Arecibo call for proposal. Deadline September 5, 2019

https://www.naic.edu/ao/scientist-user-portal/proposal-submission-system/call-for-proposals

Arecibo has an opening for a post-doc position (spectral line or pulsar) Email Anish Roshi (aroshi@naic.edu)

Arecibo training workshop details (will be announced soon)

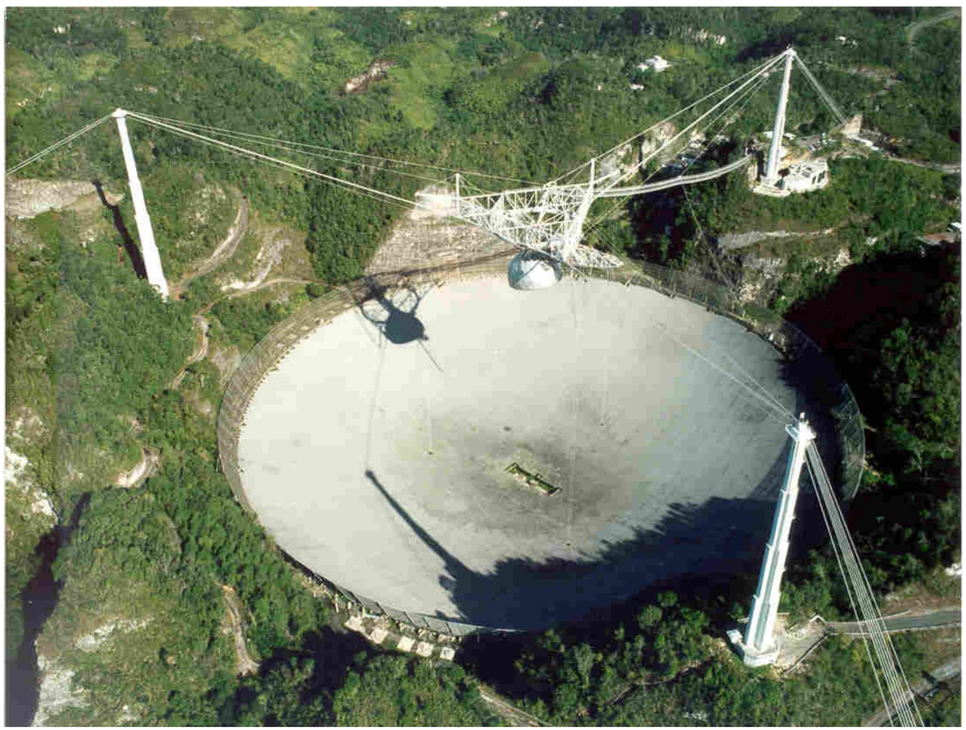
Frontend

D. Anish Roshi
Arecibo Observatory, Puerto Rico

- Feed, Receiver
- Multi-feed, Phased Array Feed
- Bolometers

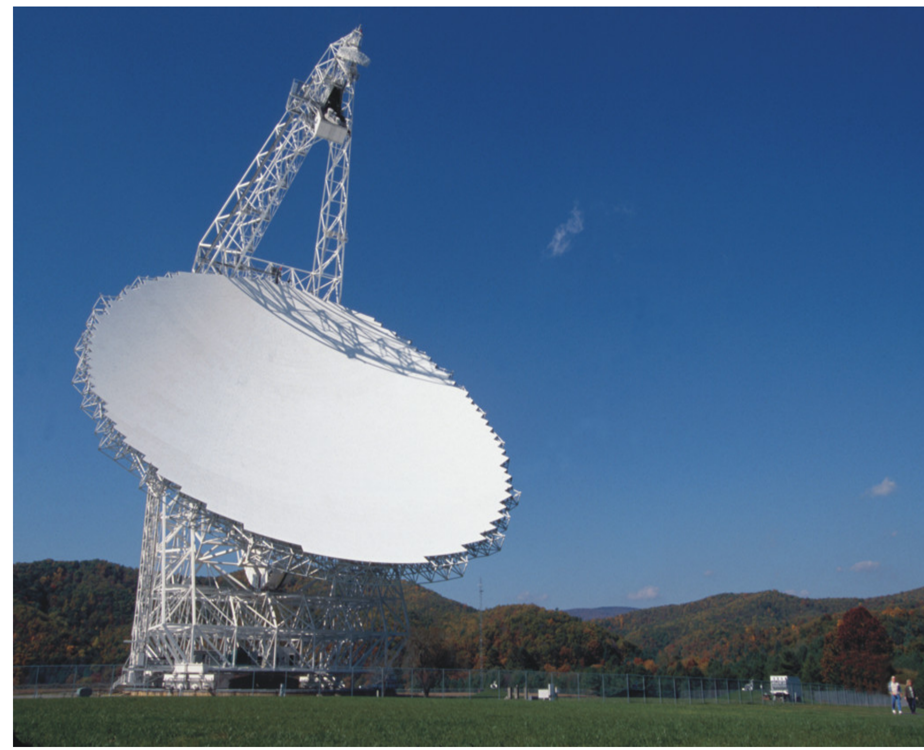
Single dish telescopes

Spherical reflector



The Arecibo telescope, Arecibo. 305m spherical reflector. `Steered' by moving the feed. Operating frequency 300 to 10 GHz

Parabolic reflector



The Green Bank Telescope (GBT), Green Bank, WV. Fully steerable 100m telescope; operating frequency 100 MHz to 100 GHz

