Phased Array Feeds at NRAO

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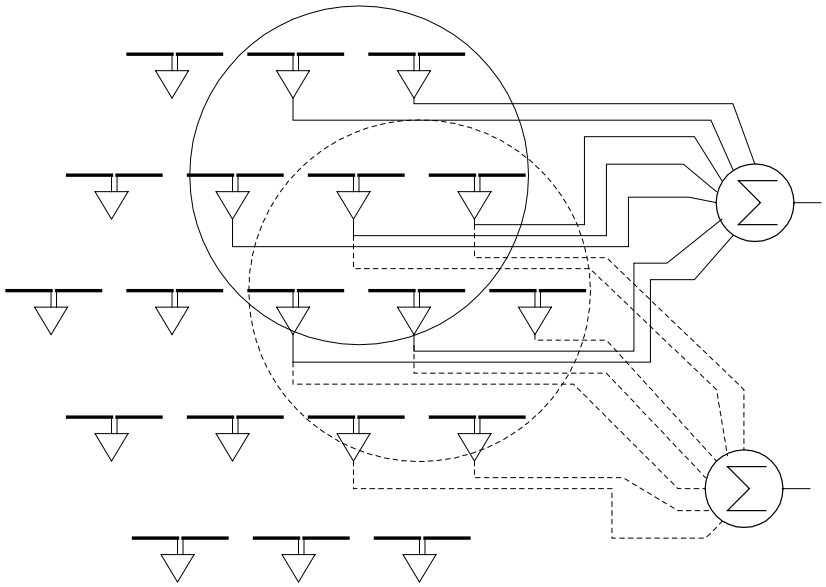
BYU: K. Warnick, B. Jeffs

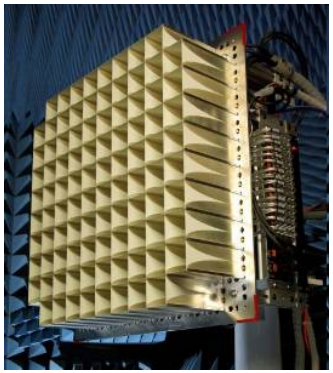
PAF Concept



Combine multiple small elements with appropriate complex weights to form multiple beams and optimize Field-of-View and increased Survey Speed

PAF Context: History and NRAO Development

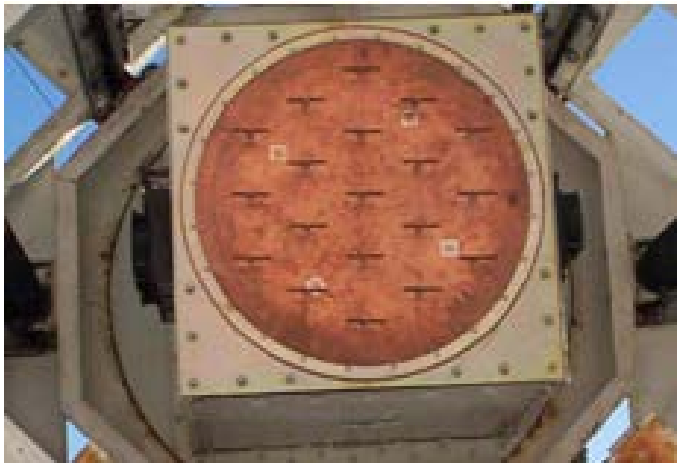
- Initial Concepts and Early Experiments: 1995-2008
- 2008 to present:
  - Pre-SKA search for new paradigms begins to push PAF to front burner: SKA and APERTIF. These are large, uncooled, high N(element count) and mid M (# antennas)



