CORE ⇒ ZEBRA ⇒ SARAS
The Zero Spacing Interferometers

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&

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CAASTRO Global EoR Workshop

Sydney, 19 Nov 2012

From CoRE I to ZEBRA

CSIRO

CoRE I (Chippendale)

⇓

CoRE II (Virtual)

RRI

⇓

ZEBRA ⇒ SARAS

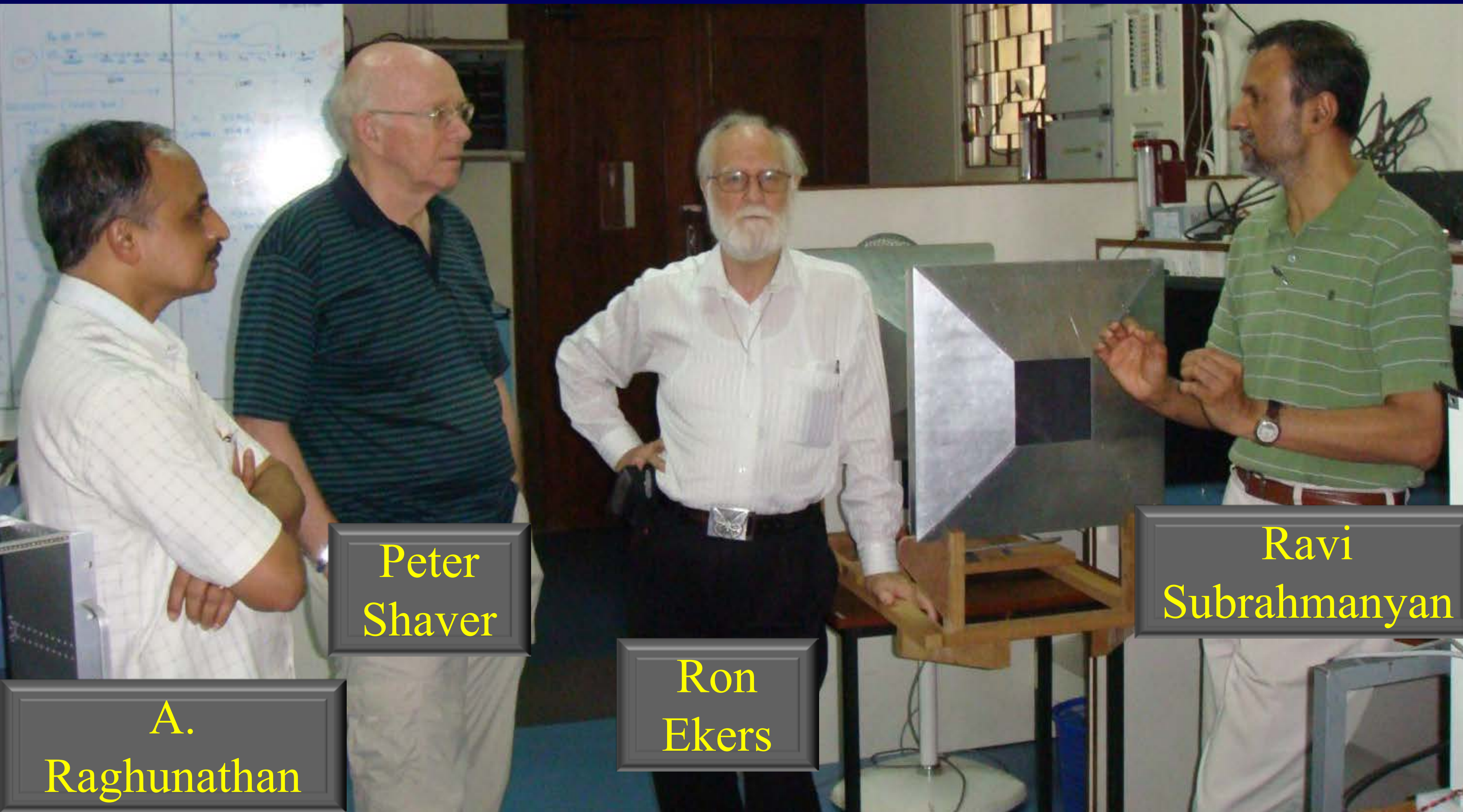
⇓

MRO

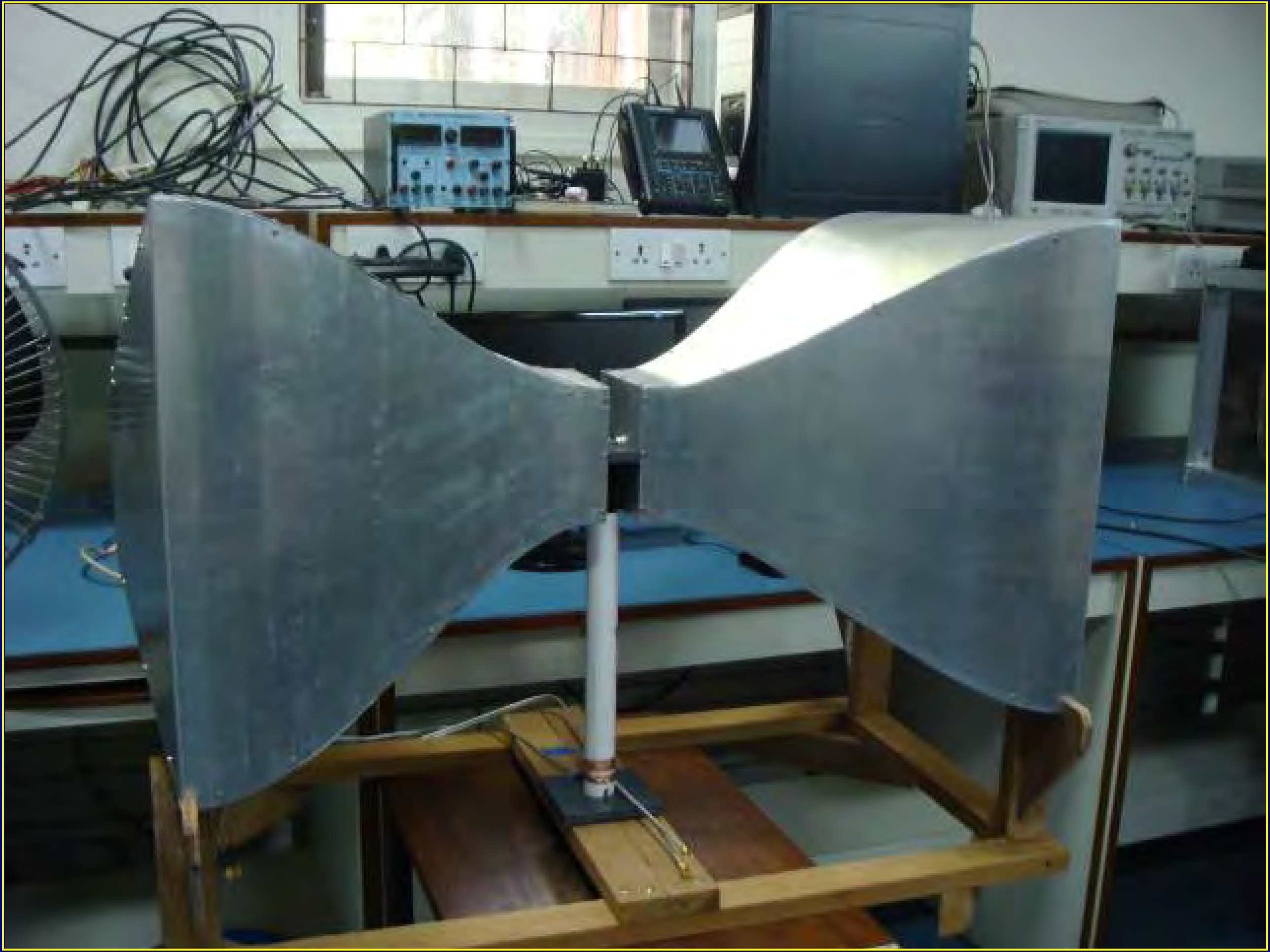
Calibratable receiver

ZEBRA II

Global EoR system
RRI Bangalore



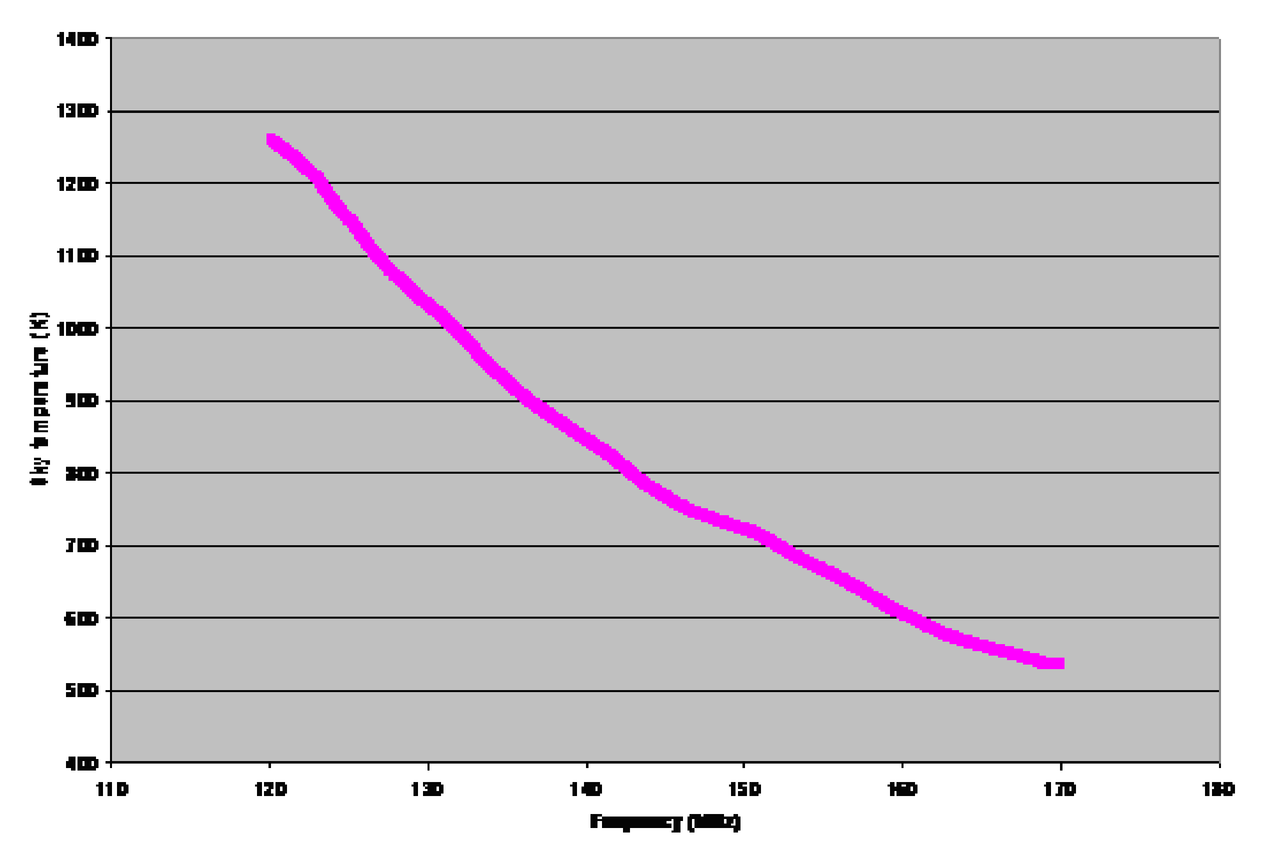
Zebra – fat dipole v1



Zebra – receiver MkI

First light
14 Sep 2010

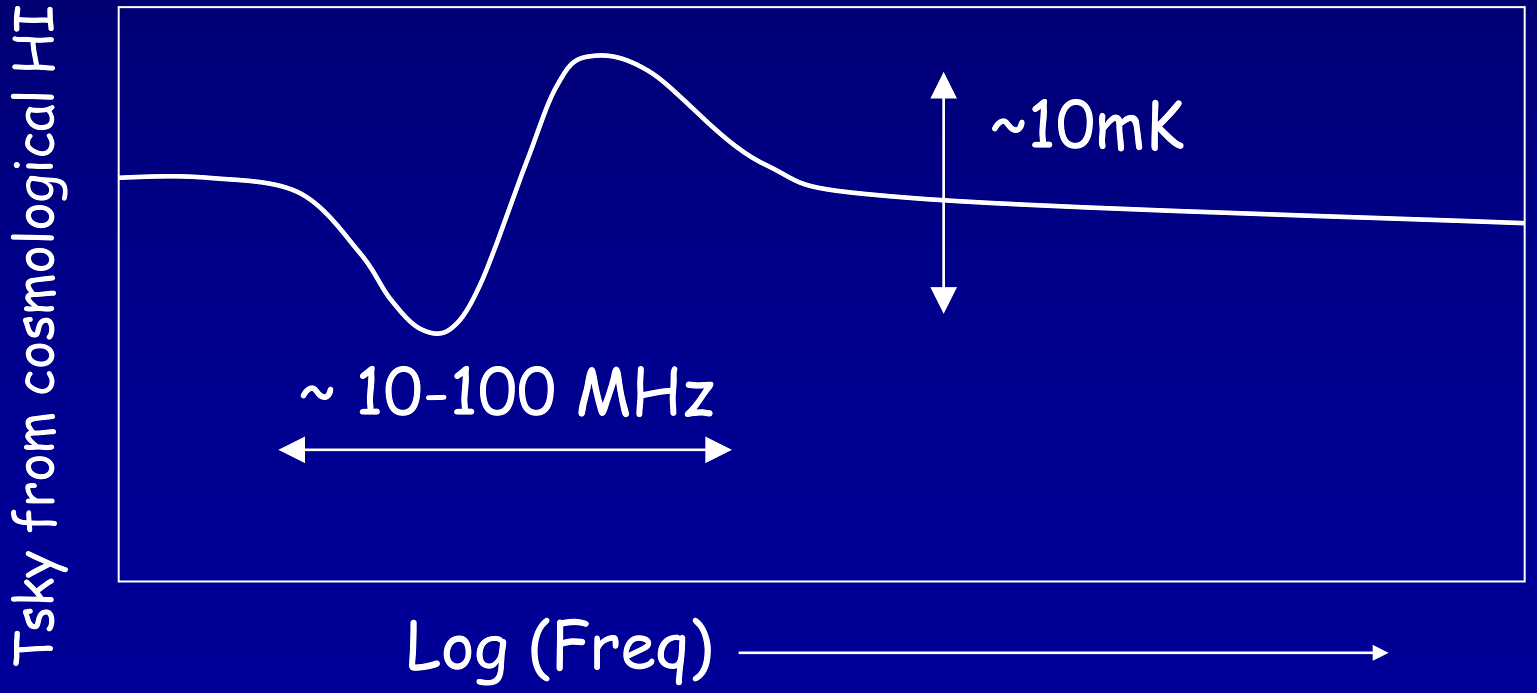
- Spectrum is the expected galactic power law.



Global EoR Signal