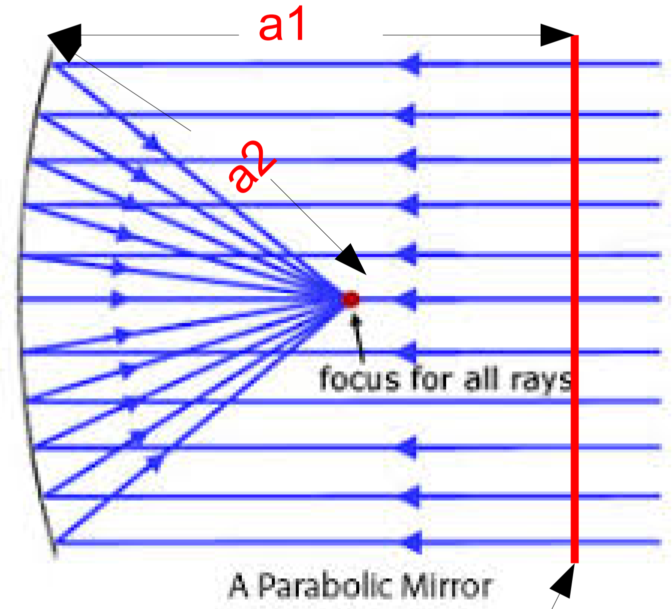
Parabolic reflector telescope

$$E_{focus} = \sum E(x,y) e^{j\frac{2\pi}{\lambda}(a1+a2)}$$

$$a1 + a2 = \text{constant for parabolic reflector}$$

$$P_{focus} = \frac{1}{2} S A_{geom} \quad \text{W/Hz}$$

Flux density of the source W/m²/Hz

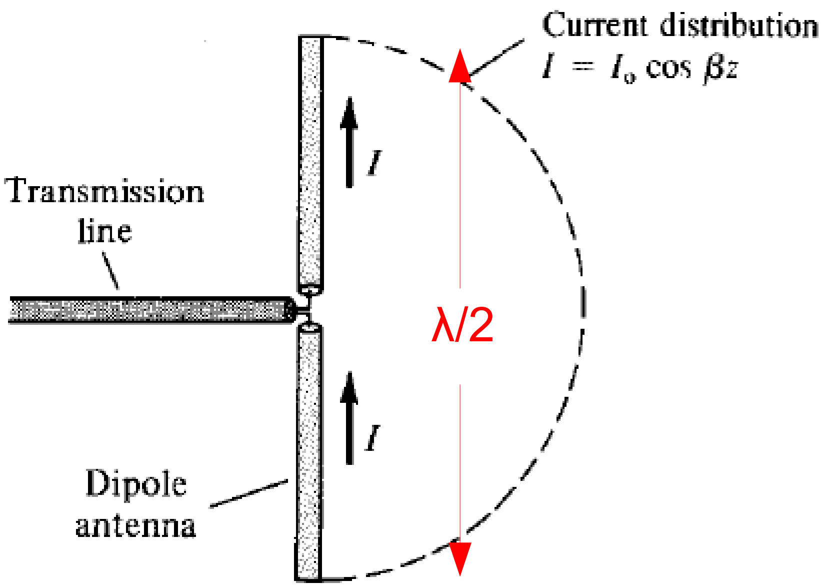


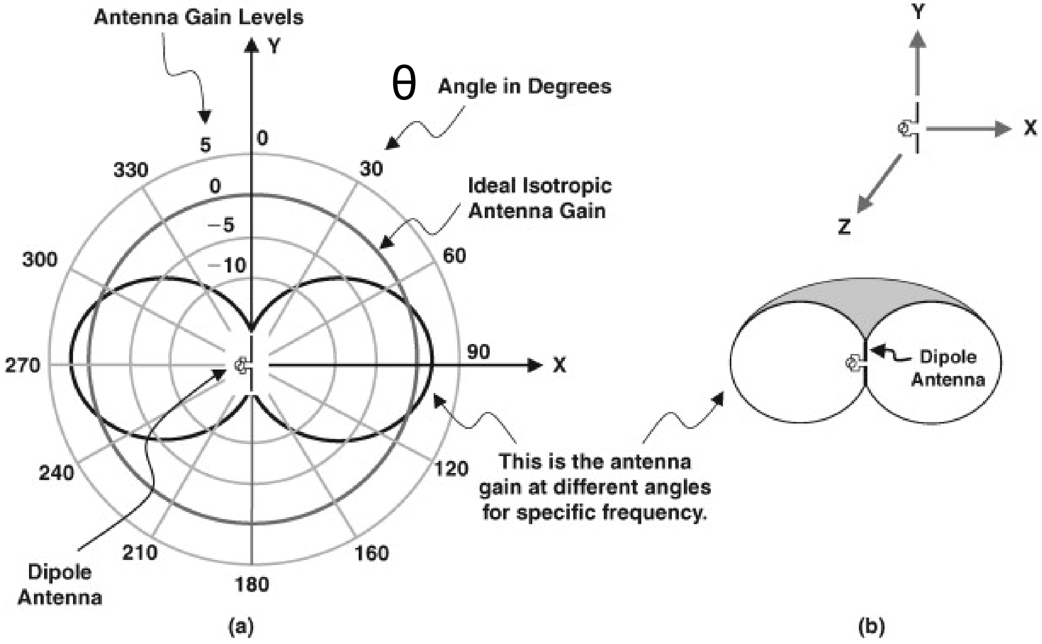
Area in the aperture plane over which the energy is collected

Feed: dipole antenna

•Signal at the focus need to be `fed' into a circuit for signal processing – feed

•Example of a feed : Dipole antenna

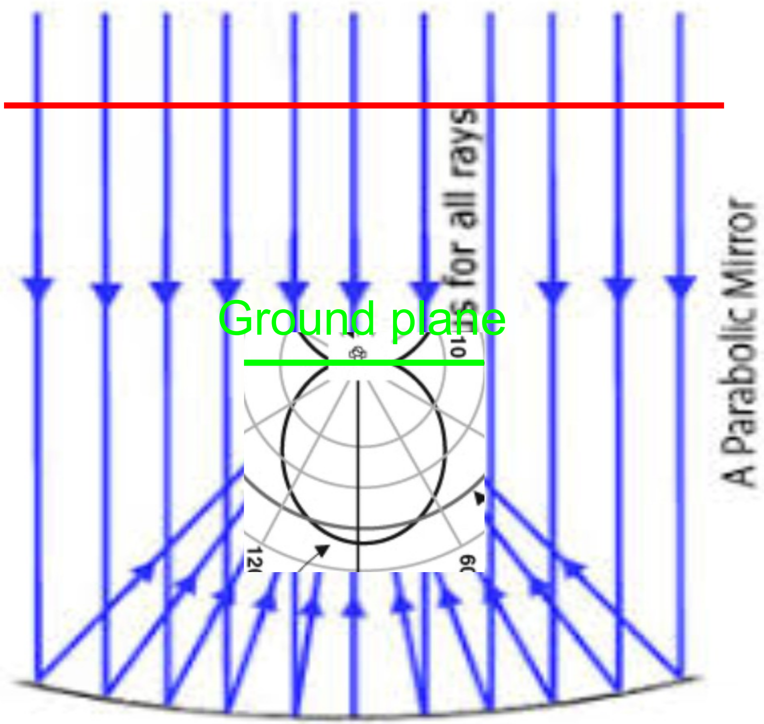


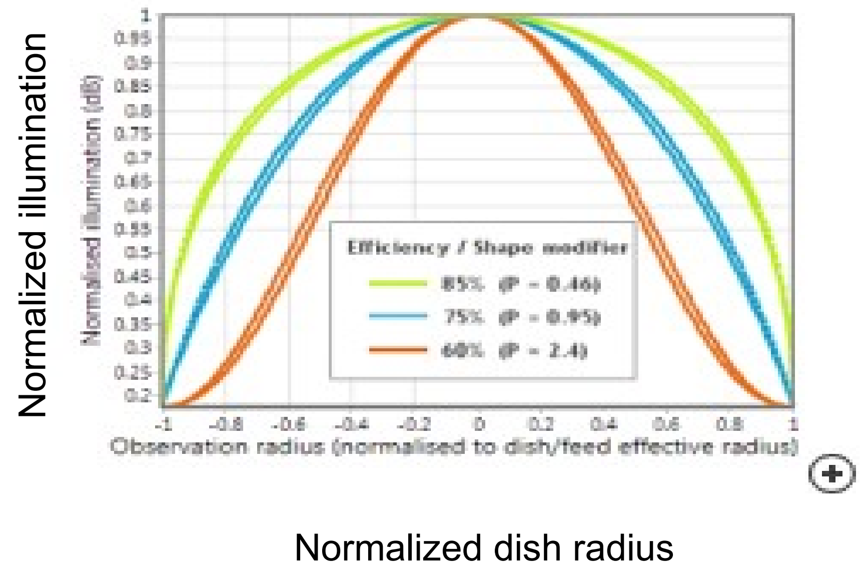


Sensitive to one linear pol

$$\boxed{P(\theta) = \sin^2(\theta)}$$

A dipole feed for parabolic reflector



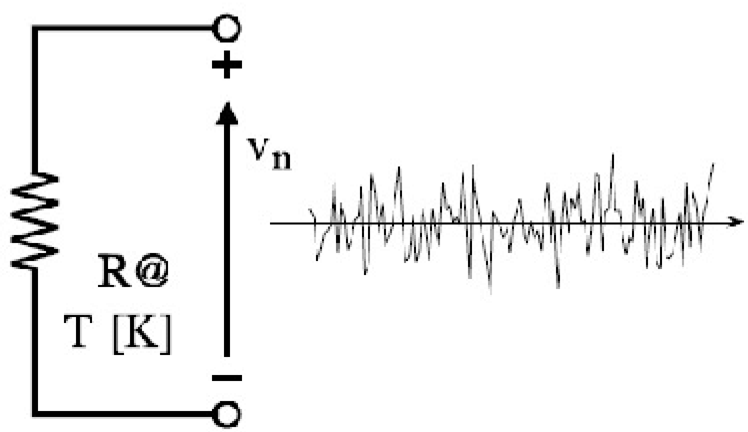


Horn feed

$$P_{rec} = \frac{1}{2} S \, A_{geom} \, \eta_{ap} = k_b \, T_A$$

Power spectral density → Temperature

Noise in a resistor



v_n should be zero mean, should depend on R, should depend on T

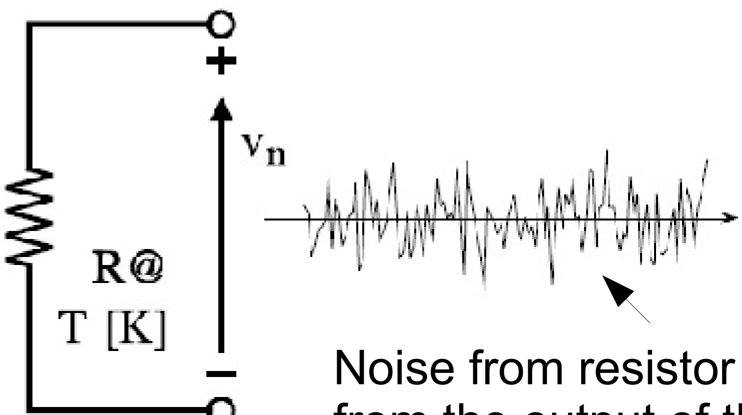
$$\frac{< v_n^2 >}{R} \times \frac{1}{\Delta\nu} = kT$$