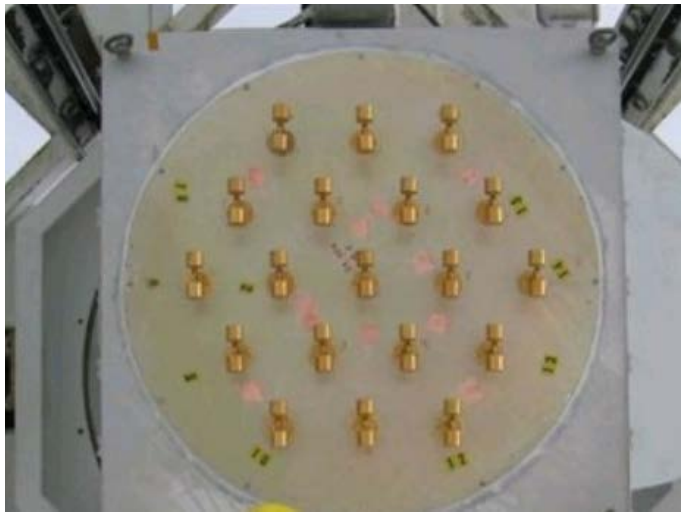
  - US-based groups R&D effort based on single dish, cooled receivers (NRAO, BYU, Cornell)
  - At NRAO this is the **F**ocal **L**-Band Array for the **G**BT (FLAG)

NRAO Focal L-Band Array for GBT (FLAG)

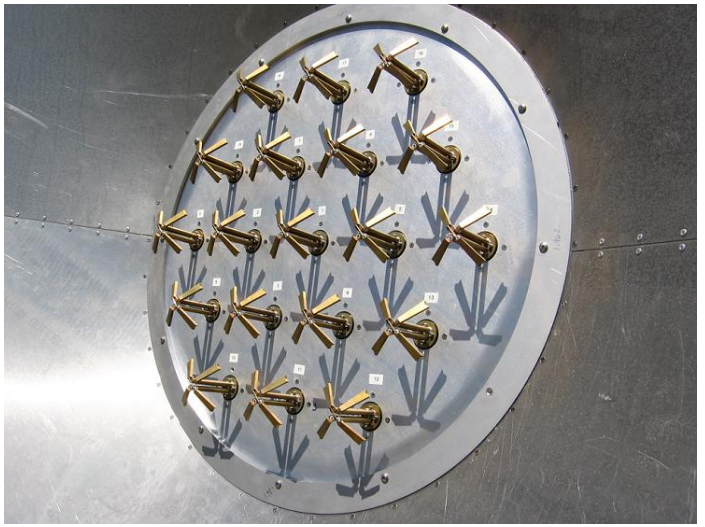
Sinuous elements 140-ft 1996



Thin Dipoles 20-meter 2007



Thick, impedance-optimized dipoles, 20-meter, 2011



Present FLAG Receiver, “Kite Dipoles”

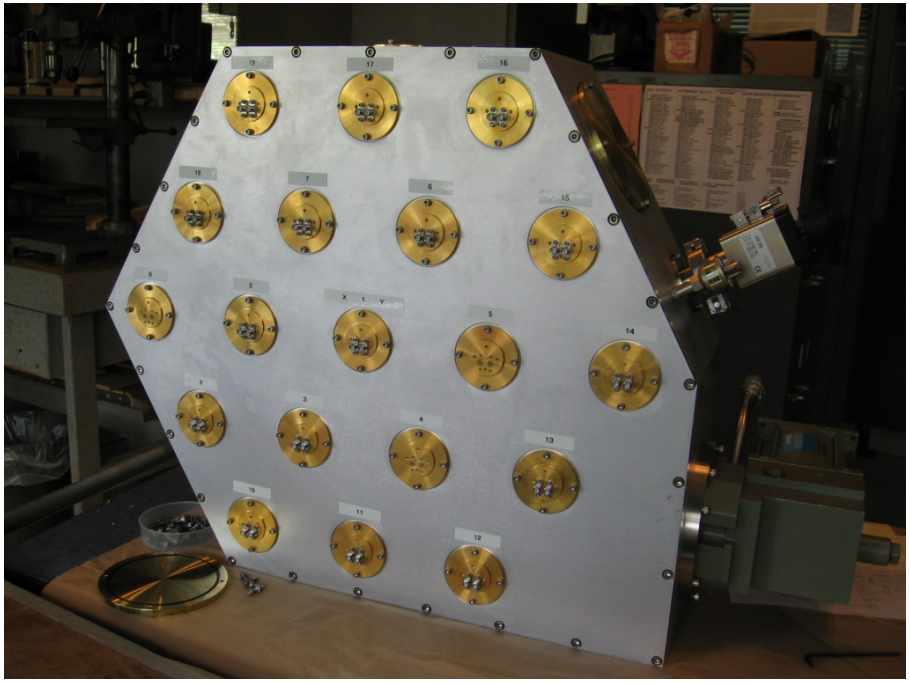
NRAO Focal L-Band Array for GBT (FLAG)

