Correlator Post-processing Algorithms for VLBI2010

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fourfit

- Mk4 fringe-fitting program
- part of the *hops* package
- produces best-fit group delays and rates from the correlator visibilities
- also used as a DQA tool

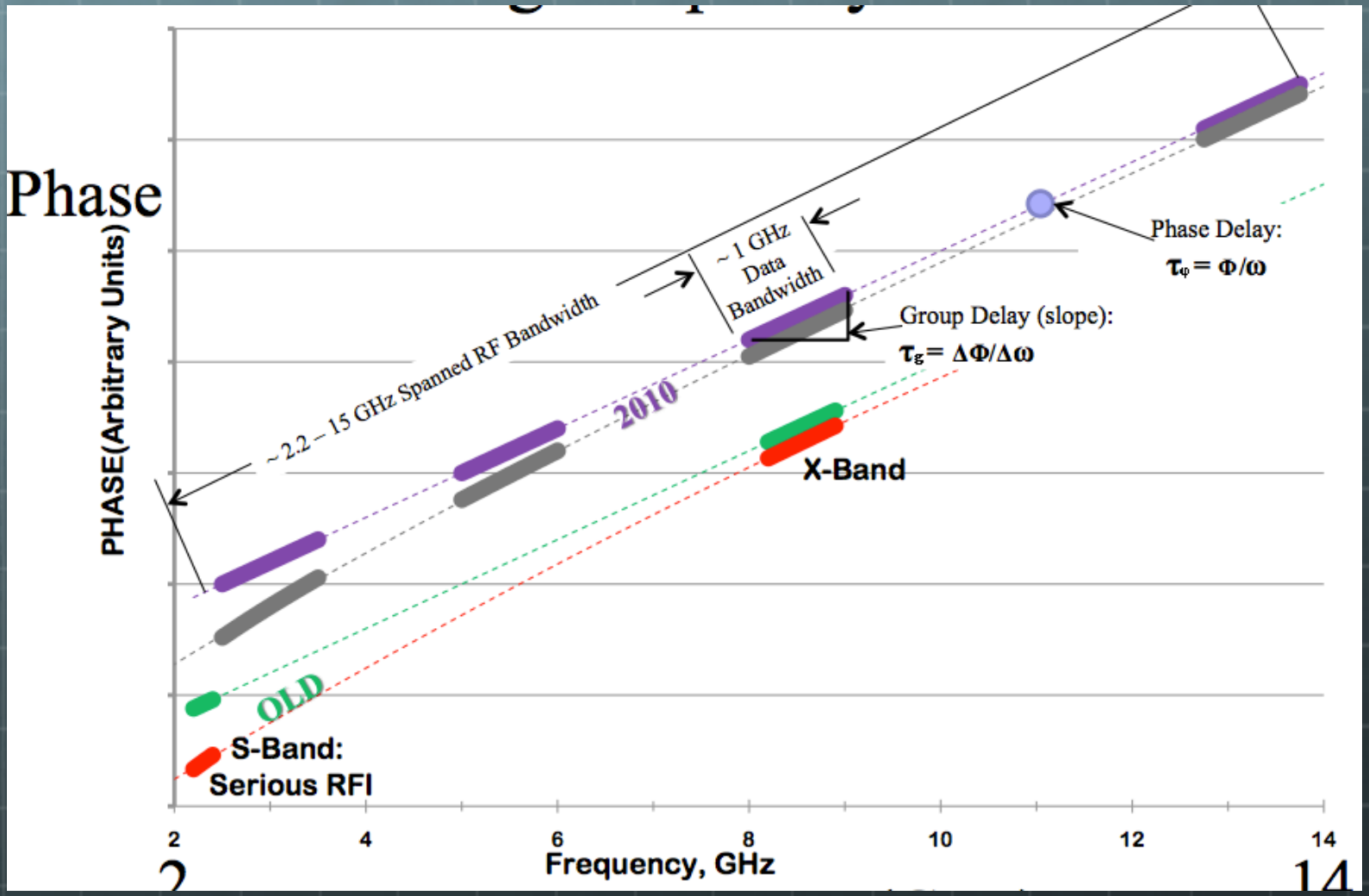
Mk4 to VLBI2010 *fourfit*-related Changes

