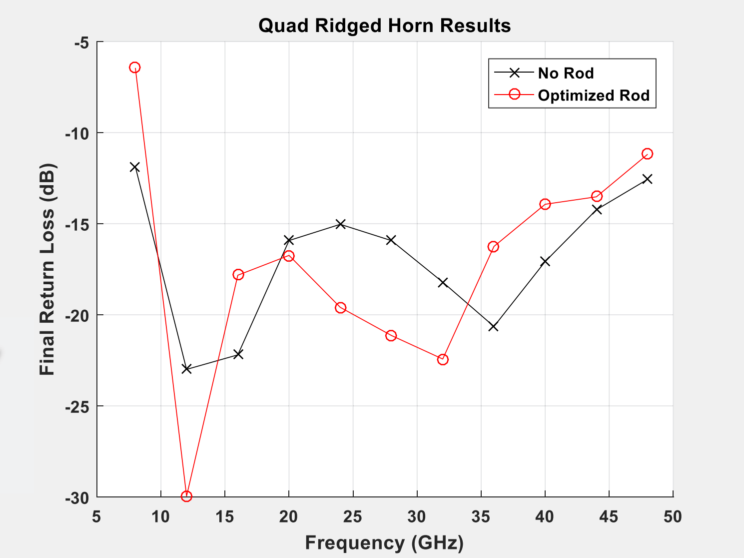
Best Rod Parameters:

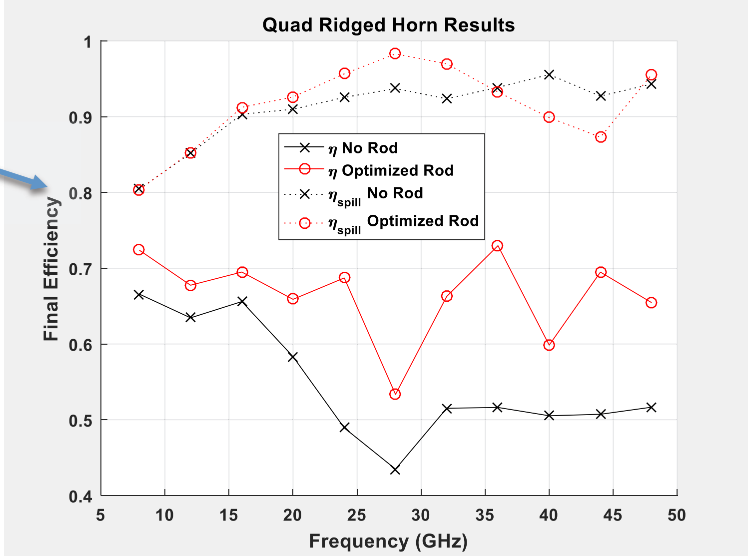
R_2=2.3 mm

L_1=L_3=5 mm

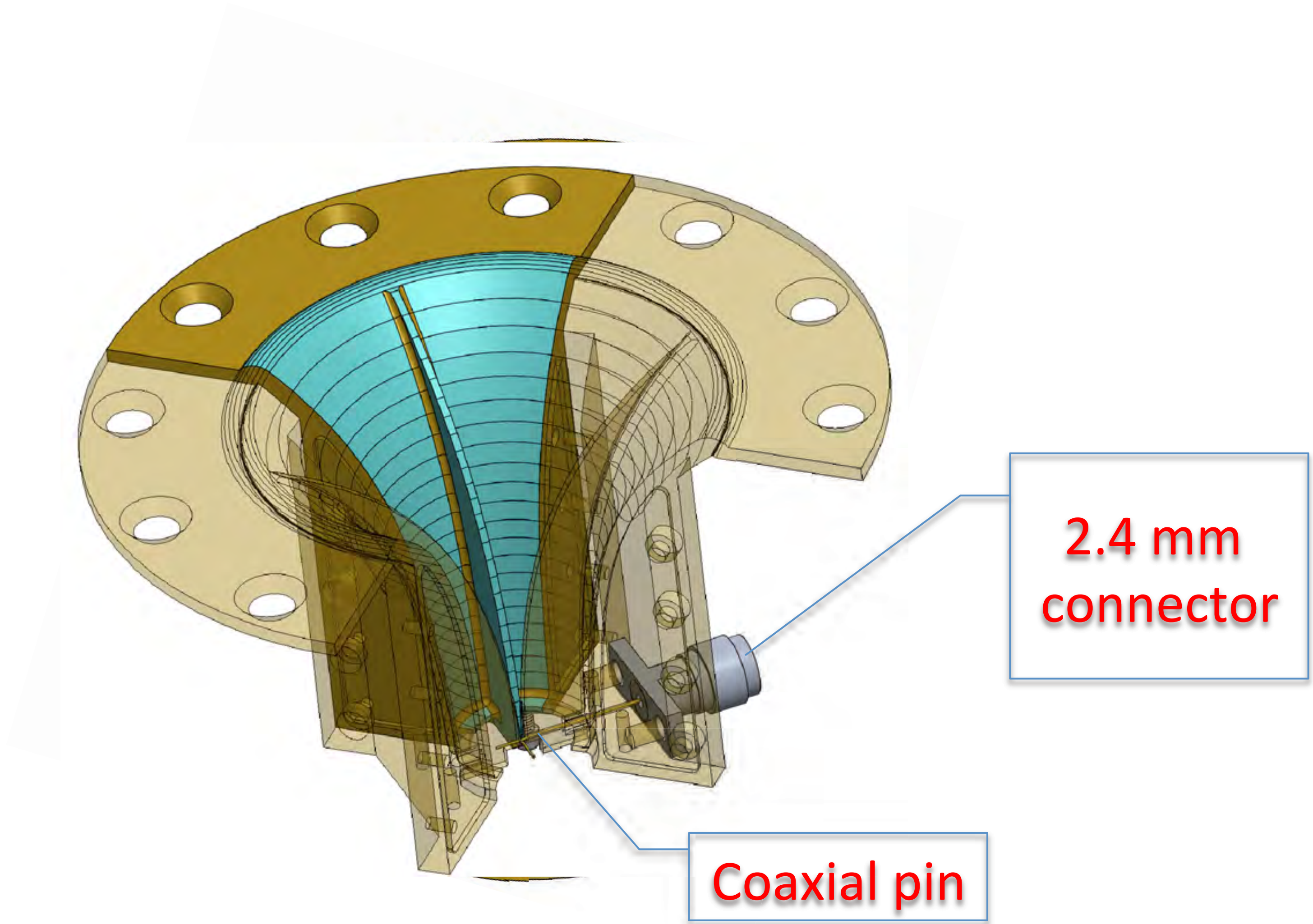
L_2=20.4 mm

- **Center radius** of the rod roughly determines the coupling from the horn to the rod vs. frequency
- **Rod length** determines the pattern beam width (Gain)