Signal in the 50-200MHz depends on the
(i) spin temperature
(ii) ionization fraction

during z = 26 - 6

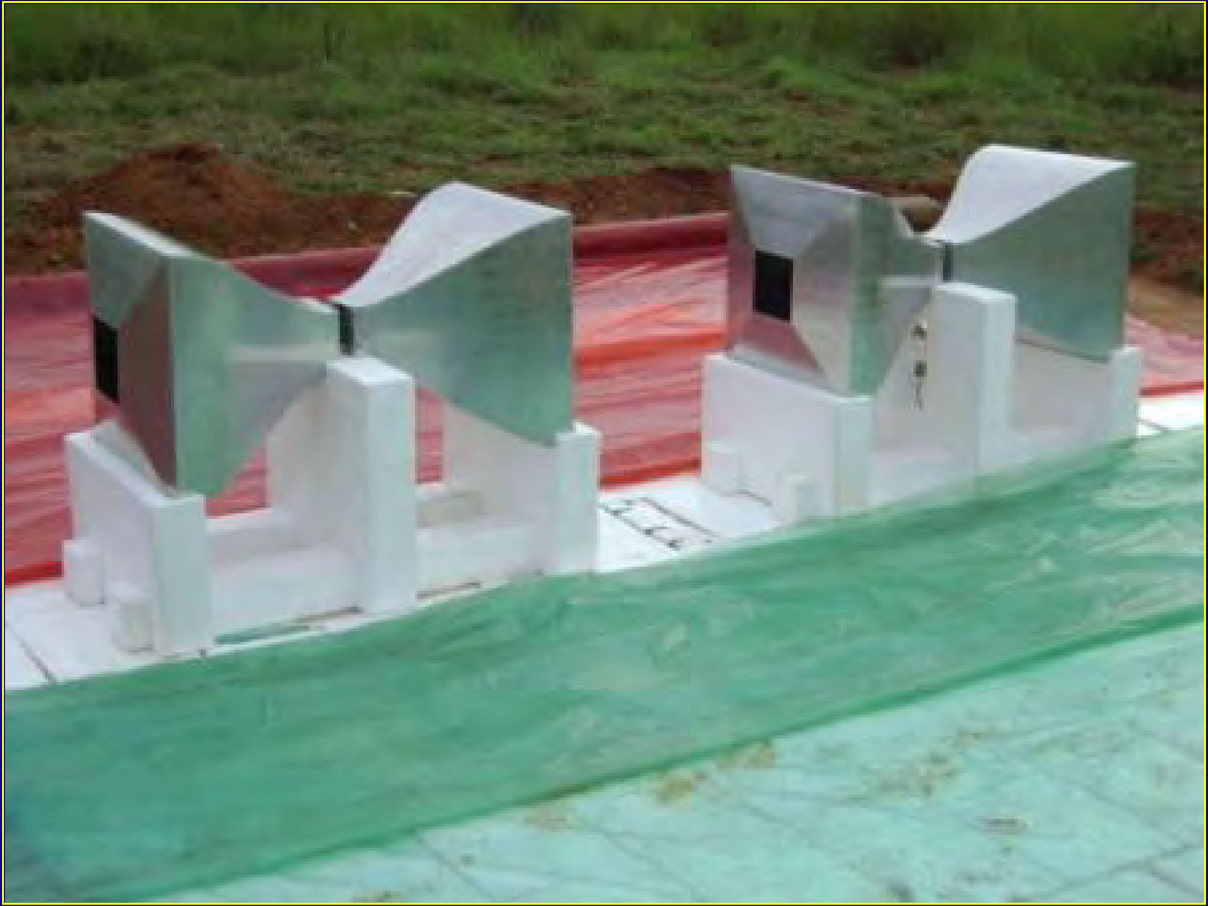


The challenge

- Global ΔT 30mK in few MHz
  - S/N easy – can reach a few mK in one ho[illegible]
- $\Delta T/T < 10^{-4}$ to 10^{-5}
- Calibrate the gain
- Minimize the number of unknowns that [illegible]n couple to EoR
- Remove the additive constant
  - Correlation receiver
    - » Eliminate LNA additive noise – but [illegible]till many problems
  - Position switching
    - » ΔT now very small so large an[illegible]tenna and long integration times
    - » Correlation interferometer
    - » Arrays
      - Statistical detection
      - Direct detection