- Independent S/X band to 4 broad bands
- Desire to phase-connect the bands
- Phase cal tone spacing
- # channels in fit going from 10 to 32 or more
- RCP-only to dual linear polarization feeds

Post-processing in *fourfit*

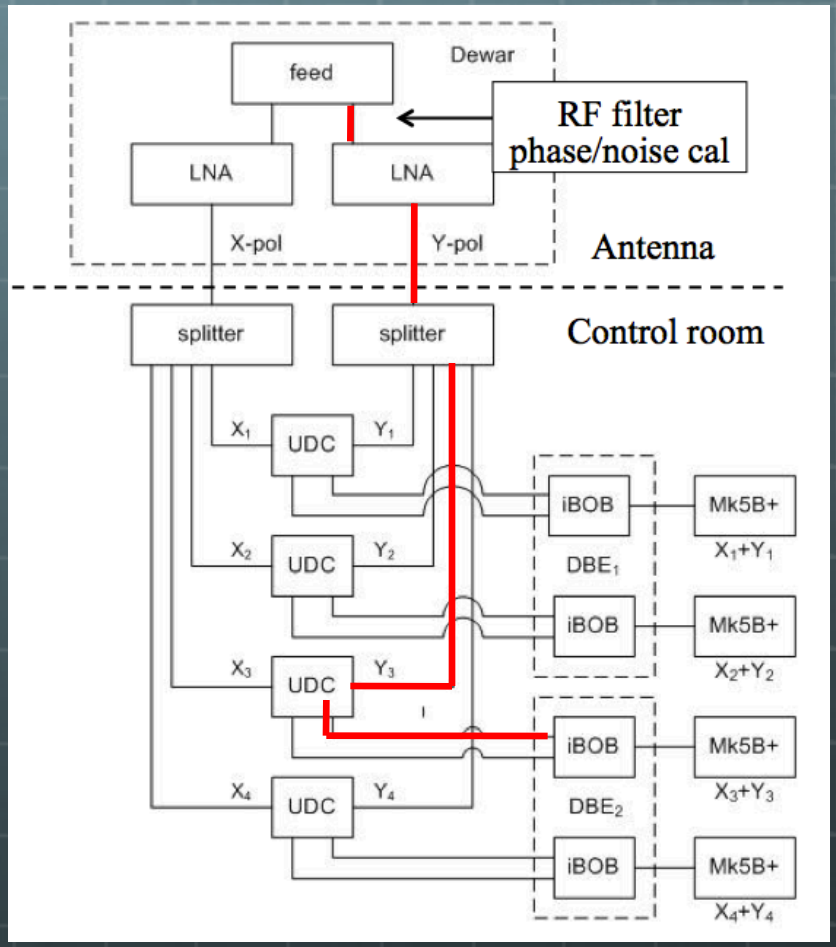
- **goal:** to output a single delay that best represents the ionospherically-corrected propagation delay between two antenna phase centers, using as much of the intrinsic signal sensitivity as possible
- **implications:**
  - need to combine all Stokes cross-correlation combinations in coherent fashion
  - need to connect the phases between widebands for optimal measurement precision