J/sec

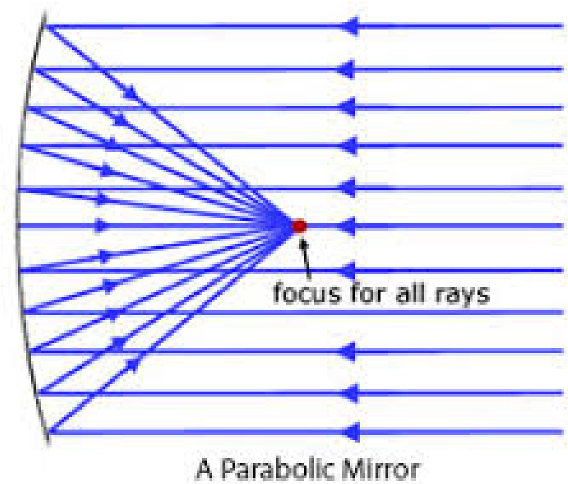
Hz

$$\boxed{P(\nu) = kT}$$

Resistor noise vs radio source noise



Noise from resistor as well as from the output of the dipiole at the focus



1 Jy

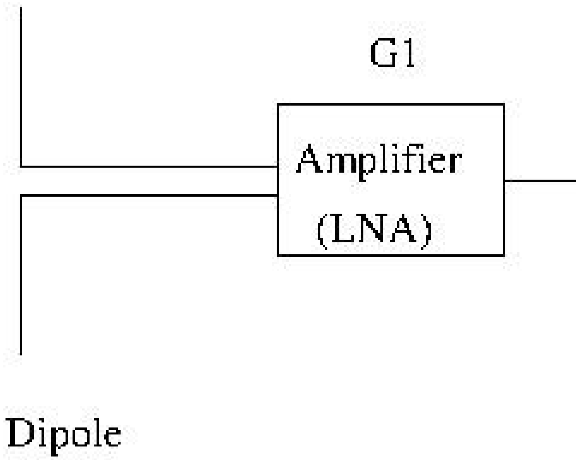
Radio source

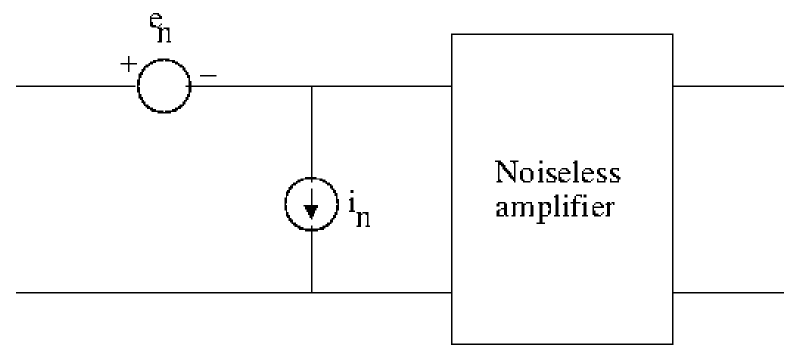
T=300K

$$P_{rec} \;=\; \frac{1}{2}\, S\, A_{geom}\, \eta_{ap} = 2.7 \times 10^{-22} \;\; \mathrm{W/Hz}$$

$$P_{res} \;=\; k_b\, T_{res} = 4.1 \times 10^{-21} \;\; \mathrm{W/Hz}$$

Amplifier noise





$$
\begin{aligned}
< |e_n|^2 > \quad &; \quad < |i_n|^2 >; < e_n^* i_n > \\
T_{min} \quad &: \quad \text{Minimum noise temp} \\
Z_{opt} \quad &: \quad \text{Optimium impedance} \\
N \quad &: \quad \text{Dimensionless parameter}
\end{aligned}
$$

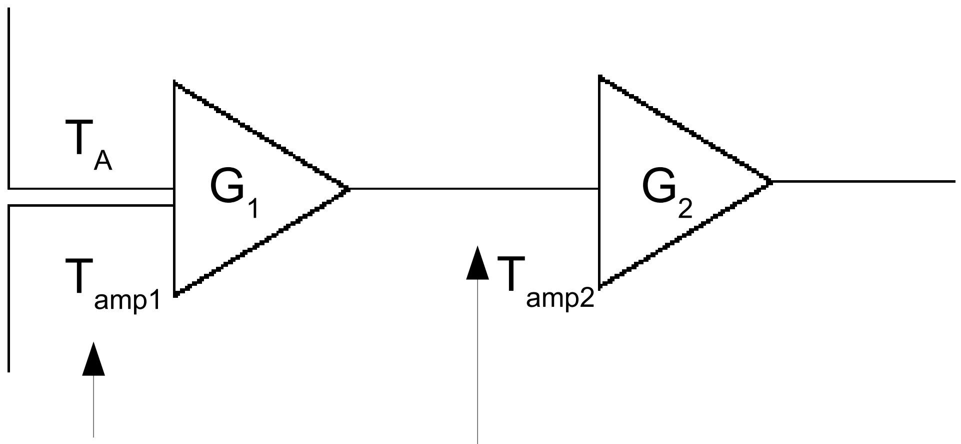
Cryogenic amp: $T_{ambient}$ = 15K

T_{amp} ~ 5K @ 1.4 GHz

$$T_{amp} = T_{min} + N\, T_0 \frac{(Z_{ant} - Z_{opt})(Z_{ant} - Z_{opt})^*}{\mathrm{Re}\{Z_{opt}\}\ \mathrm{Re}\{Z_{ant}\}}$$

