Current L-Band Radio Astronomy Conventional Receiver State of the Art

Isak Theron

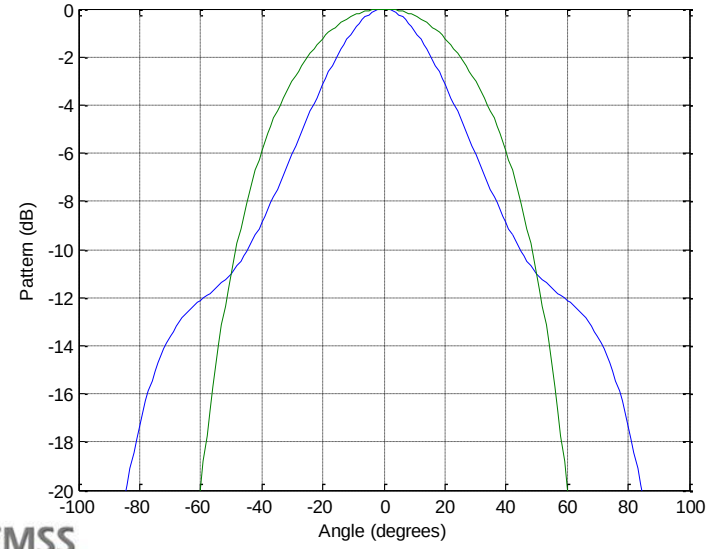
EMSS Antennas (Pty) Ltd

Karoo Array Telescope

- Initially 20-element array
- XDM prototype
  - At HartRAO
  - 15 m diameter prime focus
  - Ambient temperature
  - Cluster of 7 feeds
  - “Sky tracker rotator”

XDM

- Very green design team
- Measured the feed noise at HartRAO
  - “Milky way came up”
- Pattern lesson
  - Optimise on dish



Radio astronomy

- Receiver has significant sensitivity impact

$$\frac{A_e}{T_{sys}} = \frac{\eta A_p}{T_{sky} + T_{spill} + T_{rec}}$$

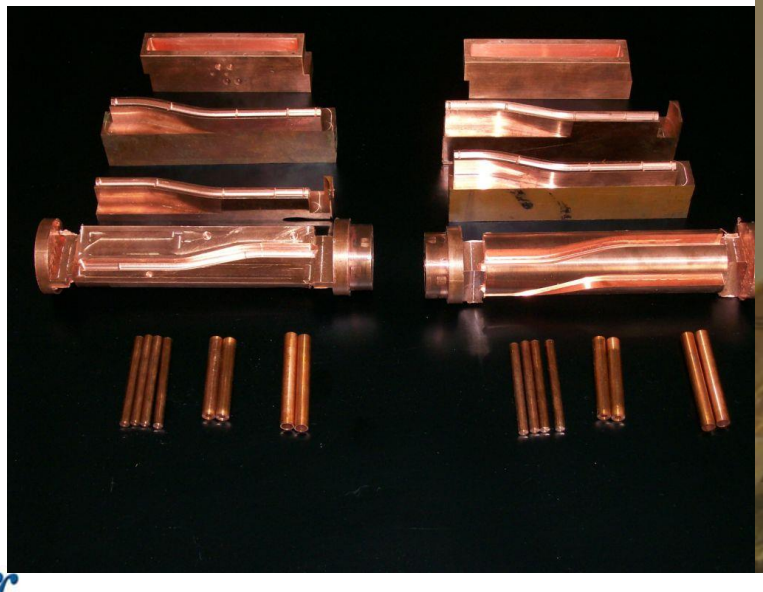
- Law of increasing returns
  - The lower T_{sys} becomes, the higher the gain from additional incremental decreases
  - Typically involves cooling
  - At some point it becomes too expensive
- Building more dish area (A_p) is expensive

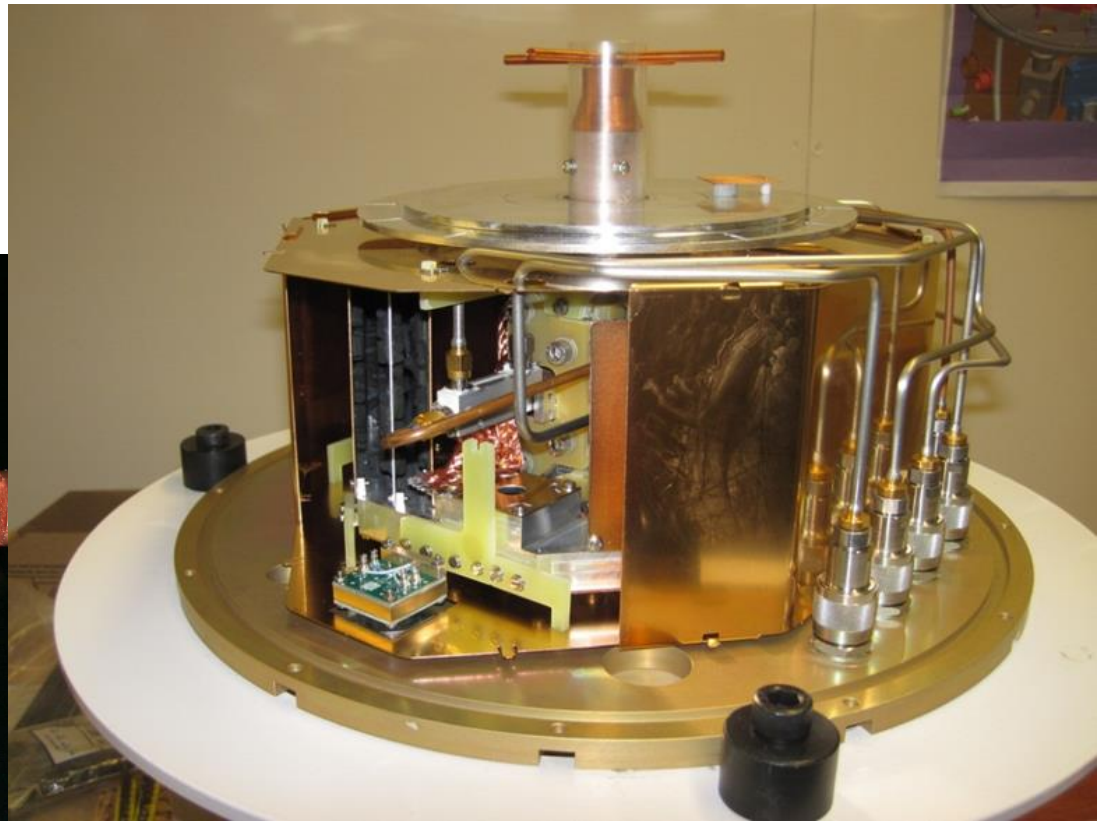
KAT-7

- Seven element engineering test bed
- Stirling cycle cryogenic cooling
- Remote operation
- Vacuum maintenance problematic

