Antennas and Feed Design at NRC

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NRC Herzberg Astronomy and Astrophysics, Penticton, BC, Canada

ngVLA Optics Workshop, Caltech, 19 June 2018

National Research Council Canada
Conseil national de recherches Canada

Outline

- Reflector antenna
  - DVA-1
  - DVA-2
- Feeds
  - Nested coaxial feed (WBSPF)
  - AFAD
  - Q-Band
- Test facilities
  - Near-field antenna range
  - Hot/Cold Test Facility
  - Surface Reflectivity
  - DVA-n

Reflector Antenna: DVA-1

$\delta_{surf} = 0.89$ mm $\delta_{surf} = 0.77$ mm (weighted)

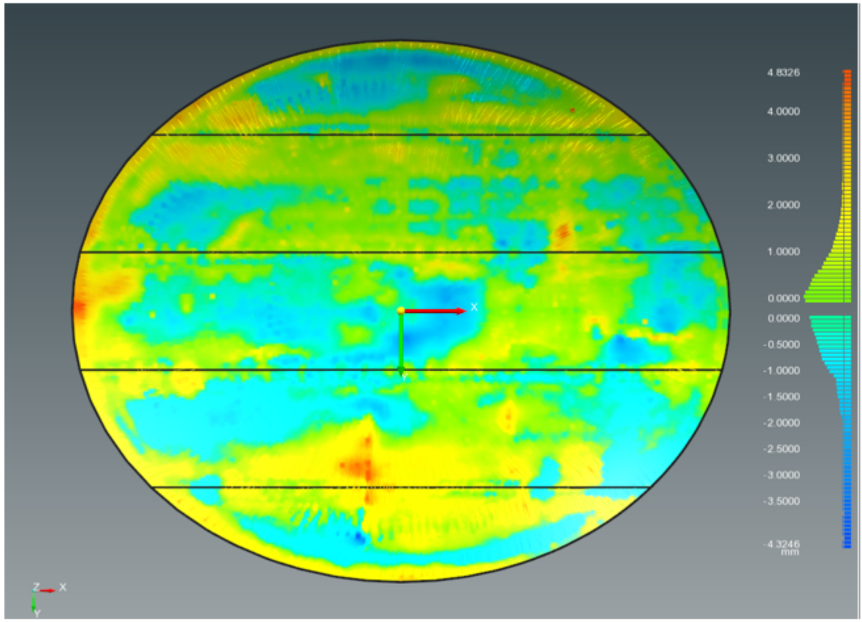
$\eta_{ap} \sim 0.78$ $A_{eff}/T_{sys} \sim 9\ \mathrm{m}^2/\mathrm{K}$

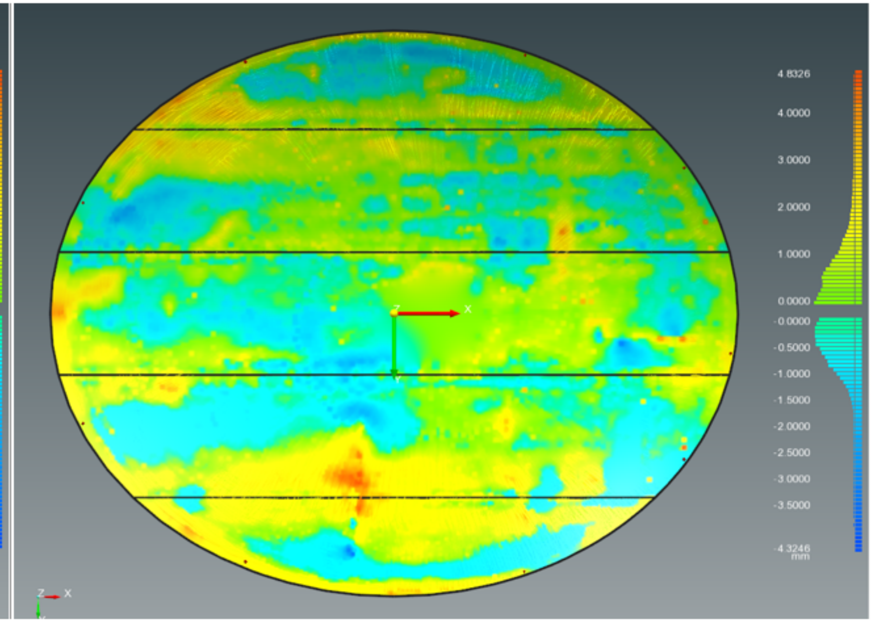
$T_{spill} \sim 4$ K $T_{sys} \cong 15$ K at 1.4 GHz

Knee *et al*., "System performance testing of the DVA1 radio telescope" SPIE Astronomical Telescopes + Instrumentation Conference, 2016

Stability of DVA–1 Primary Reflector

August 27 2014 ← 1366 days → May 25 2018





Start Time: 20:22
End Time: 21:43 (81 minutes)
Start Temperature*: 27.04°C
End Temperature*: 25.21°C (ΔT = 1.8°C)
RMS error: 900 μm

Start Time: 00:28
End Time: 01:30 (62 minutes)
Start Temperature*: 13.18°C
End Temperature*: 10.98°C (ΔT=2.2°C)
RMS error: 870 μm