3.a. Status - Feed Horn

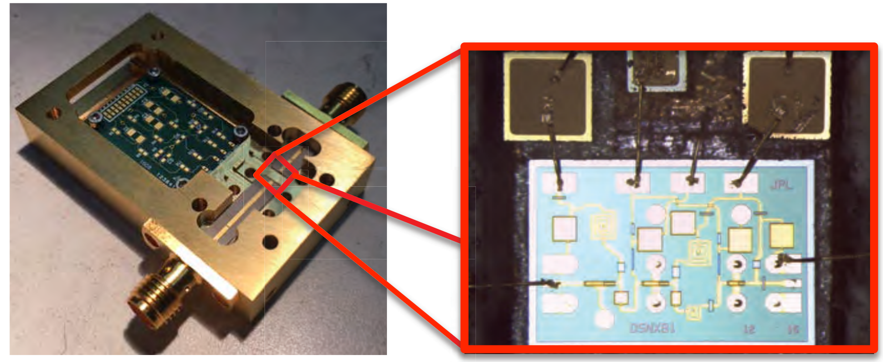


Quad Ridge Feed Horn

3.b. Status - LNA Design

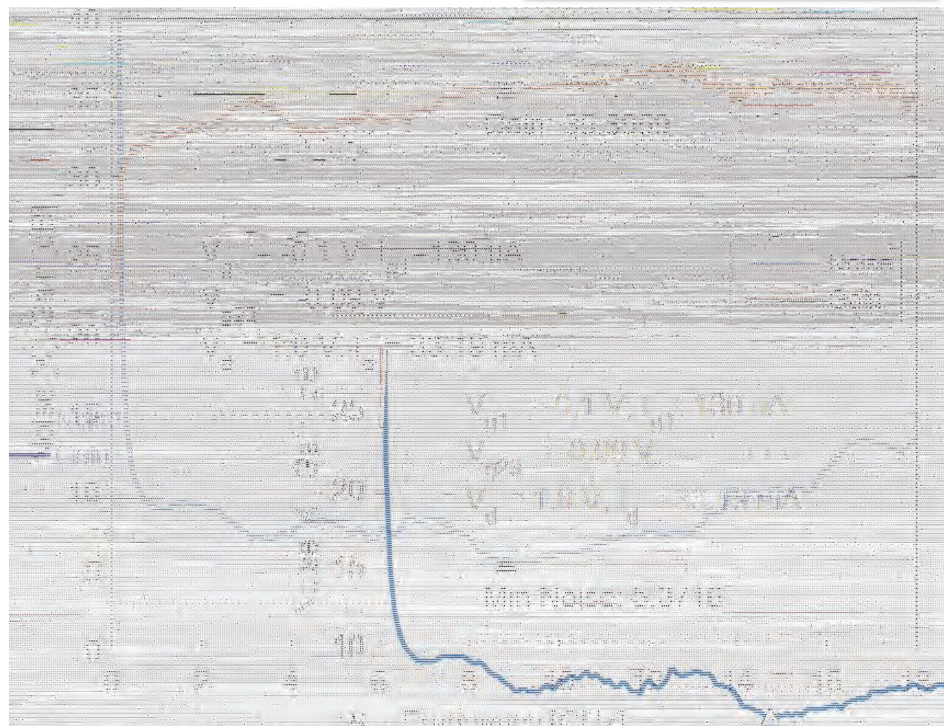
- Designing custom MMICs, getting them fabricated at foundries, installing in connectorized packages, and testing the packaged amplifiers
- We are pursuing two LNA design approaches:
  - 70-nm GaAs m-HEMT from OMMIC
  - 35-nm InP HEMT from NGC

3.b. Status - LNA Design



Preliminary experimental results obtained with **70 nm GaAs m-HEMT** from OMMIC in the **1-18 GHz**

