Antenna tile: dipoles/groundscreen & analog beamformer

Brian Corey, presenter

Function

- Swallow 80-300 MHz extraterrestrial photons
  - from as much of the sky as possible
  - but not from the horizon or below
  - with as little added noise as possible
  - in both polarizations
- Electronically form a single beam anywhere on the sky from the outputs of multiple, closely packed antenna elements

Specs implied by science requirements

Tunable frequency range	80-300 MHz
Instantaneous frequency range	≥ 32 MHz
Collecting area	≥ 10 m^2 over as much of frequency range as possible
Field of view	As wide as possible (within constraints of collecting area & physics)
Polarization	Dual

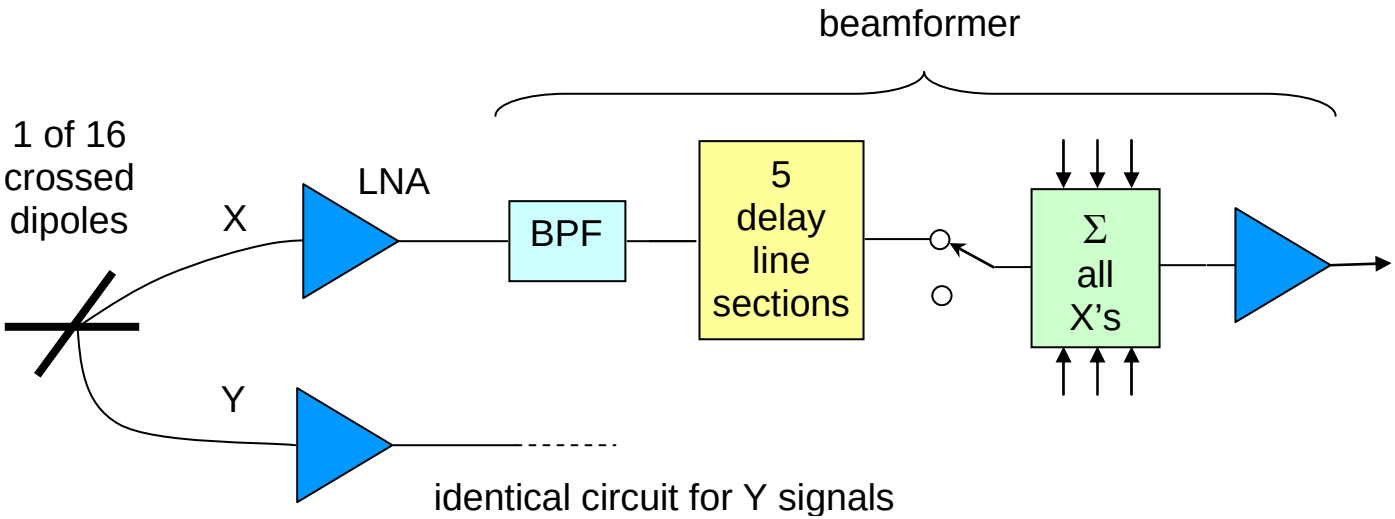
Key design features

- 16 dual-polarization, bowtie antenna elements over a ground screen
- Elements arranged in compact planar array with $\lambda/2$ spacing at 140 MHz
- Low-noise amplification integral to each element
- Analog RF beamformer with PCB tapped delay lines

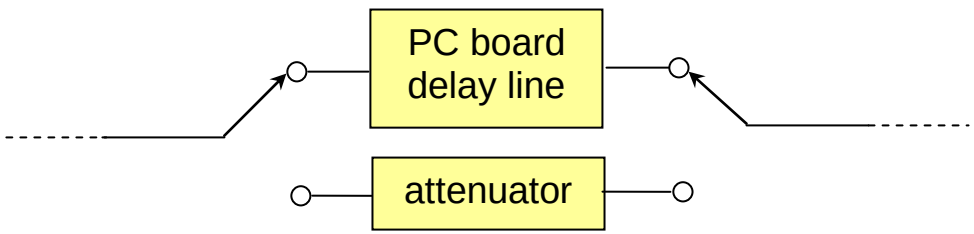
Current status of design effort

- Three prototype antenna tiles with beamformers deployed at MWA site during Early Deployment campaign in 2005
- Functionality and performance demonstrated in ED
- Prototype antenna elements, beamformer, and ground screen are too expensive to replicate in large volume