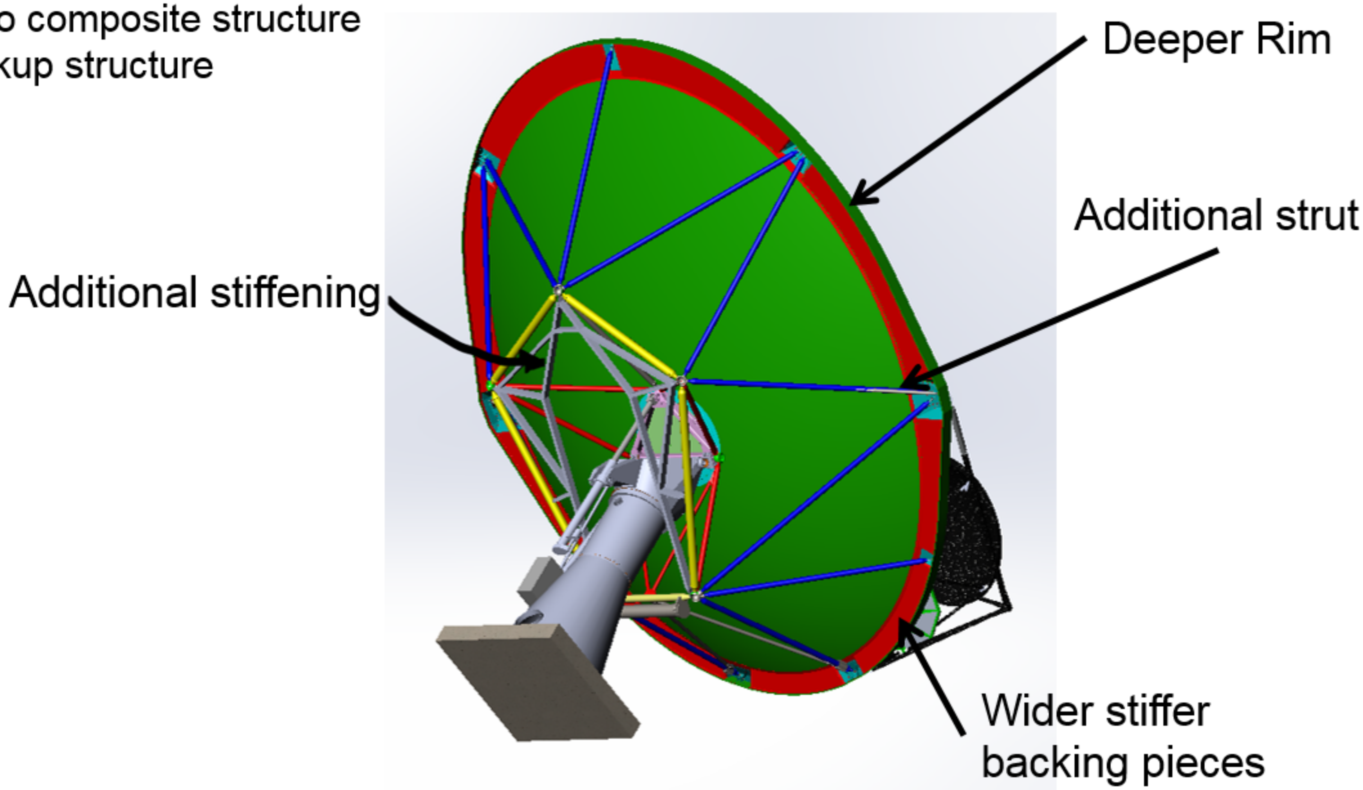
Laser tracker measurements.

Reflector Antenna: DVA-2

- For ngVLA need better surface accuracy
- DVA-1 molds were shipped back to fabricator and reworked
  - RMS mold error: 0.21 mm $\Longleftarrow$ measured
- New primary and secondary surfaces have been fabricated
  - Primary error: 0.335 mm (unweighted, measured), 0.22 mm (weighted)
  - Ruze efficiency: 80% @ 50 GHz $\Longleftarrow$ calculated
- DVA-1 surfaces will be removed from pedestal and replaced with DVA-2 surfaces
  - Removal: June–July
  - Back on air: September–October

DVA-2 Structural Improvements: Primary

Target 50 GHz max frequency.
Low shrink resin (epoxy)
Changes to composite structure
Stiffer backup structure



DVA-2 Structural Improvements: Secondary

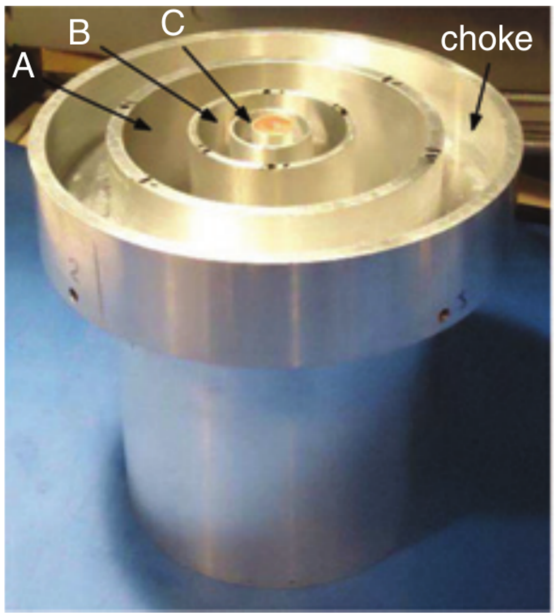
- Stiffening the ring around the secondary yields significant improvements
  - Reinforce shell near rim,
  - Add CFRP ring to rim,
  - Add a pair of tie rods