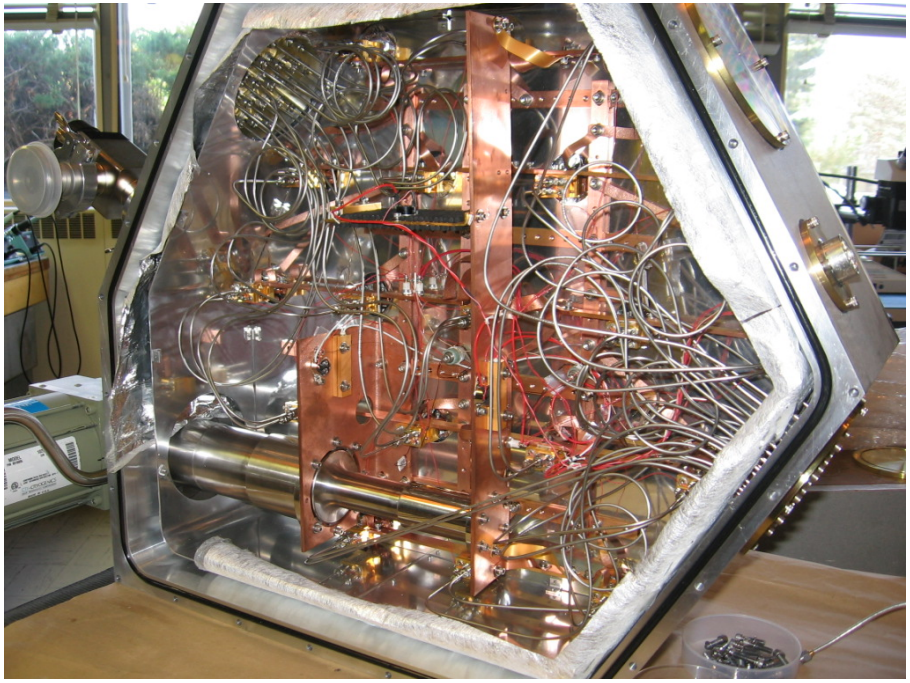
- 19 element low loss, high effficiency active impedance matched array
- 19 x 2 element dual-polarized array
- Cryogenic dewar 2-stage closed cycle refrigerator, SiGe LNAs, Downconverter and Digitizer back end
- Multichannel (40) analog downconverter boards
- 40 channel narrowband data acquisition system
- Stream-to-disk, software based correlation and beamforming

Recently…

- GBT test: 1st test of FLAG PAF on GBT, December 2013
- M&C and Observing: Integration of PAF into GBT Monitor and Control
- Modeling and Analysis: Full 19-element model of dipole, LNAs, complex weighting
- Downconverter Data Link upgrade: Dowconverter, Digitization, and signal transmission in a compact 8x5 40-channel electronics module co-located with the Front End
- Beamformer Project: 2013 NSF ATI grant to BYU-WVU-NRAO collaboration on wideband digital backend

