21cm Calibration

Ue-Li Pen

Overview

- Standard radio calibration
- Polarization
- issues

Goal of Calibration

- To measure the system response to a signals on the sky
- In interferometry, often phases are not knowable in advance: e.g. no absolute relationship between Local Oscillator and reference phase
- Real time phase calibration is essential for FFT based image formation.
- System can drift.
- Metric is ‘dynamic range’: the accuracy to which a point source can be modelled.

Phase closure calibration

- We observe visibilities: products of antenna responses
- Need to solve for individual antennae gains
- If we think of visibilities as correlations, a point source is a rank 1 correlation matrix
- The eigenvector is the gain solution

Standard Interferometry Calibration

- Flux calibrator
- Phase calibrator
- Self-cal

Flux calibrator

- Also called bandpass calibration
- Usually one of 3 bright sources on the sky: 3C286, 3C147, 3C48
- Usually observed at beginning and end of night

Phase calibrator

- Needs to be point like on all baselines
- Often, only long baselines are used for calibration: short baselines more prone to cross talk, interference, galactic emission, ground spill
- Should be near pointing target
- Frequent switching from target field to calibrator.

Self-cal

- Builds a model of the image
- Uses the model to solve for the telescope gains
- Potentially circular, can result in

Peeling

- The gain may change across the field: primary beam effect, ionosphere.
- Applying self-cal to sources across the field, resulting in multiple gain solutions, is called "peeling"

EoR calibration

- Uses pulsar as reference: very clean
- Pulsar has duty cycle of a few percent
- Gated correlator
- Subtract on gate from off gates
- calibration errors are independent from image structure

Dynamic range

- The accuracy with which a point source can be modelled
- A 100,000:1 dynamic range means that the image residual is 1 mJy in the presence of a 100 Jy point source.
- Measured away from the source, but within the primary beam
- Dynamic range can be >100 even with unity calibration errors

Polarization

- Observing an unpolarized source allows solving for all leakage parameters
- Observing a polarized sources at multiple position angles on alt-az telescope allows solving for polarization angles

Issues for CRT

- All pair correlation products needed for calibration, must be repeated on short time scales. Straightforward for software correlator.
- Polarization calibration on cylinders

Summary

- For cylinder telescope, perhaps biggest issues are real-time calibration, polarization leakage corrections, and squint.
- Calibration requires the pair product of many, ideally all, receivers