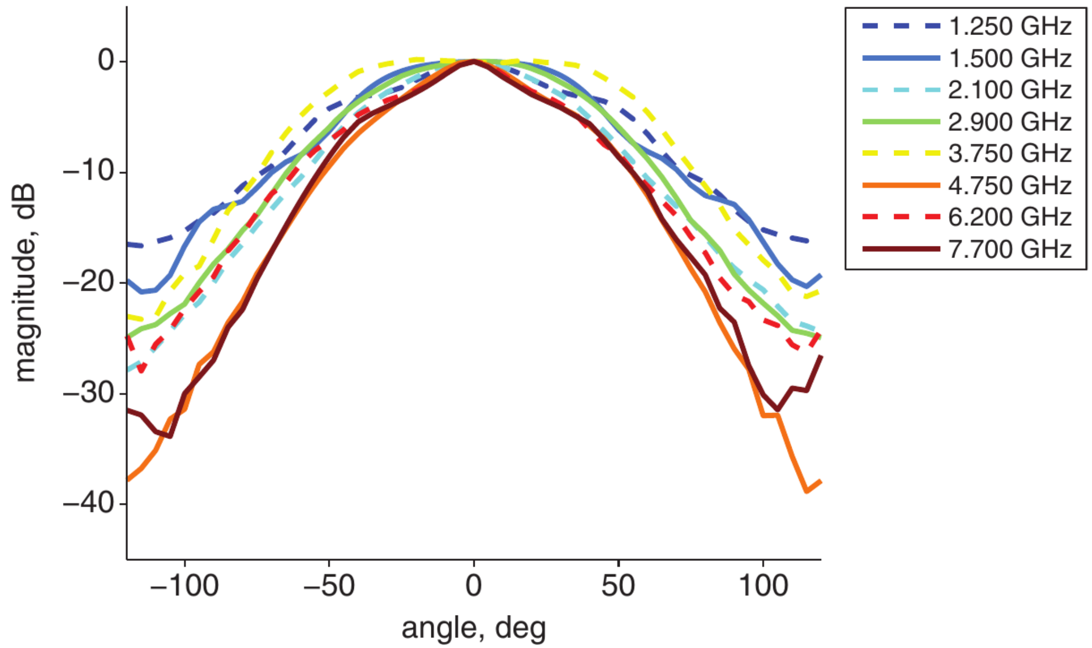
Elevation Angle	RMS Error	Fraction of DVA-1 Error
15°	26 μm	0.04
55°	16 μm	0.04
90°	24 μm	0.15

Islam *et al*., "An improved secondary reflector for DVA-2 radio telescope: A case study on application of structural optimization technique" SPIE Astronomical Telescopes + Instrumentation Conference, 2018

Nested Coaxial Feed (WBSPF)

- ▷ Based on log-periodic nested coaxial waveguide radiators
- ▷ Prototype (MSc project) had poor $S_{11} \Longrightarrow$ improve match (PhD project)



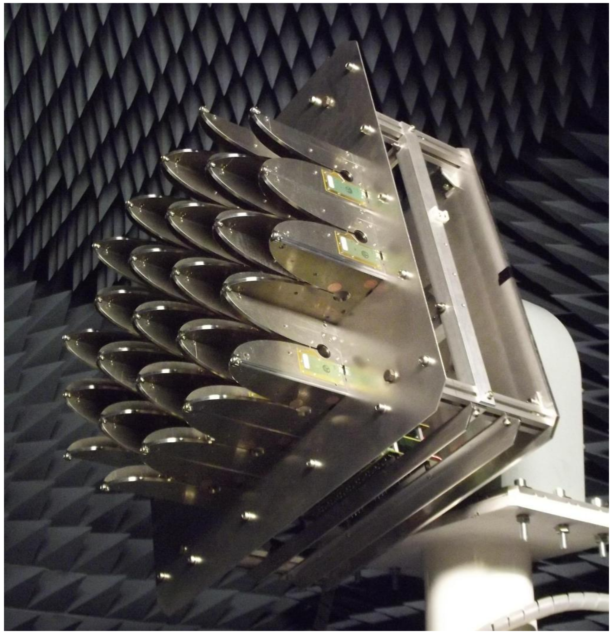


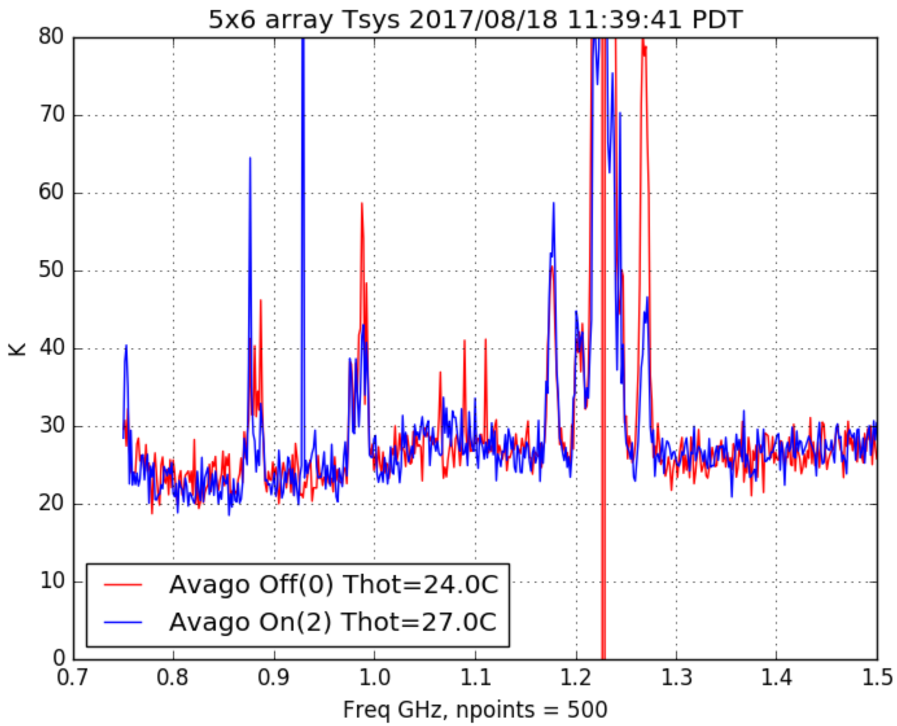
Johnson *et al*., "Frequency multiplexing excitation network for ultra-wideband coaxial waveguide feeds" Elec. Lett., vol. 51, pp.1580–1582, 2015

