Interference Cancellation and Sensitivity Optimization using an L-Band Focal Plane Array on the Green Bank 20m Telescope

Jonathan Landon[1], Karl Warnick[1], Brian Jeffs[1], David Jones[1]
Roger Norrod[2], Rick Fisher[3]

[1]Brigham Young University, Provo, UT
[2]National Radio Astronomy Observatory, Green Bank, WV
[3]National Radio Astronomy Observatory, Charlottesville, VA

Brigham Young University
Electrical and Computer Engineering

Outline

- System Description
  - Antennas – primary and auxiliary
  - Focal Plane Array
  - Analog front-end, digital backend
  - Mutual coupling and element radiation patterns
- Preliminary Results
  - OH source detection
  - Adaptive spillover noise control
  - RFI mitigation

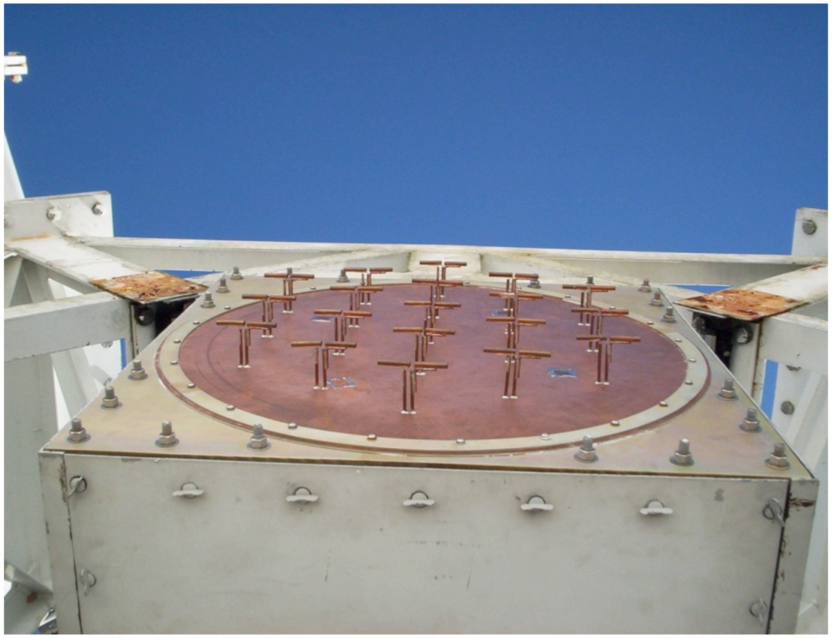
NRAO – Green Bank, WV

Antennas

- Primary antenna
  - 20m NRAO Green Bank telescope re-commissioned for this project
- Auxiliary antenna
  - 3.6m dish receives high-gain copy of interferer for better nulling

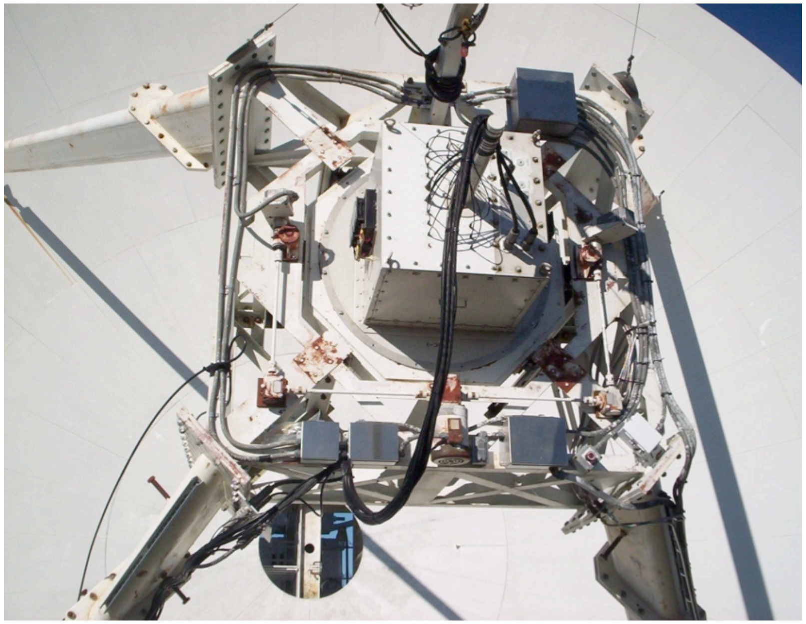
Focal Plane Array

- 19 L-band dipoles over ground plane in hexagonal pattern
  - Electrically small elements, fully sampled array (0.6λ spacing)
  - Narrowband array
  - Proof-of-concept platform for RFI mitigation