KAT-7

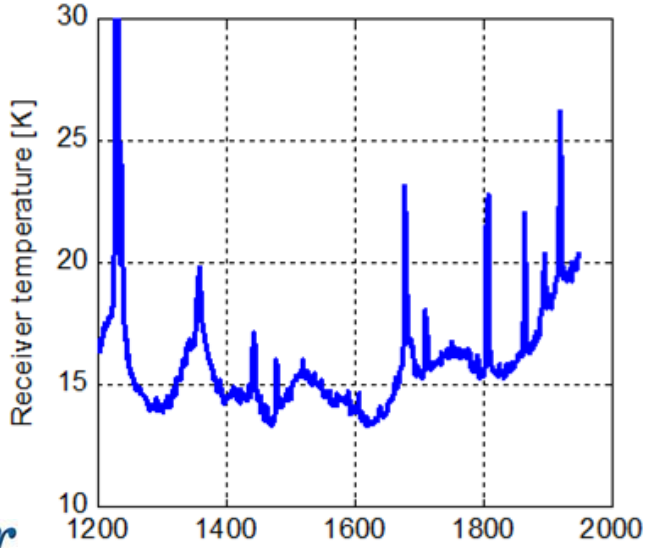
- Compact OMT – low loss and colder
- Complex and not robust
- Cryostat vibration lifetime impact

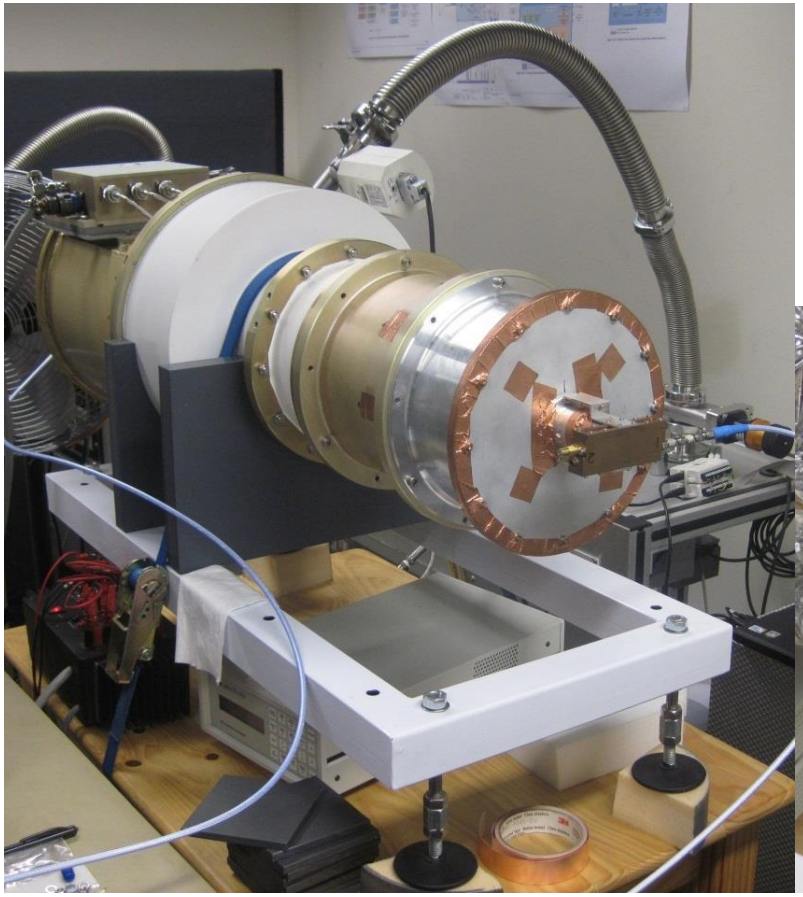




KAT-7

- Manual testing in low volumes
  - Hot / cold load
  - OMT as load
  - Coax loads
  - Suck-outs





Radio astronomy

- Receiver (& optics) even more significant

$$\frac{A_e}{T_{sys}} = \frac{\eta A_p}{T_{sky} + T_{spill} + T_{rec}}$$

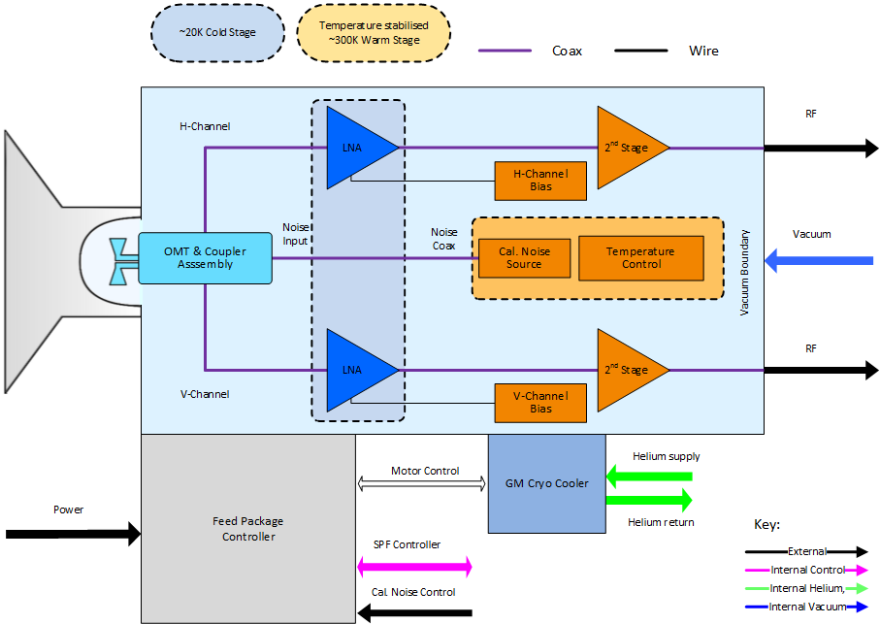
- Offset Gregorian
  - Cleaner pattern
    - Less susceptible to RFI
    - Control spillover without reducing efficiency
  - Allow multiple “narrow band” feeds in focus region
- Cool as much as possible