Du *et al*., "Wideband Matching of a Coaxial Waveguide Feed Using an Iris Matching Network " ANTEM, August 2018

Advanced Focal Array Demonstrator (AFAD)

- CMOS LNAs (UofC) for low noise temperature at room temperature
- Thick Vivaldi for low loss



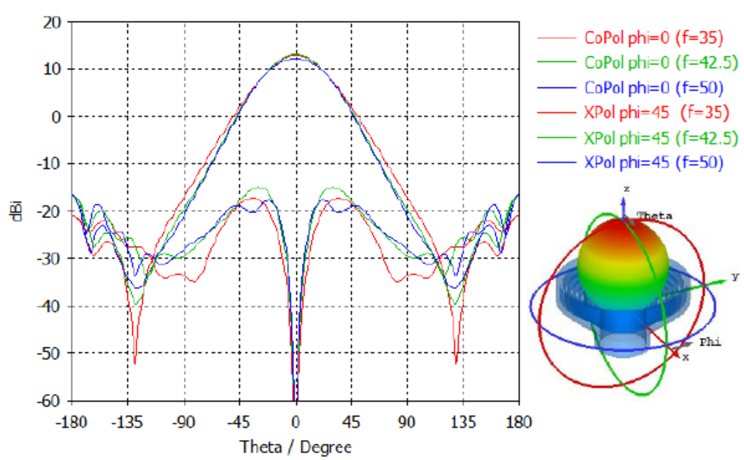


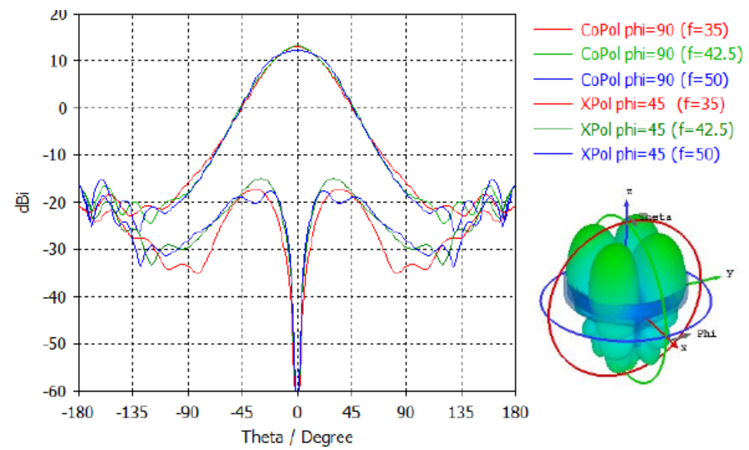
Burgess et al. "A Large Phased Array Feed with CMOS Low-Noise Amplifiers" EuCAP 2018

Q-Band Receiver

- 35–50 GHz
  - Goal: $T_{LNA} < 12\text{K}$, $T_{rx} < 25\text{K}$
  - To be tested on DVA-2
- Horn scaled from Lynn Baker's L-band design
  - Edge taper: -16 dB @ 55°
- Will use NRC turnstile-junction OMT (scaled version of ALMA Band-1 OMT)
- Will use NRC InP LNA

Q-Band Horn Patterns



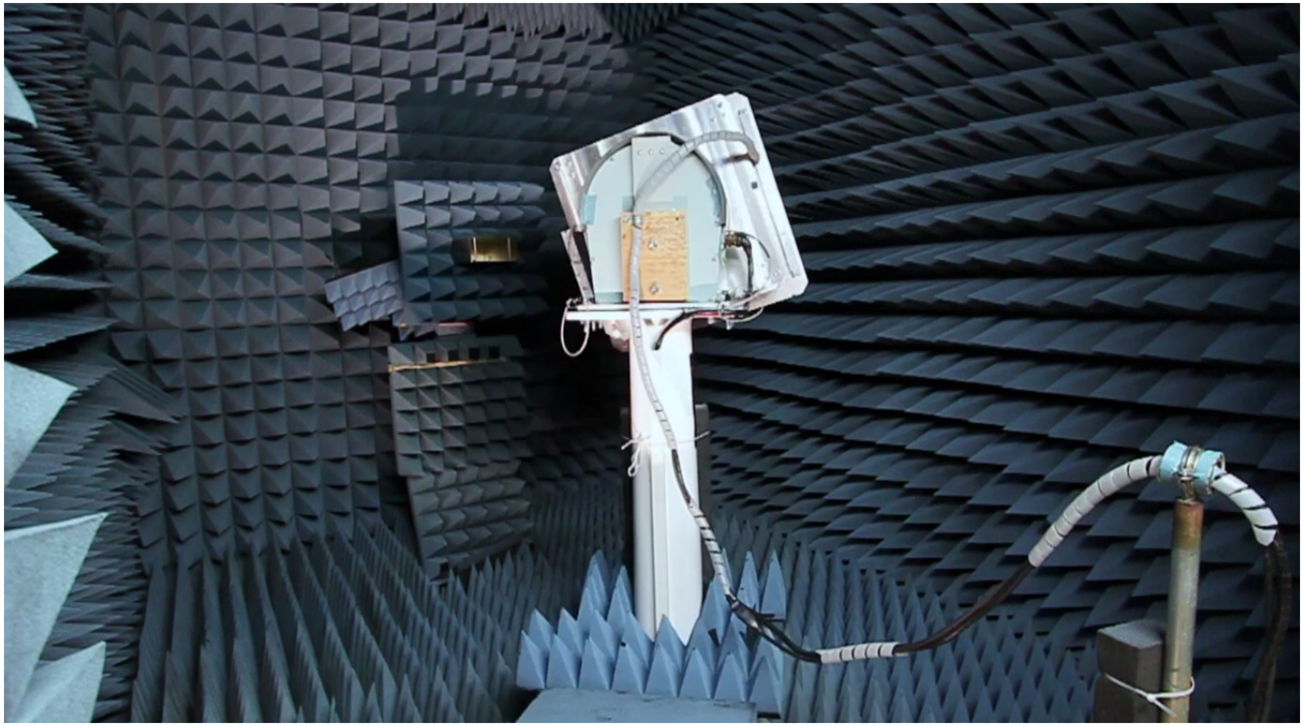


Good agreement with measurements made with a planar near-field scanner over a limited angular range ($\pm 60^\circ$).