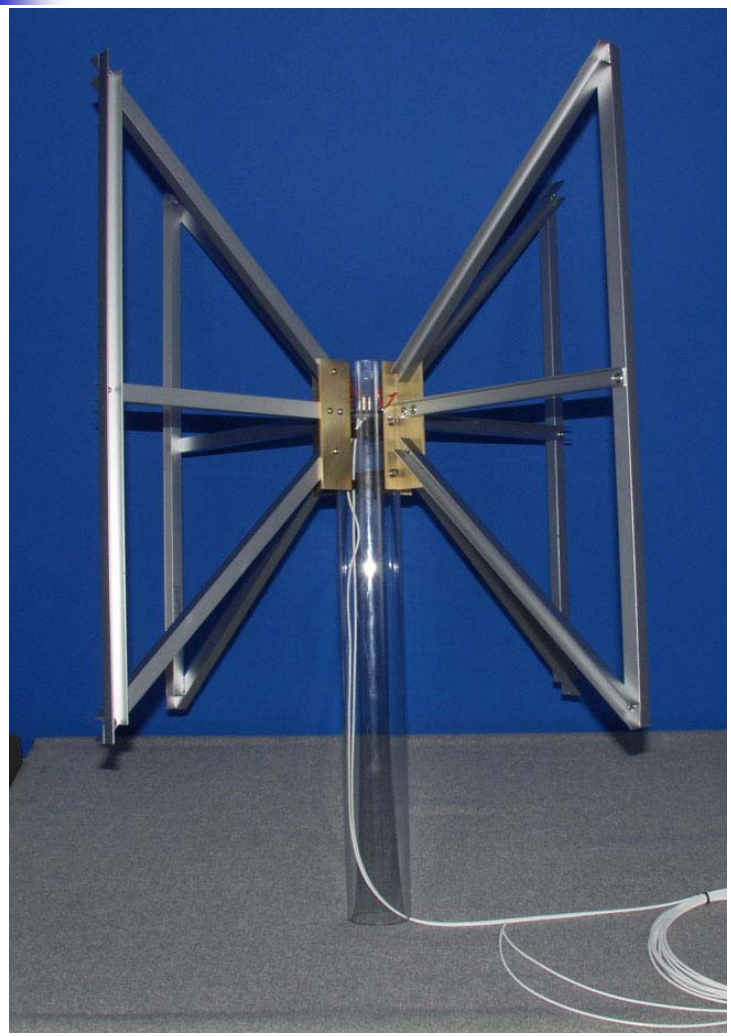
Block diagram of antenna system

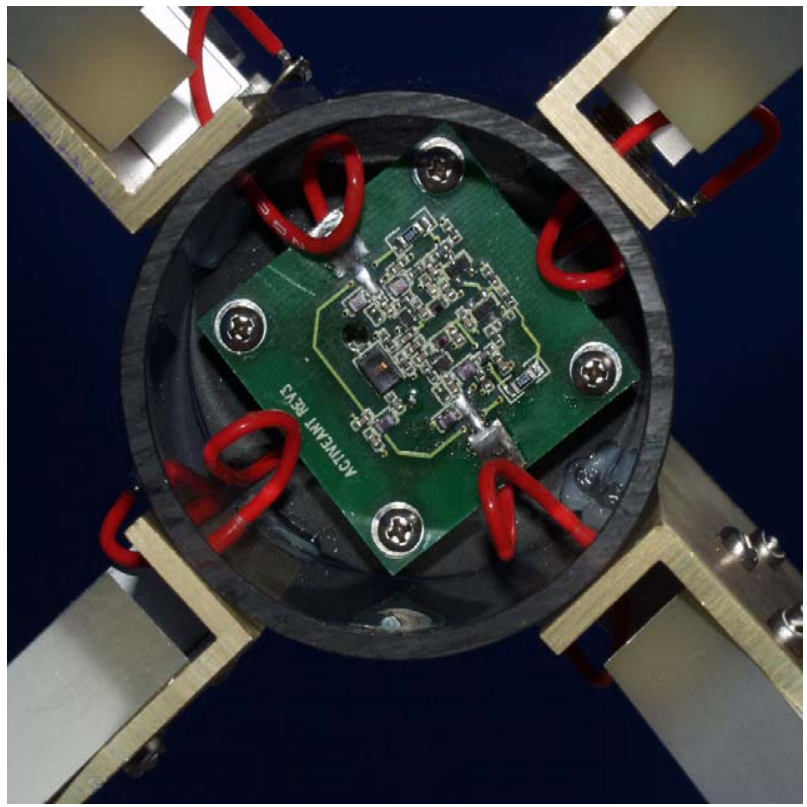


One section of 5 sections