Antennas and beamformers -- Brian Corey

What's new?

- Beamformer-receiver hardware interface
- DOC
- Beamformer feedback
- Beamformer RFI
- Tile collecting area / Tsys ratio from rms visibilities
- Results from reanalyzed drift scan data
- Beamformer 2nd-stage noise
- Beamformer transients

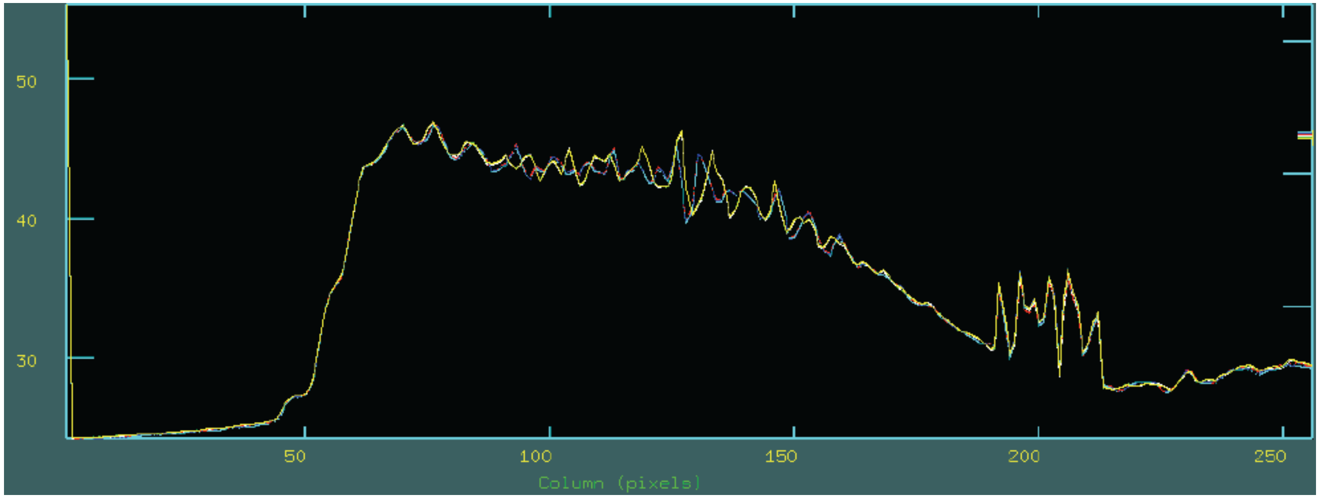
Beamformer-receiver hardware interface

- Signals to be passed between beamformer and receiver:
  - Two 80-300 MHz RF signals
  - Six digital signals:
    - Clock and data (switch settings) to beamformer
    - Clock and data (temperature) to receiver
    - Walsh signals to beamformer
  - 48 vdc to beamformer
- Original interface:
  - Two RG-6 coax cables for RF
  - Six twisted pairs for digital
  - Two 18awg wires for DC power
- New "data over coax" (DOC) interface:
  - Two RG-6 coax cables for everything
  - Band-limited pulses transmit clock, data, and Walsh signals

Data over coax interface

- Advantages of DOC:
  - Lower cost for cabling
  - Lower RFI and feedback levels
- Disadvantages of DOC:
  - Increased digital circuit complexity in beamformer and receiver
- Prototype DOC requires additions to beamformer and receiver, but not hardware modifications to exisiting circuits
- DOC has been successfully tested in lab over long coax cable runs
  - except for Walsh circuit, which has not been tested

Beamformer feedback



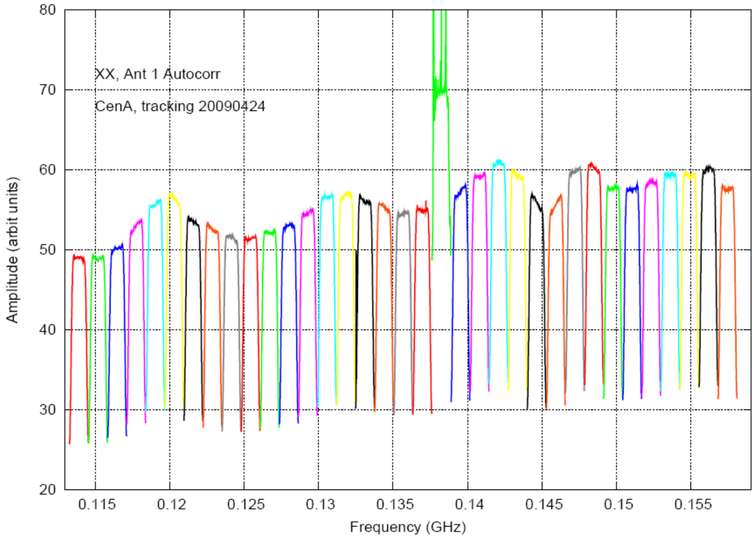
- "Ripple" noticed in X4 beamformer spectra
- Stronger ripple for "high-gain" beamformers
- Source hypothesized to be RF leakage from the beamformer feeding back into the antennas