Locke *et al*., "Feed and Receiver Development at NRC Herzberg" ngVLA Memo #32, 2017

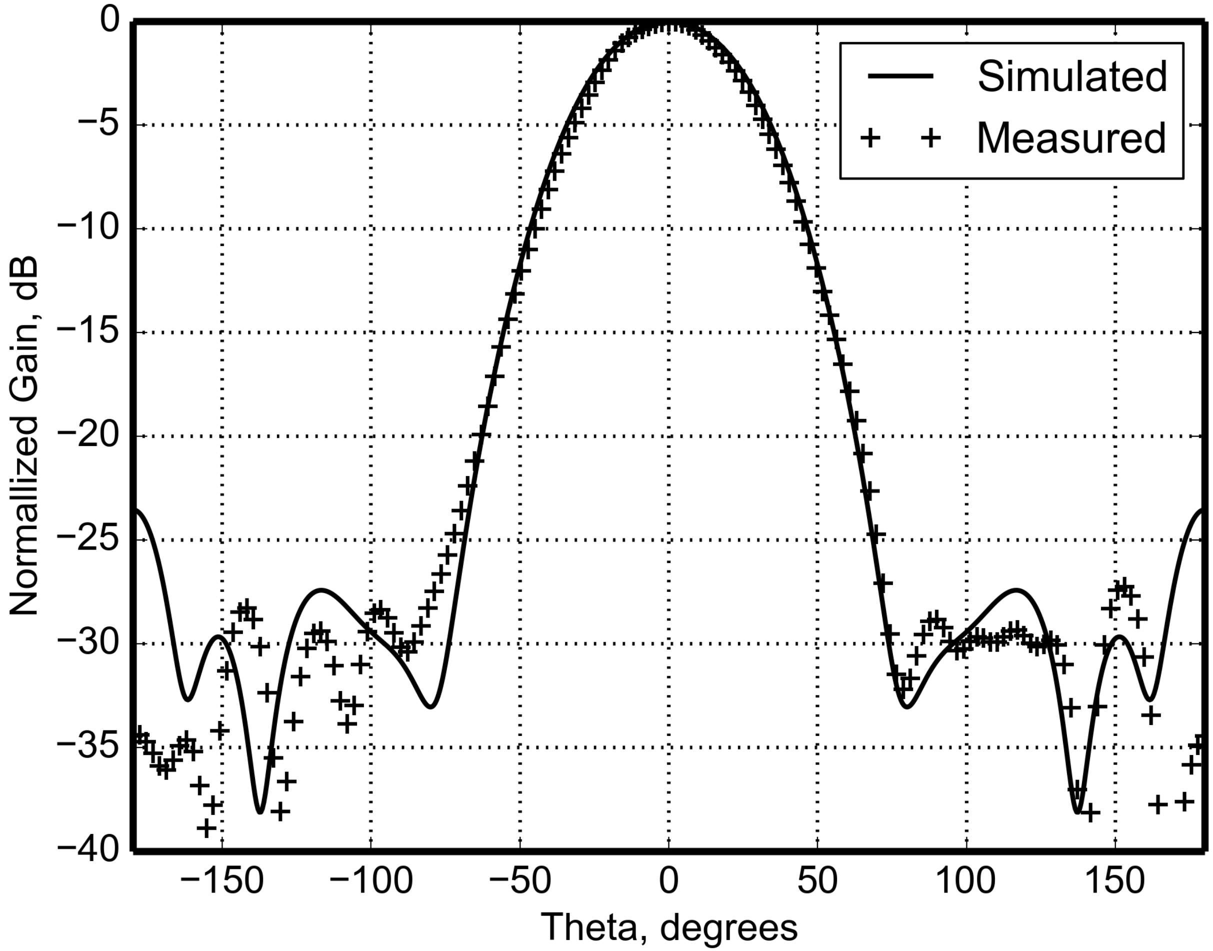
Locke *et al*., "Q-band single pixel receiver development for the ngVLA and NRC" SPIE Astronomical Telescopes + Instrumentation Conference, 2018

