First broadband results with a VLBI2010 system

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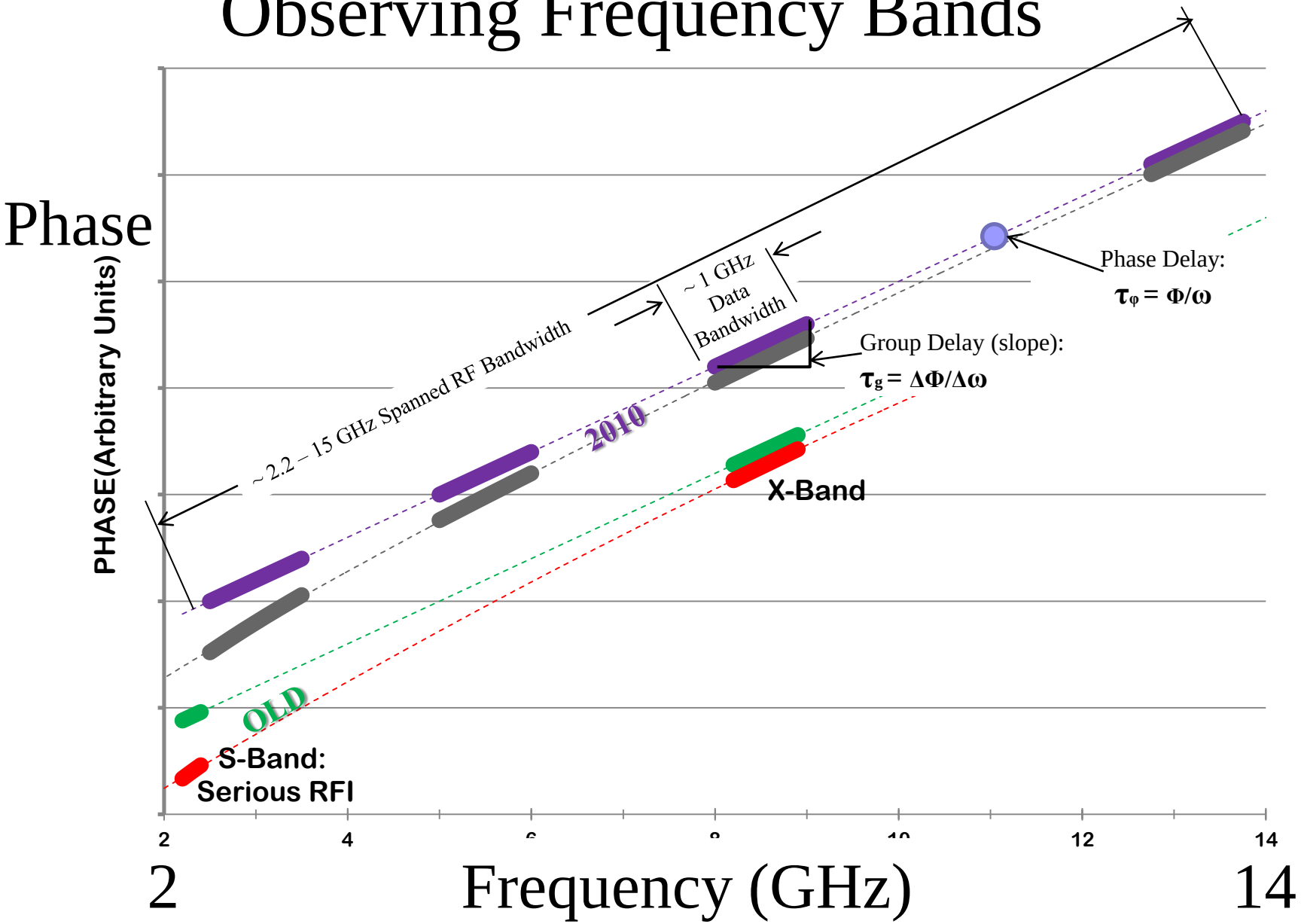
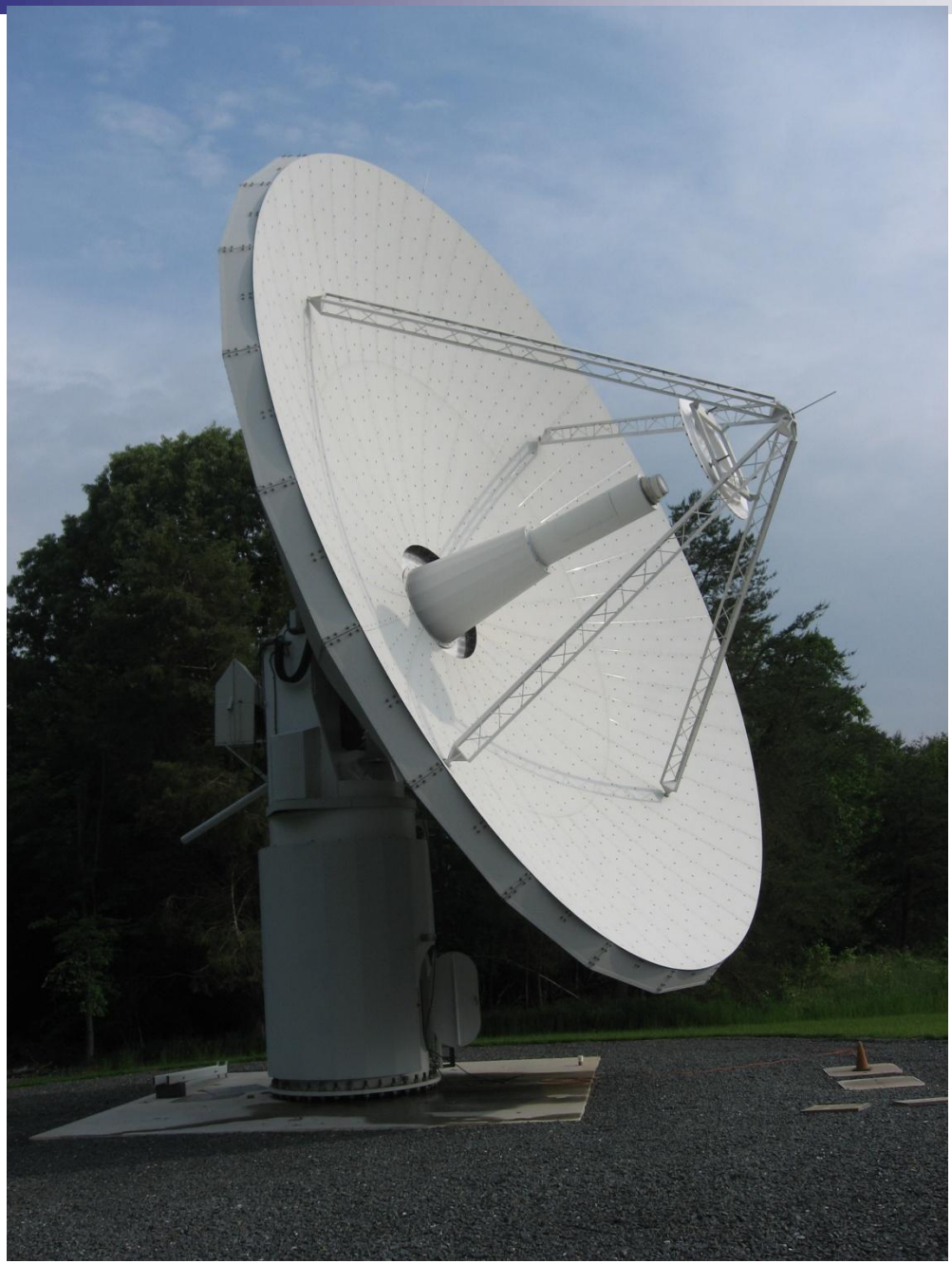
VLBI2010 development