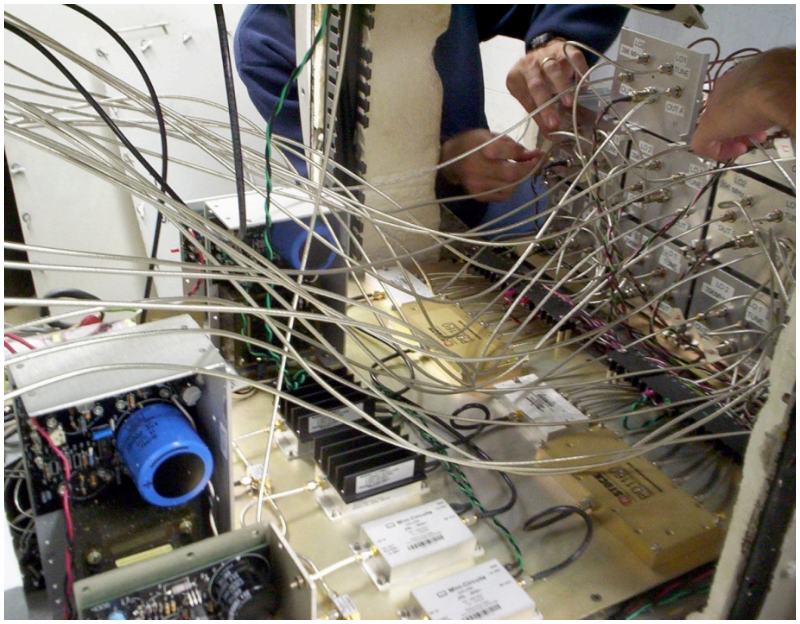
IF/Digital Backend

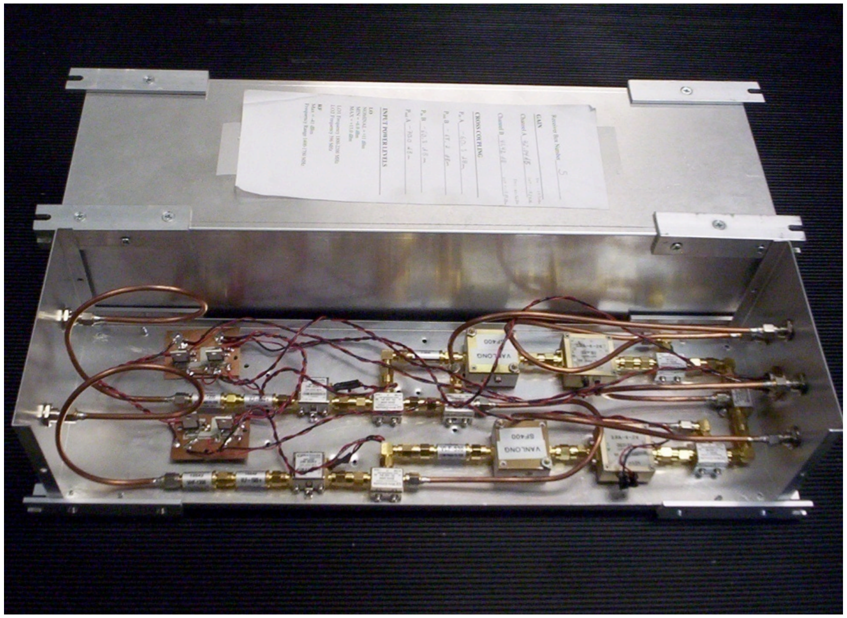
- IF cables run along feed support arm to telescope base
  - 2.8125MHz IF → low cable loss, inexpensive cables, smaller size
- 20 channel synchronous sampling at 1.25Msamp/sec
  - Stream continuously to disk for nearly 2 hours
  - 15000rpm SCSI 4 drive Raid 0 array (striping); PCI bus limited,