Spherical Near-Field Antenna Range



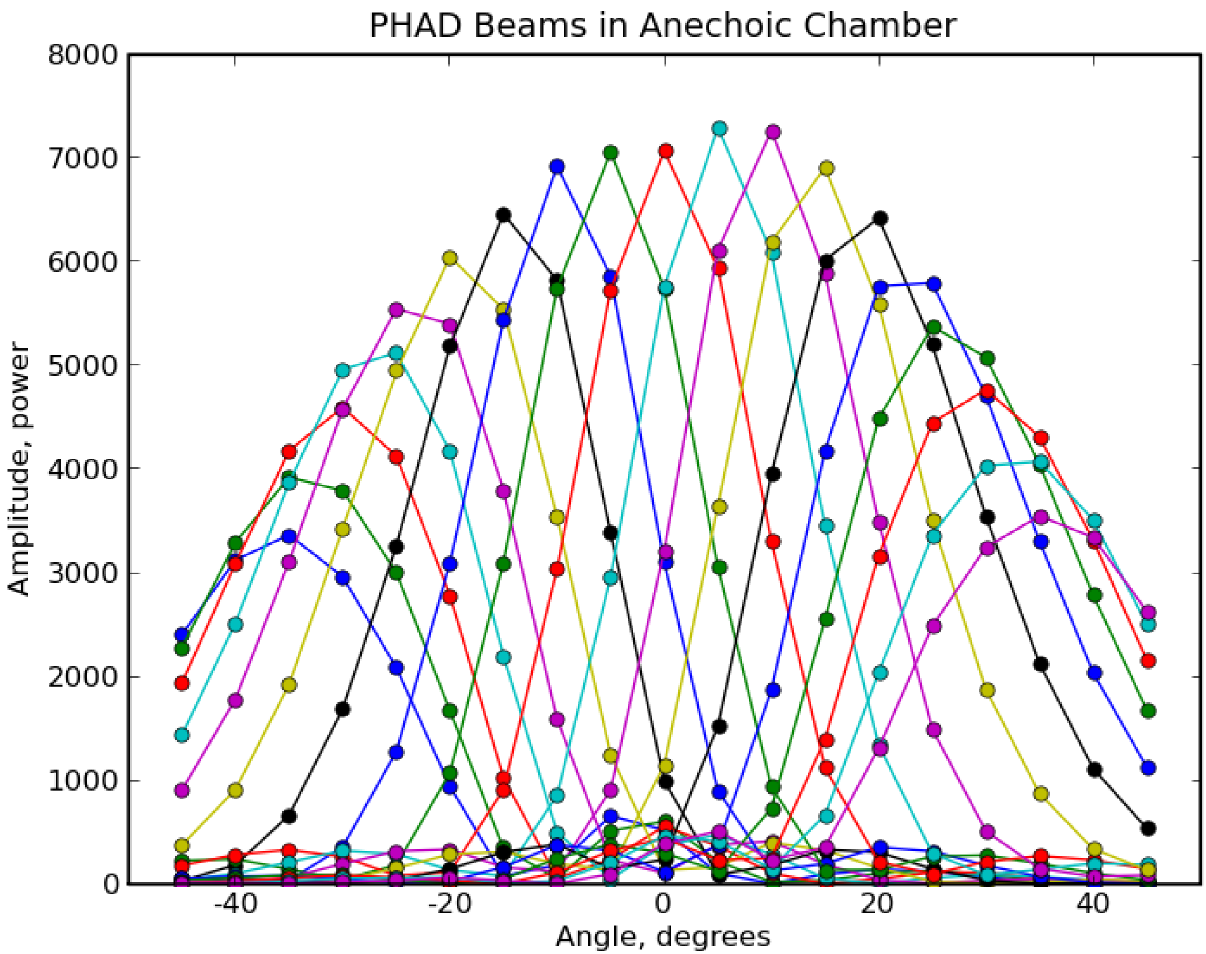
Type:	Spherical NF (Orbit/FR)
Probes:	Set of OEWGs covering 1–15 GHz
Quiet zone:	$\sim 1\,\mathrm{m}^3$
Separation:	$<$ 1.93 m (probe interface to AUT COR)

Near-Field Range: Analog Beamformer



[1 GHz]

Near-Field Range: Digital Beamforming

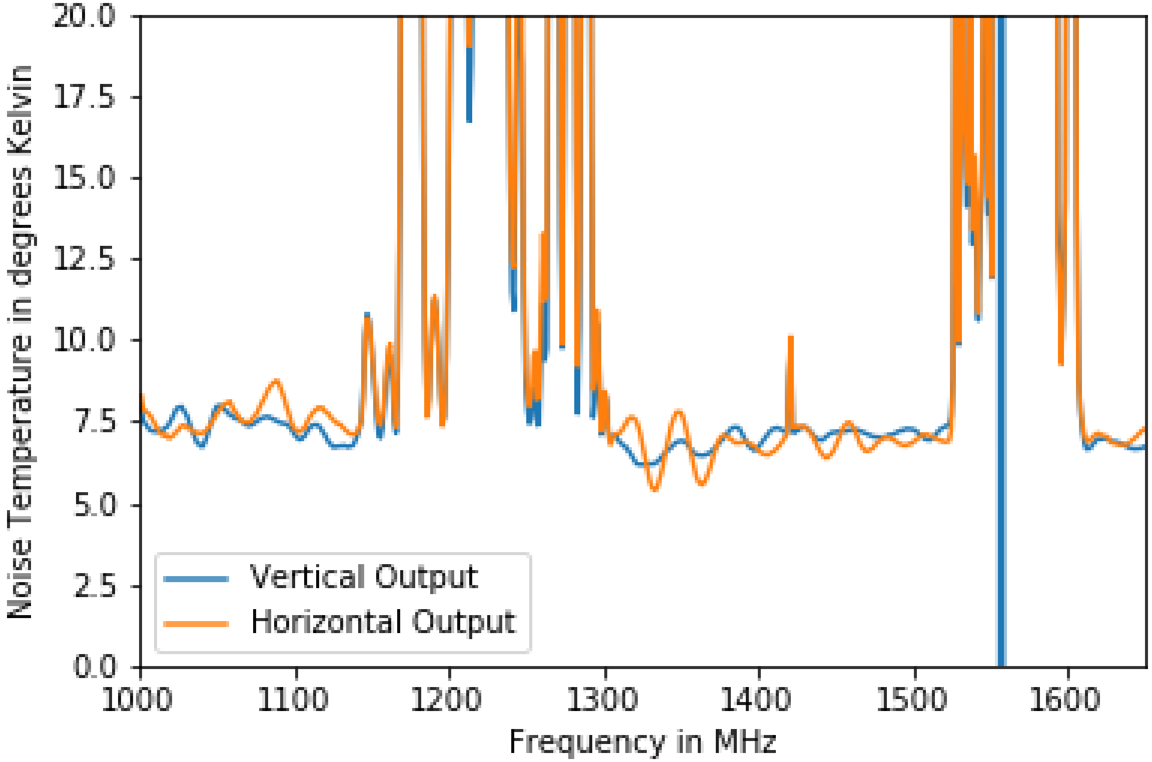


Hot/Cold Test Facility

Base:	2 m × 2 m
Opening:	4.1 m × 4.1 m
Height:	2.3 m

- ▷ Automated operation with an observing script
- ▷ Data reduction uses *Global Sky Model* to estimate T_{gal} $[T_{cold} = T_{gal} + T_{CMB} + T_{atm}]$