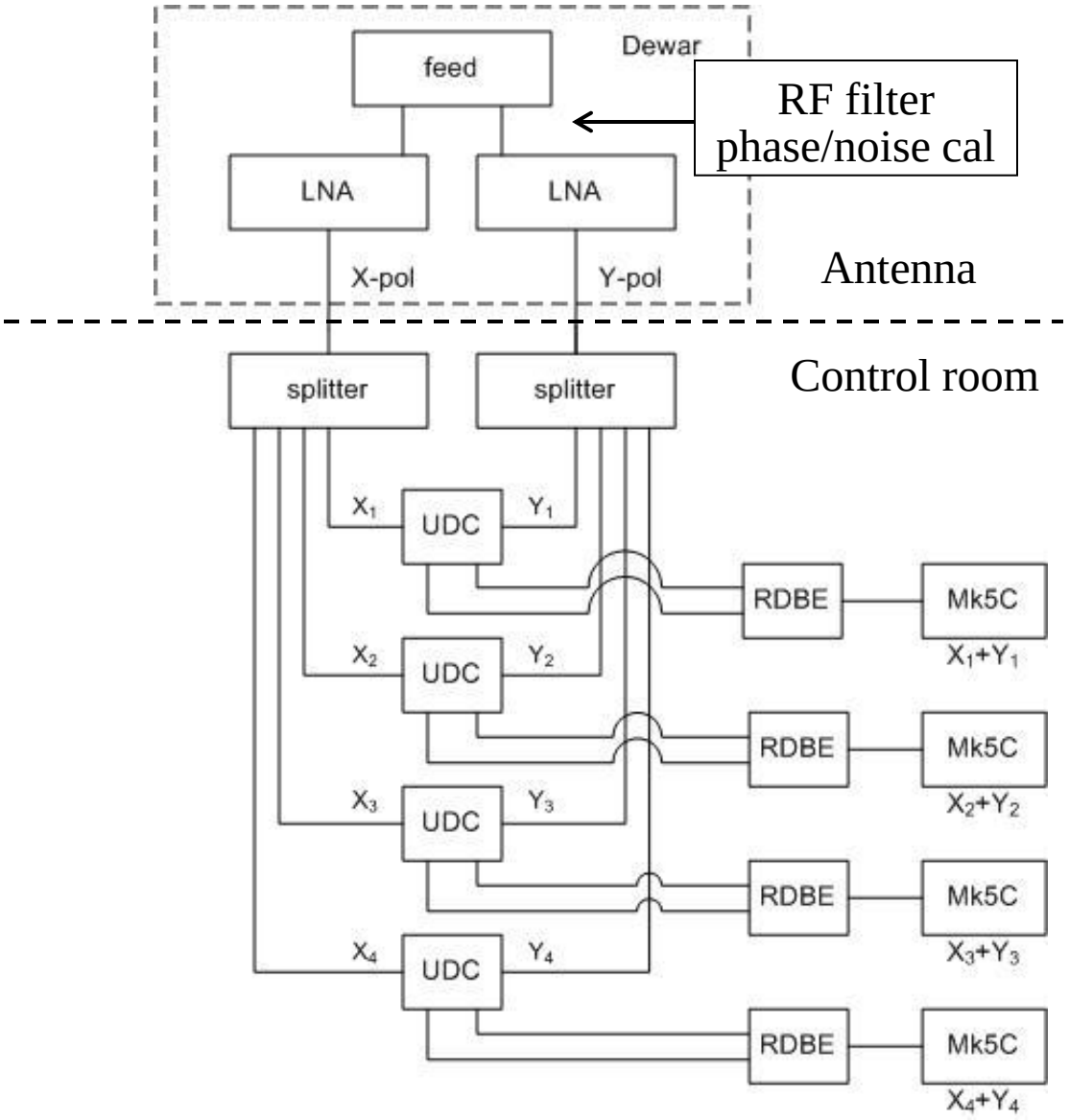
- Limiting error sources
  - Varying atmosphere delay
  - Sensitivity
- Strategy
  - Use fast-slewing antennas (5º/sec-12º/sec slew rate)
  - Obtain delay sensitivity through high data rate and wide spanned bandwidth (Broadband Delay)
- Design goals
  - Antennas of ≥12m diameter
  - Data rates >8 Gbps using four bands of 0.5 GHz to 1 GHz each
  - Spanned bandwidth 2.2 GHz to ~14 GHz: **delay uncertainty ~4 psec**
    - BUT maintain observing compatibility with current S/X systems