of switchable delay line –
lengths differ by factors of 2



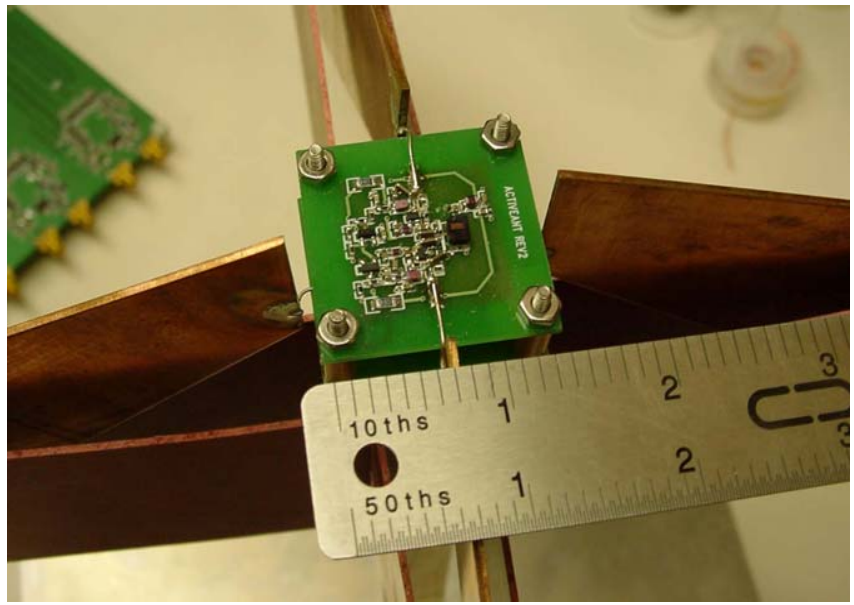
Prototype antenna element – Seavey Eng.



