Overview and Goal of Calibration and Imaging Working Group

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(Wijnholds, Grainge, Nijboer document in prep)

Limits to Imaging

- What limits the final map sensitivity?
  - Thermal noise (A/T; integration time)
  - Confusion noise (source counts; maximum baseline)
  - Calibration errors
- Related question of image fidelity
  - Issues of station and array configuration; uv-plane coverage
- Key questions: how accurate must calibration be such that it is not limiting performance? How do we achieve this?

AA Calibration

- Aim is overall model for calibration of entire AA system
  - Investigate calibration requirements at all sub-system levels
  - Comment on specs; guide design decisions
- Eventually will be limited by non-linear effects of systematics
  - Need to consider interaction of various errors
- Scope: SKA Phase I is initial priority
- Also take forward Phase II considerations

Approach

- Experience from existing mature telescopes
- Lessons from pathfinders
  - LOFAR, MWA, EMBRACE, AAVS …
  - Will become increasingly important
  - Especially for identifying “sub-optimal” design choices
- Simulations
- Theoretical studies

“Estimation noise”

- Self-calibration will be required to reach desired dynamic range
- Estimation of calibration parameters extracts information from the data
  - Effective noise in the image increases with number of calibration parameters
  - Imposes a stability requirement

Imaging issues

- What is required accuracy in knowledge of station beam? (Smirnov)
  - Translate this into tolerance requirements on physical parameters
  - Also determines the hierarchical level to which calibration is required
  - e.g. Individual beam former weights for each element of an AA-mid?
- How do we measure/assess image fidelity?

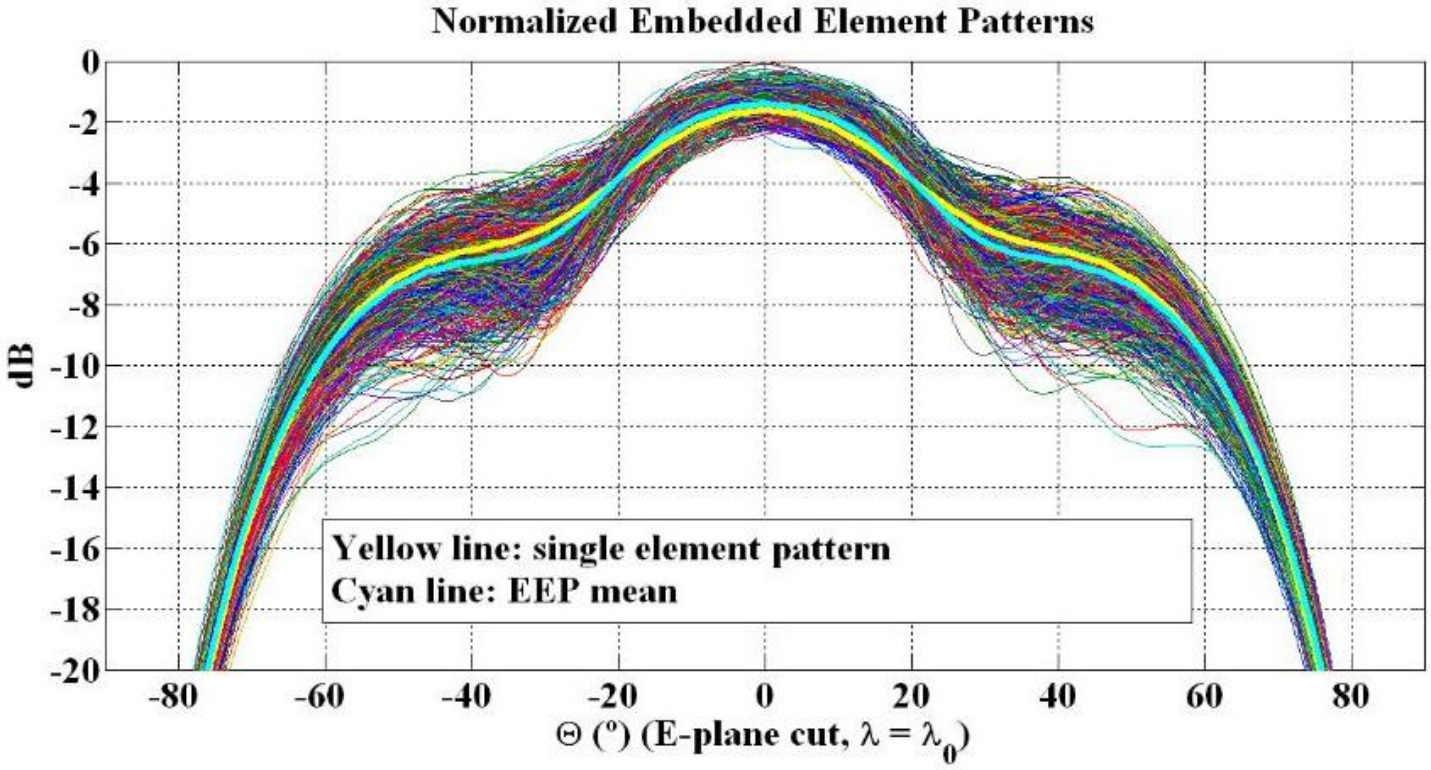
Calibration with astronomical sources

- Do astronomical sources provide sufficient SNR for accurate estimation of calibration parameters?
- Particularly an issue for time varying DDEs
- A sensitivity issue
  - Timescale
  - Collector area; bandwidth etc
- E.g. Ionosphere and implications for filling factor as a function of frequency (Wijnholds)
- May require specific calibration hardware to be built