Analog Frontend Electronics

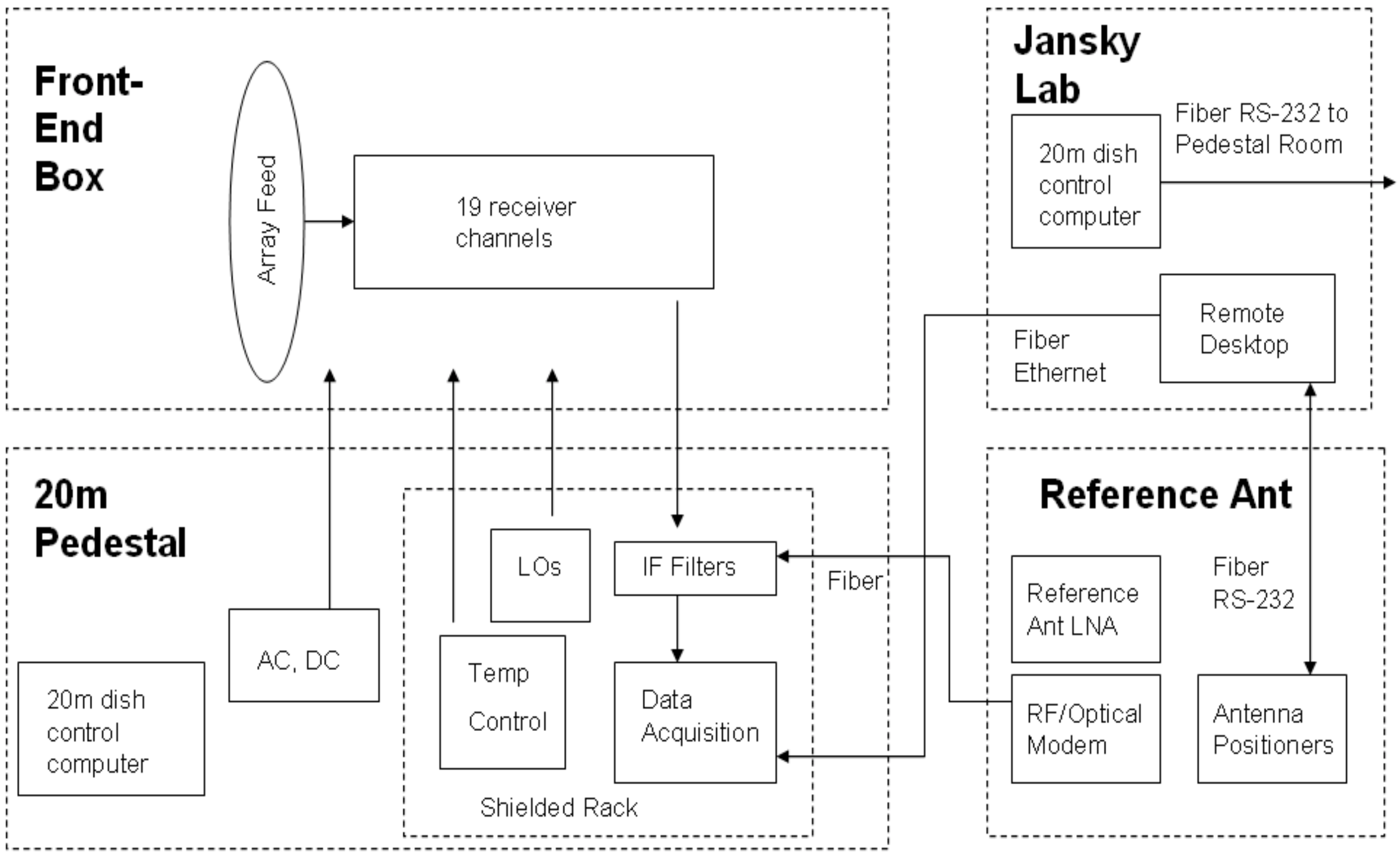
- Downconversion to IF in front-end box behind array
  - 2-stage analog receivers; 19 room-temperature receivers
  - Remotely tunable RF from 1200-2000MHz; IF bandwidths~0.5,1,5MHz
  - COTS components; connectorized system – easier maintenance