T_0=290K

Friis Equation



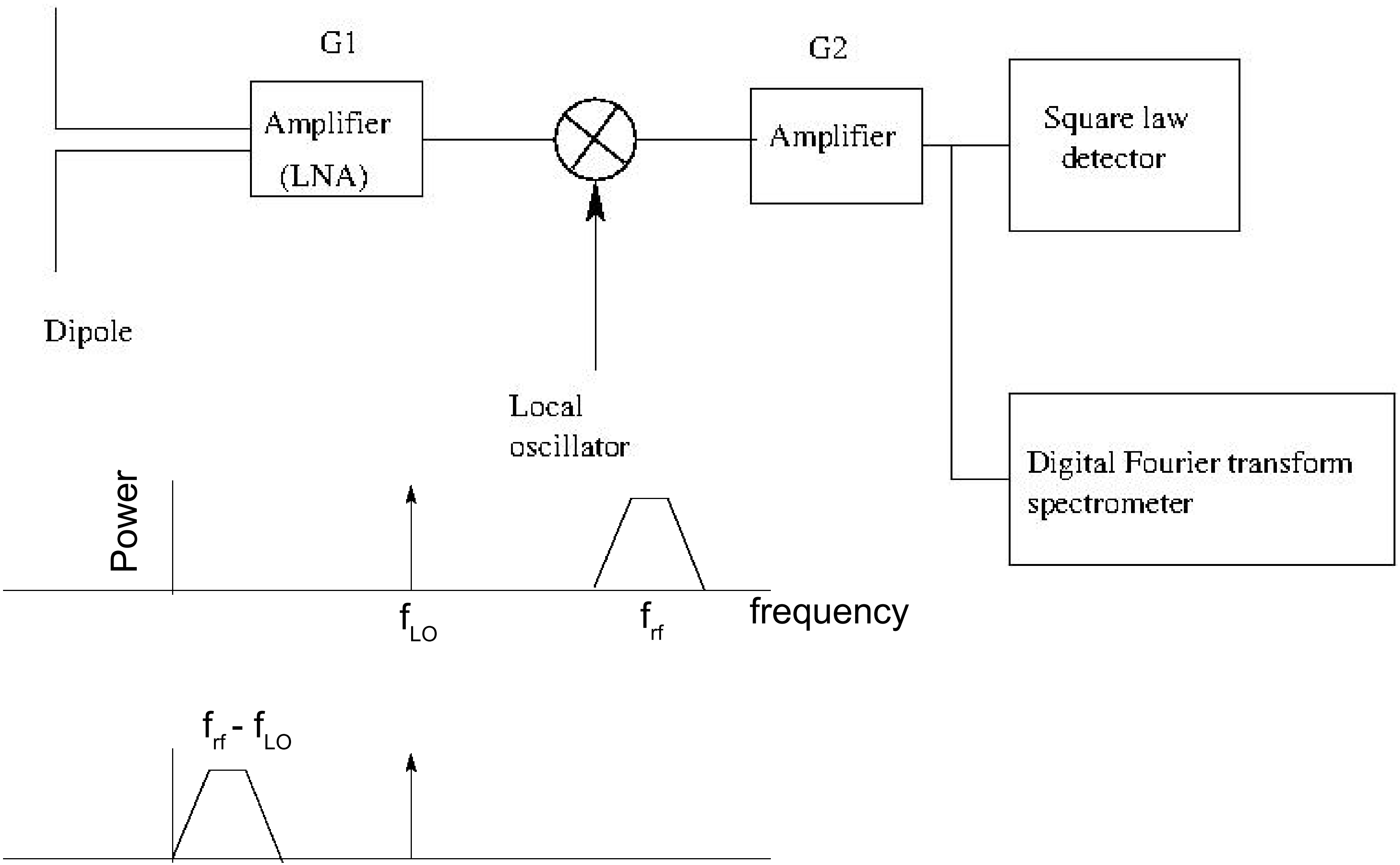
$$SNR1 = \frac{T_A}{T_{amp1}} \quad \text{Let us take } T_{sys} \sim T_{amp1}$$

$$SNR2 = \frac{G_1\, T_A}{(G_1\, T_{amp1} + T_{amp2})}$$

$$= \frac{T_A}{(T_{amp1} + T_{amp2}/G_1)}$$

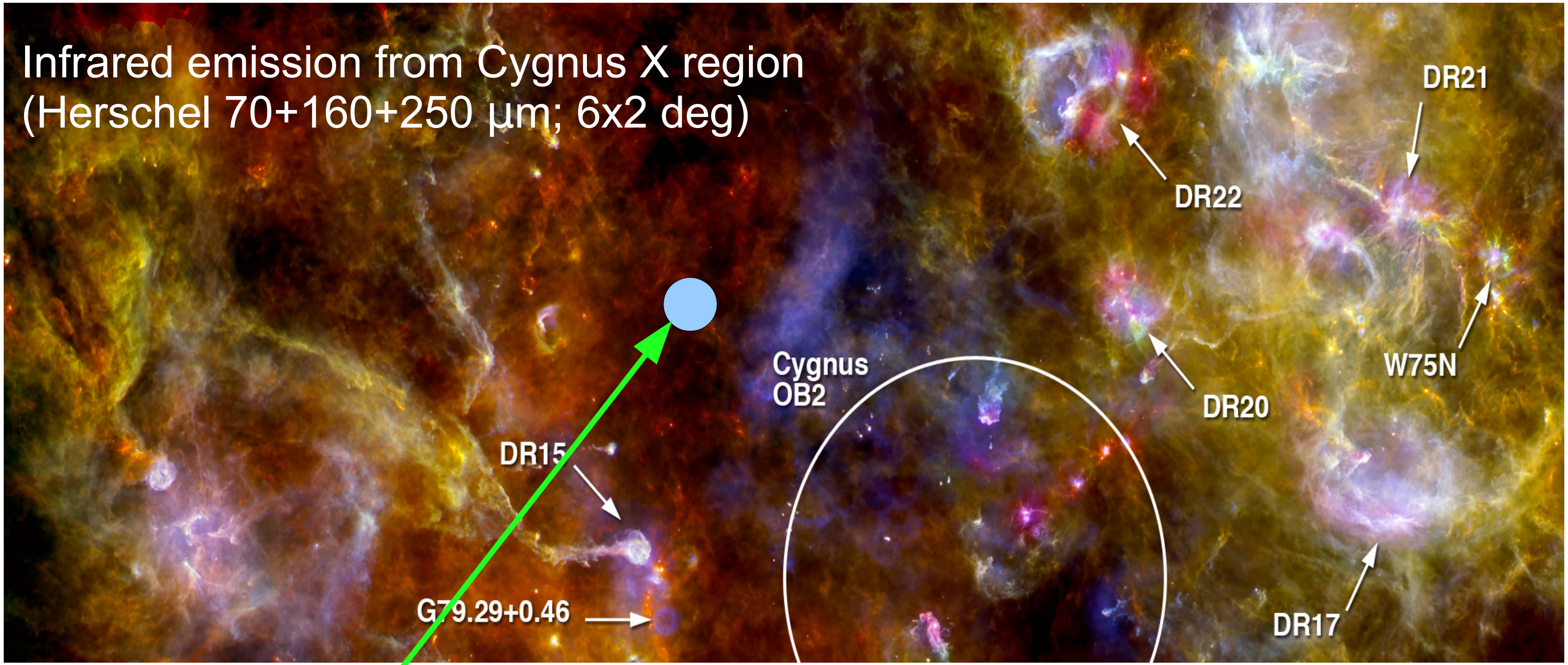
Typical G_1~100

Radio Astronomy Receivers and backends



Large telescope: angular resolution

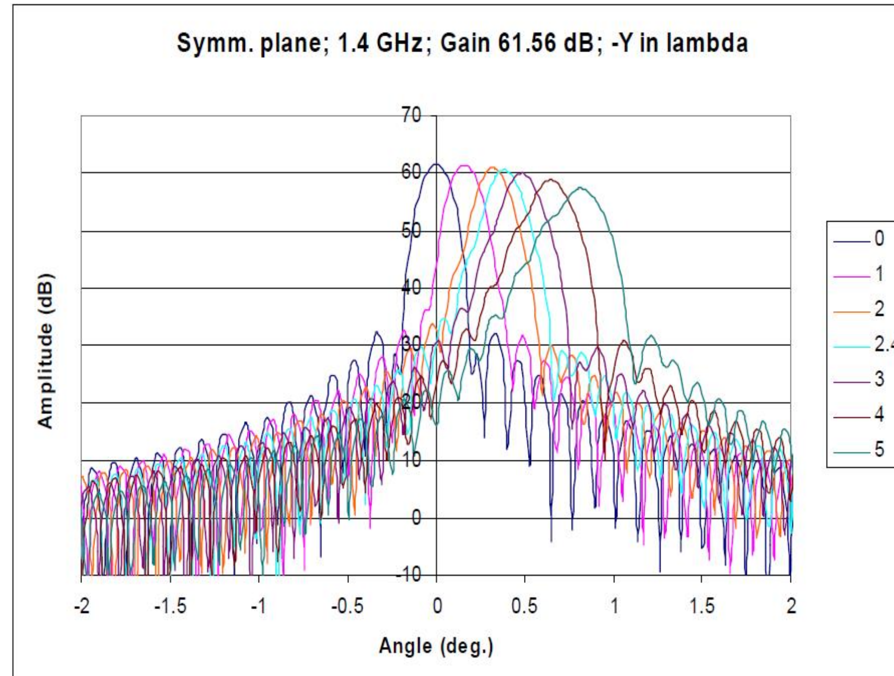
- Large telescope has lower angular resolution
- Angular resolution ~ wavelength/diameter



GBT beam for HI 21cm (1.42 GHz)

GBT beam for NH_3 line (23.6 GHz)