MeerKAT

- 64 unshaped 13.5 m diameter dishes
- 3.8 m sub-reflectors
- 2-step GM cooling

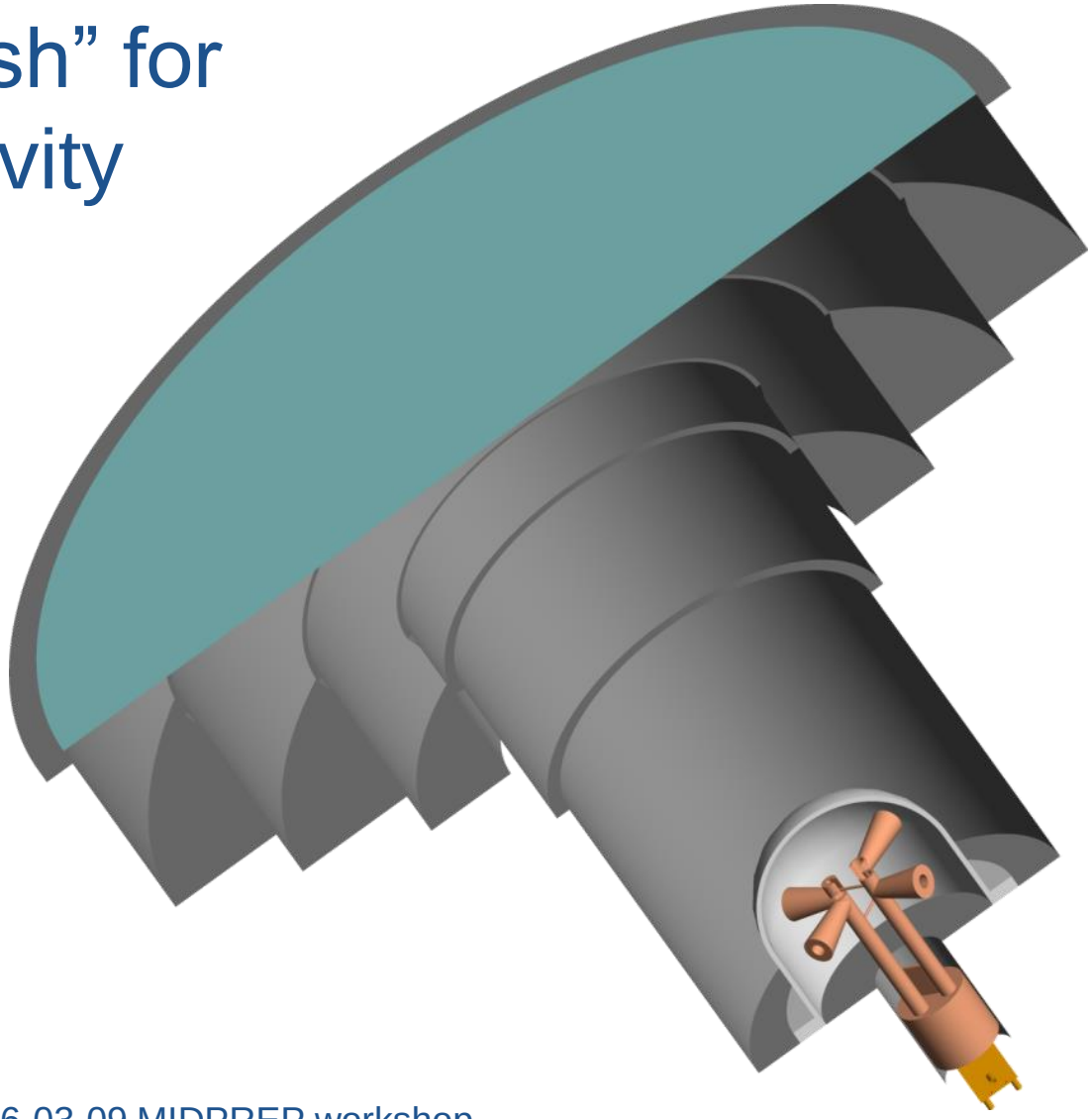
MeerKAT L-Band feed

- Optimise feed package
  - Careful feed horn optimisation
  - Low loss OMT and minimise loss before LNA
  - Selecting the best possible LNAs
- Proving performance
  - Laboratory testing
  - On dish testing