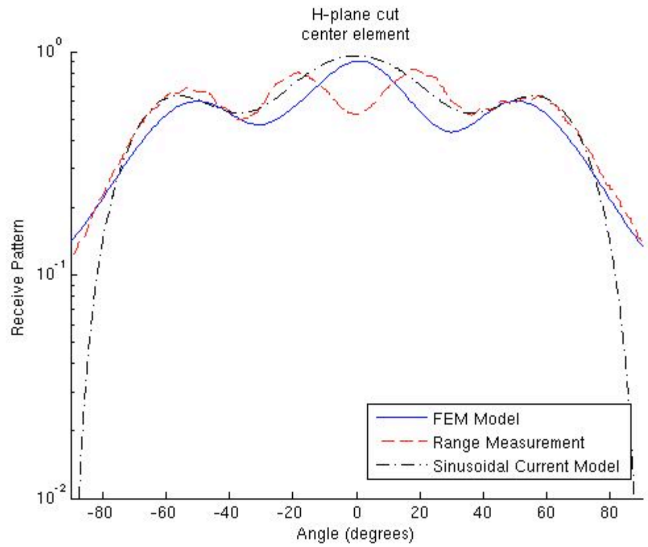
System Overview

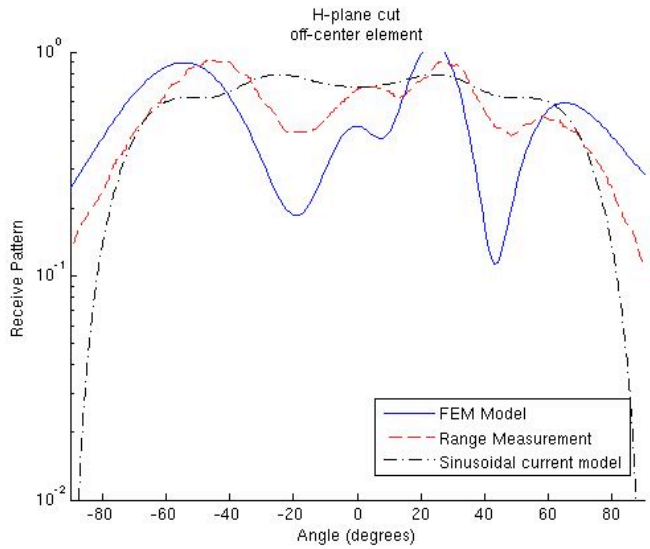
Receiving System
Block Diagram



Mutual Coupling

- Pattern variations are due to mutual coupling
  - Reradiated signal and LNA noise introduces non-ideal signal correlation
  - Affects beamformer design, noise level, sensitivity optimization