Zero spacing interferometer

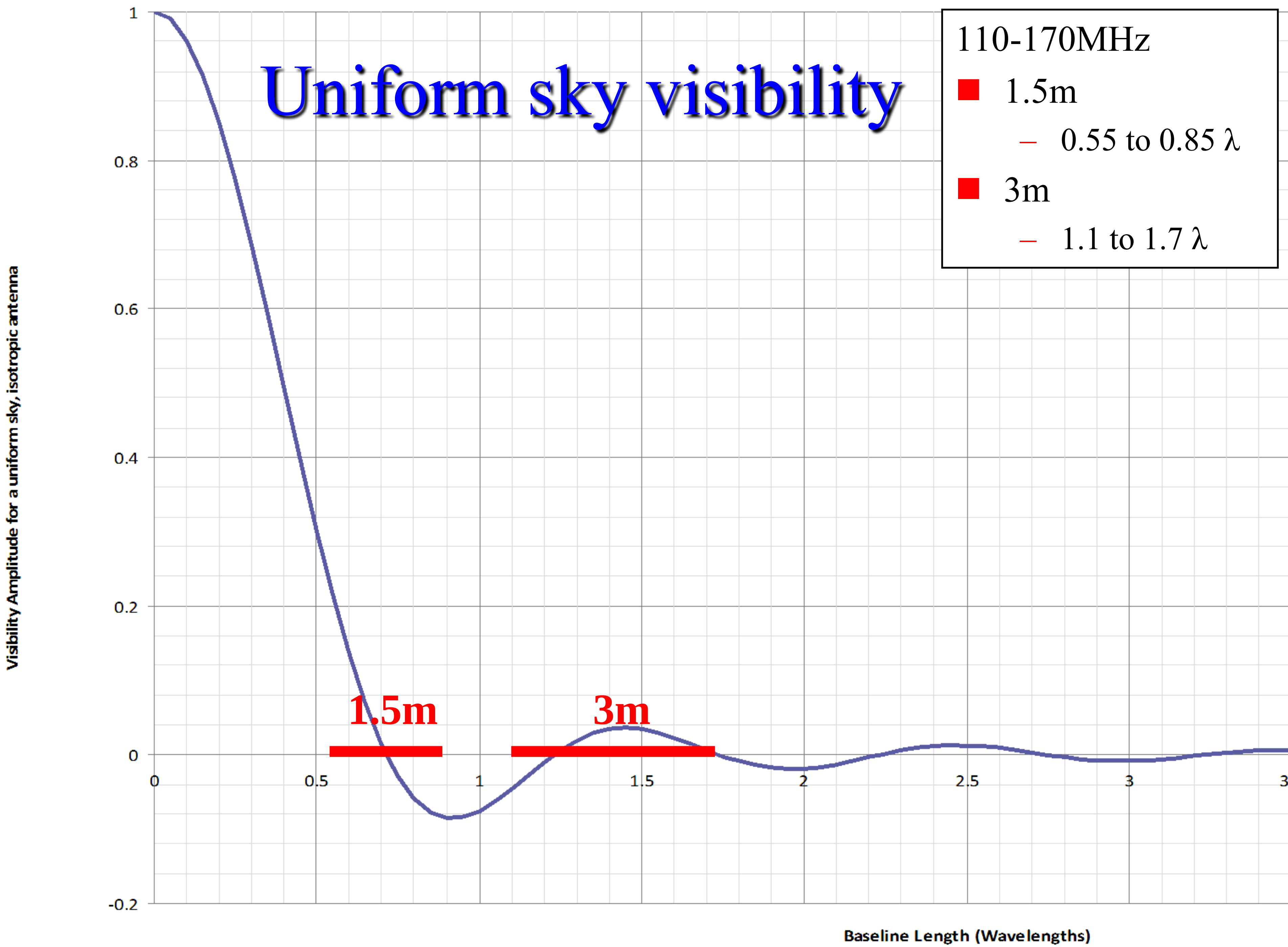
ZEBRA– interferometer



Uniform sky visibility

110-170MHz

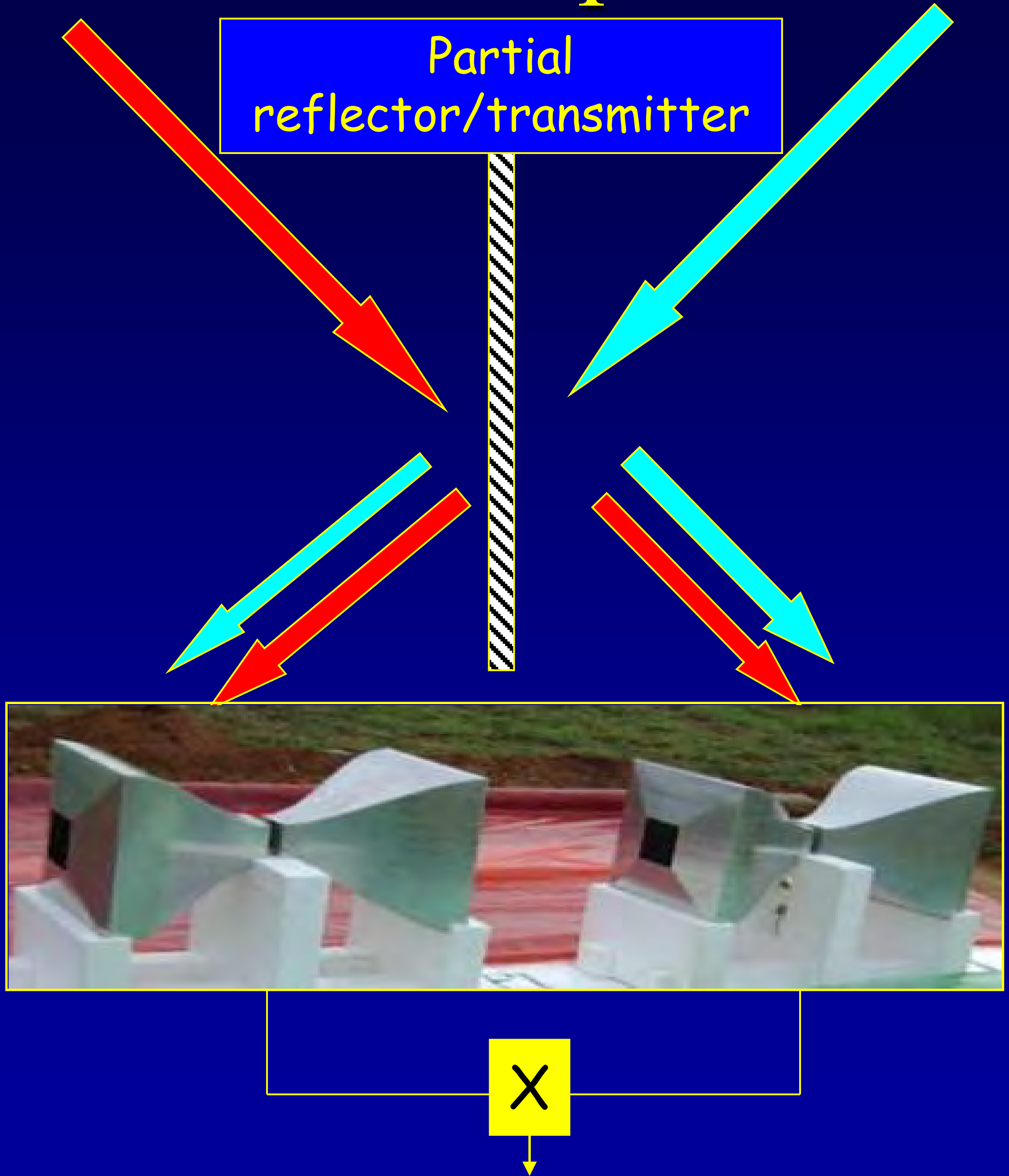
- 1.5m
  - 0.55 to 0.85 λ
- 3m
  - 1.1 to 1.7 λ



ZEBRA Global EoR Experiment

- ZEro-spacing measurement of the Background RAdio spectrum
- Partially reflecting resistive screen
- Virtual zero spacing interferometer
- Removes all additive errors
- Modulate screen ?

Subrahmanyan,
Ekers
Patra



The space beam-splitter: a resistive wire mesh

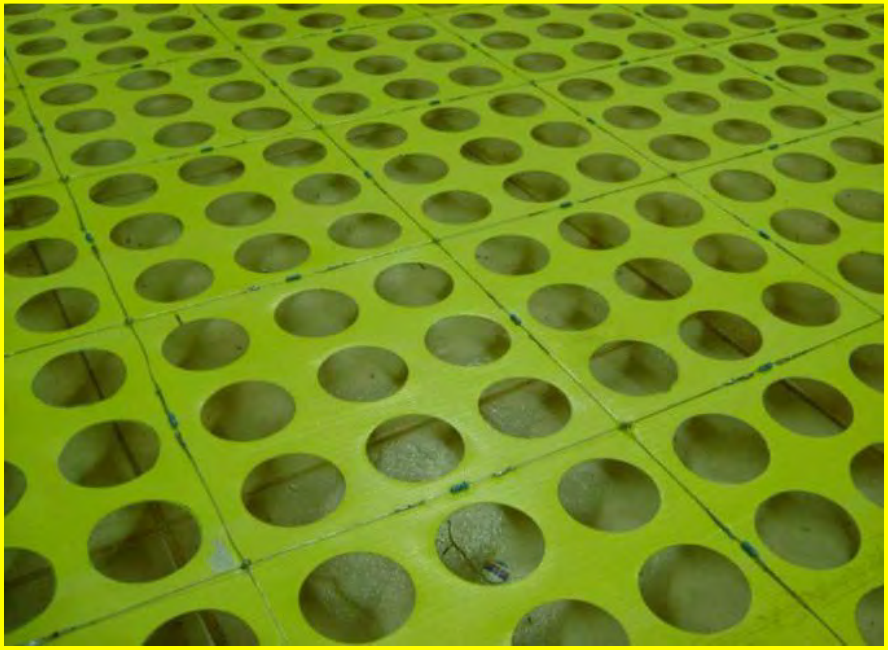
- Need a space beam-splitter before the antenna
- A lossless screen (e.g. a conducting grid)
  - transmitted & reflected waves are orthogonal
- Resistive wire mesh
  - Thickness of wire < skin depth
  - Frequency independent
  - Re-radiated fields no longer cancel the incident field on the far side of the wire screen
- Lumped resistance on scale $\ll \lambda$
  - Practical solution instead of resistance wire