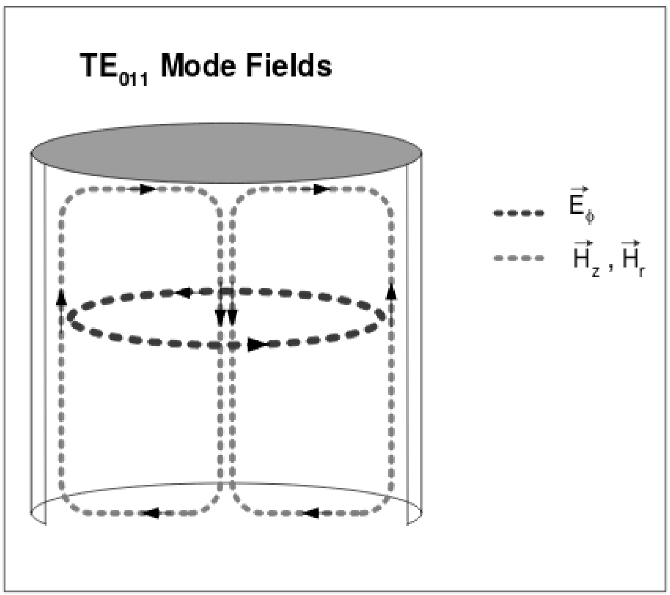
HCTF Results — EMSS Receiver



Hovey *et al.*, "An Automated System for Measurement of Sensitive Microwave Radiometers" ANTEM, August 2018

Surface Reflectivity Measurement System: Cavity

- ▷ Composite reflectors use embedded metallic foil as reflecting surface
- ▷ Resonant cavity using TE_{011} mode where transverse currents $= 0$
  - ▷ With VNA measure $Q \longrightarrow R_{surf} \longrightarrow T_{eff}$
  - ▷ Three cavities: 8.4, 14.6, and 18.4 GHz

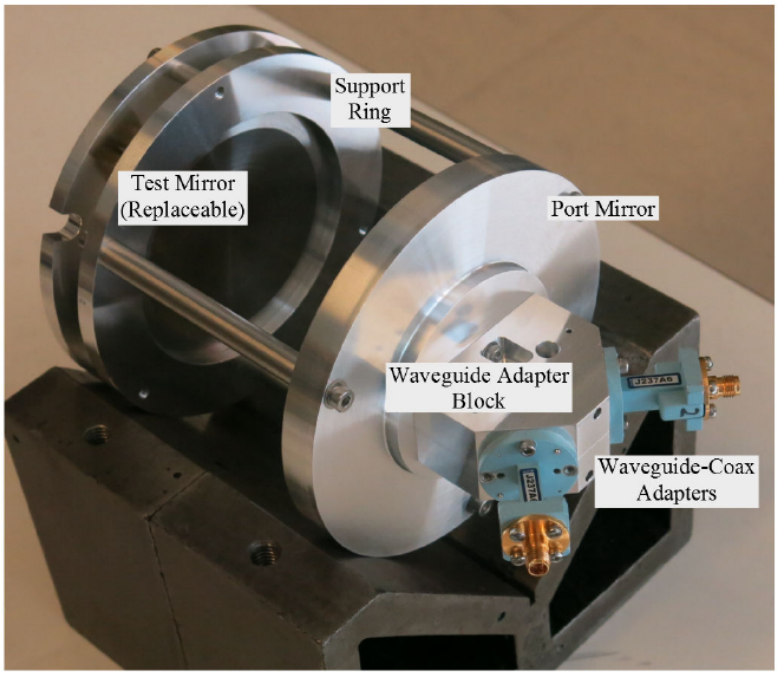


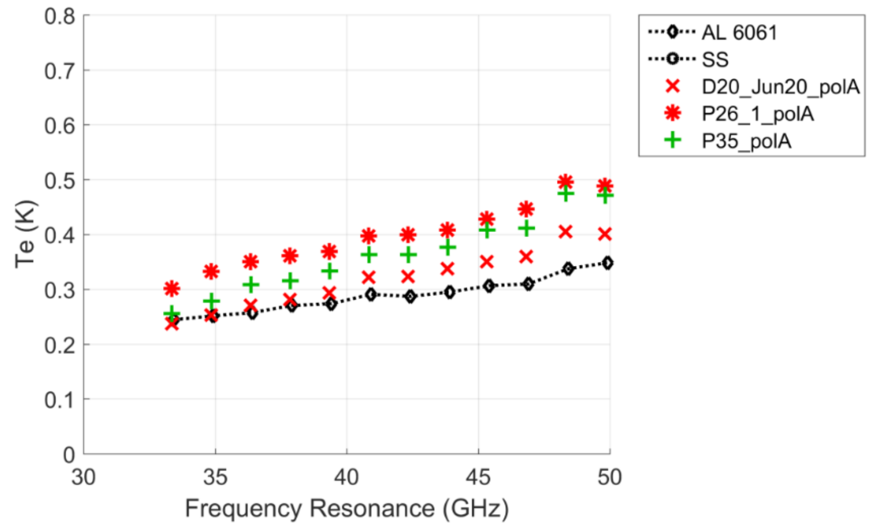
Otoshi *et al*., “The Electrical Conductivities of Steel and Other Candidate Materials for Shrouds in a Beam-Waveguide Antenna System” IEEE Trans. Instrumentation and Measurement, 1996

Surface Reflectivity Measurement System: Fabry-Pérot

At high frequencies cylindrical cavities are small so use Fabry-Pérot resonator.