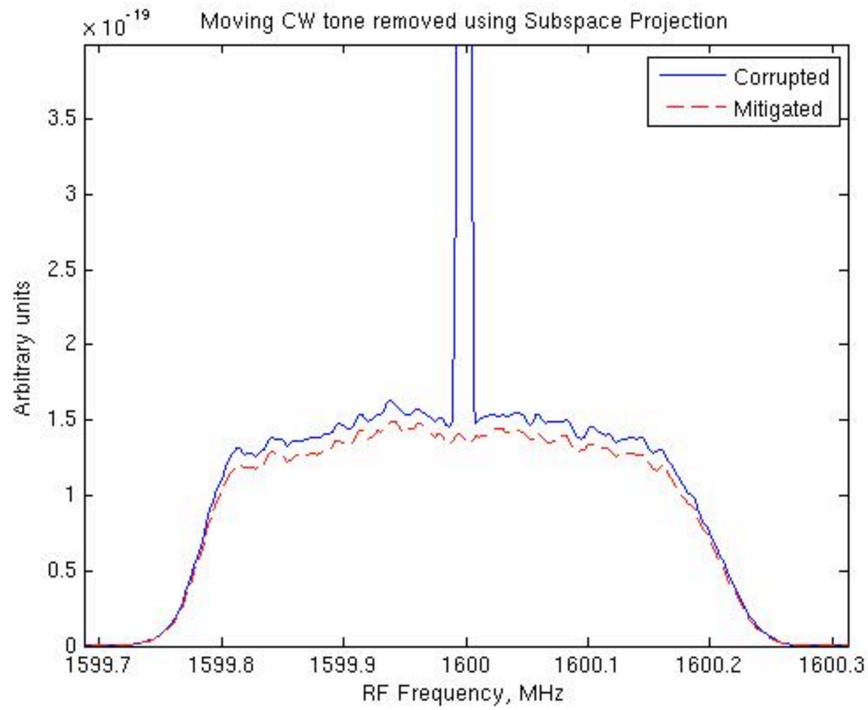


Active Interference-canceling Beamformers

- Active adaptive beamforming vs. fixed beamformer
  - Adapt to changing spillover region, mitigate RFI
  - Optimizing fixed beamformer; periodic recalibration; need appropriate weights for mutual coupling situation; requires optimal beamformer
- Examples of adaptive beamformers
  - LCMV/MVDR
    - Optimizes beampattern for noise structure; drive down overall power subject to constraint, i.e., unity mainlobe response
  - Subspace Projection
    - Zero forcing algorithm – places deeper nulls than LCMV
    - Can use LCMV as initial weight to shape noise response

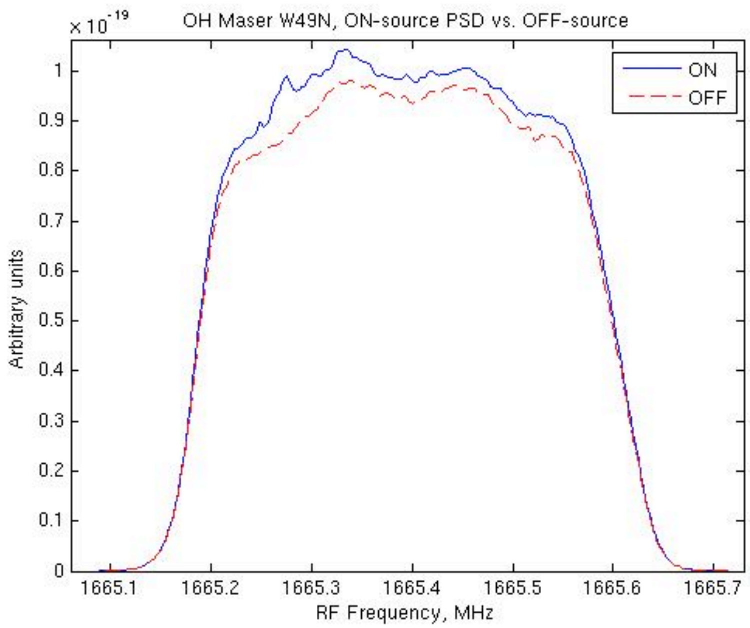
RFI Mitigation

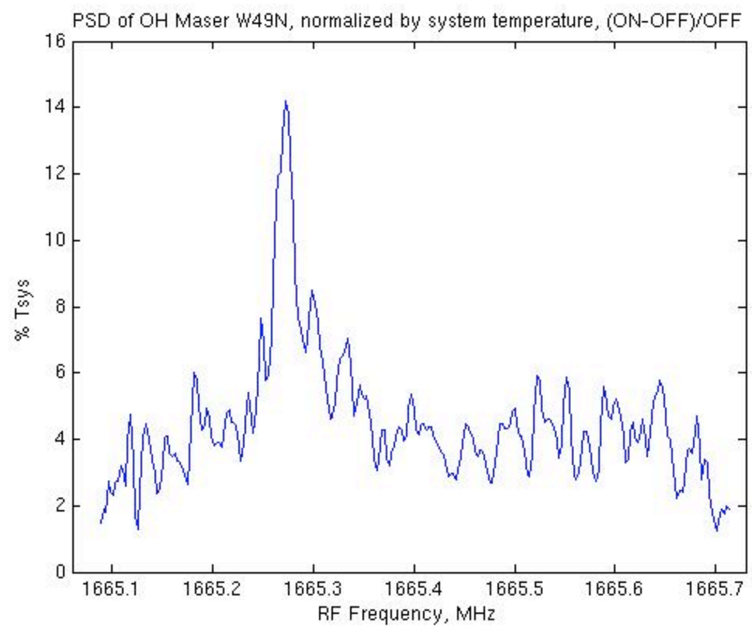
- Experimental data collected on 20m
  - 20m tracking CygA while we broadcasted CW tone from bed of moving truck