Building resistive screen

The Resistive Screen

copper wire + lumped resistors

resistor value
= free space impedance/2



3x4 metres

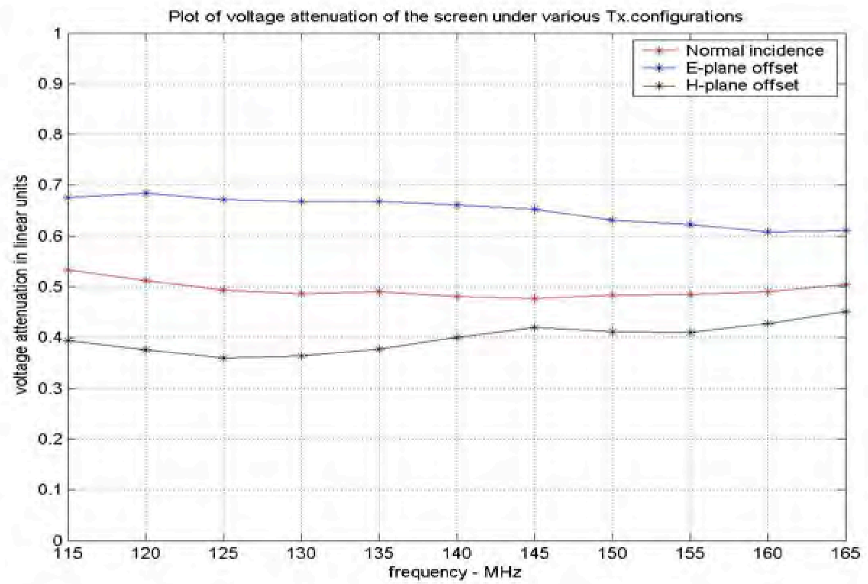
holes to reduce wind loading

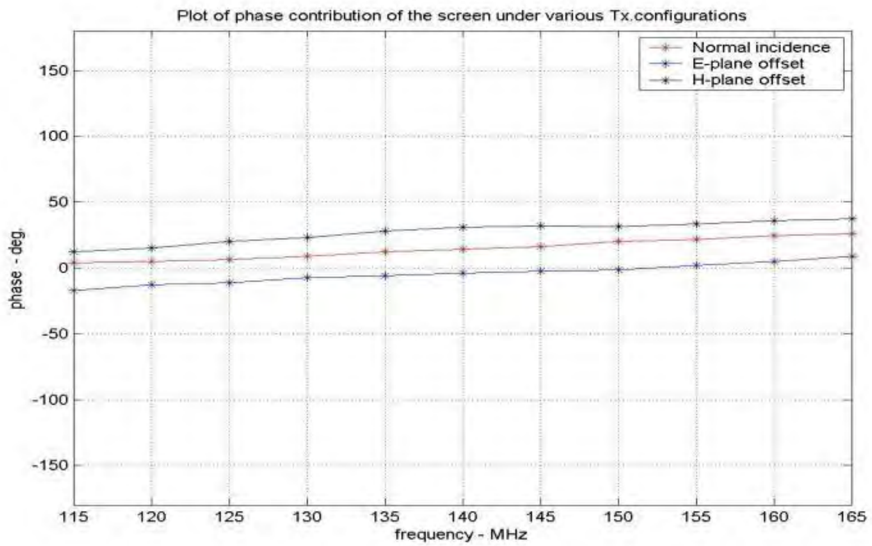
Roll up for transport

Measurements of propagation
Amplitude & phase through
the resistive mesh

For normal and oblique incidence

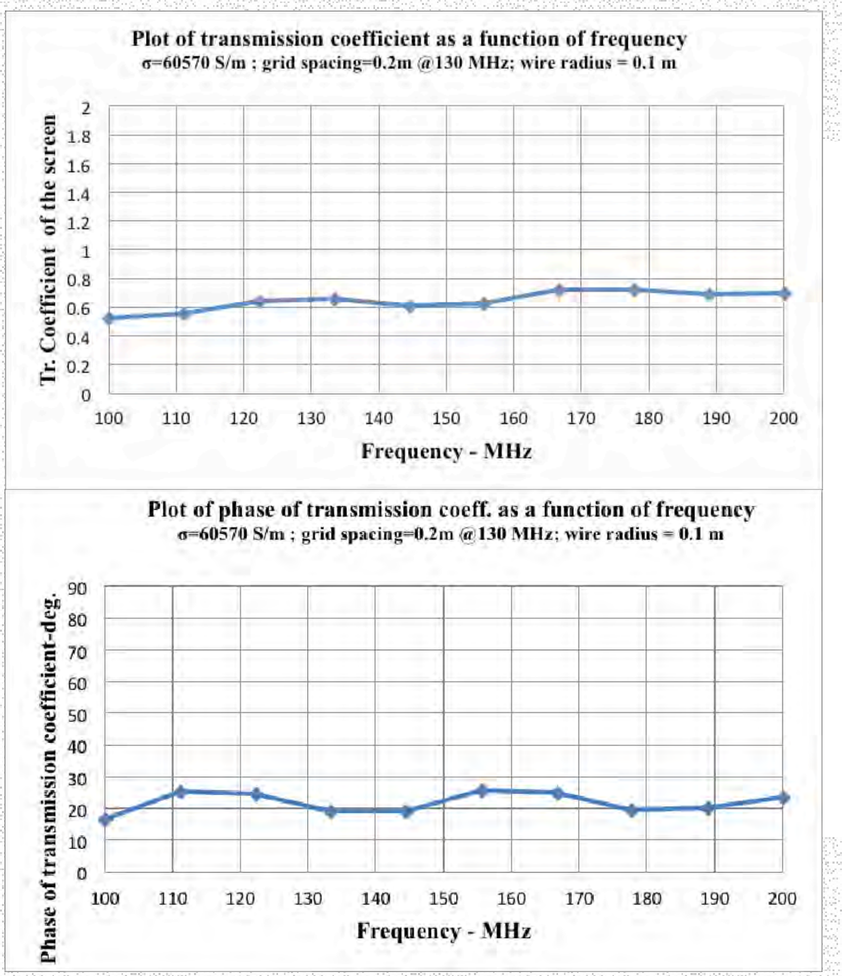
Measurements of
E and H plane fields



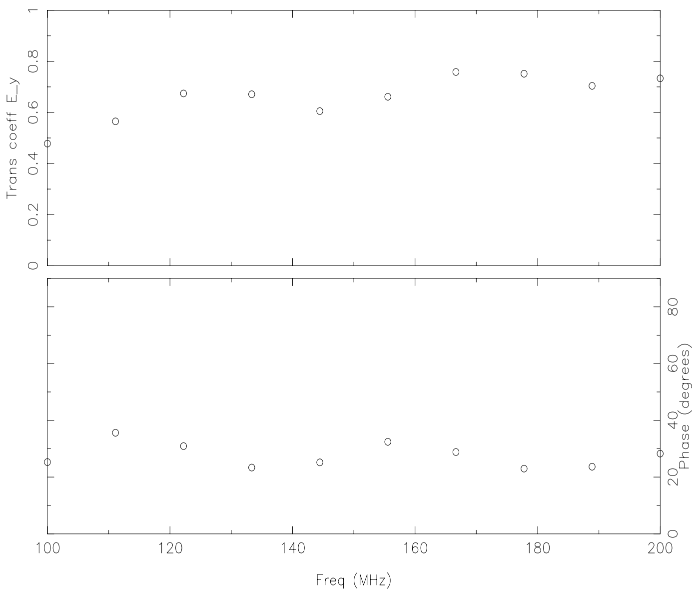


Modeling the transmission amplitude and phase for FINITE SCREEN

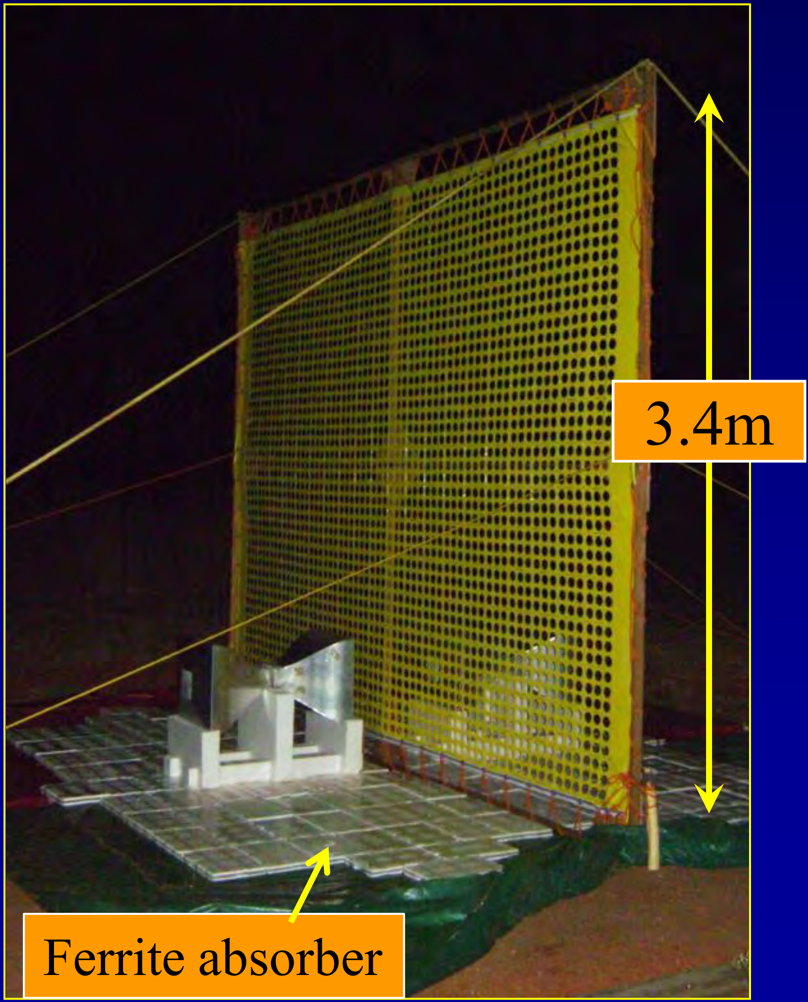
Predictions based on WIPL-D model vs



Predictions from analytic formulation of transmission thro' a mesh plus physical optics