NRAO PAF Receiver





- Cooled LNA receiver-dewar, CTI-102 refrigerator, 19 element dual polarization

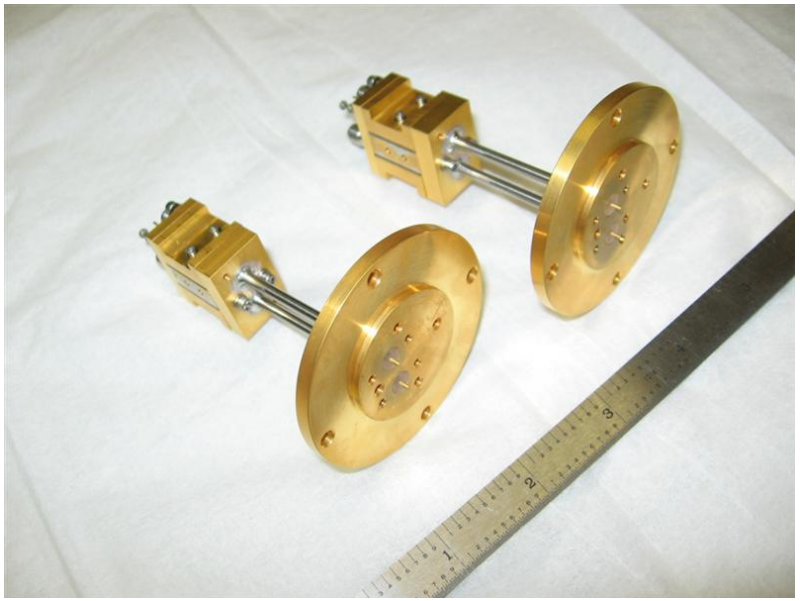
Dipole Elements

"Kite" Element, BYU design for 20-m telescope

New GBT2 Element, BYU design 2013, optimized for best efficiency on GBT (over seven dimension parameters):

- Element pattern
- Bandwidth
- Impedance

Dual-Polarization LNAs and Thermal Transition



Pair of two-channel LNAs with integrated low-loss coaxial lines for transition from 15 to 300K

NXP SiGe transistors.
Thin-wall SS tubular coax.
Quartz beads for vacuum seal and center conductor heat sink.

LNA design based on: S. Weinreb, J. Bardin, H. Mani, G. Jones, “Matched wideband low-noise amplifiers for radio astronomy”, Rev. of Sci. Instr., vol. 80, 044702, 2009.