Observing Frequency Bands





12m antenna at Goddard Geophysical and Astronomical Observatory, Greenbelt, Maryland



Feed and LNAs cooled to ~20K

Both senses of linear polarization used

Odd channels from each pol'n for one band output to each Mk5C.

2 Gigabits/sec recorded on each Mk5C.

Total data rate: 8 Gbps

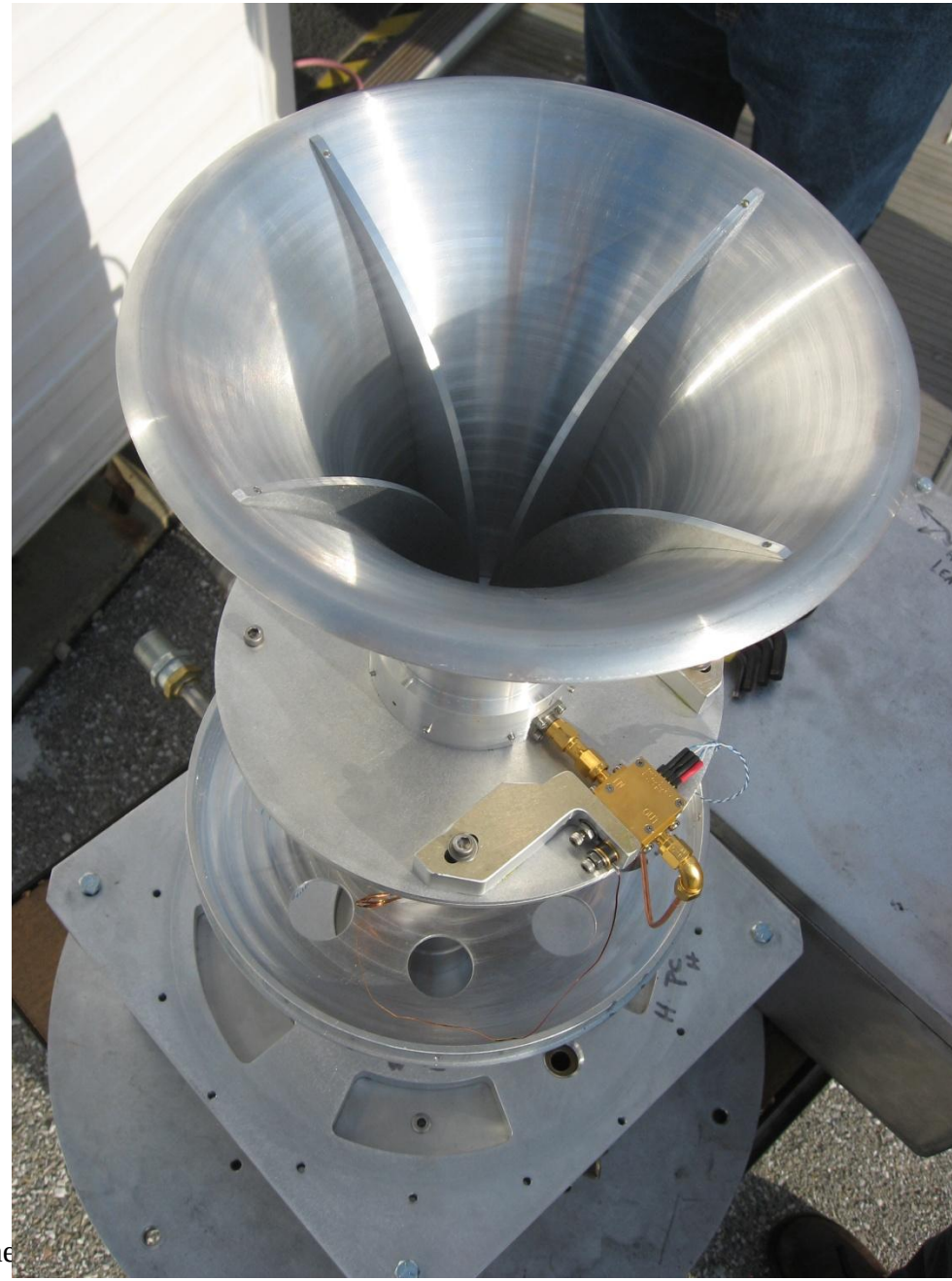
VLBI2010 signal chain

- Cooled broadband QRFH feed and LNAs (Caltech)
- UpDown Converters (4) (Haystack)
  - Select frequency bands in the range 2 to12 GHz
- RDBE digital back ends (4) (Digicom)
  - PFB to get 16 32-MHz channels (8 from each pol'n)
  - Noise diode control for power measurement for Tsys
  - In use by VLBA and NASA
- Mark5C recorder (4) (Conduant)
  - In use by VLBA and NASA

VLBI2010 System