Band Distribution



Niell, 2010

Hardware Setup Drives Processing Treatment

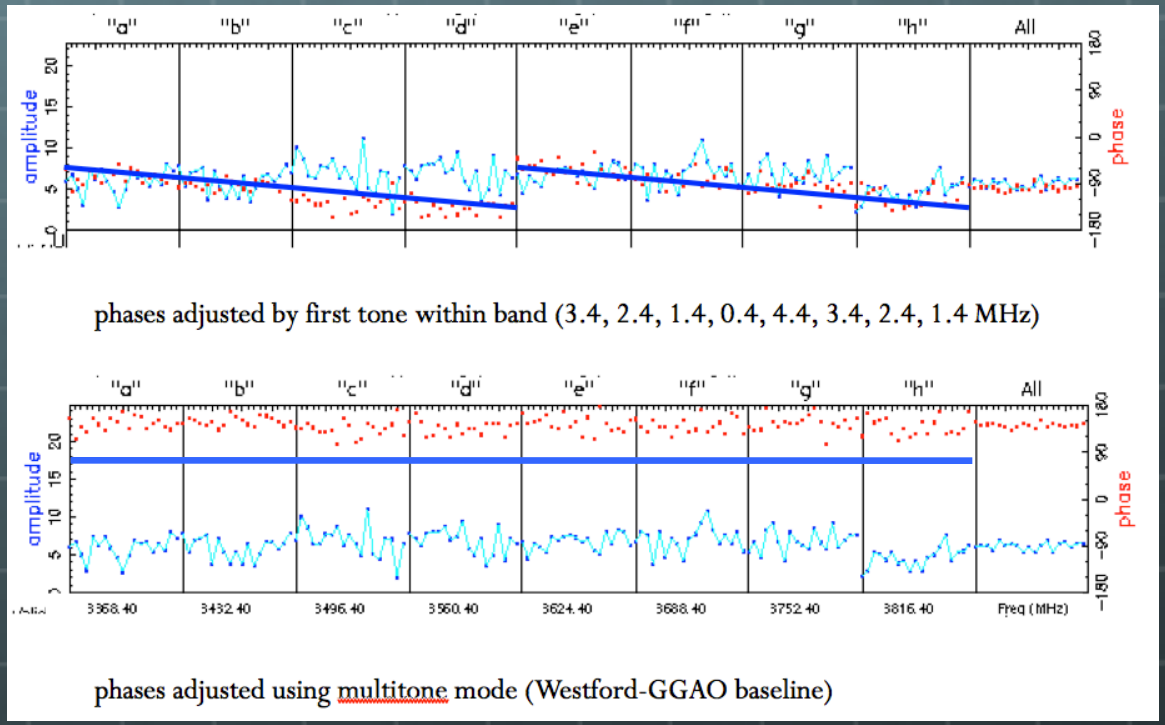


- feed characteristics cause different delay and phase of pols.
- 8 analog paths have different delays & phases
- sampling clock epochs vary between iBOB's
- path effects from pcal injection to digitizer can be removed in principle

Phase Cal Tone Usage

- **key concept:**
  - "baseline" phase cal gives instrumental phase for removal to tie together different bands
- **steps:**
  - process all of the tones within each polarization of each band
  - solve for instrumental delay
  - correct each band's fringe phase at midband
  - coherently combine the bands and polarizations