Detection

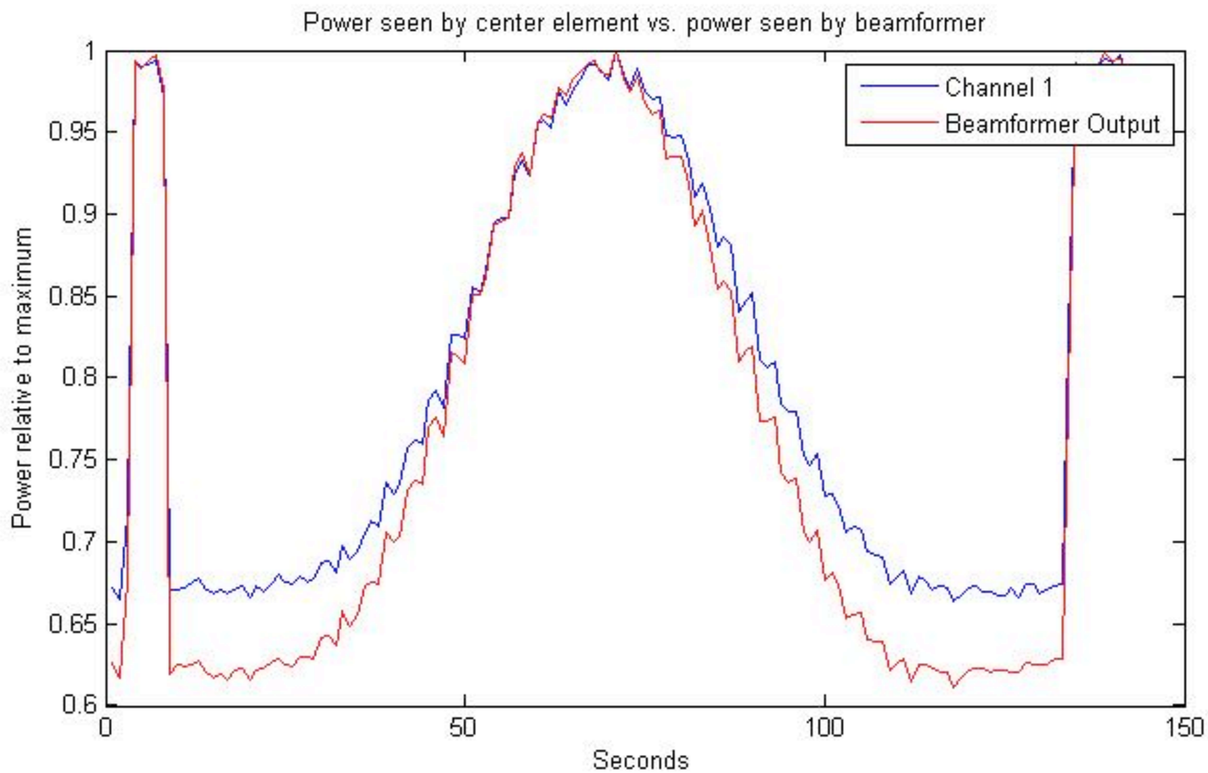
- OH maser W49N detection
  - Phase and gain stability over multiple days (calibration data from different day)