- Antenna and data acquisition
  - Cooled broadband frontend 2 – 14 GHz
  - Flexible RF to IF frequency conversion
  - Digital backends
  - High data rate recorder(s)
- DiFX software correlator
  - Cross correlate the signals from both polarizations in each band
  - Extract all phase-cal tones
- Post-correlation
  - Coherent fitting of all bands for each polarization cross-product
  - Estimate differential ionosphere


T-221
N100



Observations

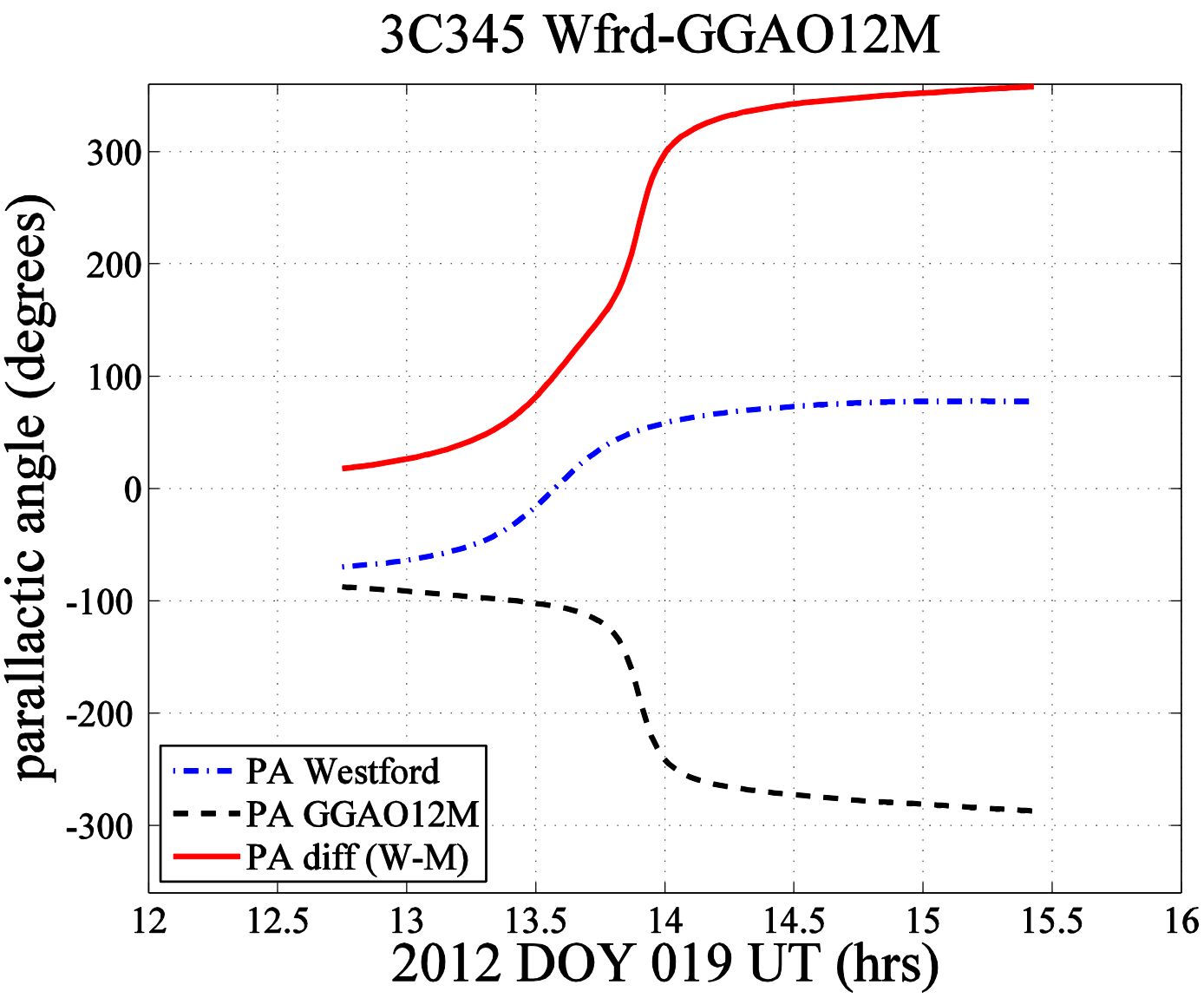
- Antennas
  - GGAO12M
    - 12m VLBI2010 antenna
    - At Goddard Space Flight Center, Maryland, USA
    - Full VLBI2010 signal chain
  - Westford
    - 18m prime focus antenna
    - At Haystack Observatory, Massachusetts, USA
    - VLBI2010 except Lindgren feed
  - Baseline length approximately 600 km.