Field of View of a telescope



Srikanth (2006)

Figure 2. GBT beams at 1.4 GHz for offsets (λ) in symmetric plane towards the feed arm

Angular resolution at 1.4 GHz is 9'

FOV – angular region where the beam aberration is within a specified tolerance. (for GBT ~ 1^o x 1^o for 1 dB loss in gain)

Field of View in HPBW vs frequency

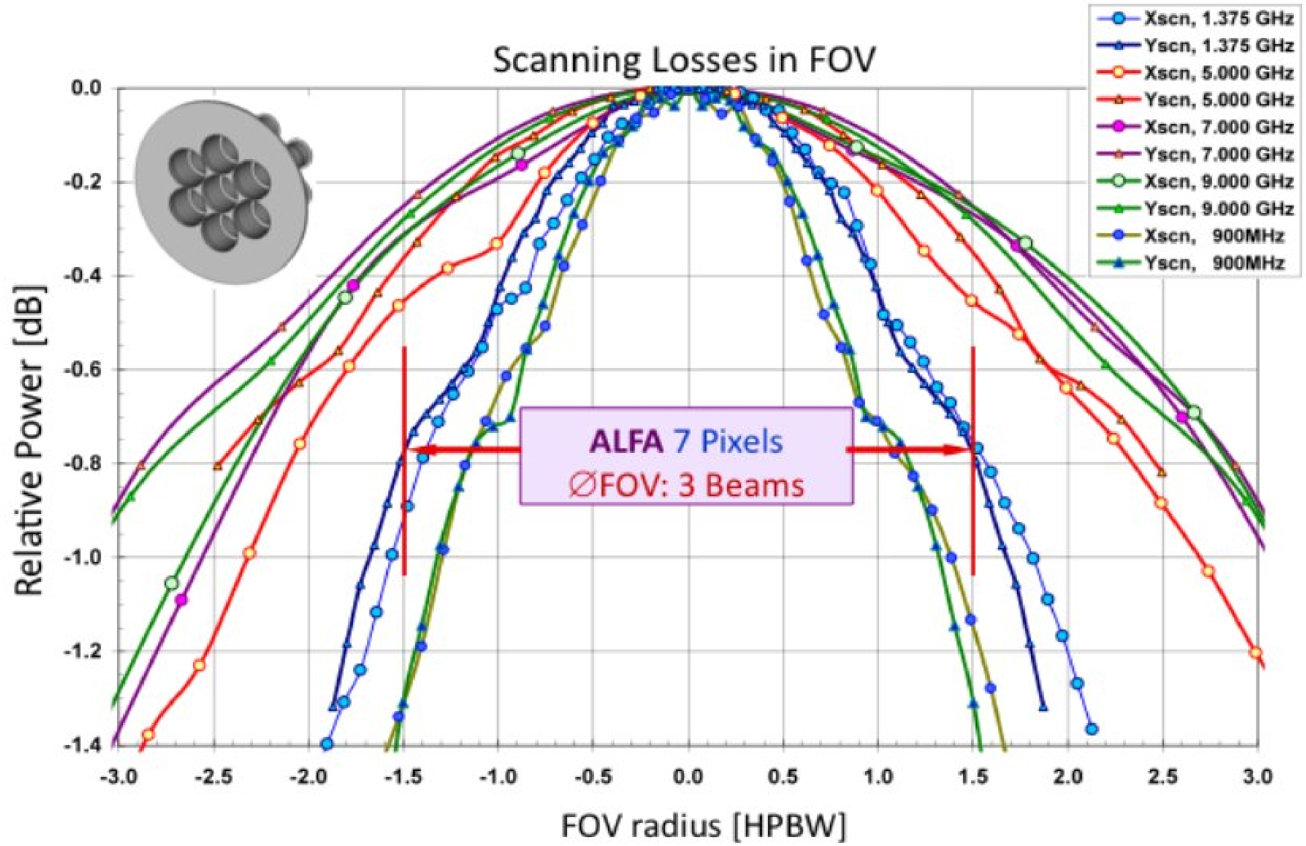


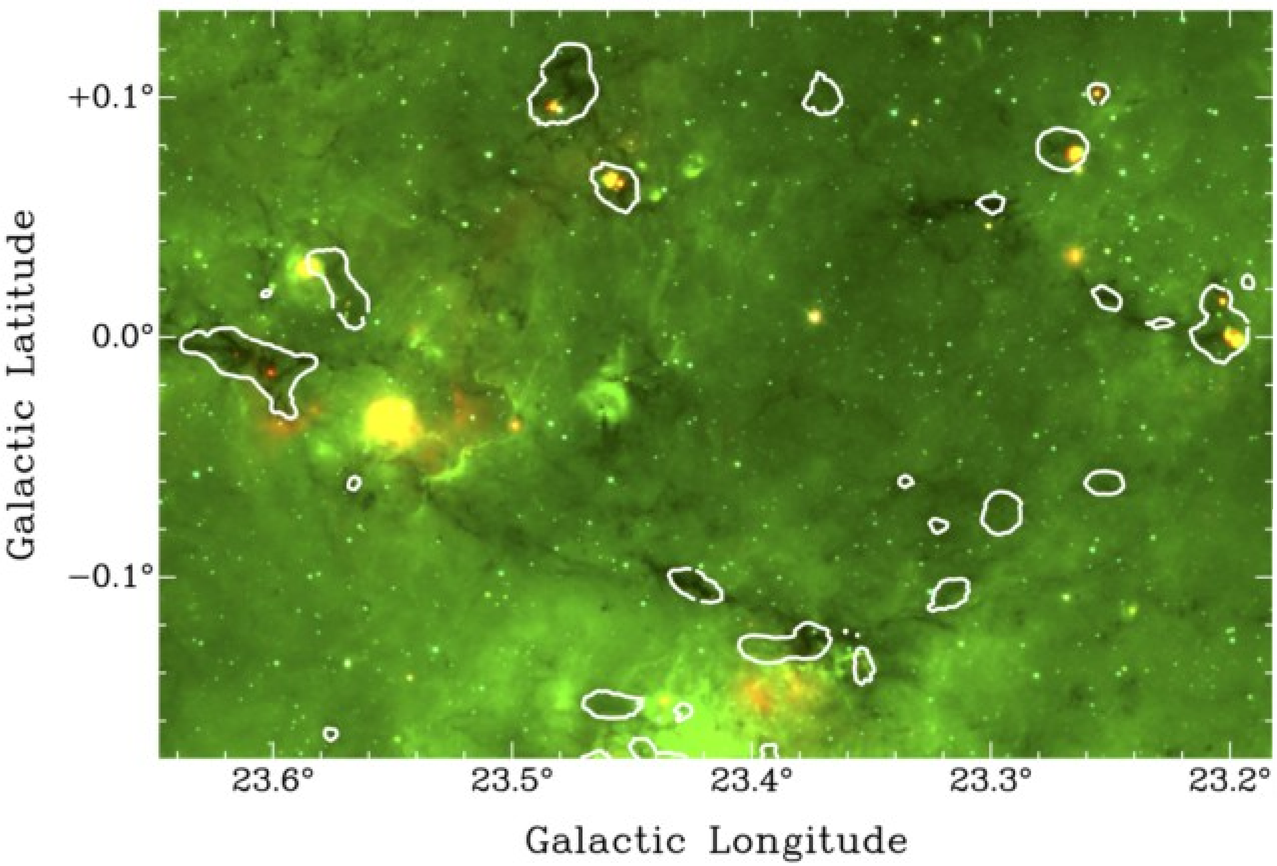
Figure 3. Scanning loss of the AO optics as a function of sky beam displacements

Note: For Arecibo telescope (Cortes-Medellin 2010)

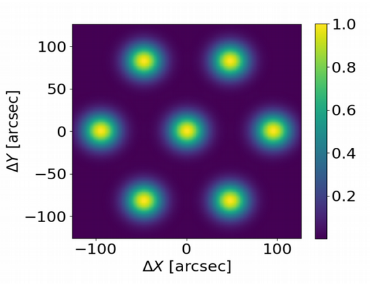
Focal Plane Array (FPA)