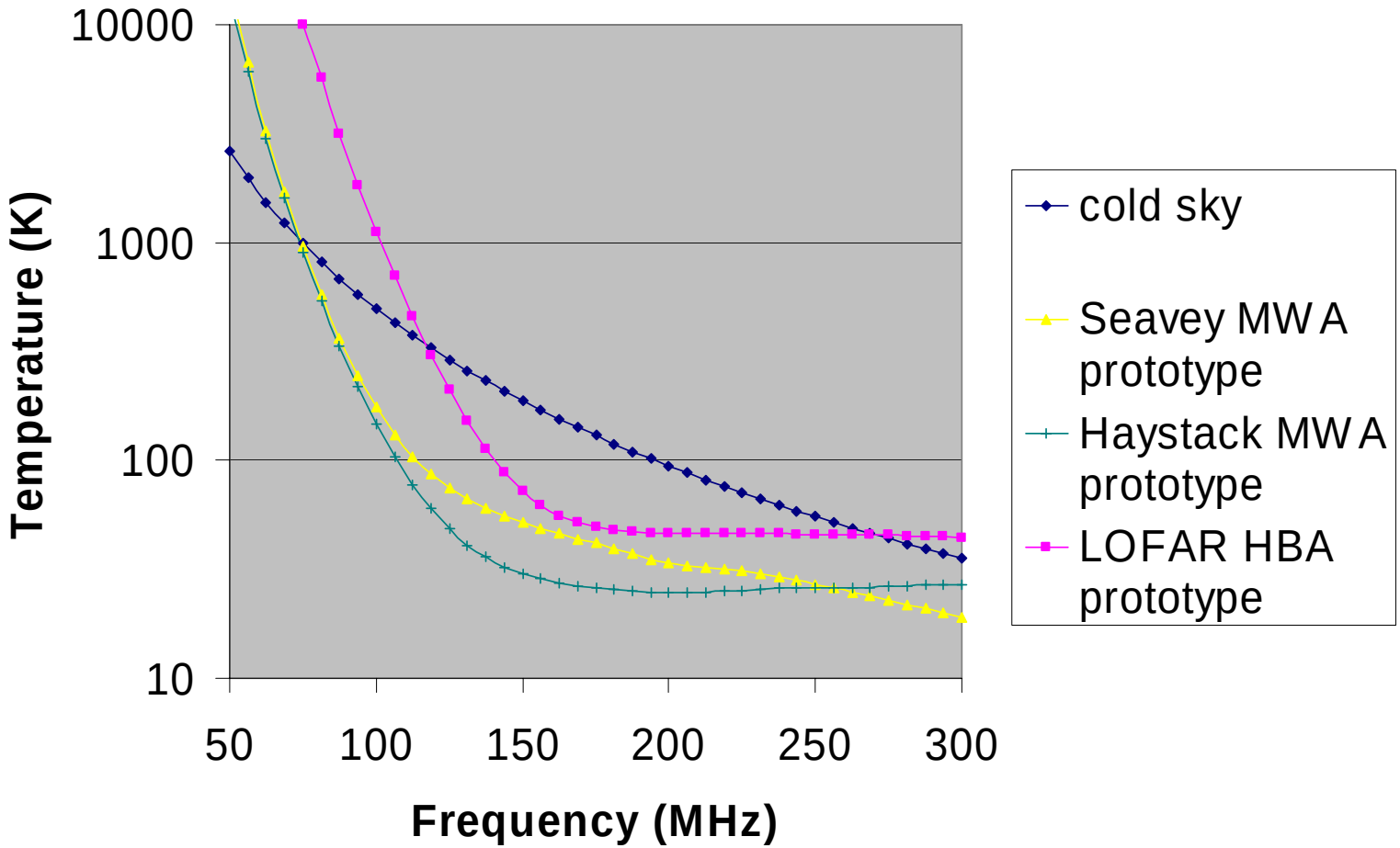


Low-noise amplifier

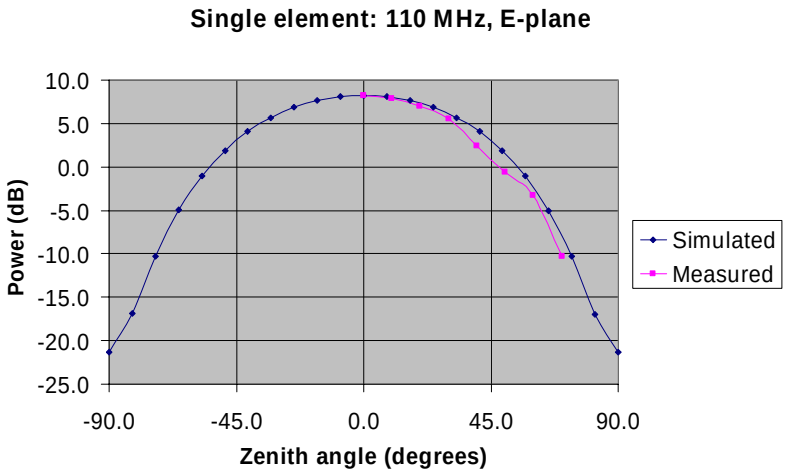
- Balanced design using two ATF-54143 HEMTs
- Measured noise temperature 14-17 K with 50 ohm loads on inputs, in agreement with simulation
- Measured OIP2 > +63 dBm, OIP3 = +27 dBm
- With LNA connected to prototype element, simulated noise temperature < ½ x sky temperature