Observations - 1

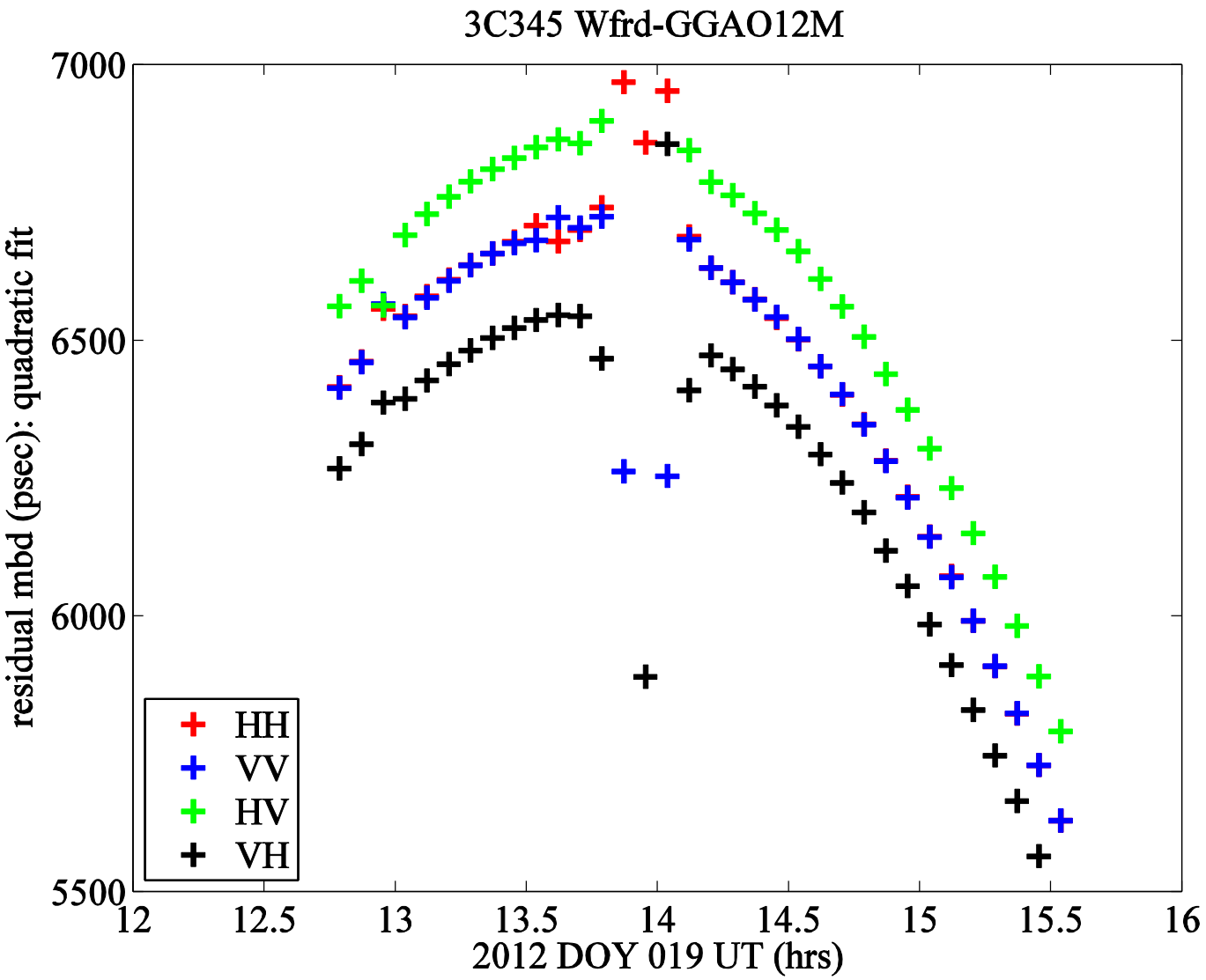
- Objectives
  - Several hours on one source to check system.
  - Observe a source with polarization rotation
- Scans
  - Five minute scans for high SNR
  - Source 3C345
  - Approximately four hours total
- Frequency bands
  - Contiguous bands spanning 2 GHz: 6.4 – 8.4 GHz