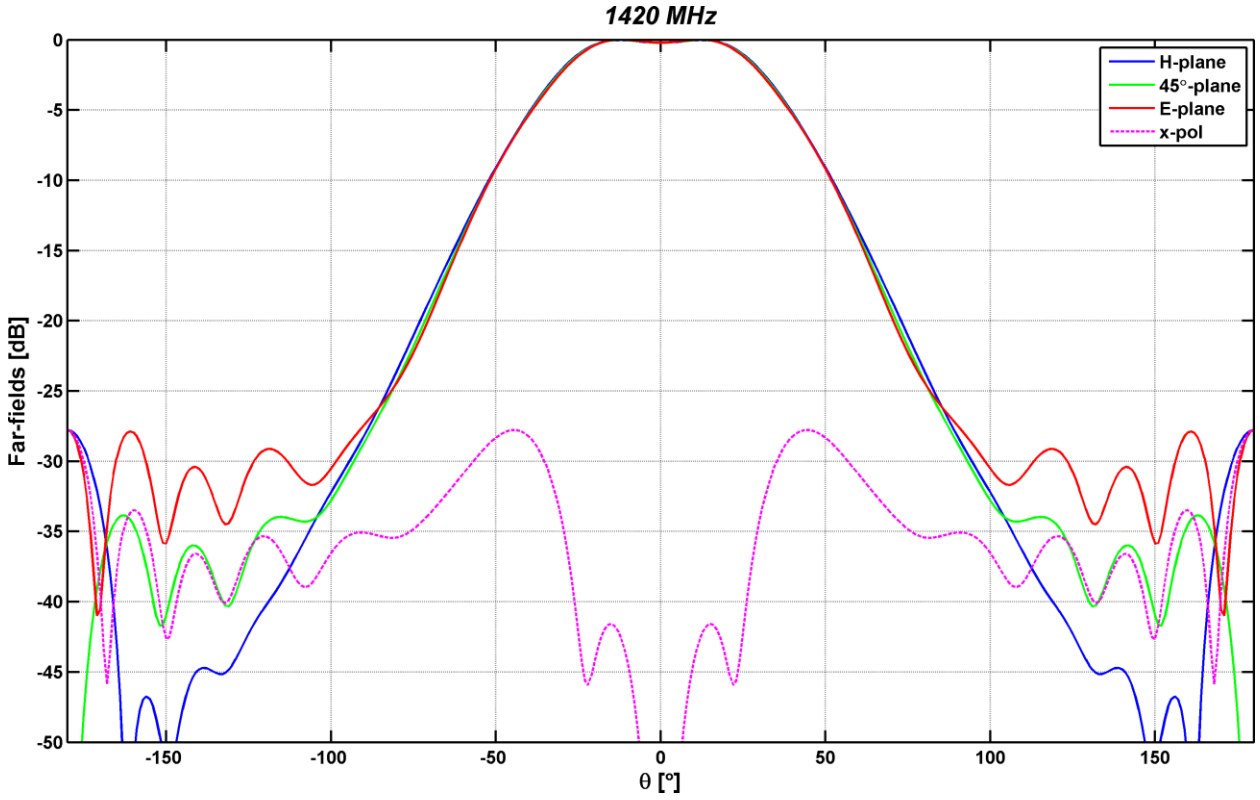
Feed horn

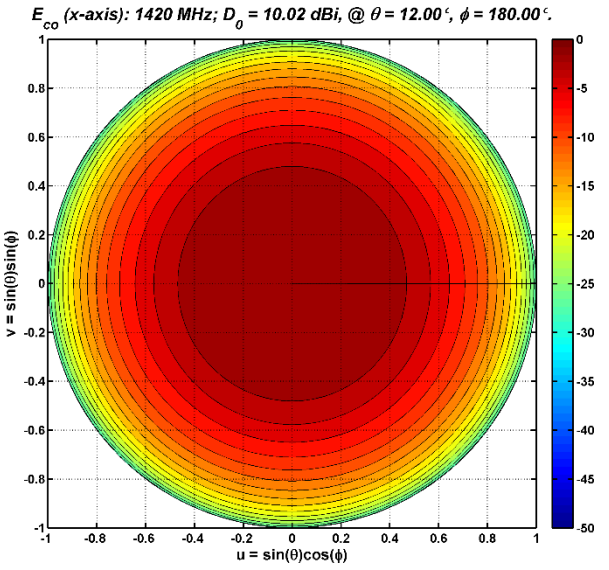
- Optimised “on dish” for maximum sensitivity
  - Good efficiency
  - Low spill-over
  - Good match
- Extension on sub-reflector