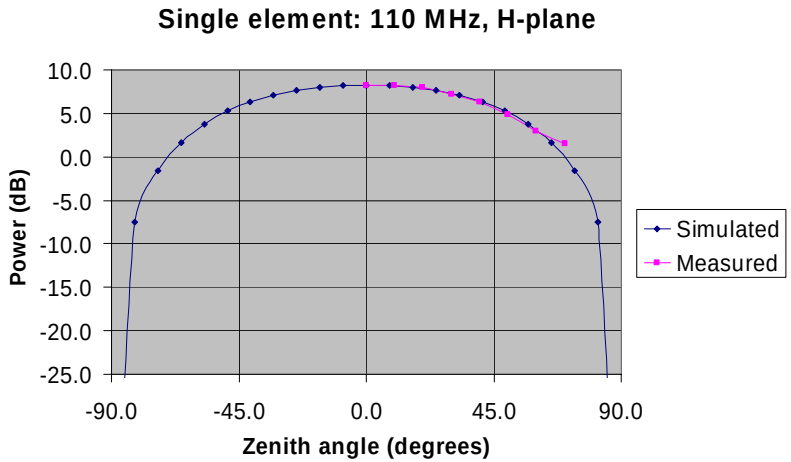


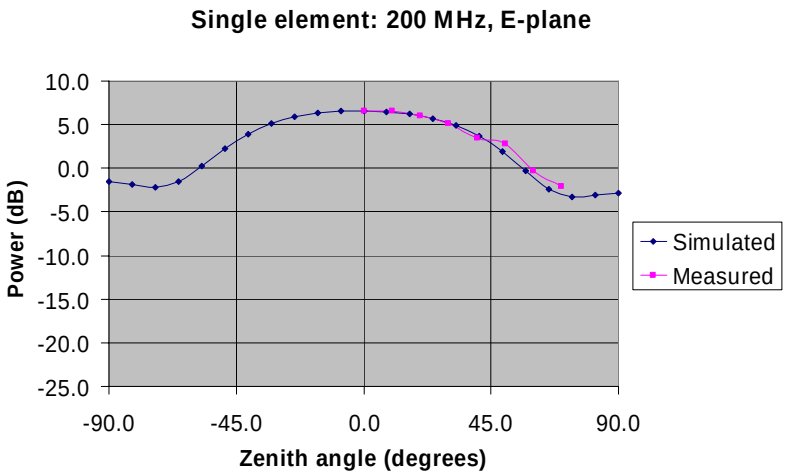
Simulated receiver noise temperature (antenna-LNA impedance mismatch included)