- **35 dB** gain @ 8.4 GHz
- **5 K** noise @ 8.4 GHz



Experimental LNA test results at 1-18 GHz range

3.b. Status - LNA Design

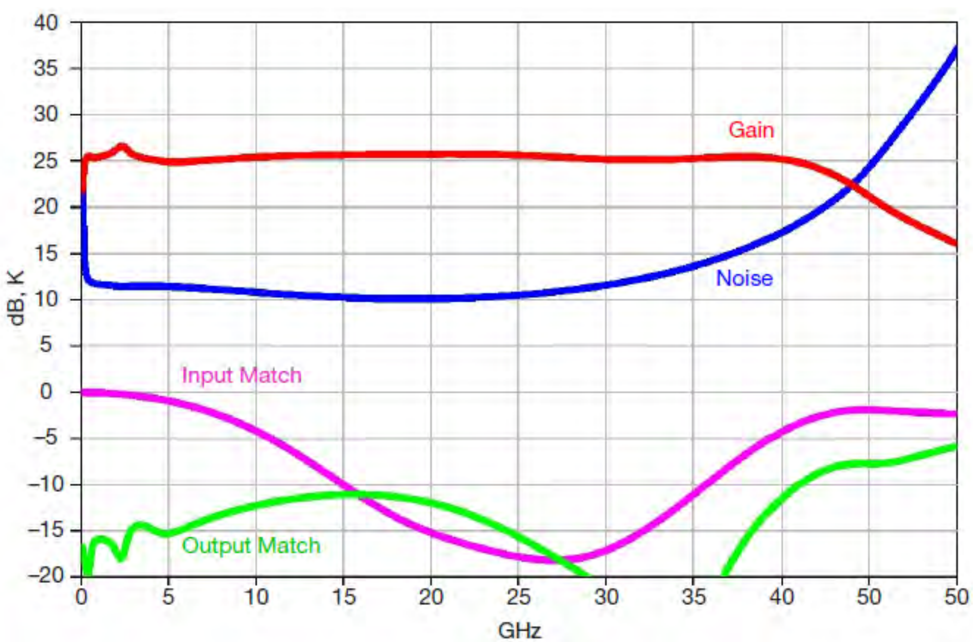
LNA design for 8-48 GHz operation,

- **70 nm GaAs m-HEMT** from OMMIC

Wideband LNA Requirements

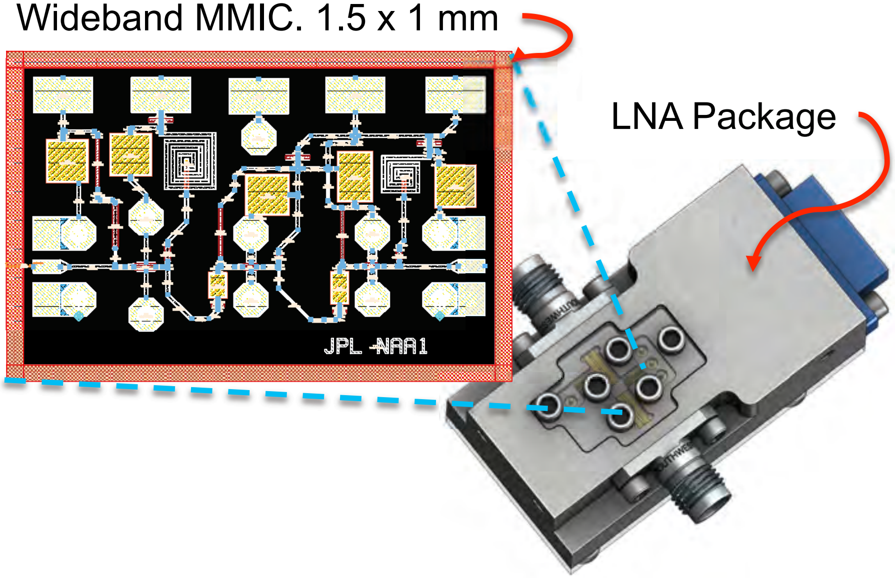
Parameter		Requirement
Noise Temperature	8-40 GHz	≤ 12 K
	40-48 GHz	≤20 K
Gain		≥ 30 dB
Gain Flatness		≤ 6 dB
Input Match	8-15 GHz	≤ -5 dB
	15-48 GHz	≤ -10 dB
Output Match		≤ -10 dB