Observations - 2

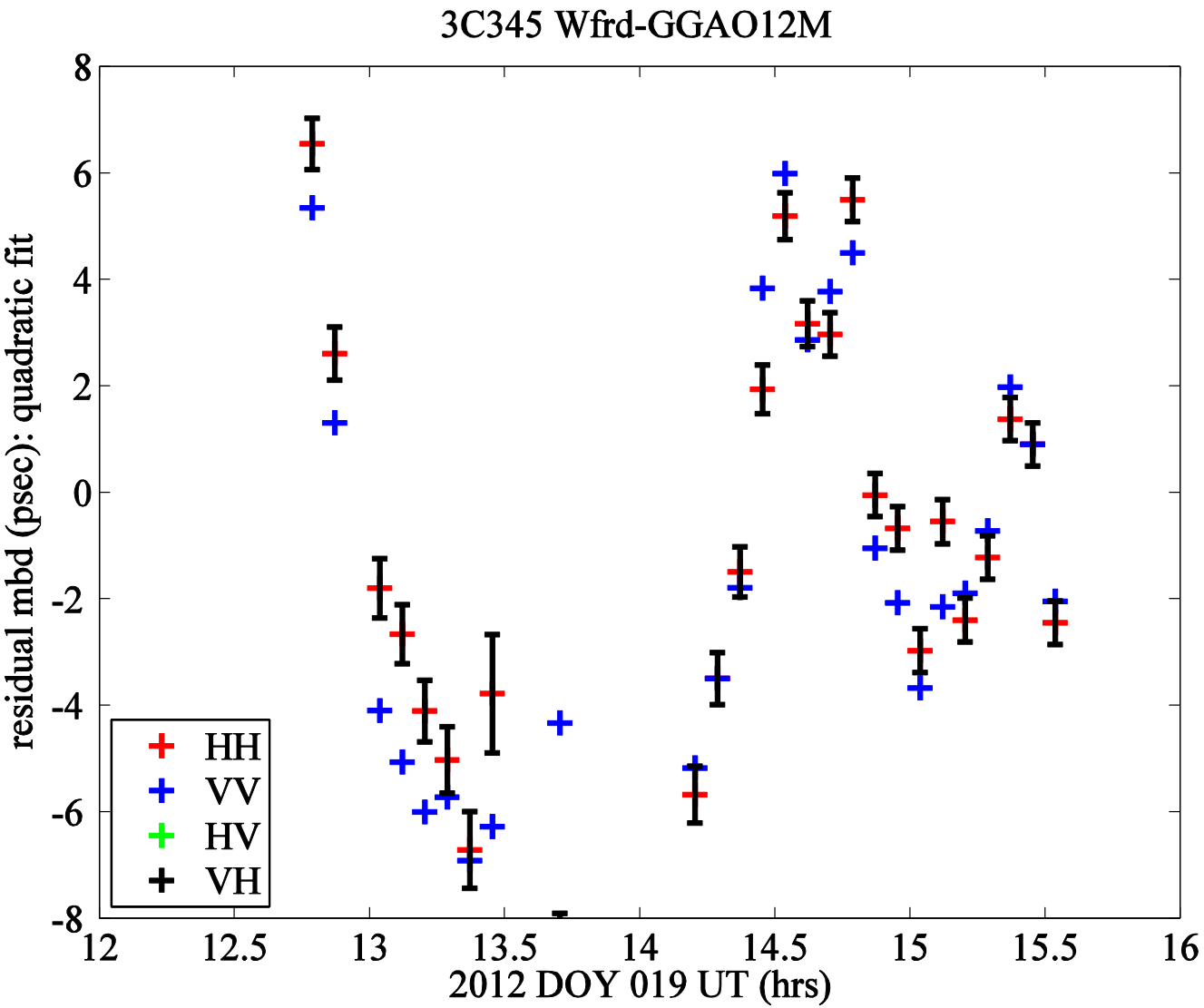
- Correlation
  - DiFX software correlator at Haystack Observatory
- Phase calibration
  - All phase cal tones in each channel used for instrumental delay calibration
- Delays and phases
  - All four bands used for estimation
  - Polarizations not combined
  - Next step: estimate delay and phase for each scan using all polarizations and bands
    - see talk by Roger Cappallo this afternoon