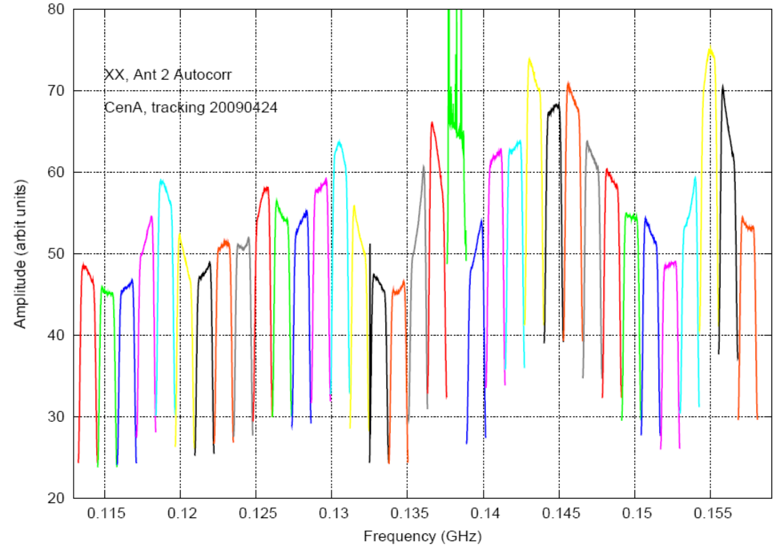
Beamformer feedback tests

- Lab tests with a test signal injected into a beamformer, a wideband antenna, and a spectrum analyzer on the antenna output
  - confirmed leakage at about the right level to explain the X4 spectra,
  - found significant RF leakage from
    - SMA connectors
    - unshielded power/digital (non-DOC) cable
    - single-shielded (not quad-shield, as in 32T) RG-6 coax.
- Grounding the SMAs and converting the beamformer to a DOC interface decreased the feedback by ~27 dB (with quad-shield RG-6).
- Feedback scales with beamformer gain.
- Painted rain shield increases feedback by ~10 dB.
- Field tests with grounded SMAs showed lower feedback levels in some cases, not in others.
- Need field tests with scrubbed rain shields and DOC circuits.

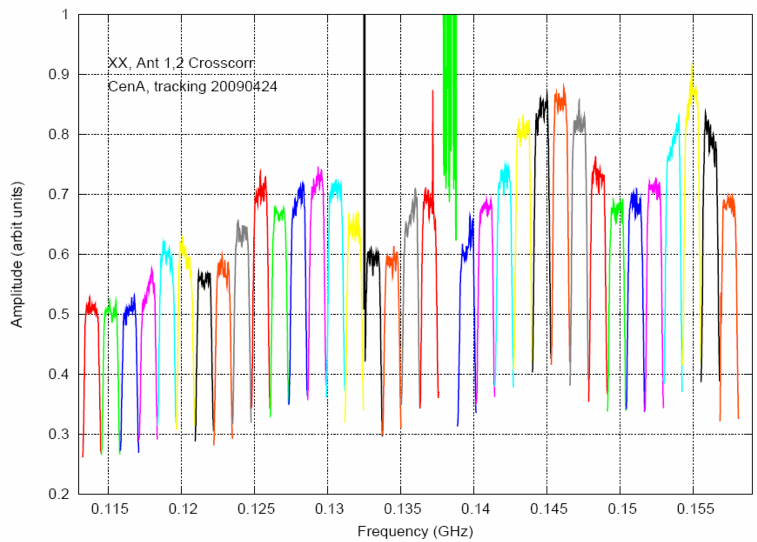
Feedback evident in cross-correlation?   Yes!