Simulation of OMMIC Wideband LNA



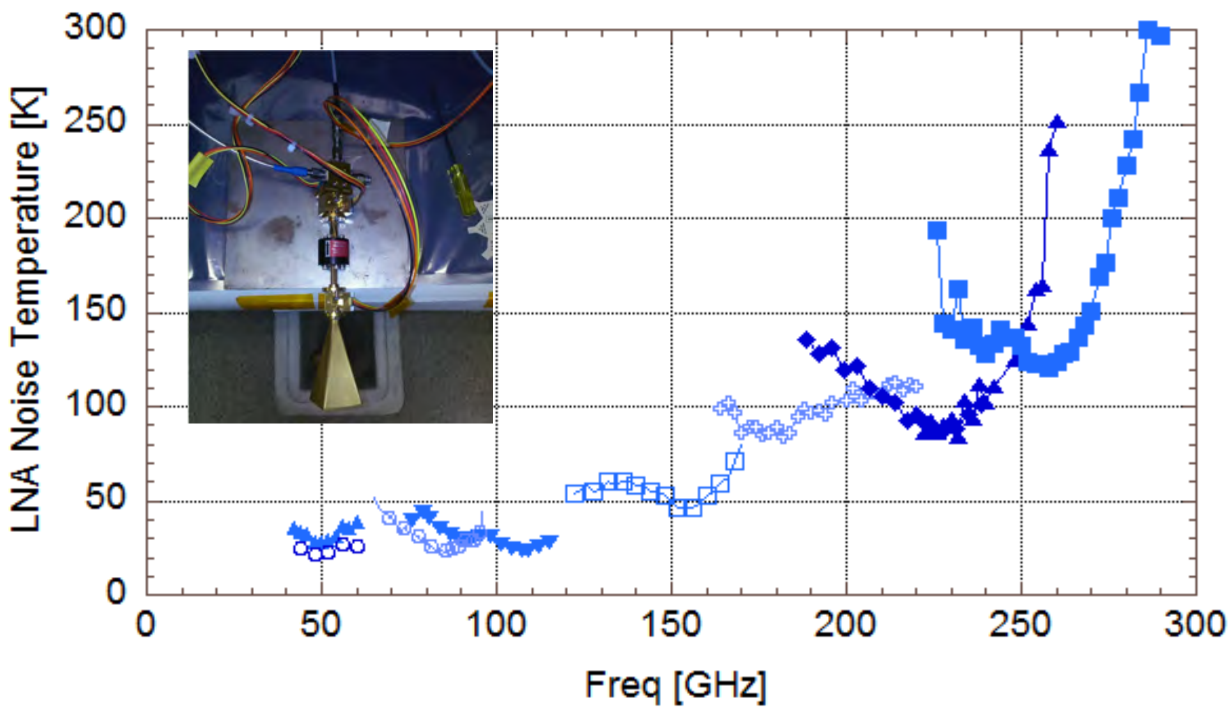
Wideband MMIC. 1.5 x 1 mm

LNA Package



3.b. Status - LNA Design

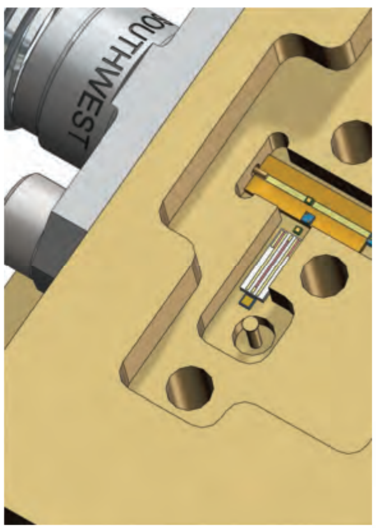
- Earlier InP HEMT (NGC) testing at higher frequencies (40--300 GHz) showed outstanding performance, suggesting similar performance is possible below 40 GHz