3C345 Wfrd-GGAO12M
parallactic angle (degrees)
300
200
100
0
-100
-200
-300
PA Westford
PA GGAO12M
PA diff (W-M)
12
12.5
13
13.5
14
14.5
15
15.5
16
2012 DOY 019 UT (hrs)

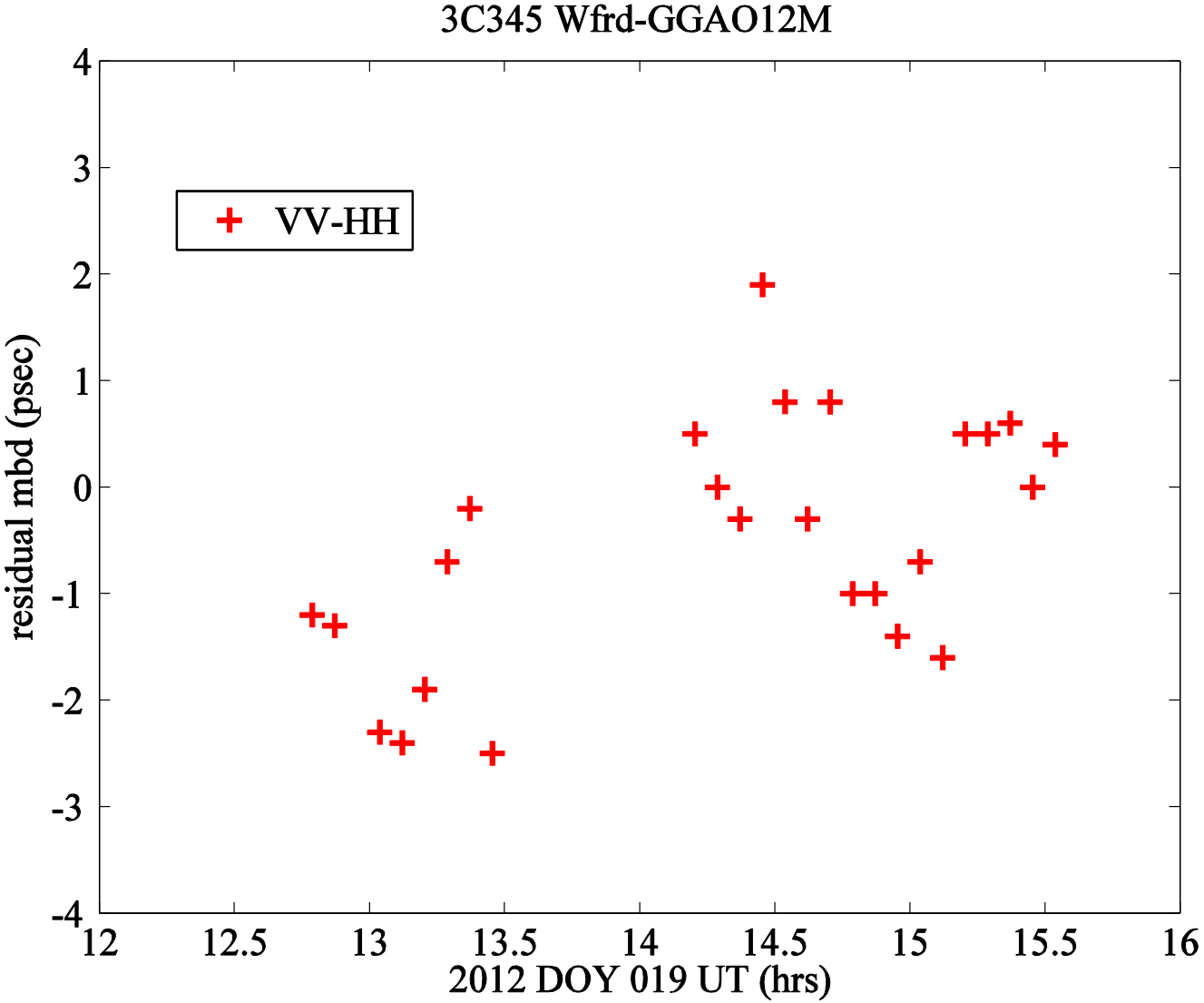
Residual delays to correlator model spanning 2 GHz bandwidth



Residual delays to correlator model spanning 2 GHz bandwidth after removal of quadratic: note change of scale.