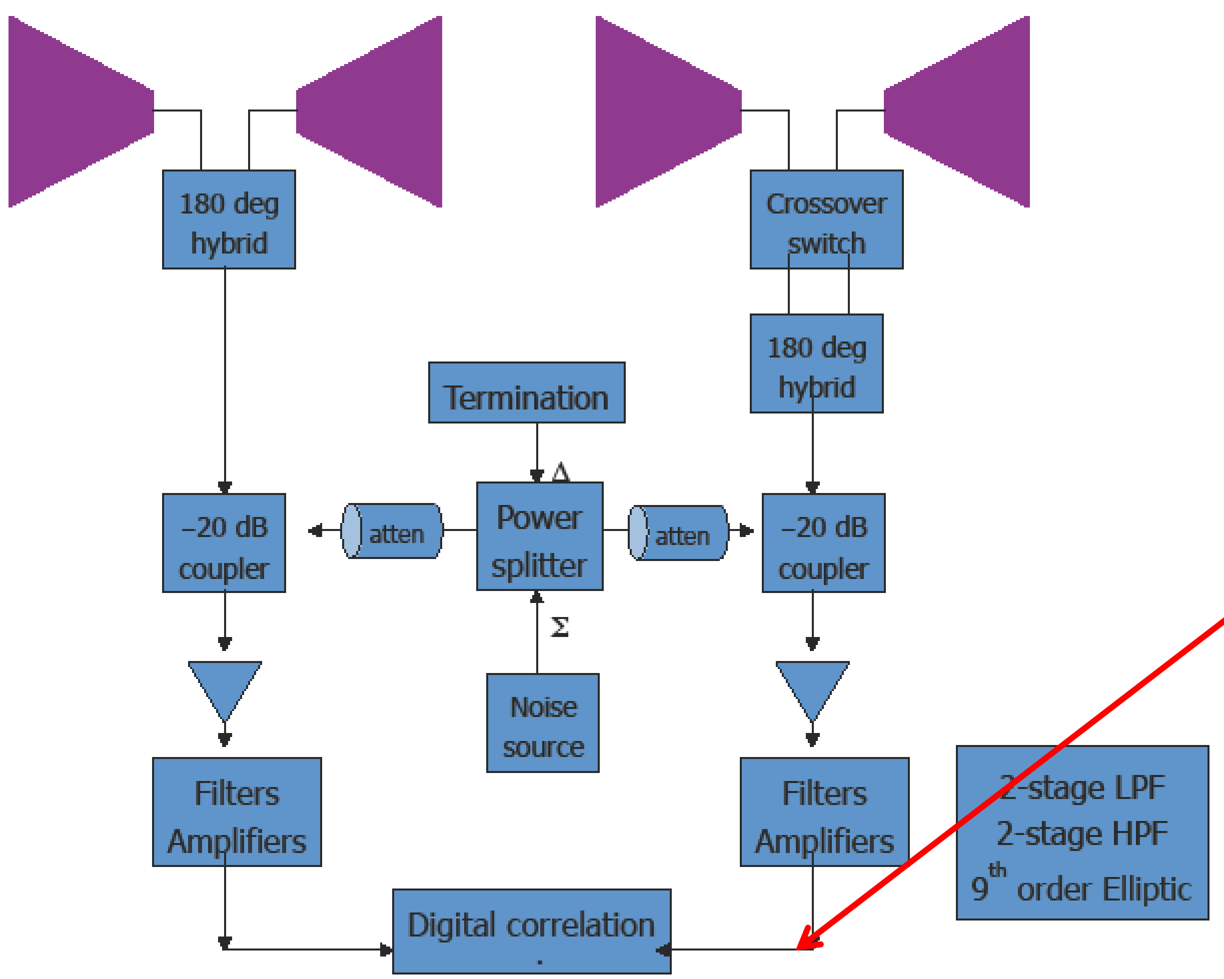
ZEBRA – interferometer first CMB correlation 20 Jan 2011



- 1.5m separation
- Max sky coverage at zero spacing 26%
- Contributions to correlated output
  - Global sky signal
  - Screen radiating
  - 1.5m interferometer sky correlation
    - One path through screen
    - Both paths miss screen

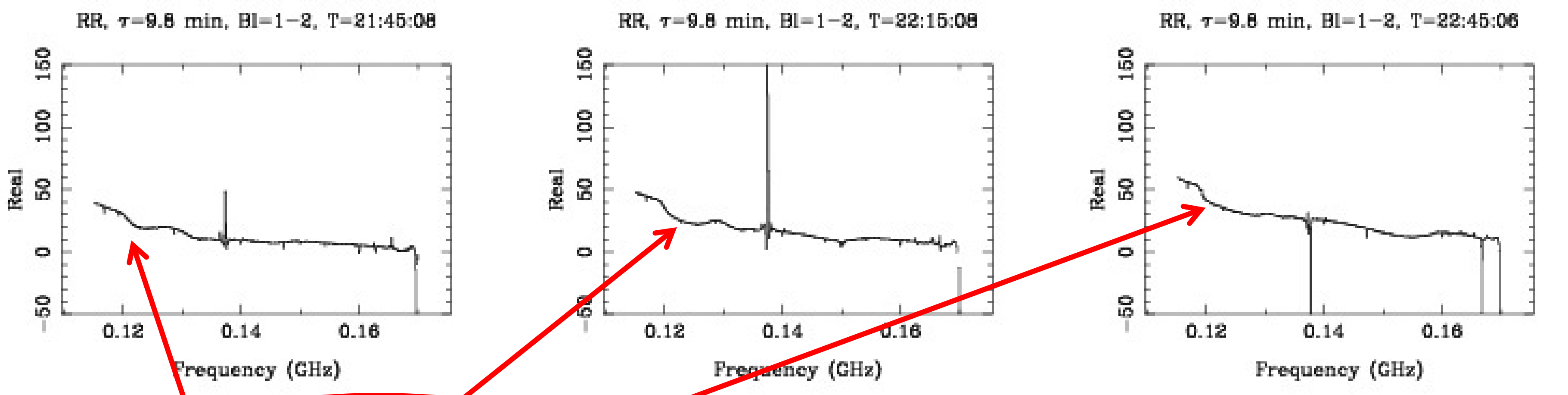
ZEBRA at Gauribidanur

ZEBRA receiver schematic



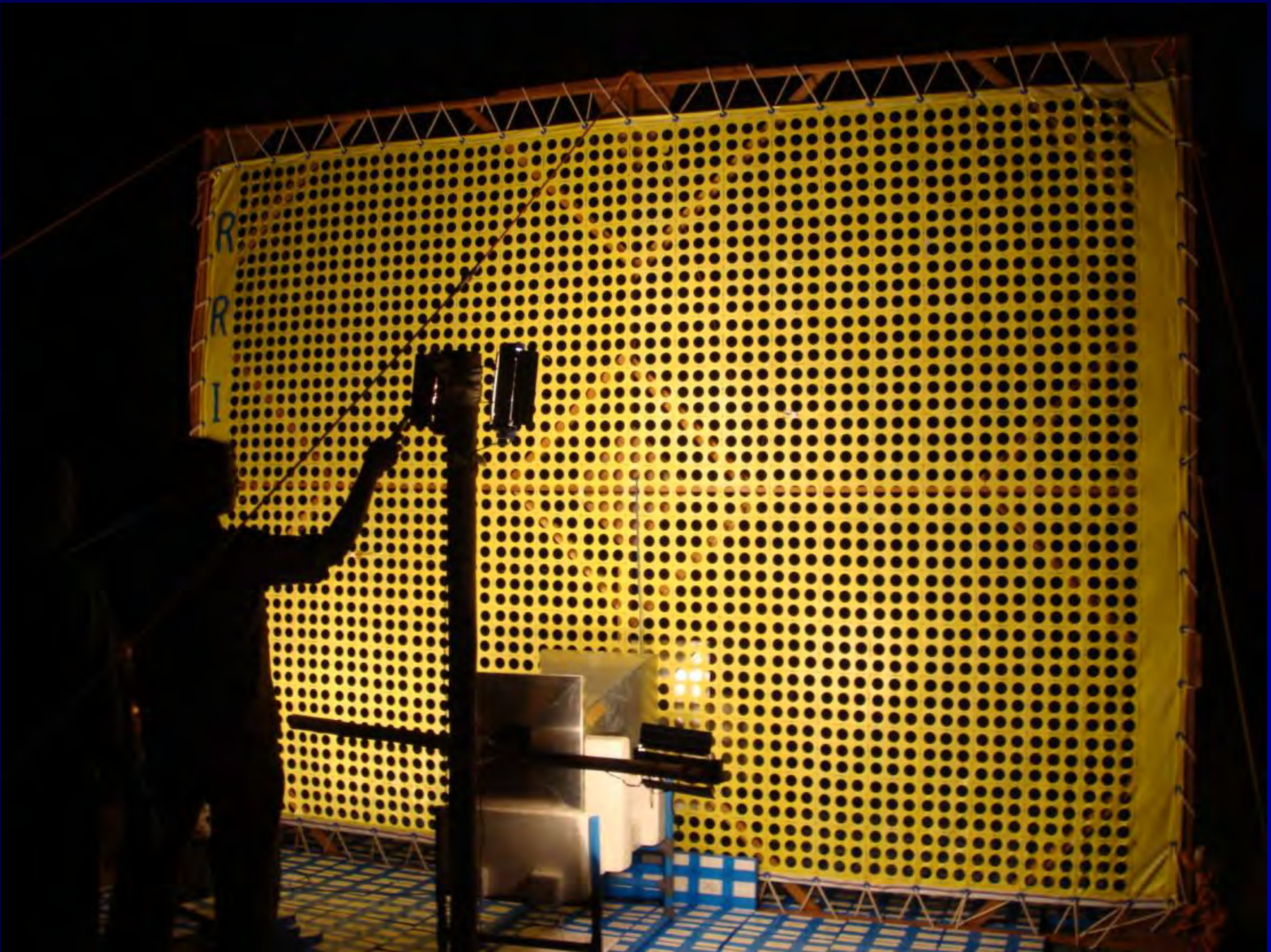
- Raghunathan
- Fat dipole
  - 87.5-175MHz
- Correlator
  - 2x ACR's
  - 1x XCR,
  - 12bit, 250MHz
- Correlator 100m away
  - Replace coax by fibre