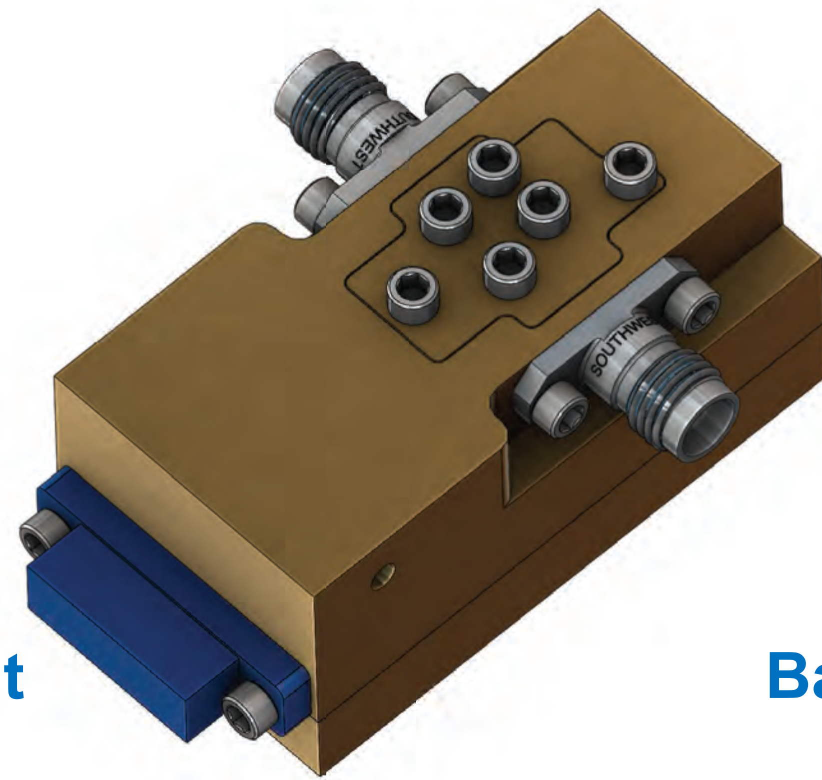


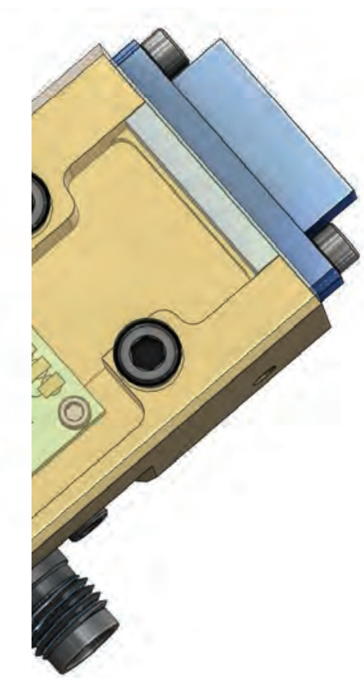
Measured results for 35 nm InP HEMT MMICs (NGC) over 40-300 GHz, with record noise temperature throughout