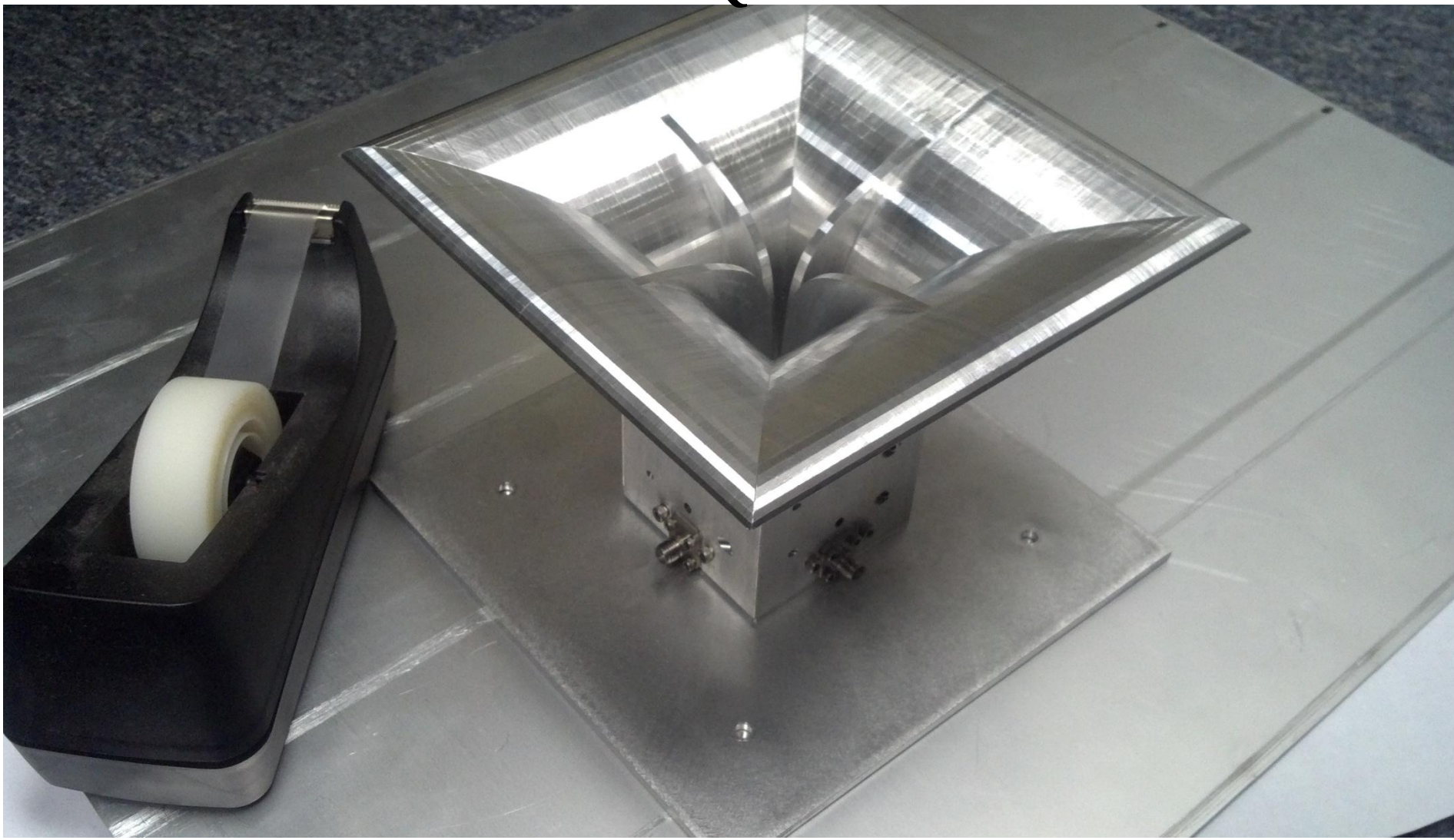
Difference of delays across 2 GHz for vertical and horizontal polarizations. Receiver noises in VV and HH are independent. Note that scale is ±4 psec, which is goal for RMS delay variation for VLBI2010. Three picosec = 1 mm.



Next steps

- The QRFH feed that was made specifically for Westford is being implemented. (see talk by Chris Beaudoin this afternoon)
- Sources of RFI need to be isolated and mitigated.
- The system temperature measurement capability will be tested.
- Observations will be made to evaluate the sensitivity at all frequencies.
- Geodetic sessions will be scheduled to evaluate the capability of the new systems.

Westford QRFH feed



Summary

- A 12m antenna has been implemented with the full VLBI2010 signal chain.
- The Westford 18m has been implemented with the same electronics but a prototype feed.
- Four hours of data were taken with electronics set to record four contiguous bands spanning 2 GHz: 6.4 – 8.4 GHz.
- The RMS delay difference between the independent polarizations is less than 1 picosecond over an hour.

GGAO12M Development Team

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Thank you