Autos:





Cross:



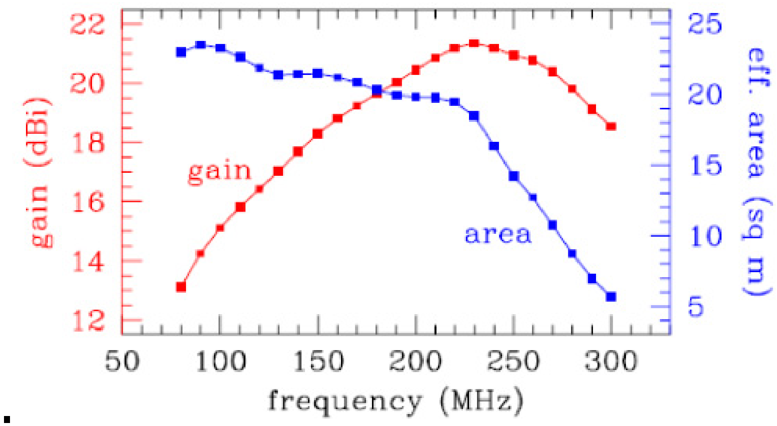
See Divya's "Investigating Beamformer Feedback" presentation for more info.

RFI from beamformer

- Digital circuitry running at ~100 kHz in beamformer emits RFI.
  - Duty cycle in normal operations is ~0.001%.
- With M/C operating at 100% duty cycle, power measured 2 m away with an isotropic antenna is:
  - -135 to -150 dBm/Hz over 80-300 MHz with original interface
  - < -166 dBm/Hz over 80-300 MHz with DOC interface
- EMC specs to which MWA equipment must adhere are framed in terms of MIL-STD-461F, category 102, which prescribe E-field measurements with specific types of antennas, chamber, and measurement equipment.
- With allowance for the 0.001% normal duty cycle, a DOC-equipped beamformer may meet the EMC spec.
  - But a beamformer with the original interface does not.
- Definitive measurements require a suitably equipped test chamber.
- Additional reduction in RFI can be achieved with RF gaskets, closer spacing between screws holding the cover, etc.

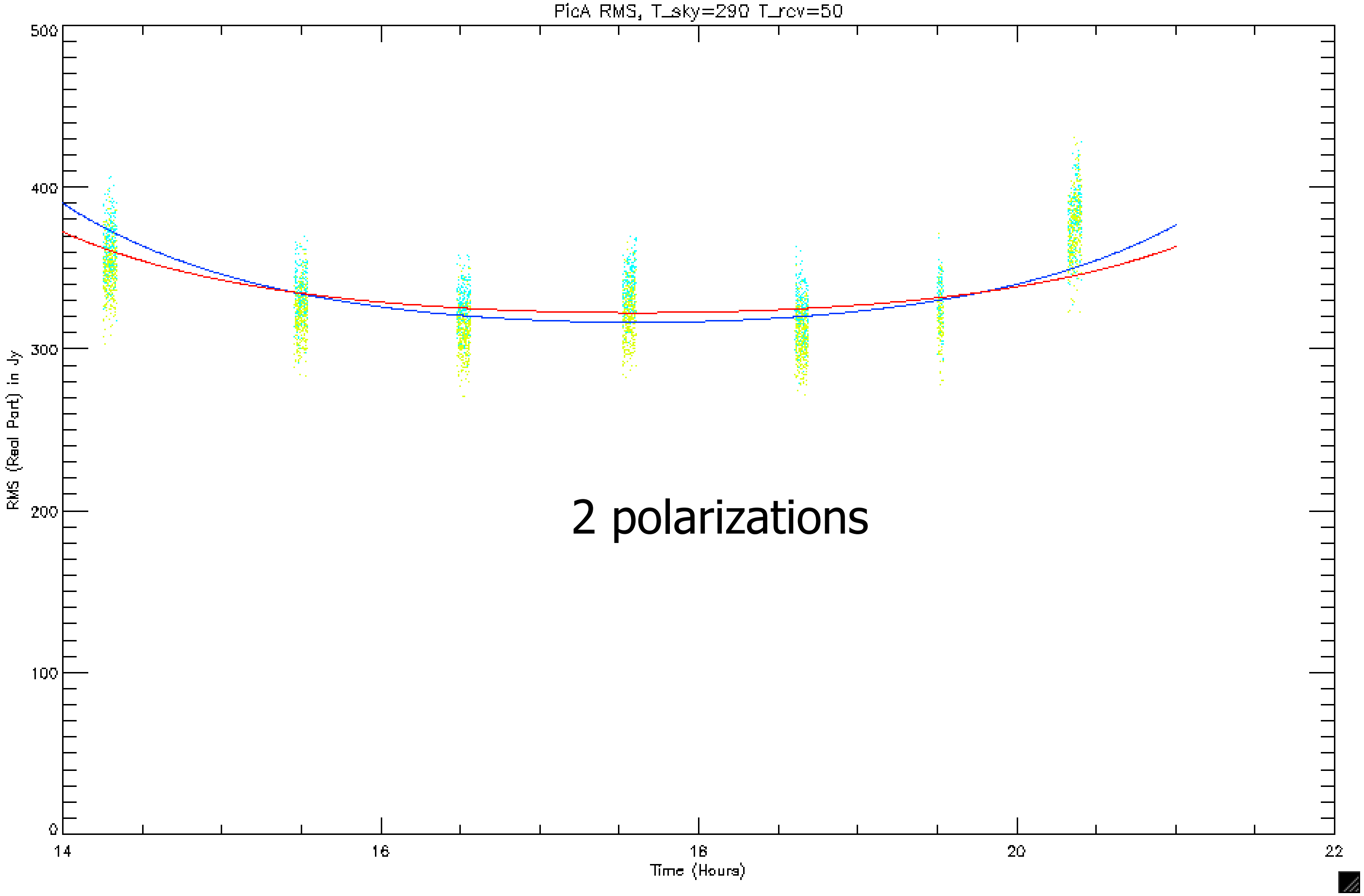
Collecting area / Tsys from rms visibilities