3.b. Status - LNA Design

- Design of 8-48 GHz wideband LNA housing nearly completed







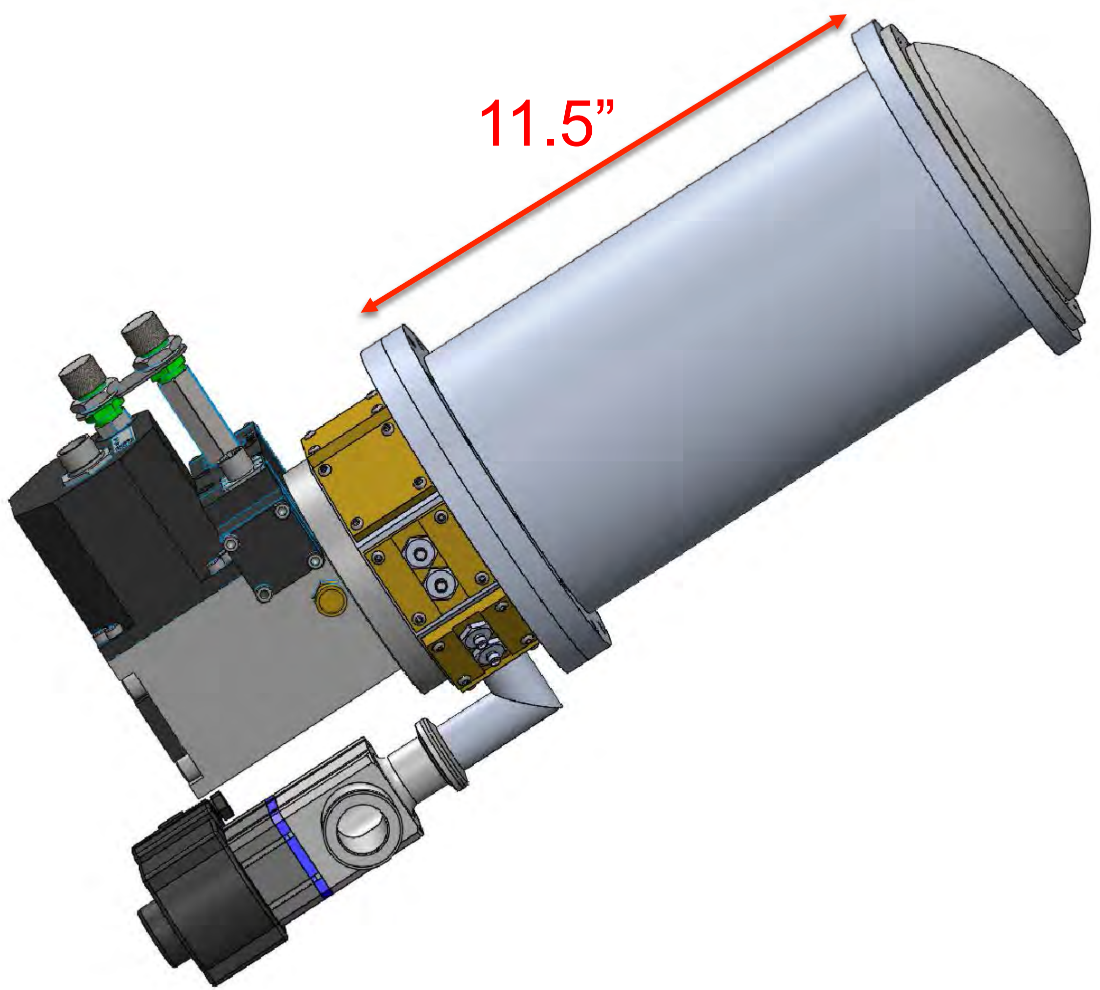
Front

Back

3.c. Status – Cryo-package

- Design has been implemented in SolidWorks
- Currently performing thermal design analysis for ~5 K operation
- Quantum GA1 cryogenic system purchased for evaluation and comparison with Sumitomo/CTI