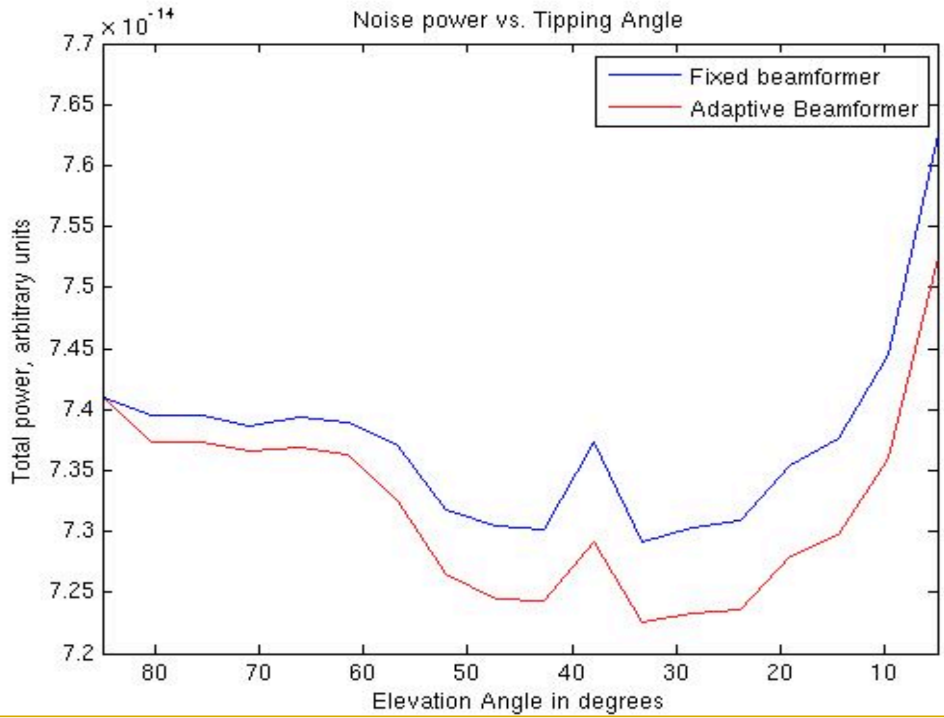
Dish illumination control

- Center element vs. fixed beamformer
  - Array can taper illumination to give good spillover response



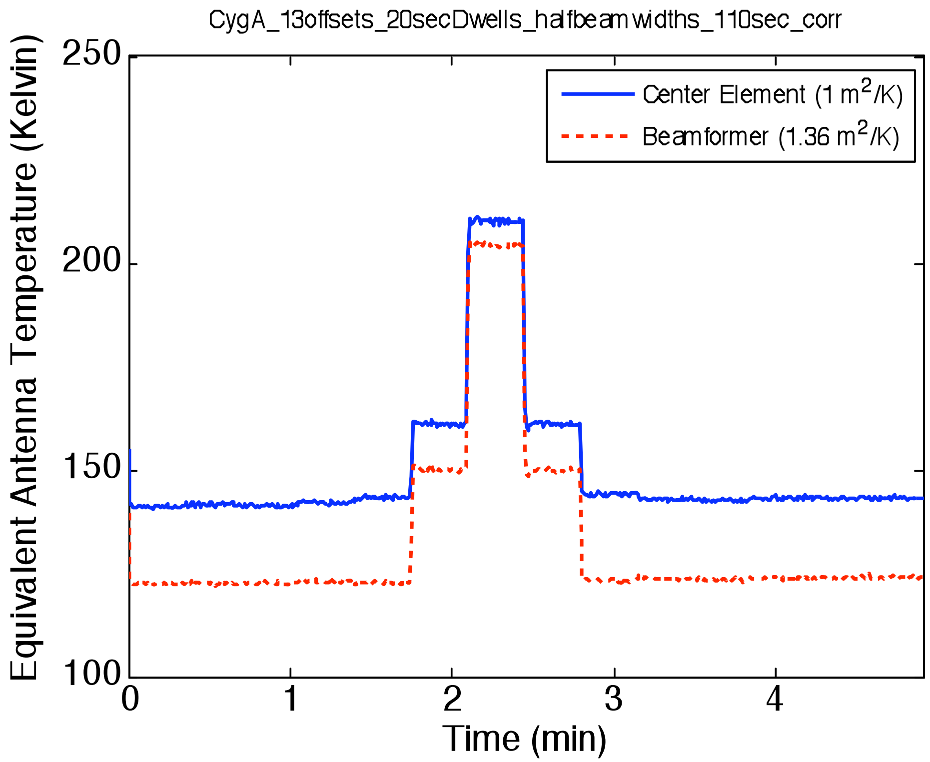
Spillover Noise Adaptation

- Tipping dish changes spillover region
  - At lower elevation angle, large part of spillover is cold sky
  - Tradeoff hot ground sidelobes for cold sky sidelobes for lower overall noise power



Beam Sensitivity

- Signal of interest: CygA
  - Source flux density: 1380 Jy
  - 24 arcmin steps (half beamwidth)
  - 20 seconds per pointing
- Beamformer:
  - Maximum SNR
- Using preliminary Tsys calibration:
  - Gain: 0.06 ± 0.005 K/Jy
  - Aperture efficiency: 53% ± 5%
  - Signal processing sensitivity improvement: 36%



Conclusion

Brigham Young University
Electrical and Computer Engineering

- Successful detection of astronomical sources using COTS components
- Mutual coupling affects element beampatterns
- Adaptive beamforming can shape illumination and improve spillover noise response
- Future Work
  - Pattern rumble control -- variation in beampattern due to adaptive interference cancellation
  - Looking at array matching networks to deal with mutual coupling for optimal sensitivity
  - Improving interference null depth