7 beam, 24 GHz KFPA on GBT

Infrared (3.6 + 8 + 24μm) image of starforming region with 24GHz NH_3 emission (white contour)



A subset of KFPA feed system



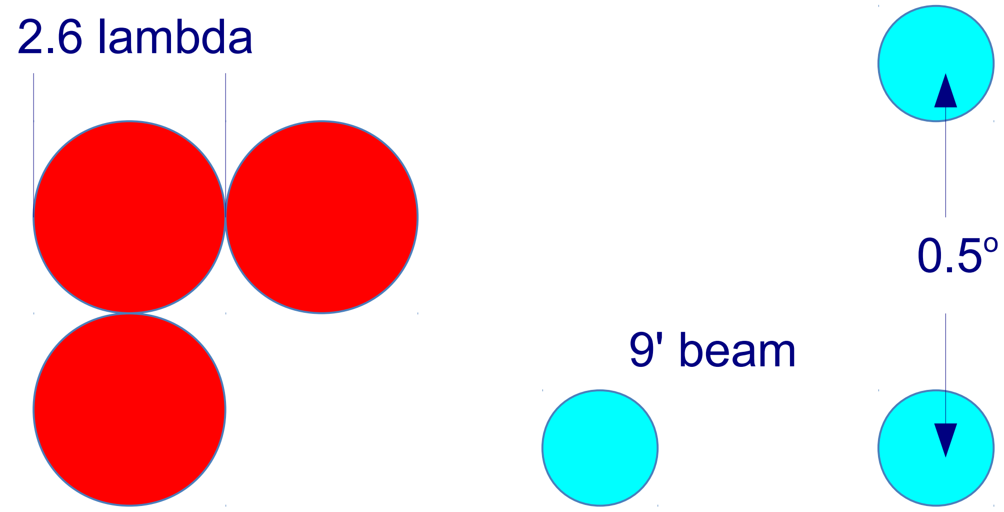
Foot print of the 7 beams

Beam ~ 30''
Separation ~ 90''

FPA: Difficulty at lower frequencies

An example 1.4 GHz prime-focus feed array for GBT

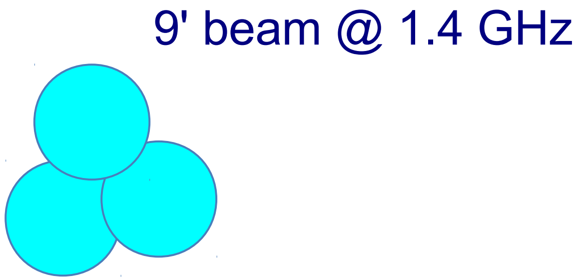
Beam ~ 9'
Feed size ~ 2.6 lambda ~ 55 cm



- Feed designed to maximize telescope gain and minimize spillover
- FPA with L-band feed – 9' beam separated by 0.5° (FoV ~ 1° x 1°)
- Sky sampling not good for imaging

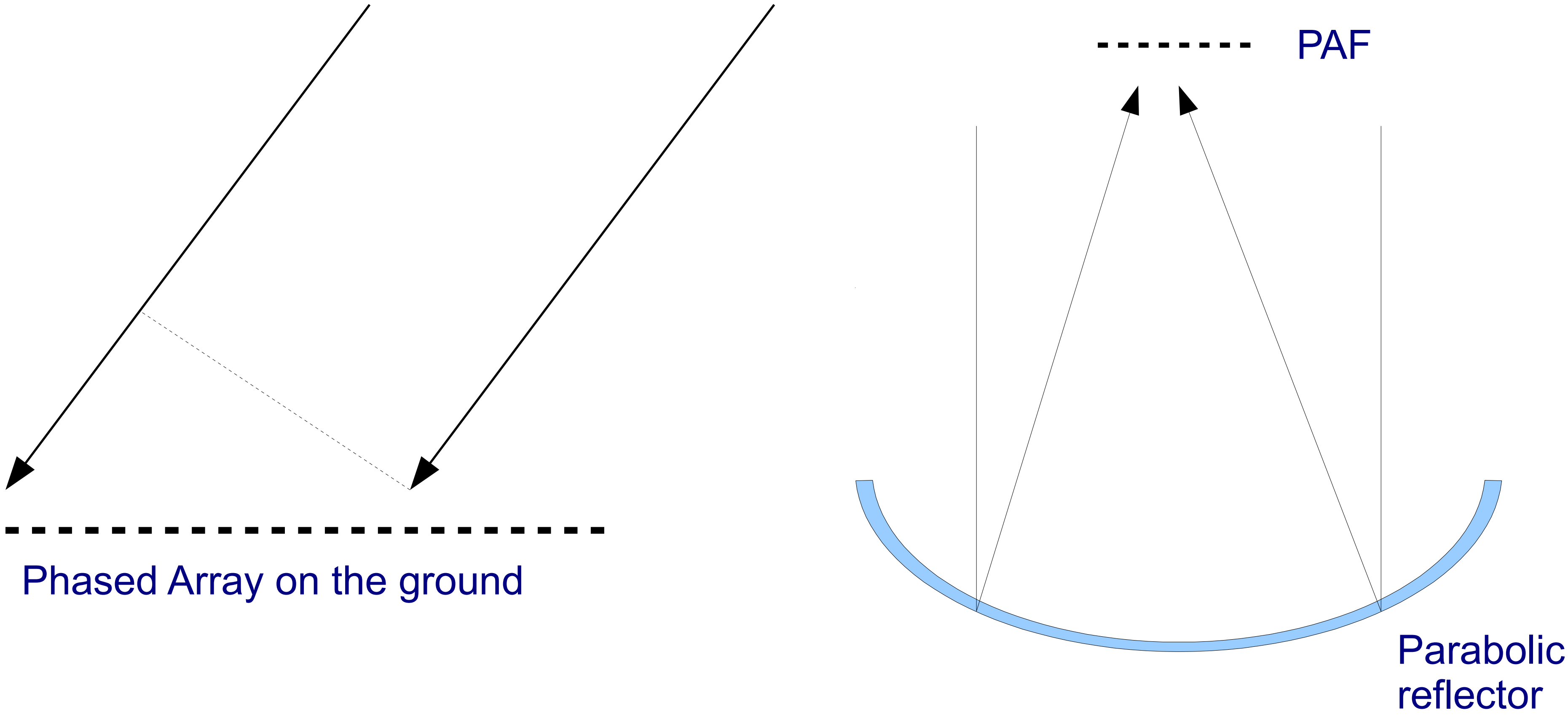
Phased Array Feed (PAF)

PAF: 19 element, 1.4 GHz dipole Array



- PAF uses electrically small elements & combines signals from their output (beamforming)
- Beams can be placed at HPBW or less (or more if needed); Beam shape can also be changed
- More beams → increase the survey speed.
- However, mutual coupling makes it difficult to design PAF; needs detailed modeling.