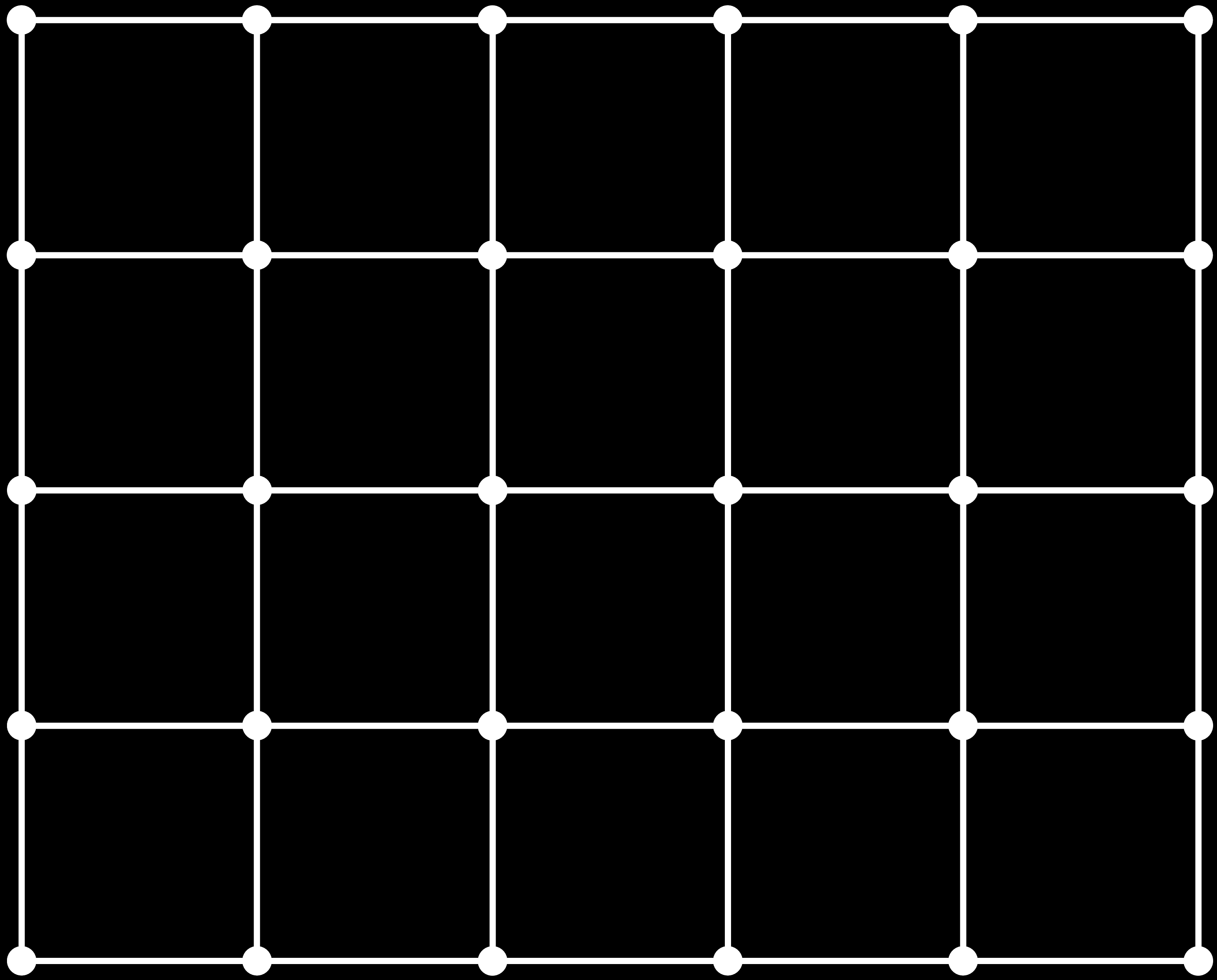
Zebra correlated output

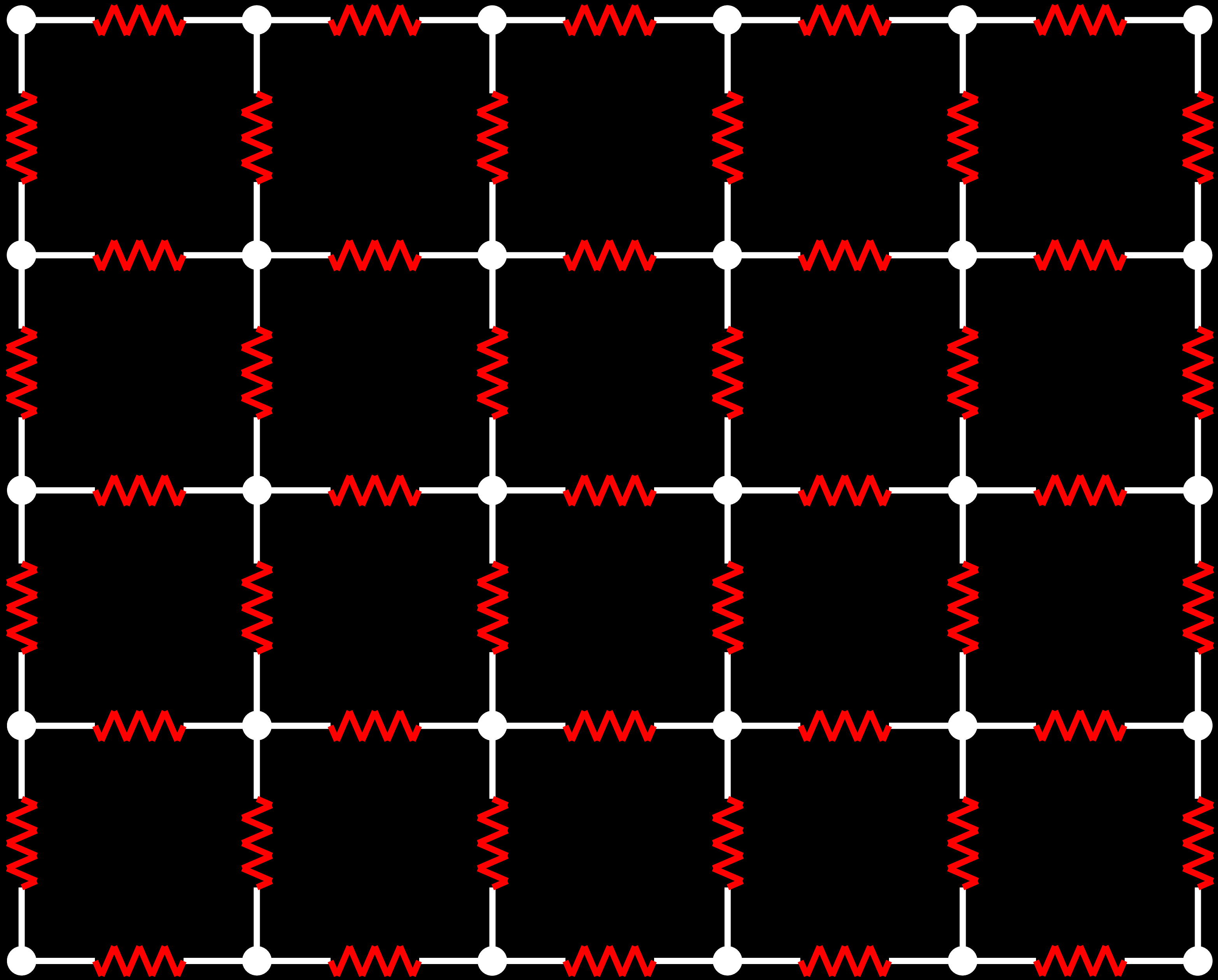


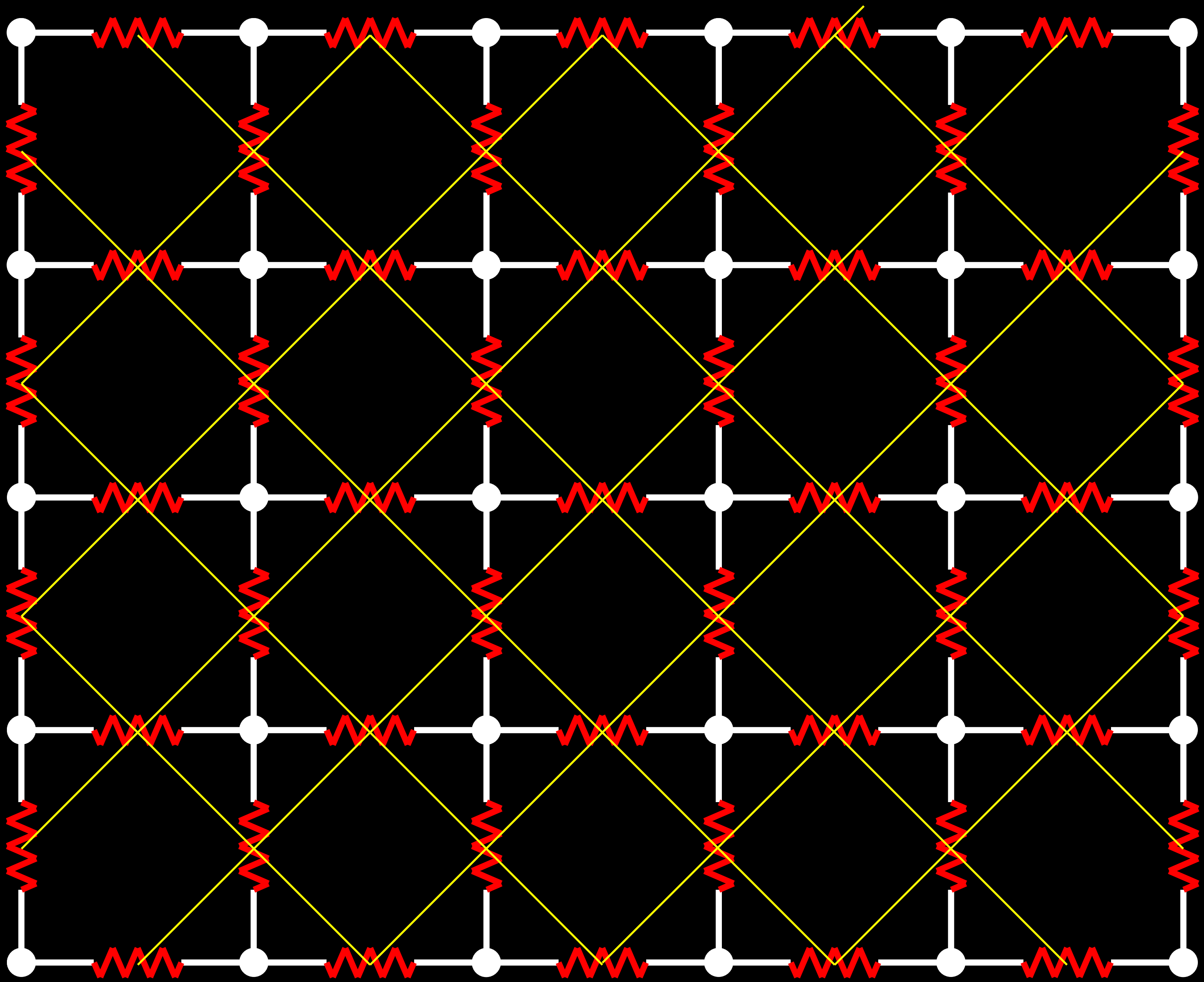
- Baseline ripple
  - changes with LST
  - Repeats each day
  - Multipath scattering of galaxy foreground signal
  - Shifted location …….