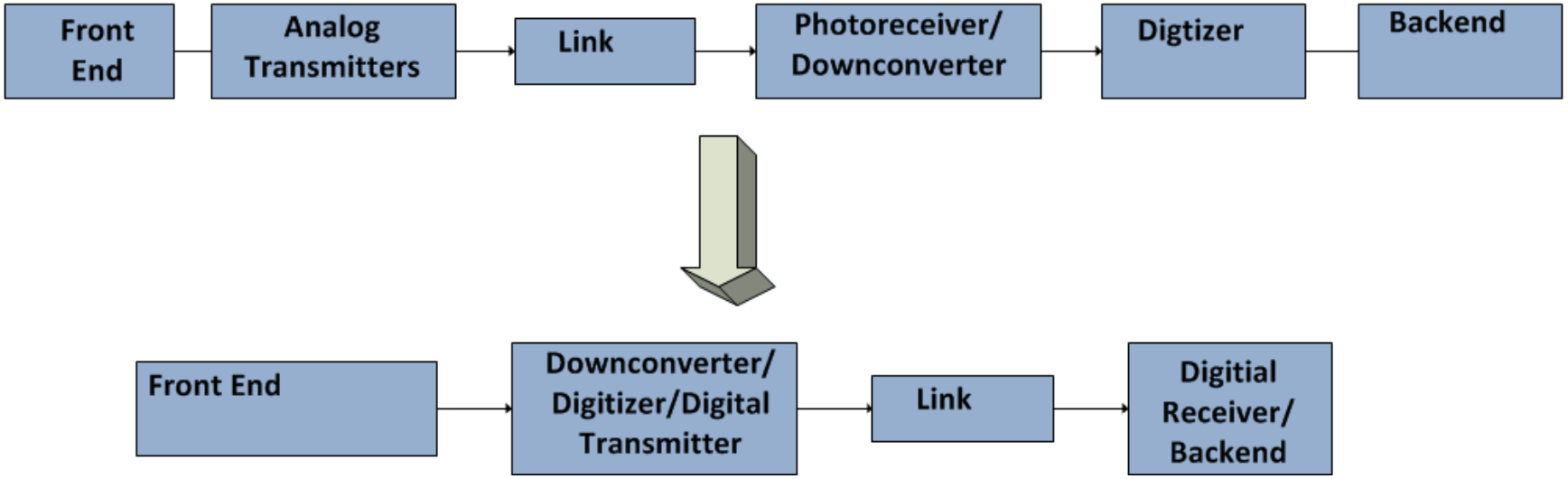
Phased Array Technologies

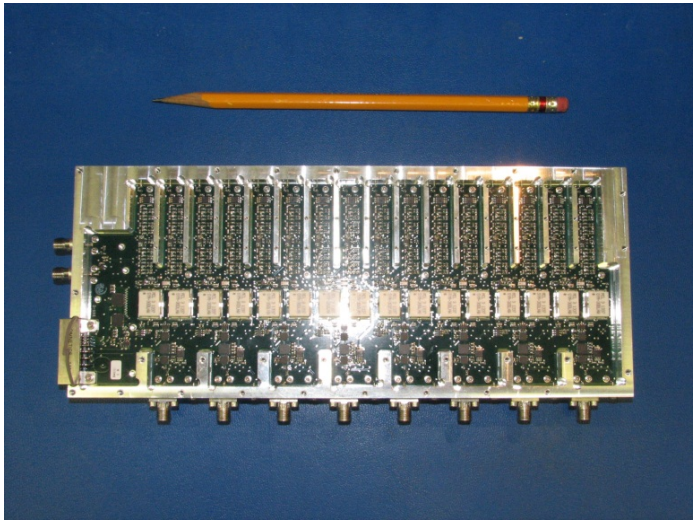
- **Receiver element design and modeling**: bandwidth, element pattern, impedance
- **Amplifier design**: device, gain, reliability
- **Front end and cryo design**: Thermal transition, balun, maintainability
- **Downconversion and signal transport**: fiber link design, moving toward digital
- **Beamforming and Correlation**: real time digital backend
- **Modeling**: Theory vs measurement
- **Observing and mapping**

“Beamformer” Project

- External NSF ATI project funded in Sept 2013
- Wideband 150/300 MHz downconverter and digital backend project
- Digital data link
- Roach2 based 40-channel polyphase filterbank
- Correlation and Beamforming by GPUs
- Supporting HI and Pulsar Science

Instrumentation Upgrades





In the next two years, NRAO is planning to improve the instrumentation in all three critical areas:

- Front End
- Downconverter/Digitizer (shown left)
- Digital Receiver

Conclusion

- NRAO is working on key technologies and collaborating wit partner instituions to advance Phased Array R&D
- The goal is to demonstrate:
  - Low-noise PAF receivers
  - Efficient electronics and signal processing
  - Accurate Modeling
  - Science demonstrators

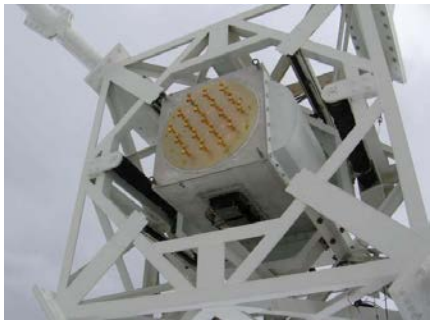
So that PAF can be a viable choice for future radio astronomy instruments