PAF Signal Processing



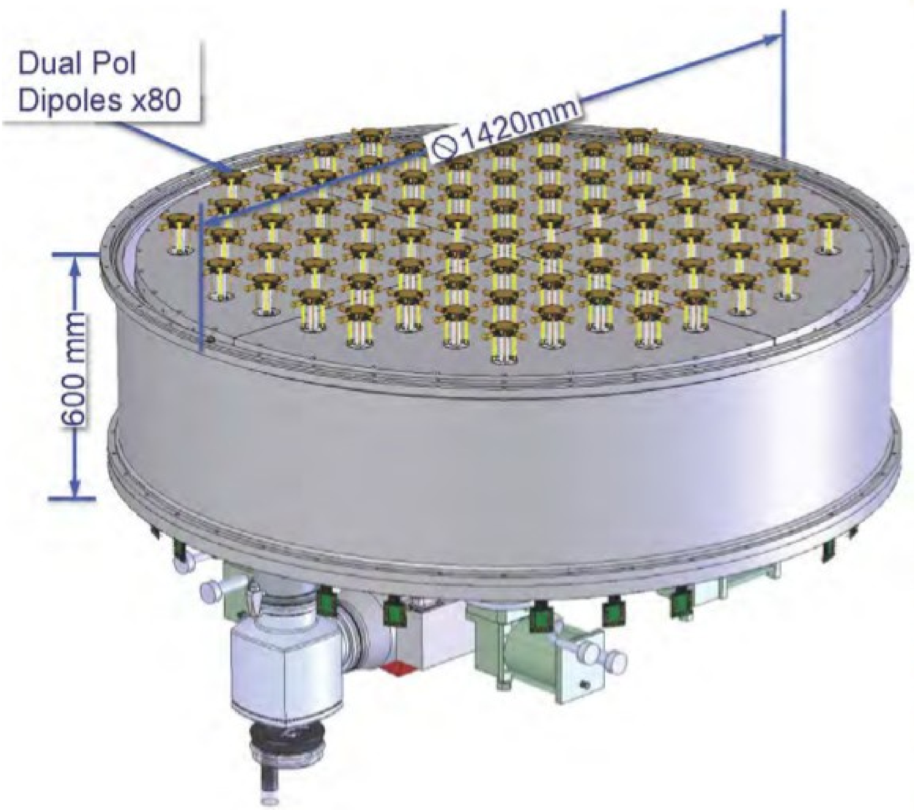
$v_{out} = \mathbf{w}^T\mathbf{V}$; **w** is beamformer weights

(For PAF **w** has strong amplitude dependence)

FLAG and ALPACA

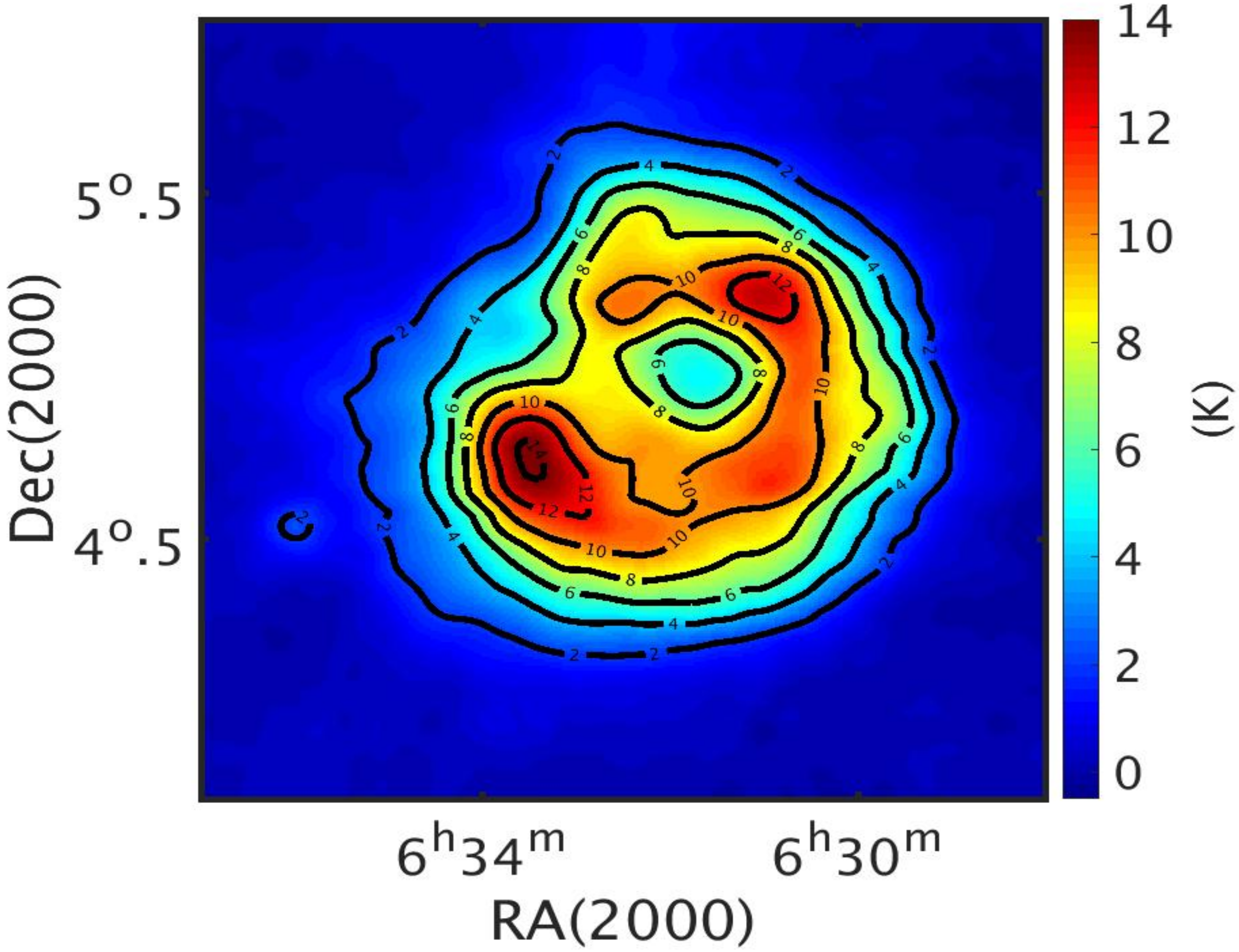
FLAG: 19 elements; 7 beams

Dipole spacing = 0.68 λ_{center}
(f_{center}=1350MHz)