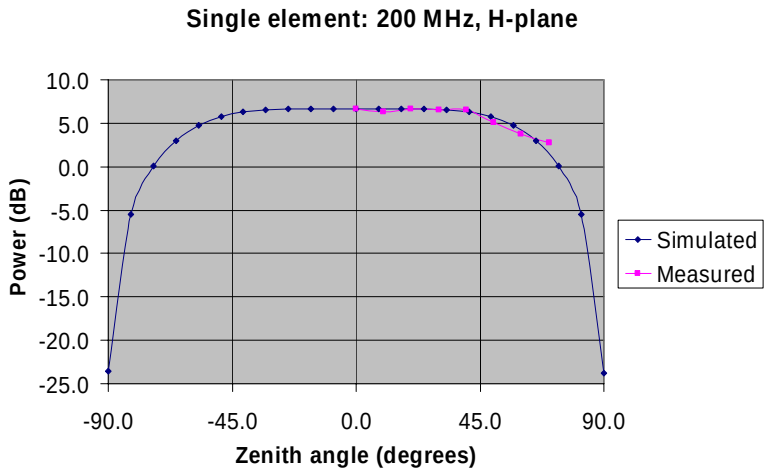


Single element power patterns

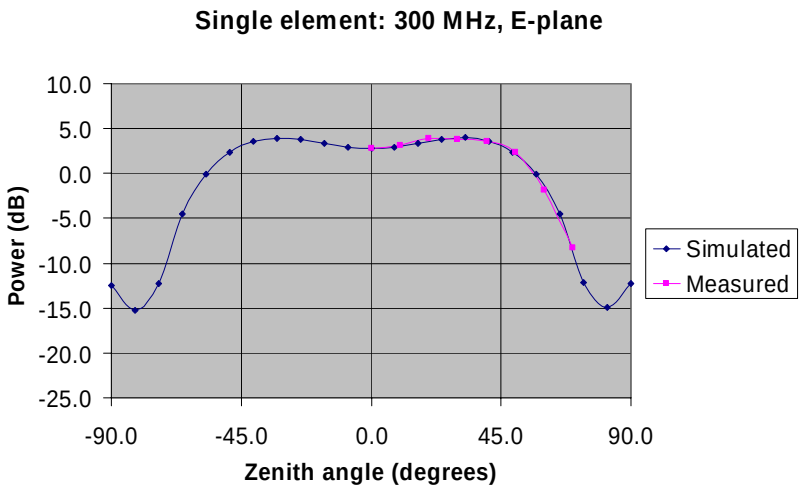


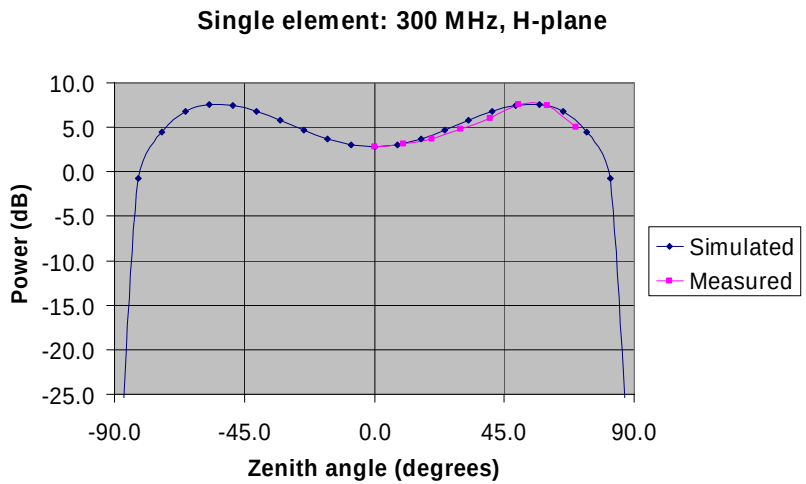






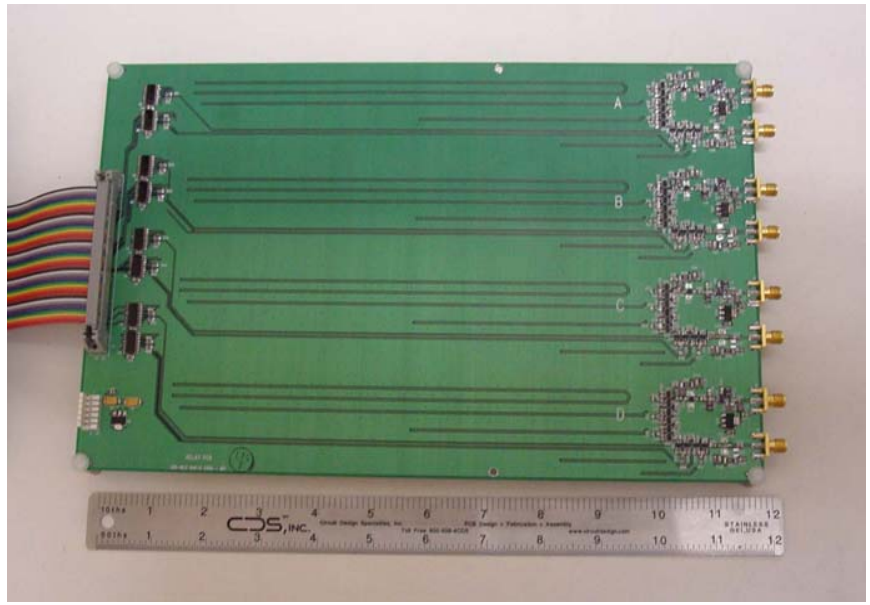
Single element power patterns (cont'd)