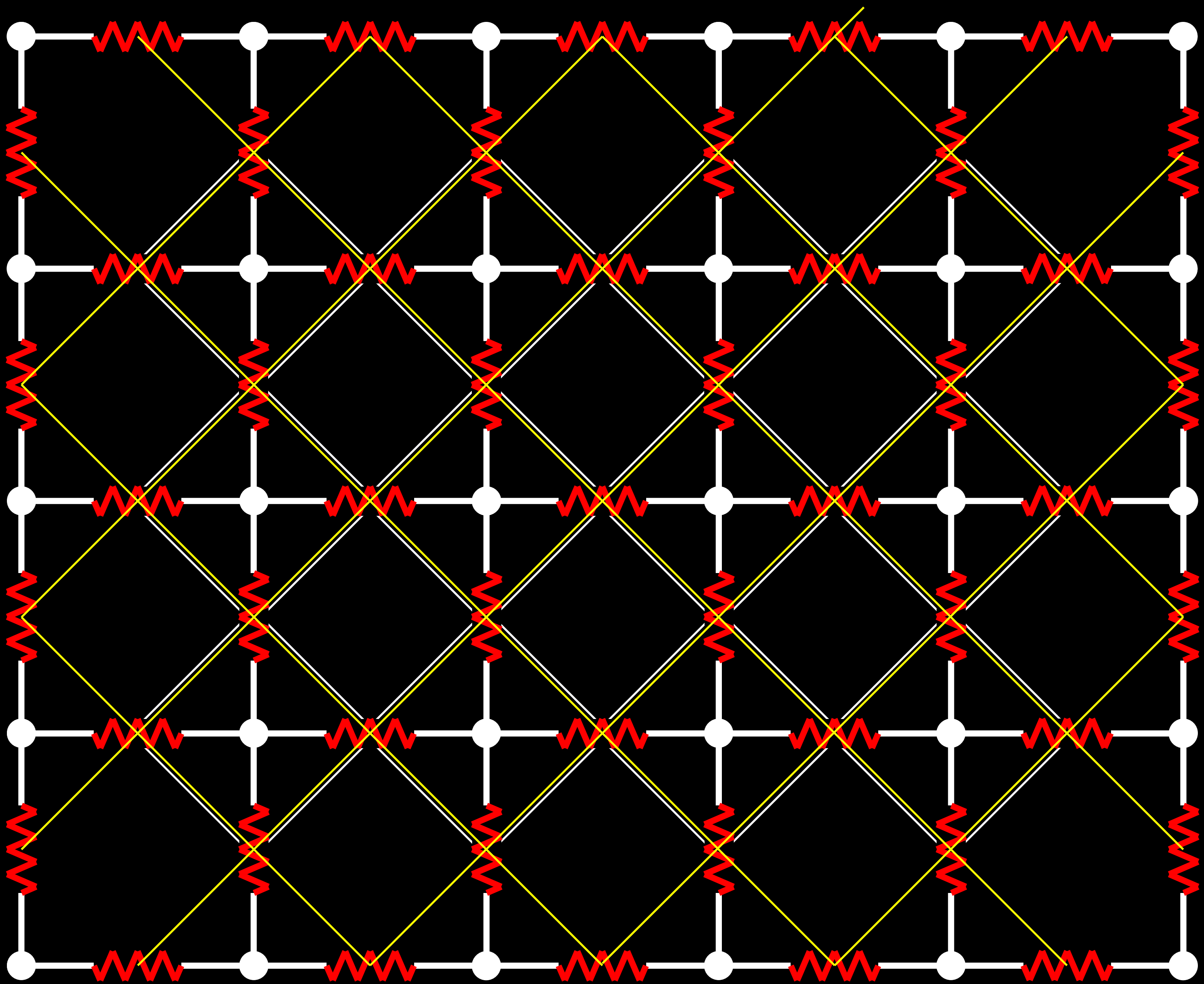
Try heating the screen

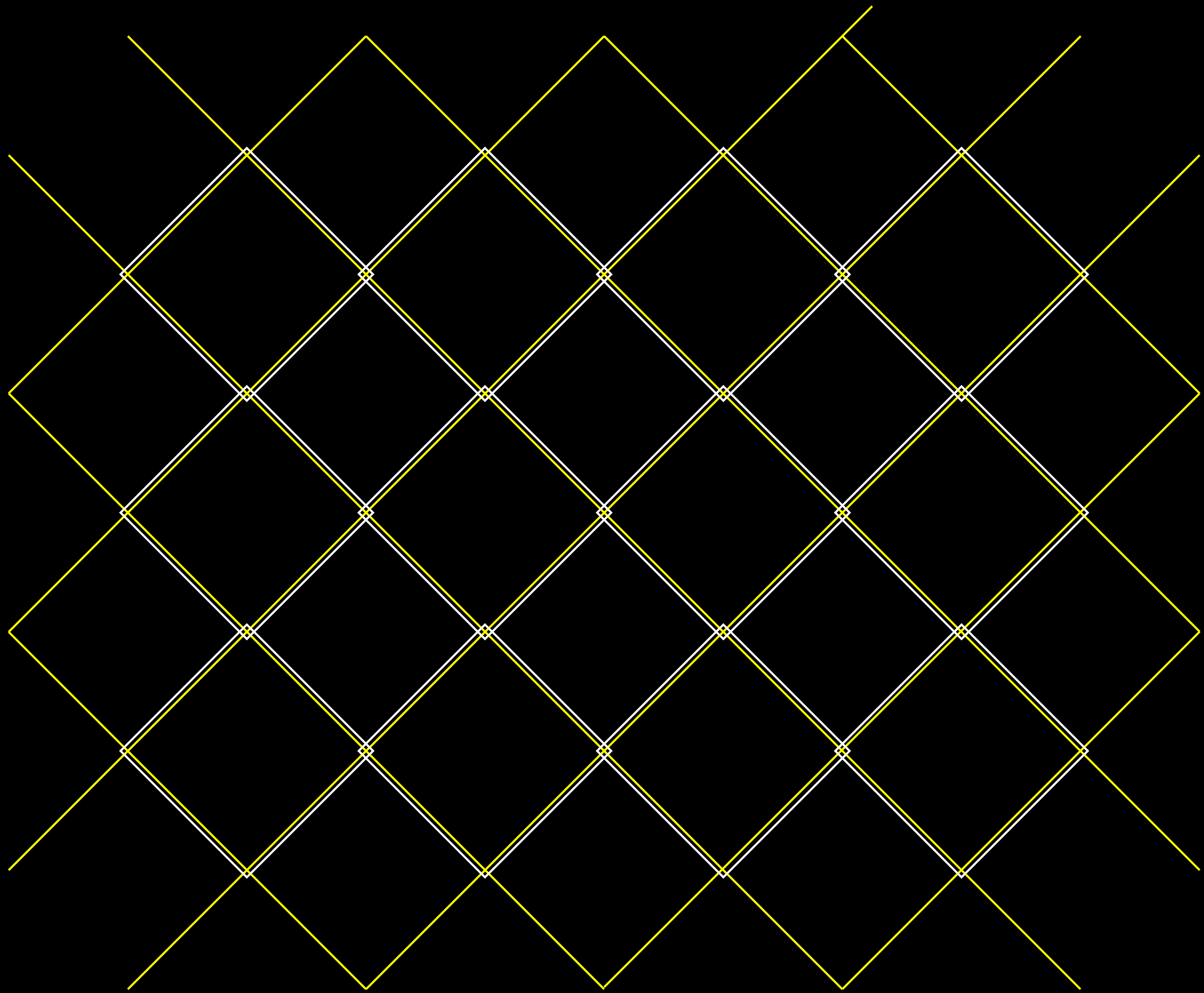




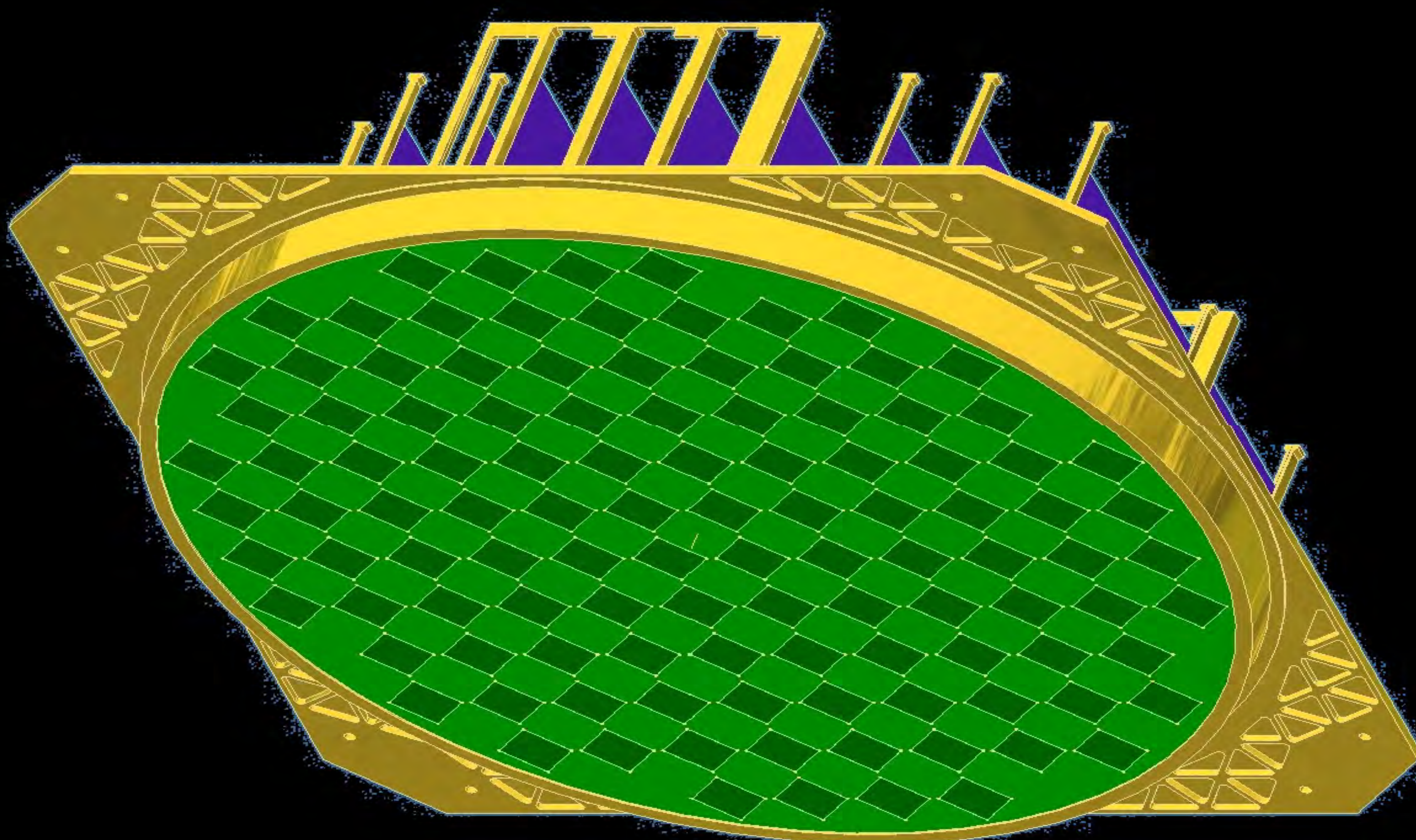




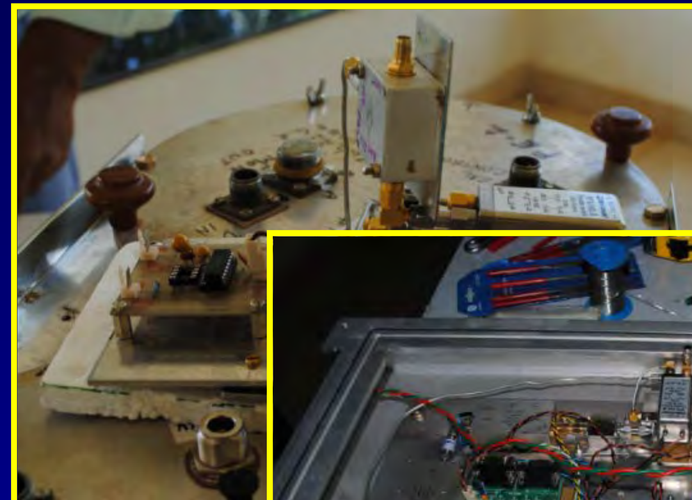


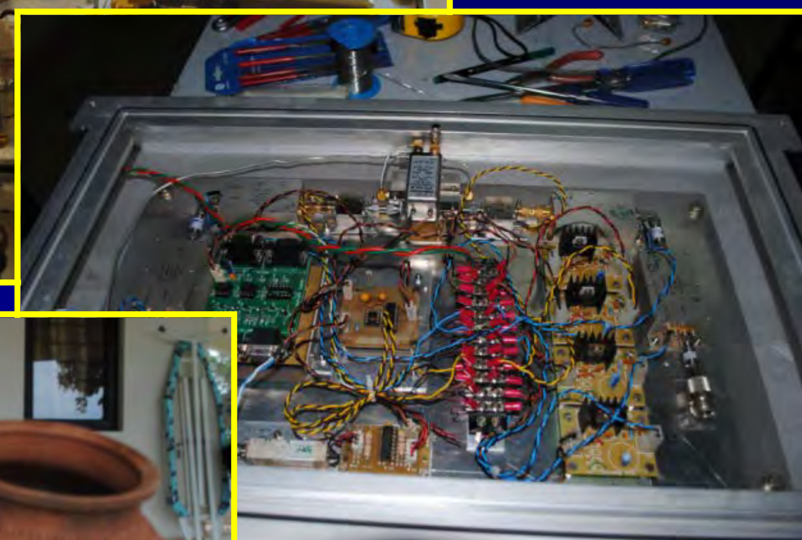


ASKAP Phased Array Feed



SARAS receiver evolution

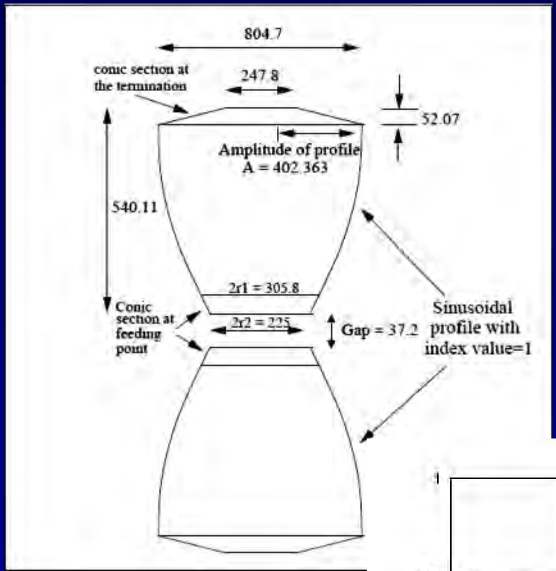


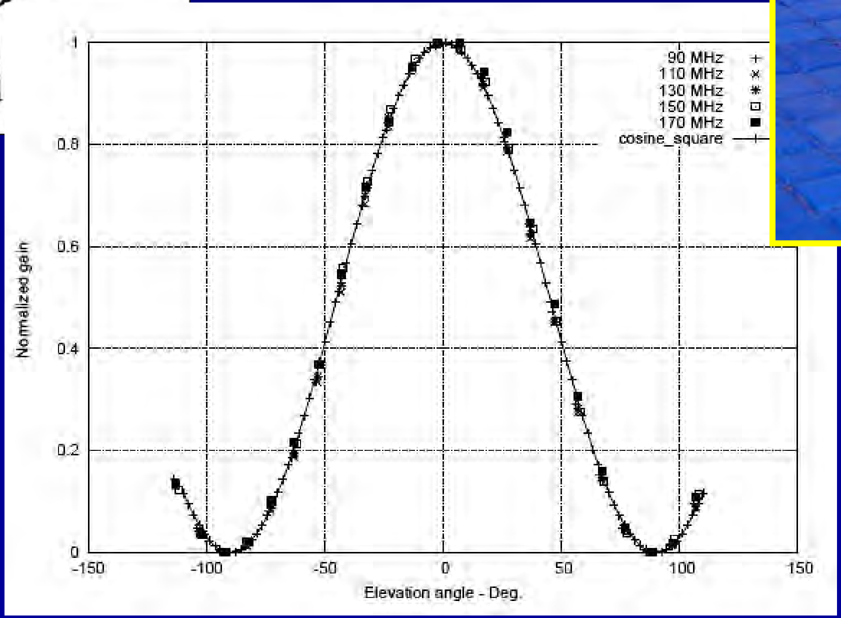


Antenna Requirements for EoR measurements

- Half-power beamwidth variation < ±2.5%
  - For a frequency range 87.5 to 175 MHz
  - Keeps un-modeled foreground residuals < 5mK
- An electrically small antenna
  - No spurious high order frequency components
- Return loss > 10dB and constant over band
  - antenna gain losses and internal reflections of the receiver noise must be low and vary smoothly with frequency.

Fat Dipole Antenna Prototype II