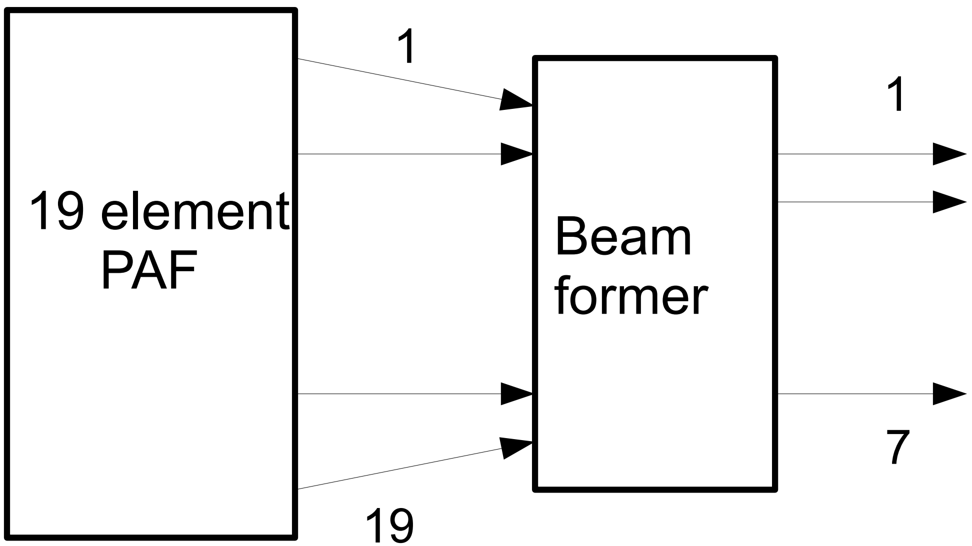
ALPACA: 69 dipoles; 40 beam

Rosette image with FLAG @ 1.3 GHz

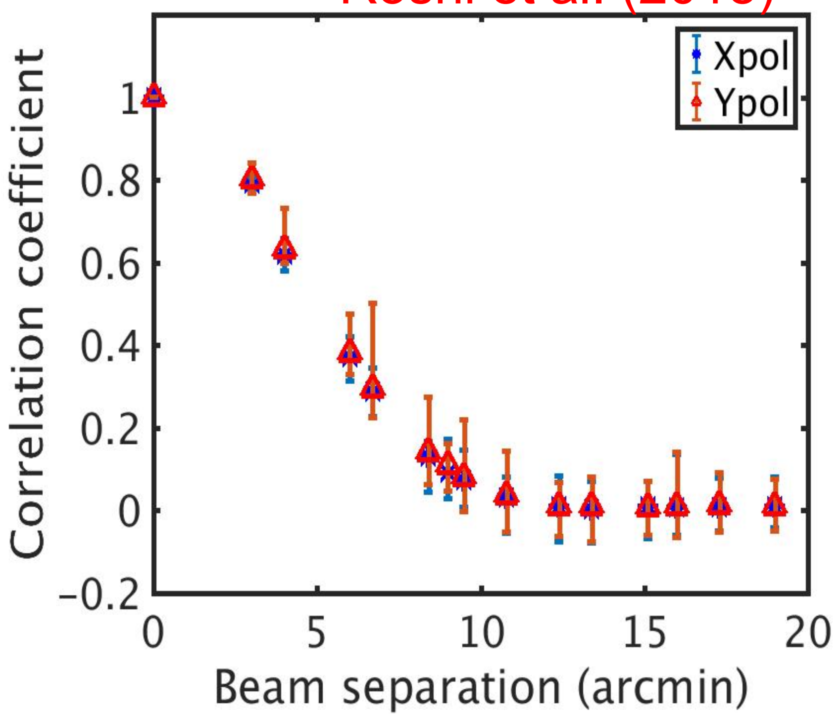


Observing with the PAF

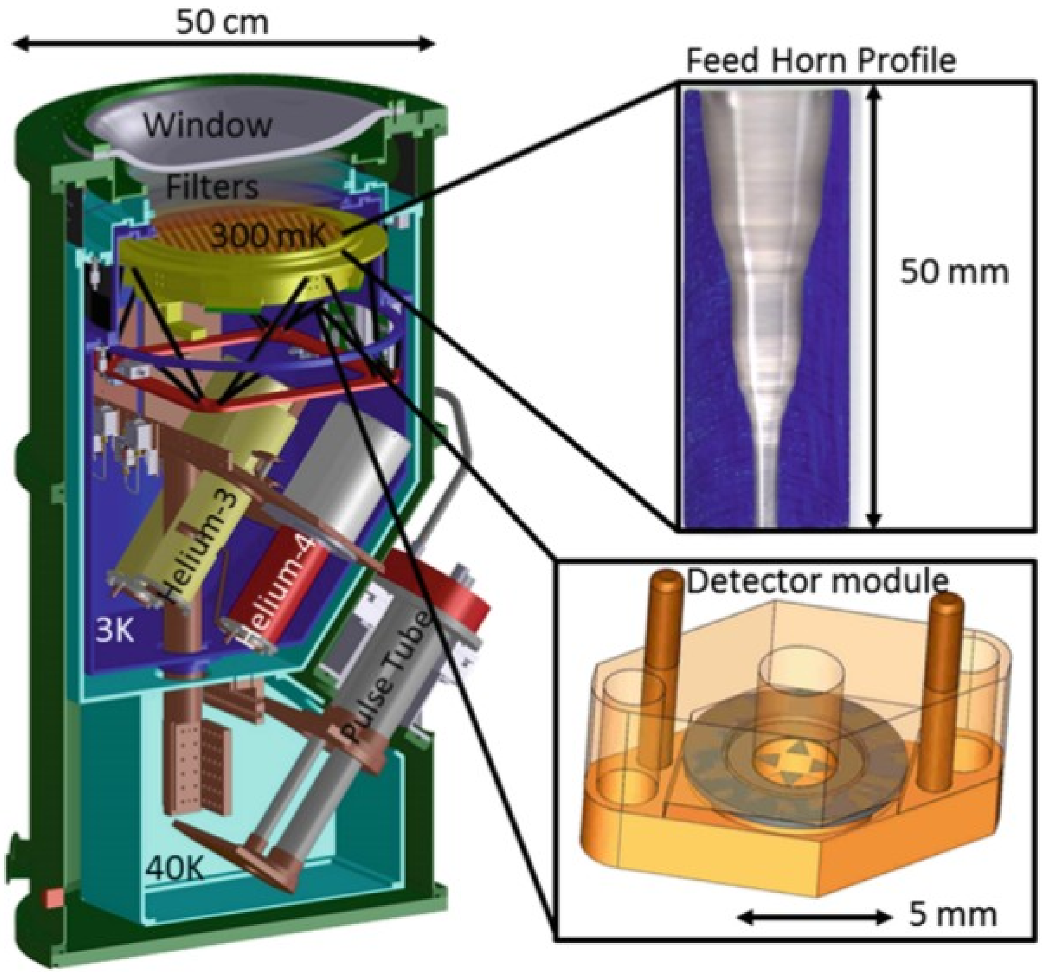
Noise correlation



Roshi et al. (2018)



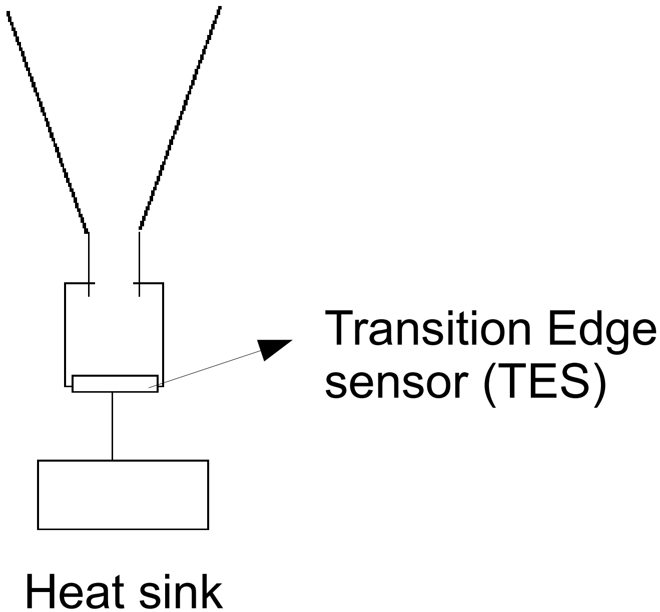
Bolometers

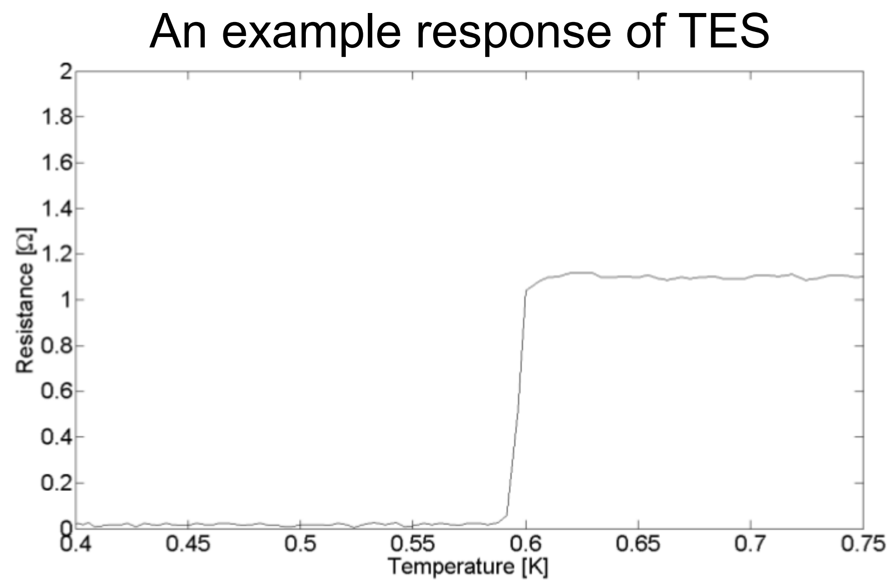


Dicker et al 2014

Mustang2: 223-feedhorn, TES bolometer array
FoV 4'; beam 9''; freq range: 75-105 GHz

Bolometers





$$\Delta T \;\propto\; P = \frac{1}{2} S\, A_{eff}\, \Delta\nu = k_b\, T_A\, \Delta\nu$$

ΔT is increase in temperature of TES
P is the incident radiation power

$$(\Delta T)_{rms} \;\propto\; \frac{T_{sky}}{\sqrt{\Delta\nu\, \tau}} \quad \Delta\nu \text{ - bandwidth, } \tau \text{ - integration time}$$

RMS temperature fluctuations

Valid in the Rayleigh-Jeans limit
(see Mason, 2012, GBT memo 279)

Thank You