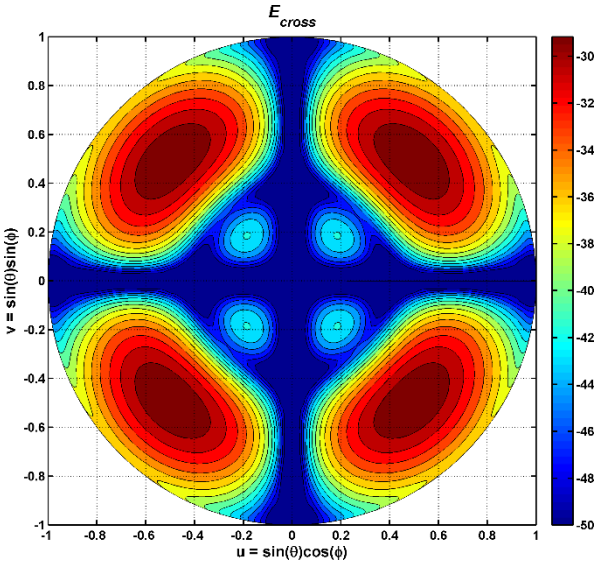


Feed horn

- Flat top pattern

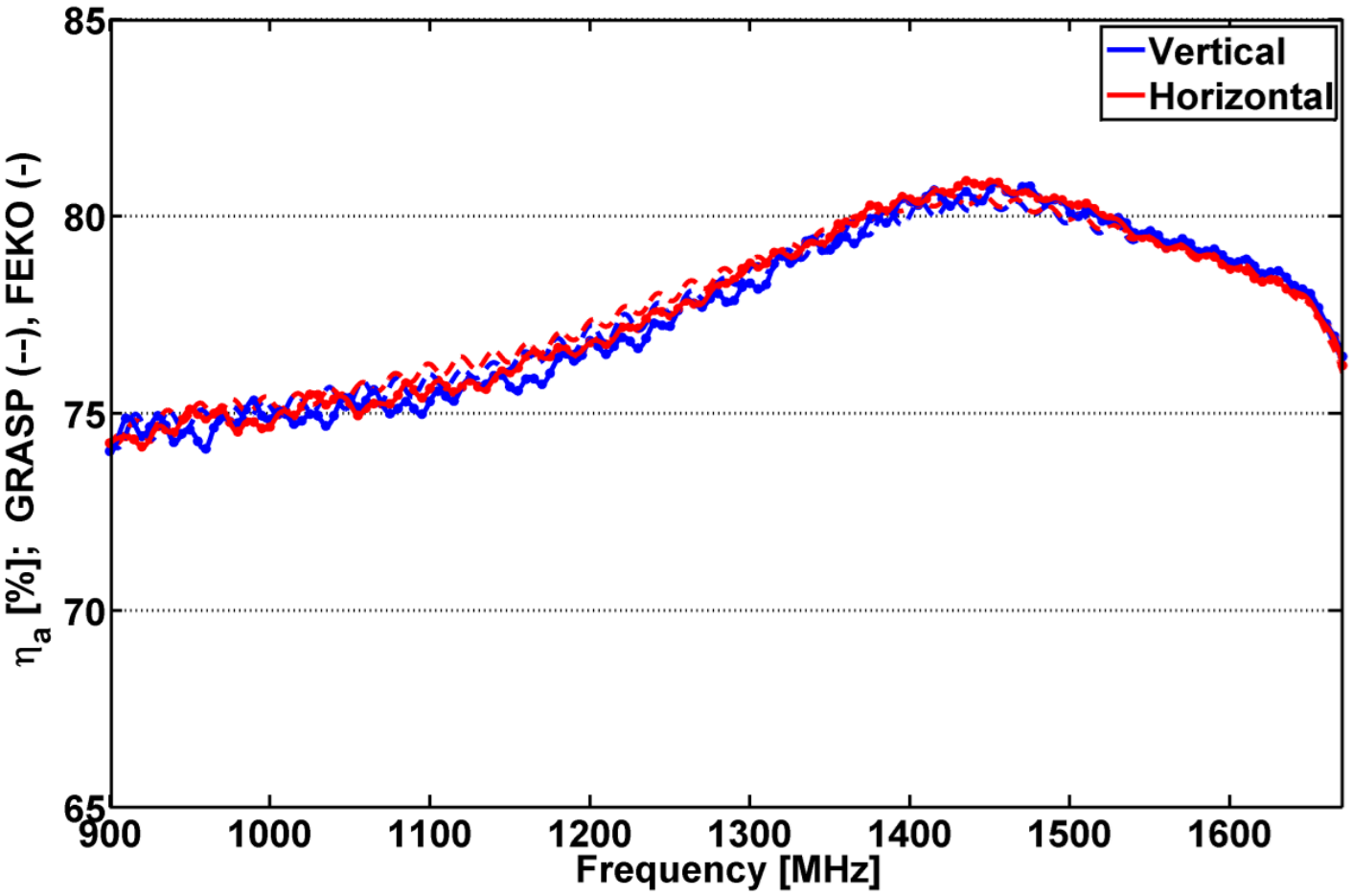






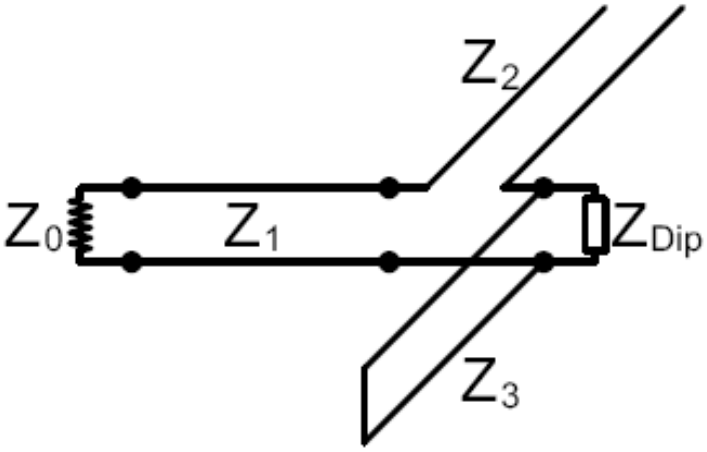
Feed horn