RF analog beamformer

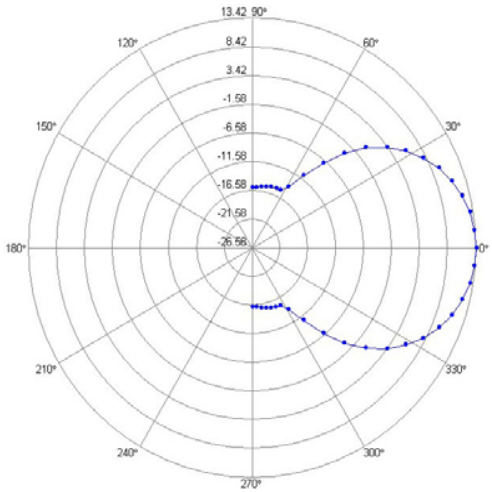
- 4-channel prototype board constructed using coplanar waveguide in 4-layer PCB with 10-ns max delay
- Isolation > 40 dB between channels and between switched lines within a channel
- Delay reproducible between channels to ~0.1 ns (1σ)
- Gain reproducible between channels to ~0.3 dB (1σ)
- Gain independent of delay selected to <1 dB

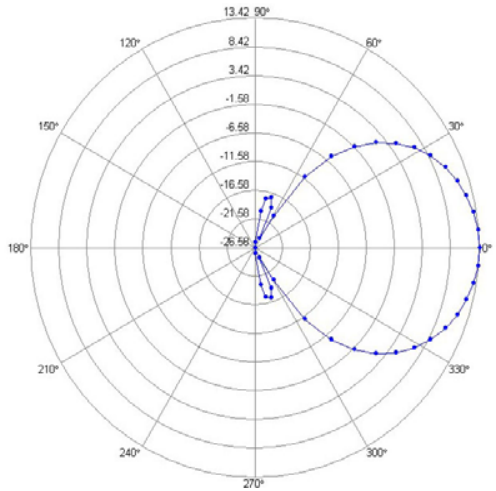


Simulated antenna tile patterns for beam steered to zenith

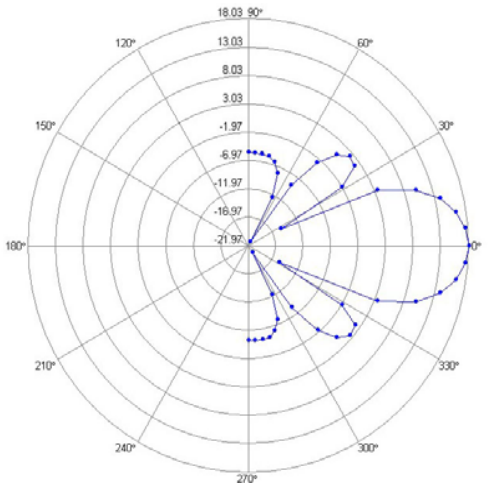
E plane **H plane**

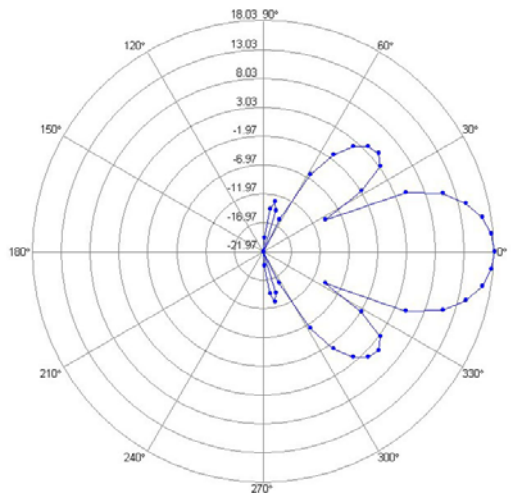
80 MHz





153 MHz

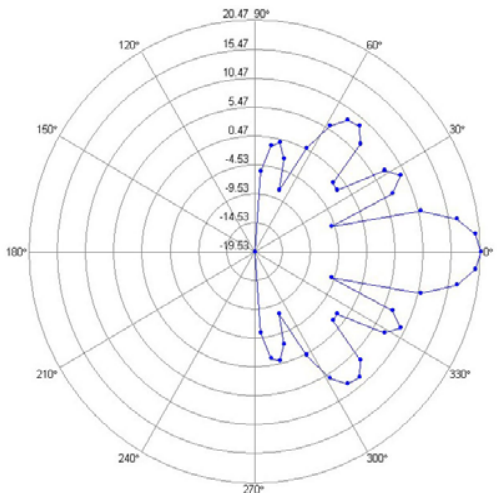


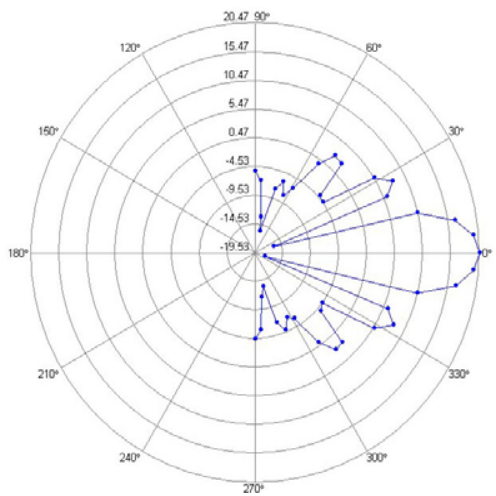


Simulated antenna tile patterns for beam steered to zenith (cont'd)

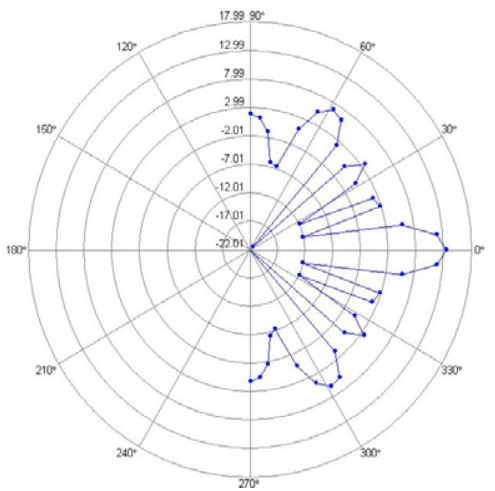
E plane **H plane**

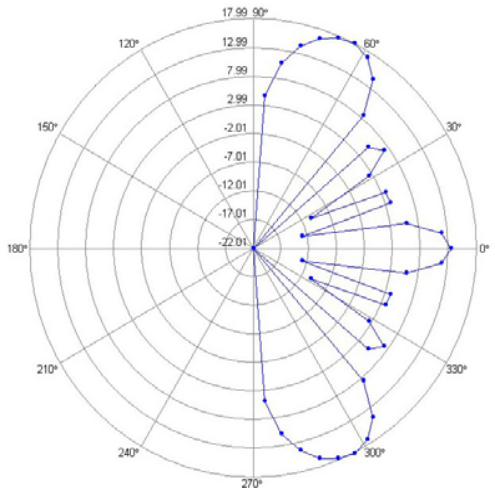
227 MHz





300 MHz





Challenges & risks – technical

- No major technical challenges foreseen
- Remaining technical issues:
  - Put 16 channels on a single beamformer board, together with 16-way signal combiner
  - Put both polarizations on a single LNA board (for cost reasons)?
  - Redesign digital interface?

Challenges & risks – cost

- Cost reduction is a major challenge – we can't afford to do **this** 500 x 16 times!

- Cost target, including installation, is 2K $US per tile.
- Greatest challenge is to reduce cost of antennas (exclusive of LNAs) and groundscreen to ~700 $US.
- Antenna/groundscreen redesign for manufacturability has been initiated with RDI Inc.

Challenges & risks – schedule

- Design at the CDR level needs to be completed by ~December 2006.
- Pacing item will most likely be redesign for cost reduction.

Skills required

- RF engineering for LNA & beamformer
- RF simulation for antenna modifications (as needed to reduce cost)
- Digital engineering for digital interface
- Mechanical design/engineering for manufacturing

Dependencies on other systems

- Monitor/control
- Receiver

Interface definitions

- Input: sky
- Output: 2 coax cables per tile to receiver
  - Need gain equalization and level adjustment at receiver input
- Monitor/control
  - Set delay line switches and on/off switch for each polarization of each antenna element
  - Set 180° phase shift for each polarization?
  - Read beamformer temperature?