Using copper foil reflecting layer (high conductivity, high corrosion resistance)





Henke *et al*., "Fabry-Perot resonator design for the measurement of surface reflectivity" Global Symposium on Millimeter Waves, 2016, DOI:10.1109/GSMM.2016.7500310

Henke *et al*., "Measurements of Composite Reflectors across Q-Band (33–50 GHz) and W-Band (75–115 GHz)" ANTEM, August 2018

HCTF and DVA-n as Test Facilities

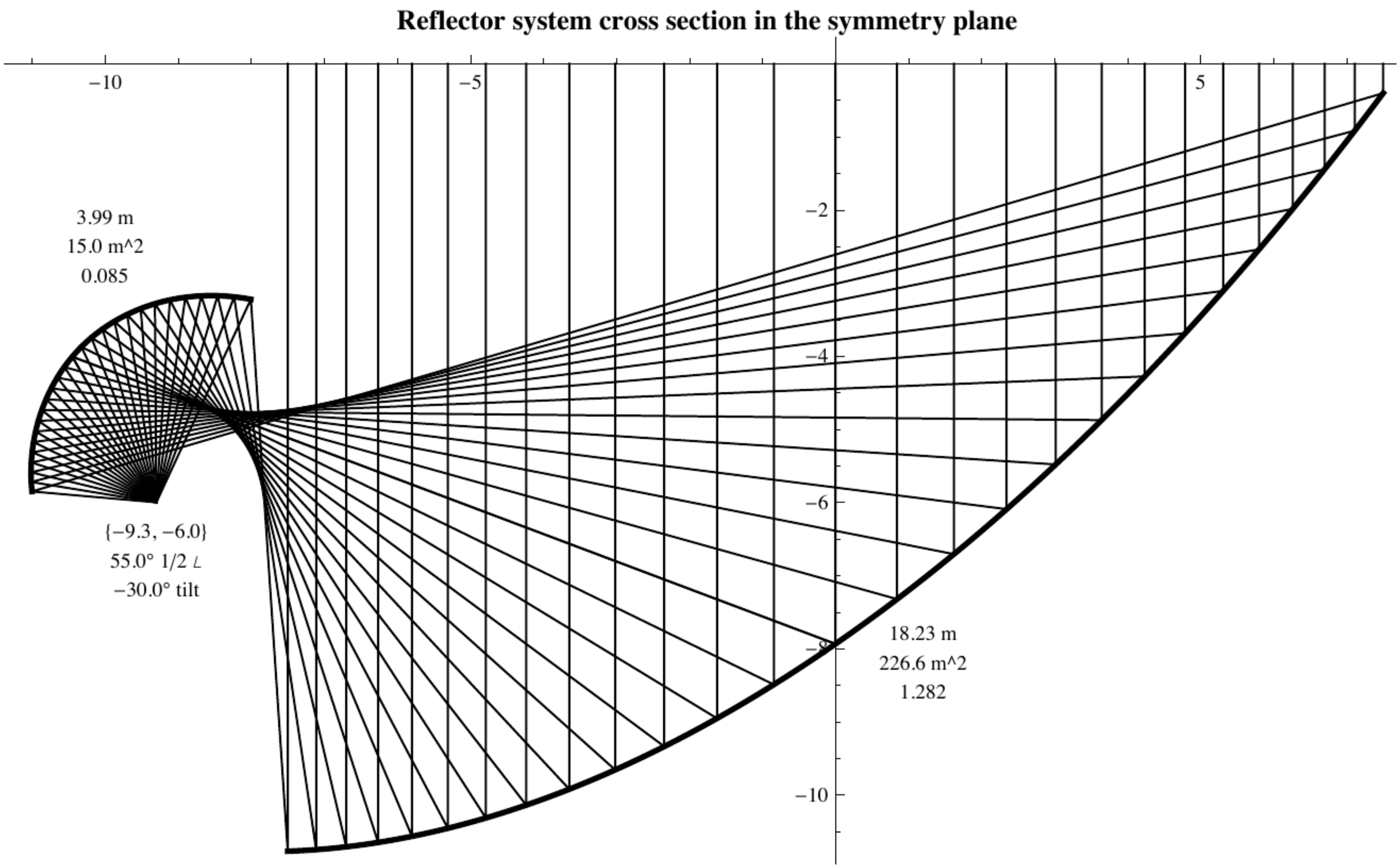
- EMSS L-Band receiver (uses NRC LNAs & Lynn Baker horn)
  - $T_{sys} \cong$ 15 K at 1.4 GHz (zenith)
  - $T_{spill} \cong$ 4 K
  - $\eta_{ap} \cong$ 0.78
- Onsala 0.35–1.05 GHz QRFH + Low Noise Factory LNAs
- Series of astronomical observations is planned
  - After upgrading surfaces will be back on air $\sim$ Sept.–Oct.
  - Polarization studies using EMSS and Onsala receivers (Tim Robishaw)
  - Q-band when available

Knee *et al*., "System performance testing of the DVA1 radio telescope" SPIE Astronomical Telescopes + Instrumentation Conference, 2016

Flygare *et al*., "Beam pattern measurement on offset Gregorian reflector mounted with a wideband room temperature receiver for the Square Kilometre Array" IEEE Int. Symp. Ant. Prop., July 2018

Thank You

DVA-1 Optics



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Corrosion Resistance References

- Aluminum: http://www.conways.co.za/pdf/afsa_corrosion_pocket_guide.pdf
- Copper: http://www.totalmateria.com/Article16.htm