L-Band Astronomical PAF Milestones

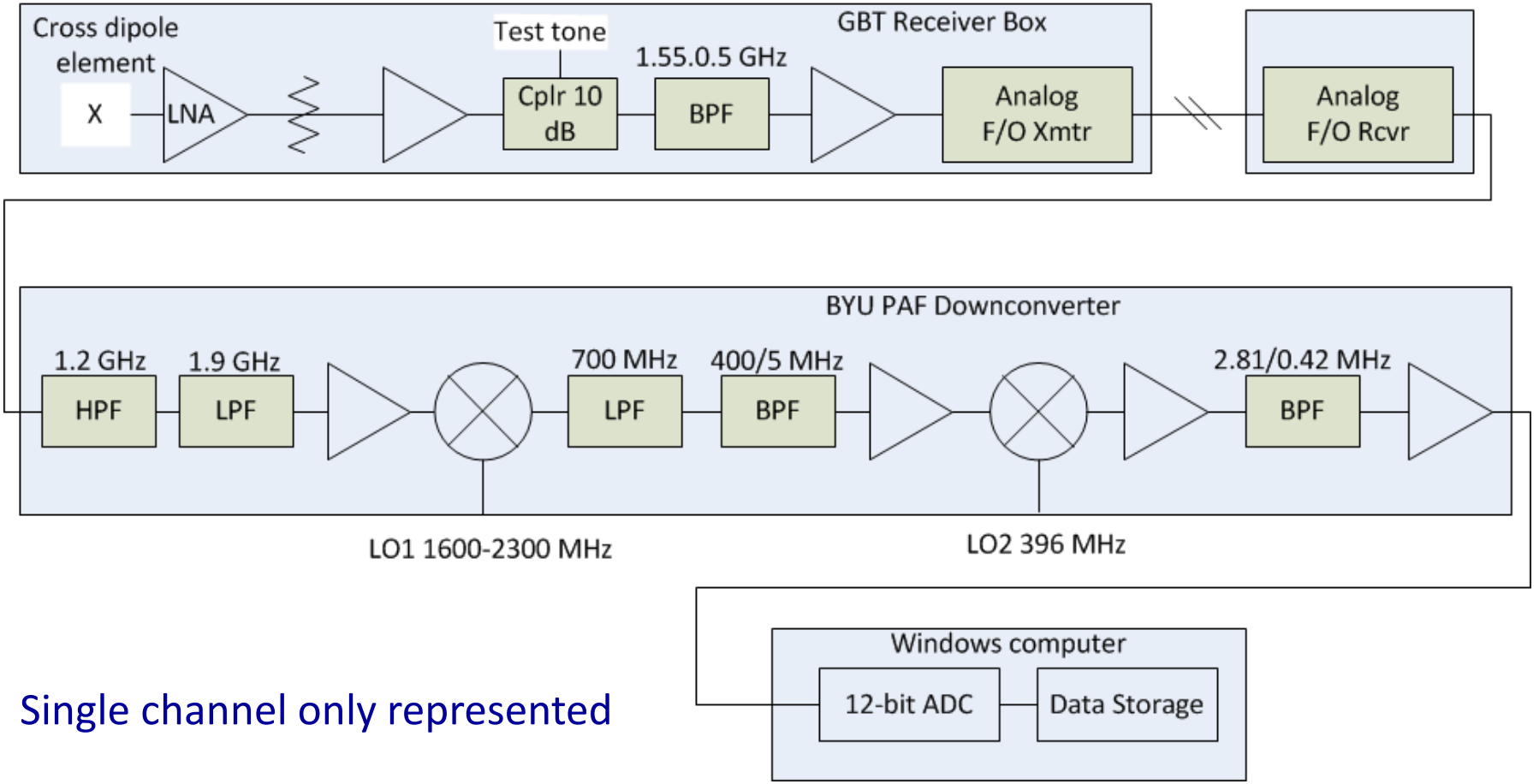
Feed	Tsys/efficiency
2010 BYU uncooled PAF	**87 K measured**
2011 BYU/NRAO cryogenic PAF on 20 meter dish	**50 K measured**
2013 Cryogenic Focal L band array for GBT (FLAG)	**35 K goal**
GBT horn feed (state of the art)	25 K