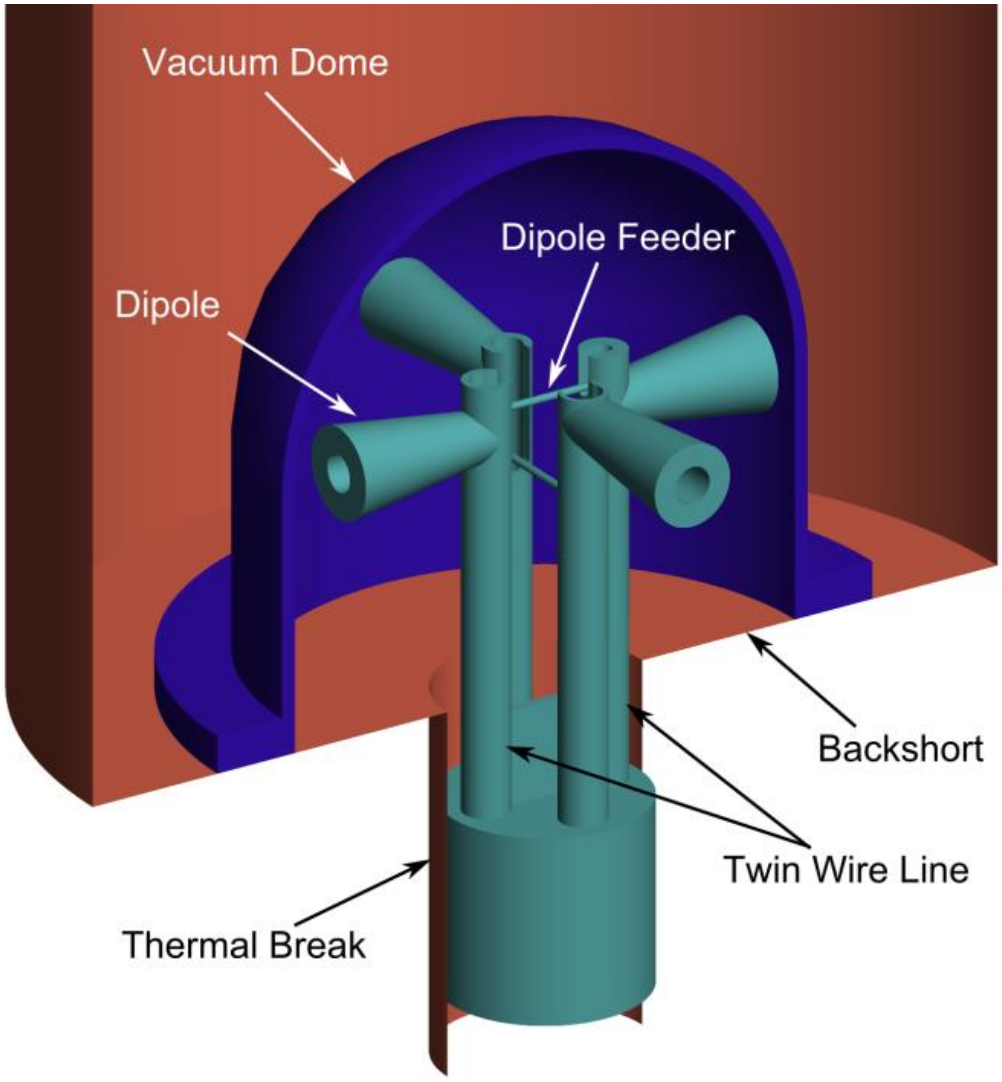
- Dish efficiency



OMT design

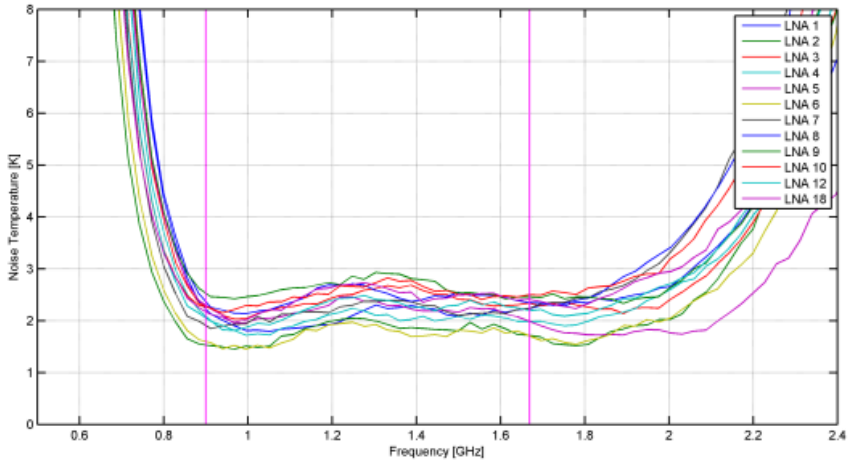
- Dipoles now much more robust
- Integrated coupler
- Non foam vacuum window