multiple tones allow proper correction to midband

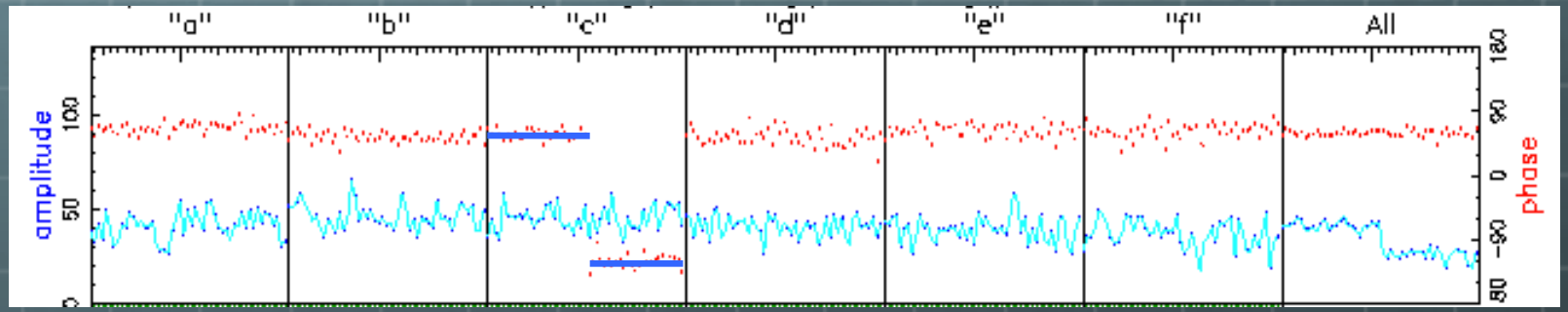


phases adjusted by first tone within band (3.4, 2.4, 1.4, 0.4, 4.4, 3.4, 2.4, 1.4 MHz)

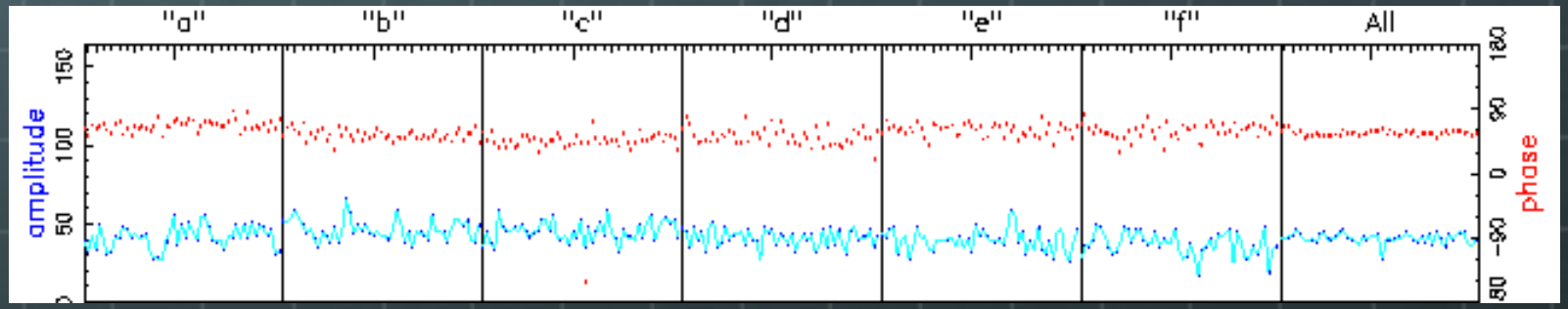
phases adjusted using multitone mode (Westford-GGAO baseline)

correction of fringe phase jumps via pcal

before



after



Handling Linear Polarization

- can be broken into 3 components:
  - intrinsic polarization of source + propagation medium
  - observing geometry (differential parallactic angle Δ)
  - instrumental response differences
- source effects just project into 2 polarizations
- form sum with complex phase factors that maximize the combined magnitude $|C_{ab}|$