3.c. Status – Cryo-package



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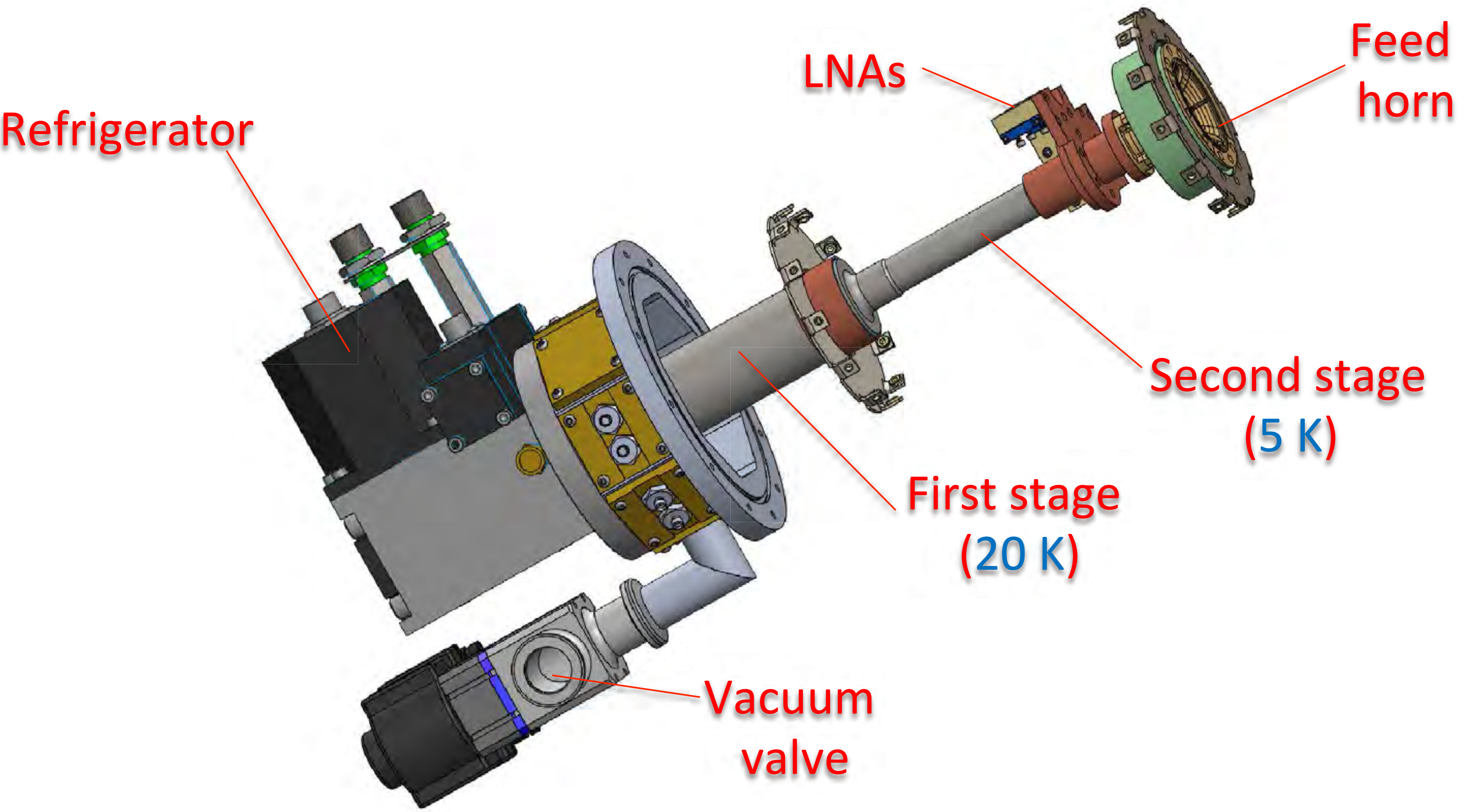
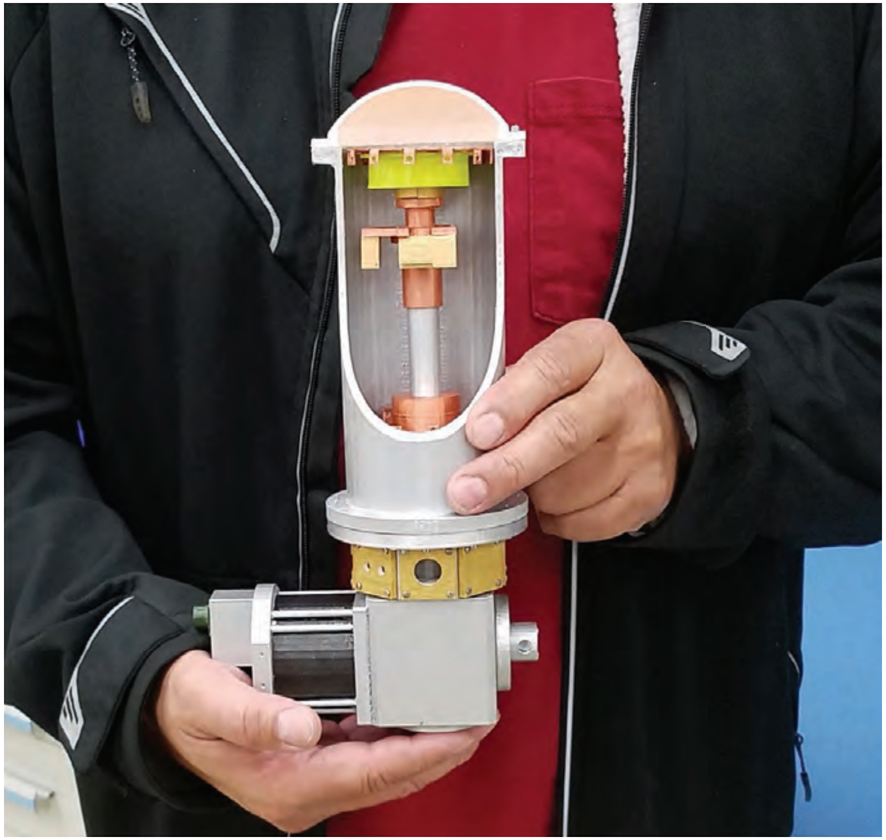


3.c. Status – Cryo-package

3-D model
(1/2 scale)



4. Summary

- Test and evaluate performance of first OMMIC wafer run
- Second wafer run with revised LNA design scheduled for April
- Optimize design for QRFH with dielectric rod and fabricate feed
- Evaluate performance of Quantum GA1 cryogenic system, finalize cryogenic system design.
- Work on downconverter design
- Prototype receiver expected to be complete in September 2017. It will then be tested on an existing antennas comparable to the ngVLA antenna.