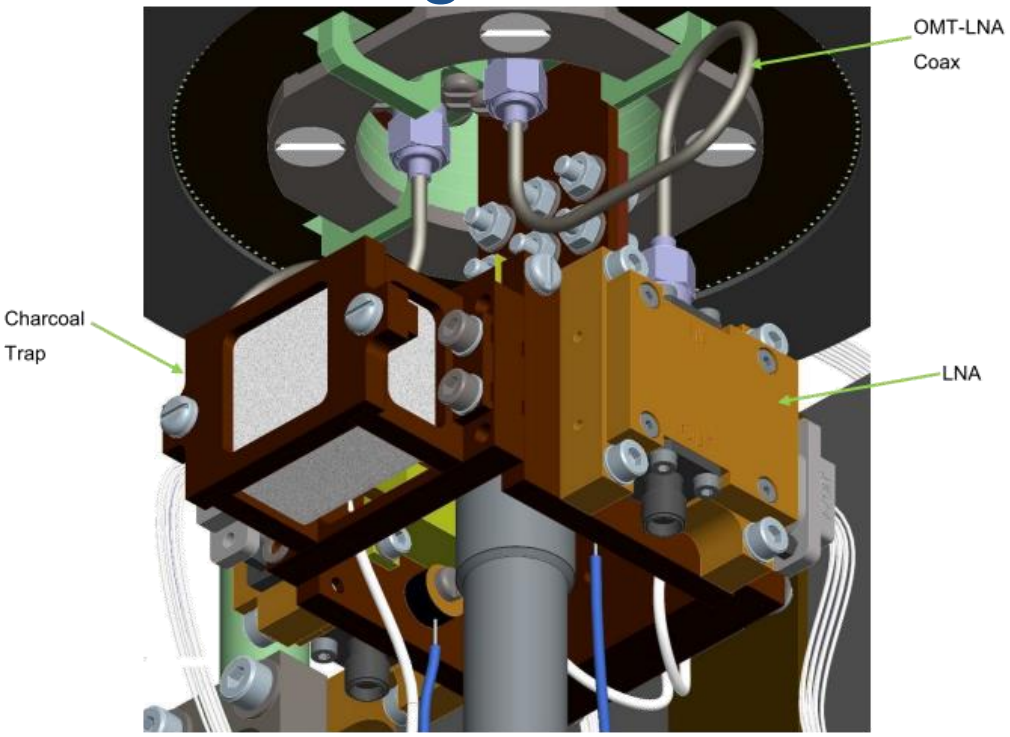




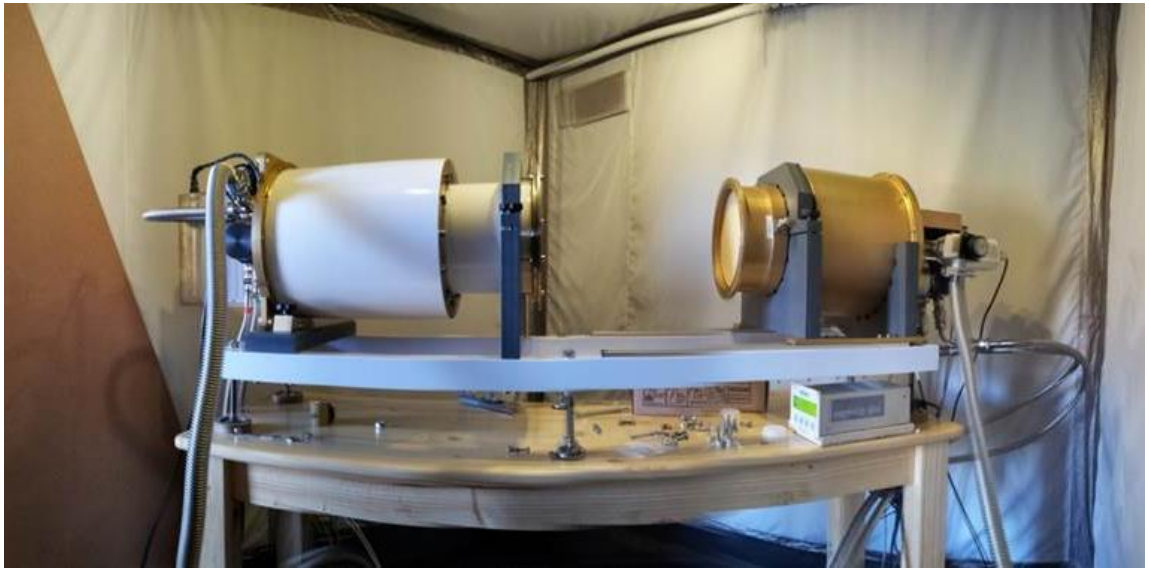
LNAs

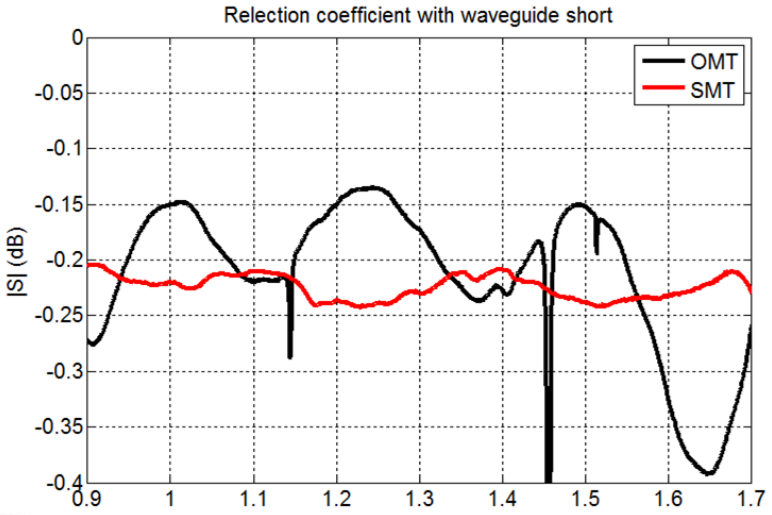
- Short aluminium semi-rigid – thermal isolation
- NRC Herzberg Institute of Astrophysics LNA
- InP technology with wire bonding