- Analysis steps:
  - Map source from interferometric data, scaling map to give correct flux.
  - Calculate rms visibilities.
  - Calculate area/Tsys from rms visibilities.
  - From assumed value of area, calculate Tsys, then subtract Tsky to get Treceiver.



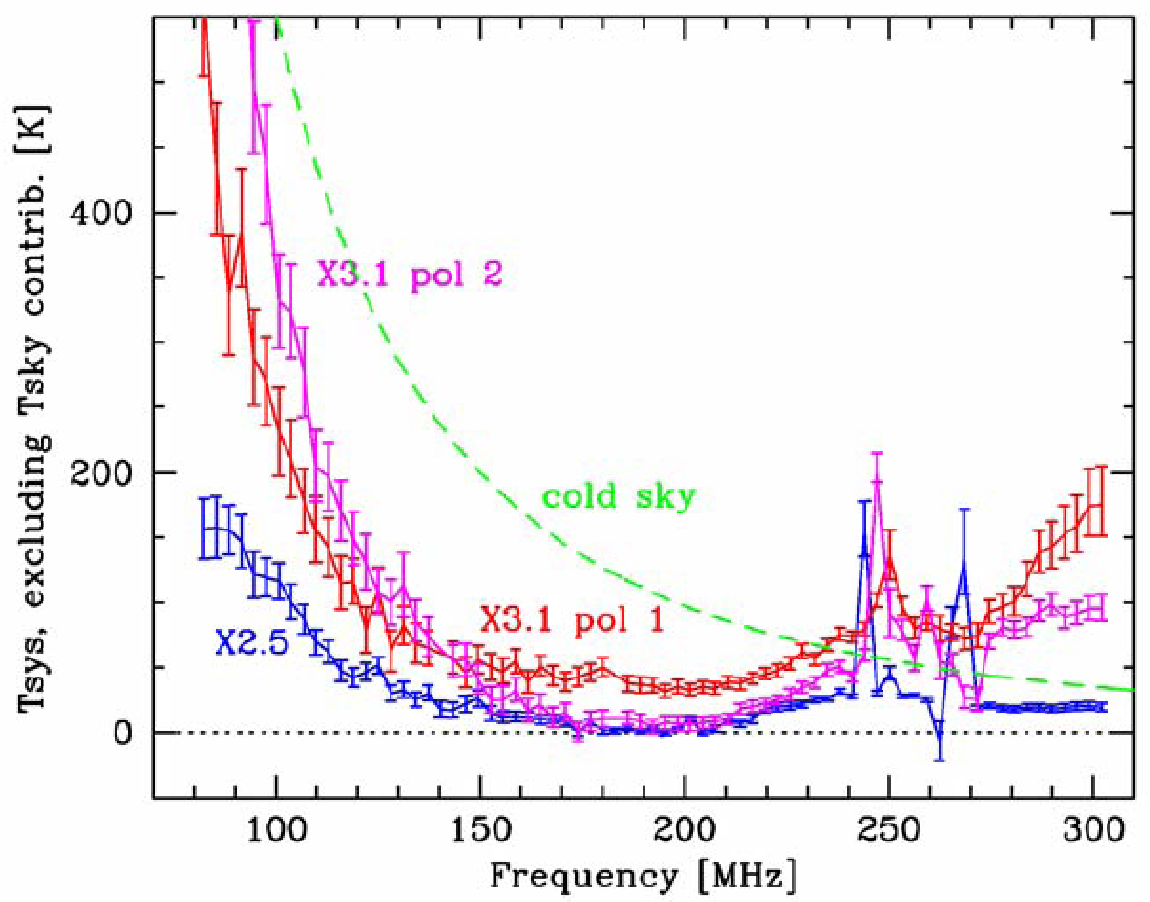
- Results from Chris W. for Pic A field at 159 MHz, mapped from X4 data:
  - For Tsky = 240 K, Treceiver = 82 K.
  - For joint fit, Tsky = 290 K and Treceiver = 50 K.
- Previous result from Randall W. and Judd B. for Hyd A at 110 MHz: Treceiver = 240 ± 80 K.