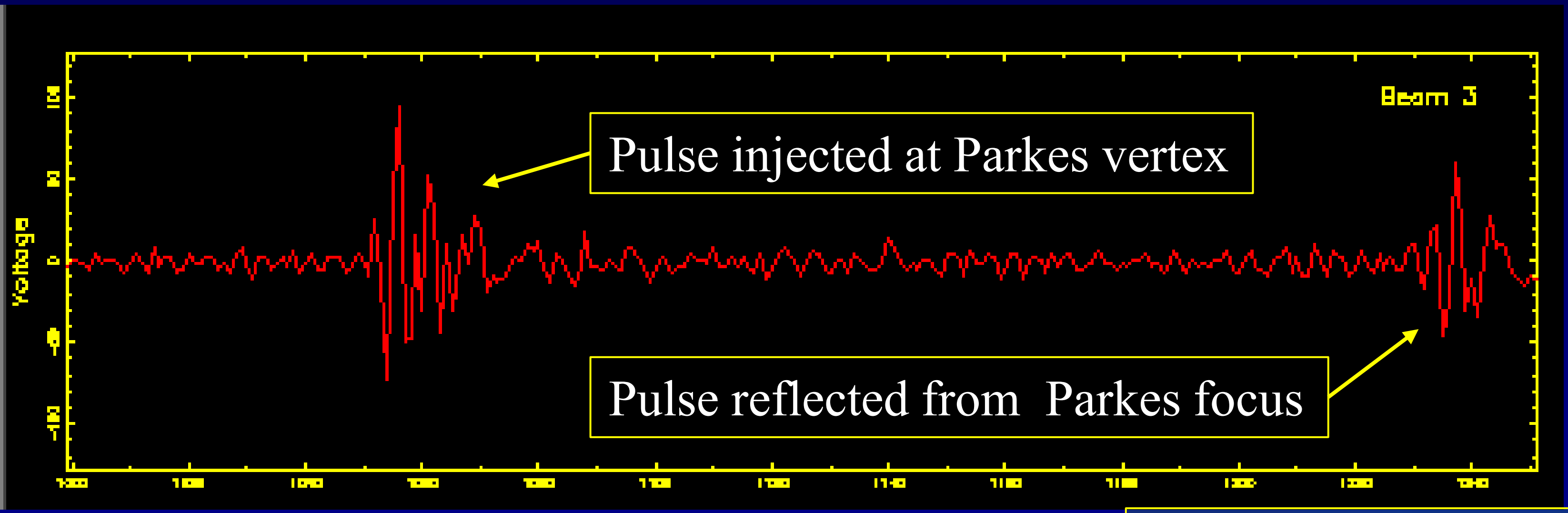
Fat Dipole Antenna

- A. Raghunathan, Udaya Shankar, Ravi Subrahmanyan
  - *submitted to IEEE AP*
- A wide-band fat-dipole antenna
  - sinusoidal profile
  - frequency independent performance 87.5 to 175 MHz
- Structure optimized using electromagnetic modelling
  - Adopt a sinusoidal profile
- Design validated by constructing a prototype
  - The input return loss > 15 dB
  - Radiation power pattern is a frequency invariant (< 2.1%) cosine square over the octave bandwidth
- Now used in SARAS by Nipanjana Patra

RRI gets some interesting visitors!

- Composition by Ravi
- Snake photo by Nipanjana

Pulse calibration ?



- Inject and integrate short (ηsec) pulses
- Calibrated noise spectrum
- Understand & calibrate reflections
- Nipanjana Patra, Paul Roberts