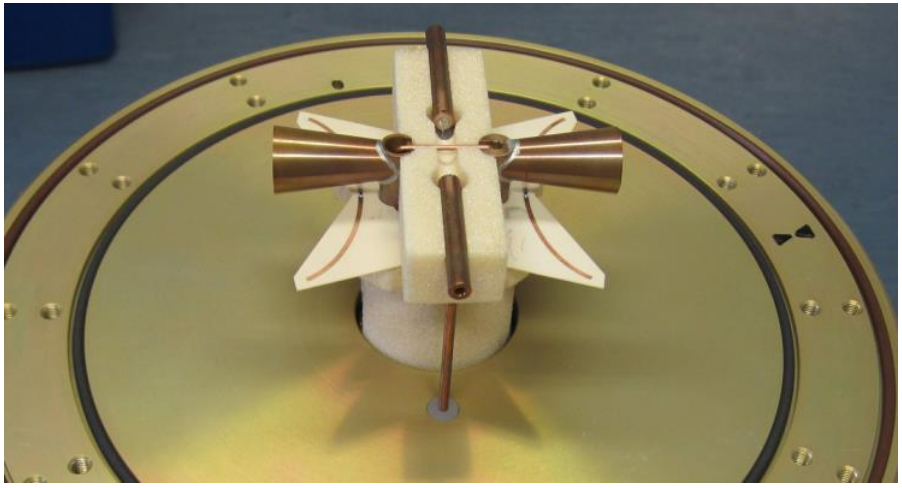




Receiver noise measurement

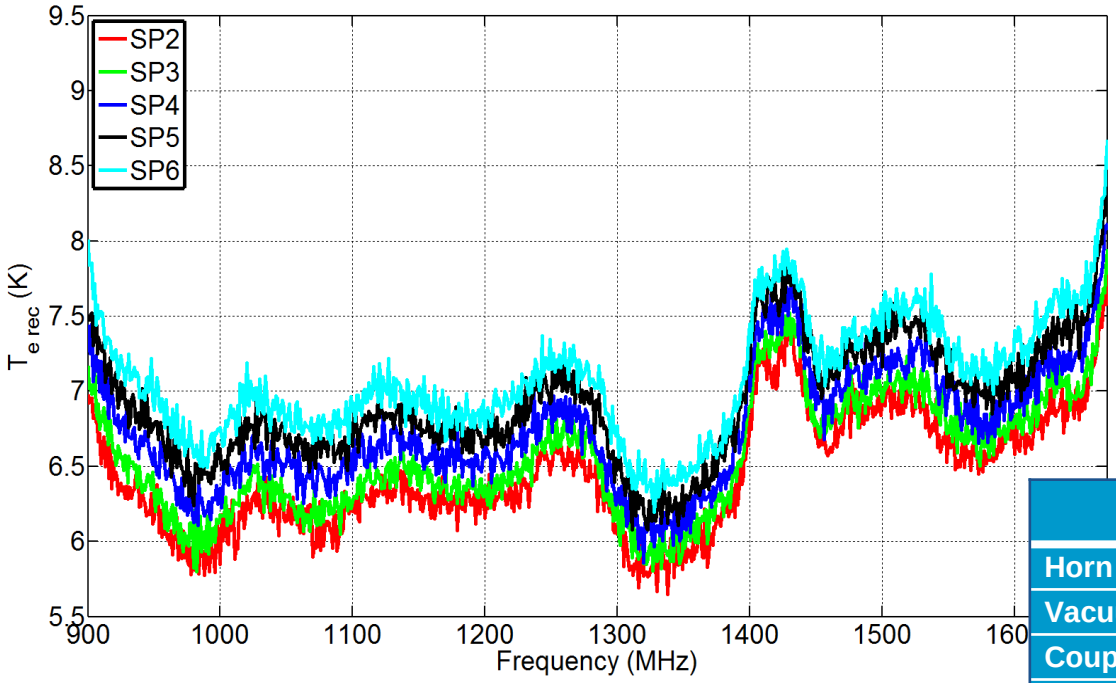






MeerKAT receiver temperature

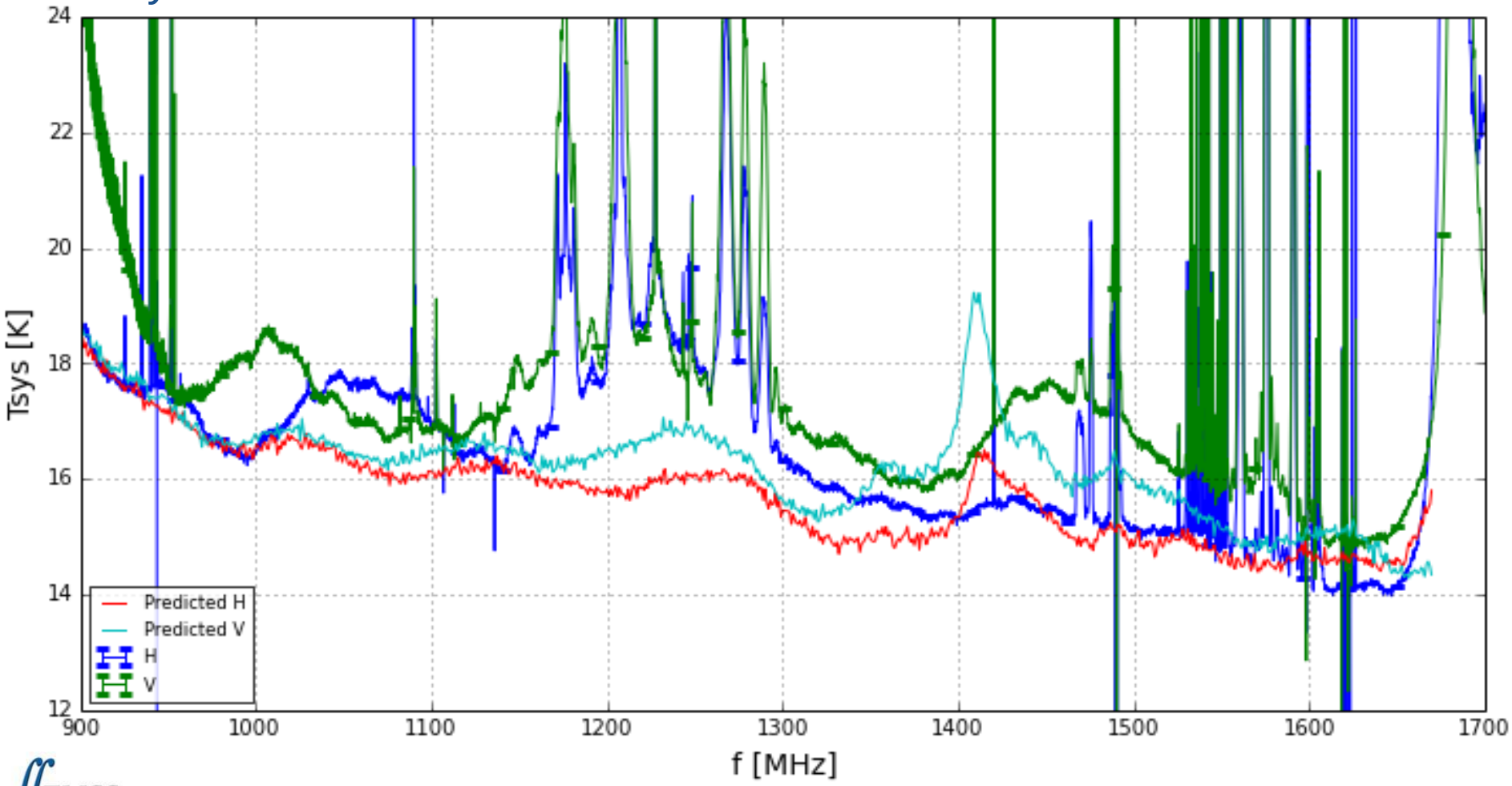
- Physical 15.7, 17.7, 19.6, 21.6, 23.4 K



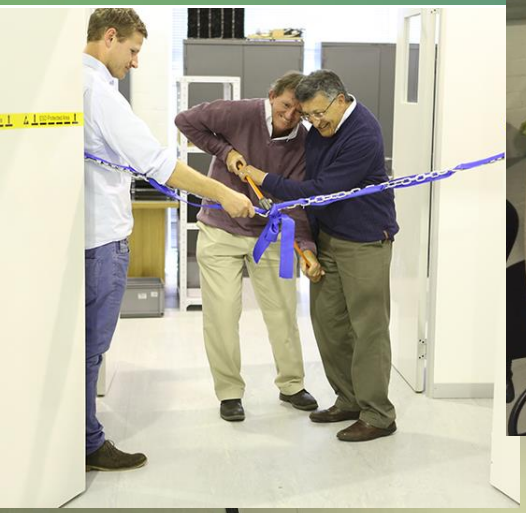
	900 MHz	1670 MHz
Horn and radome	0.1 K	0.1 K
Vacuum window, OMT, Coupler	1.1 K	1.3 K
Coupler to LNA thermal isolation	1.0 K	1.5 K
Coupler output connector	0.5 K	0.5 K
LNA	3.0 K	3.0 K
Post-LNA RF	0.5 K	0.5 K
Dish structure and digitiser / back end contributions	2.0 K	2.0 K
$T_{Receiver}$	8.2 K	8.9 K

On dish testing

- T_{sys} @ 65° elevation



Production Facility



Production lessons

- Stepper motor driver
  - Relies on motor inductance to smooth current
  - Compensate for stepper losing torque
  - RFI filter capacitive (add inductance, but less)
  - RFI requires linear power supply
  - Stepper driver supply voltage a function of power
  - At higher voltage compensation kicks in
  - Stepper loos torque when supply high!
  - Cold head warms up

Production lessons

- LNA noise temperature
  - Getting optimum noise performance need tuning
    - Highly skilled personal
    - Lots of time due to cool down cycle
  - Difficult in production
  - Specification was higher than initial run of 16
  - Now a lot of LNAs achieve only this
  - Avoiding hand tuning very expensive
    - 2 K noise similar to destroying 6 dishes

Questions?