Fitting Tsky and Treceiver to Pic A rms visibilities



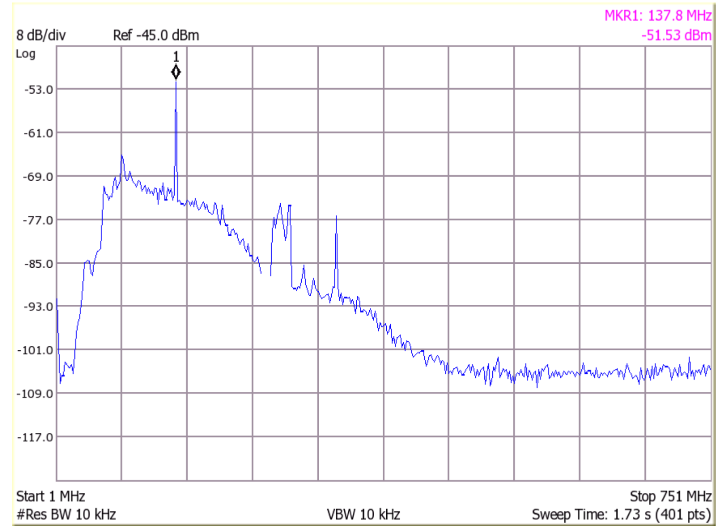
Treceiver from drift scans

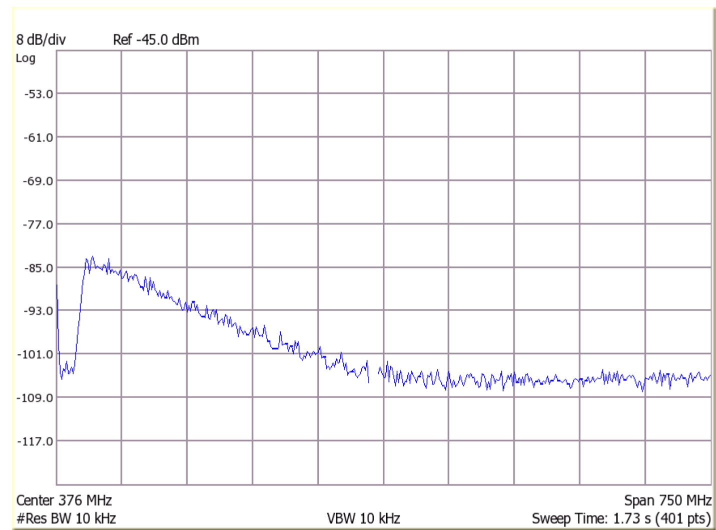
X2.5 (Acqiris backend) & X3.1 (MWA receiver in burst mode) drift scan data reanalyzed with full-tile EM-simulated tile patterns:



Beamformer 2nd-stage noise

- Compare spectra with 16 dipoles (top) and no dipoles (bottom) connected to beamformer.
- With no assumption about BF noise temperature, BF contributes ~5% to total noise, worst case.
- For BF noise temperature of 180 K (measured value), BF contributes ~2% to total noise, worst case.
- With old PFB, spectra measured in burst mode through receiver have noise floor comparable to power level at 300 MHz.





Beamformer transients on start-up

- Beamformer needs to receive a proper pointing command in order to set latches for delay switches. Absent such a command, the spectra immediately after power-on may look like this…..