Polarisation

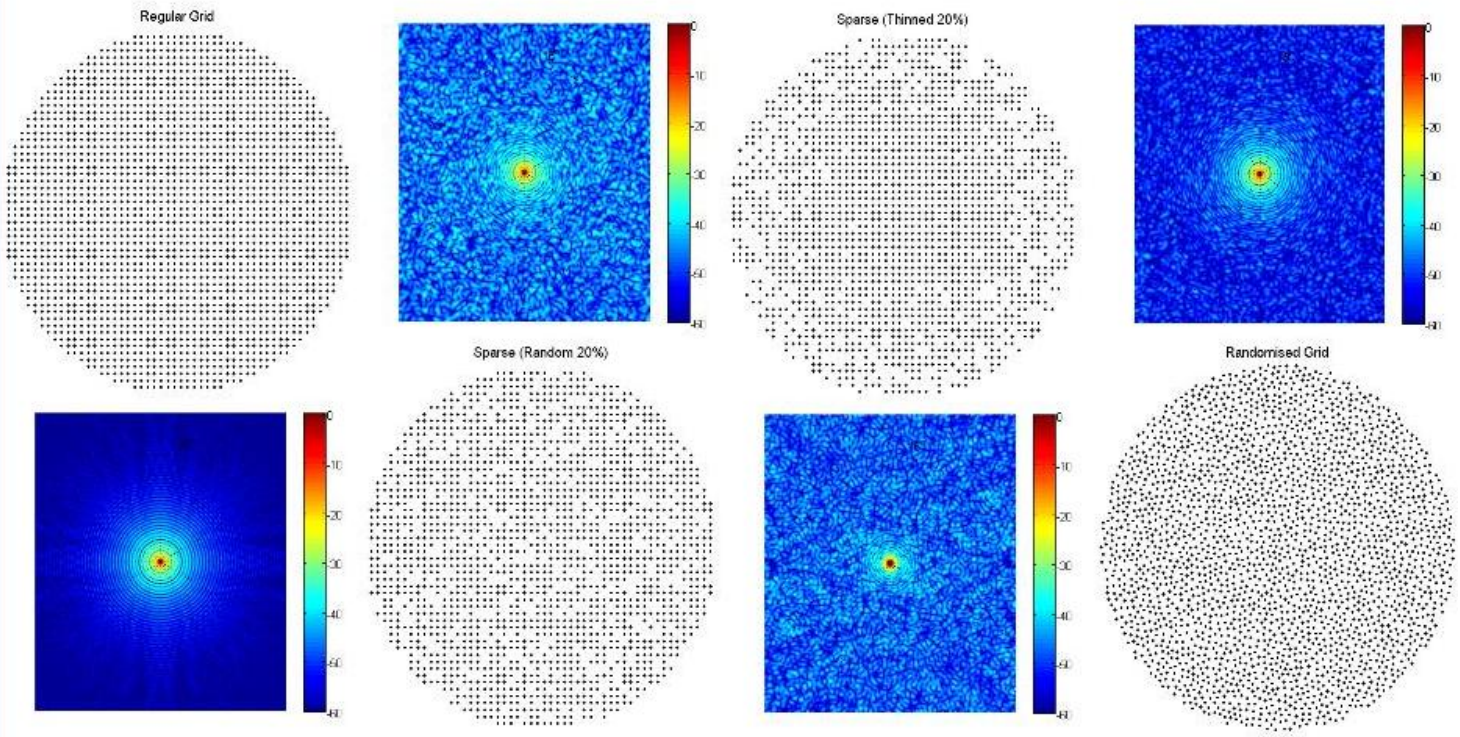
- Standard polarimetric performance (co-, cross- pol) is not meaningful for AAs
  - Use IXR instead (Carozzi)
- Are element level polarimetric corrections required?
  - Apply during beamforming
  - Only one point in FoV correct
  - A LOFAR study exists

Effects of Coupling



- AA elements very strongly coupled
- Use macro basis fns (Craeye)
- Issues: sparceness; configuration; channel bandwidth

Beam Forming - Array Factor



- Station beam from Array factor and mean embedded element pattern (Razavi-Ghods, Lera Acedo)
- Array factor: configuration; convolutional gridding; FFT
- Interpolation for different directions and frequencies

Station configuration

- Bright sources in sidelobes are a major issue
- How best to assess station beam shapes?
  - Some useful metrics exist (Zarb-Adami)
- Need to consider interferometric case
- Seemingly sensible criteria may not lead to optimum design in practice

Simulation: OSKAR2

- Oxford OeRC: Salvini, Mort and Dulwich
- Simulates AA visibility measurement sets
- Very powerful tool for investigating calibration
  - Extended / polarised sources in sidelobes
  - System design aspects e.g. element geometry / alignment errors
- How best to analyse the results?

Other Calibration Issues

- What is allowable gain/phase error in analogue chain
  - Encompasses all electronic and temperature effects
- Absolute amplitude calibration
- Can calibration be applied in real time?
- Beam formation
  - Bandpass changes; filter performance (aliasing)
  - Sample bit count through processing chain
  - What levels of frequency / time smoothing can be applied

Future

- Increasing maturity of simulations allows:
  - Simulation / comparison with existing instruments
  - Calibration “Challenges” data sets
    - Provides focus; creates interest
    - Drive to formulate problem well
    - Define a metric
    - Extremely useful approach in other fields

Summary

- Calibration critical to realise potential sensitivity
- Guide AA design decisions at station and system level
- Will specific calibration hardware be required?
- Address issues with pathfinders and simulation tested against measurements
- A great deal of progress in many areas
- Simulations should be extremely powerful ways of investigating several issues