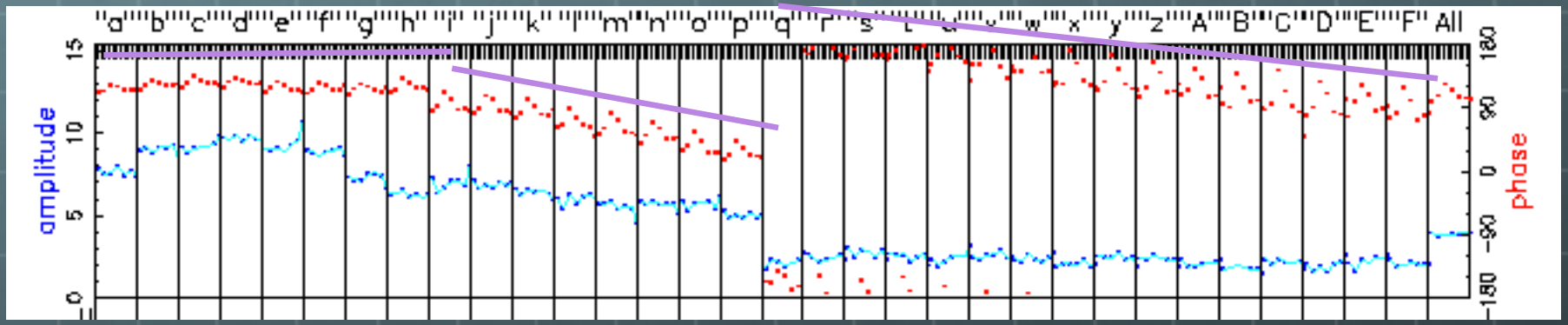
$$C_{ab} = (X_a \times X_b \times e^{i\phi_1} + Y_a \times Y_b \times e^{i\phi_2}) \cos\Delta$$
$$+ (X_a \times Y_b \times e^{i\phi 3} - Y_a \times X_b \times e^{i\phi 4}) \sin\Delta$$

Ionospheric Estimation and Removal

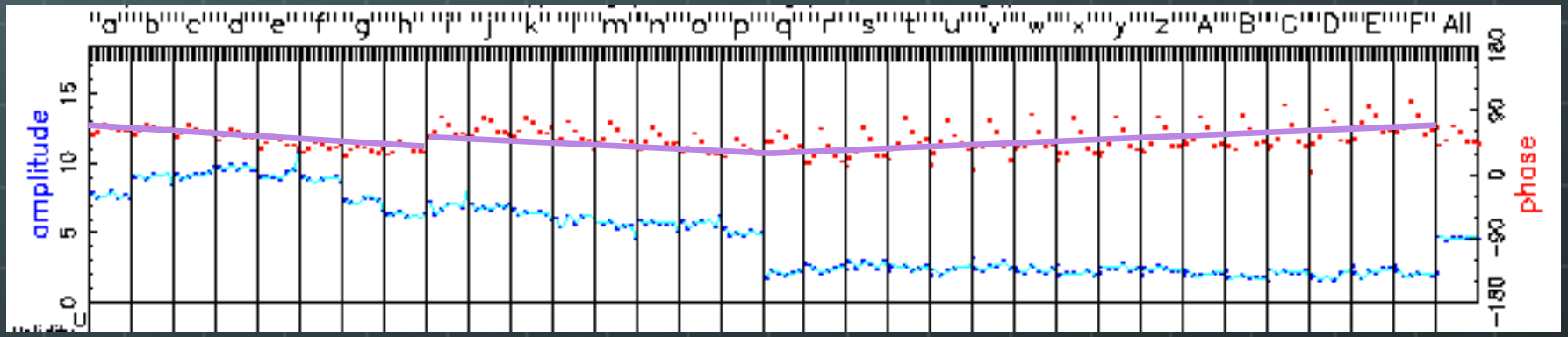
- complexities:
  - dependence of the differential ionosphere on the coherent sum, taken across all bands, is non-linear
  - ionosphere models can provide only poor a priori values
  - snr may be low enough to prevent a bootstrapping method from one band to another
- the plan:
  - perform fringe fits for a variety of coarsely-spaced ionosphere (differential TEC) values
  - identify the coarse value that maximizes the fringe amplitude
  - search a second round of finely spaced values to find optimum
- performance penalty will be a factor of 5 – 10 in execution time (only a fraction of the full fit is repeated)

Ionosphere removal and merging of widebands

before



after removal of hand-fitted ionosphere & automatic pcal alignment



Status & Summary

- more robust pcal treatment now allows combination of widebands

- under progress:
  - flexible control for combination of 4 bands with 4 polarization products
  - automatic estimation and removal of the ionosphere