World record sensitivity for a phased array



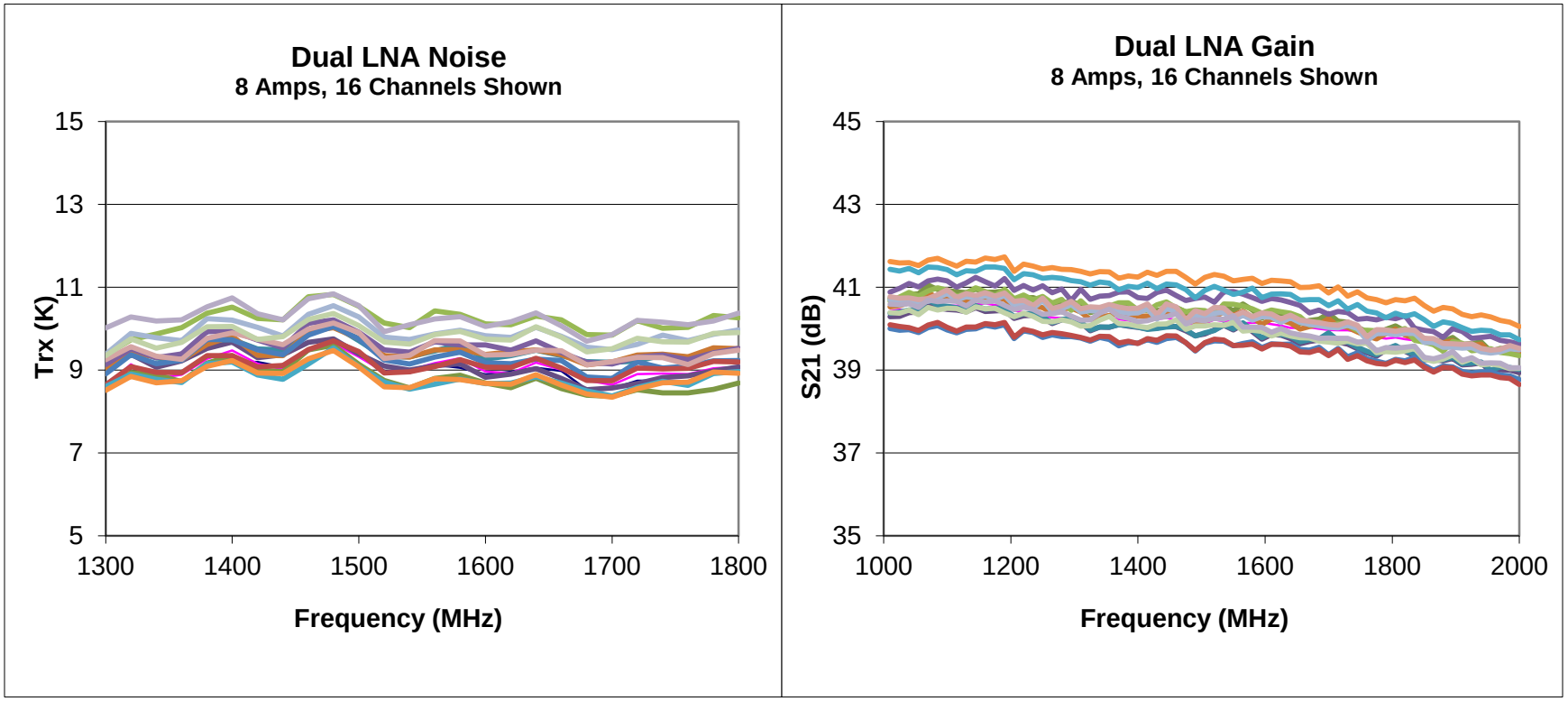




GBT PAF System



Single channel only represented

LNA Measured Performance



- Noise Y-factor measured with LN2 cold load at room temperature SMA connector.