Aperture Arrays and the SKA

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Contents

- Aperture Arrays after site selection
- Requirements
- Calibration in the SKA pre-construction phase
- LOFAR practice
- Open door

Site Decision Consequences (SKA1)

- LFAA (=AA-low)
  - 50* stations of 11,200 elements
  - 180 m diameter

- MFAA (=AA-mid)
  - AIP
  - 250 stations of 110 k elements
  - 56 m diameter

* baseline. SOWG report refers to 280 stations

Science Requirements

- Key science requirements for calibration and imaging tasks
  - Imaging dynamic range (74 dB capable)
  - Spectral dynamic range (61 dB)
  - Polarisation purity

Derived Requirements

- From Labropoulos in Path to SKA-low workshop in Perth, 7 September 2011

Leakage of Polarized FGs to the Eo signal

rijksuniversiteit groningen

ASTRON

While I maps are smooth along frequency, Q,U,V maps might have significant polarization signatures. Galactic synchrotron polarization can be as high as a few Kelvin

This translates to 29 dB (or 36 dB) for model A – Faraday screen (sync. – f.f. separated) (or B – Strong DFR)

Requirements for System

- As important is the flow back of “calibration requirements” back to the Element and System level to steer the design space
- Examples (over various dimensions):
  - Flatnesses
  - Smoothness
  - Stability
  - …
- Iterations on all these levels required

Preconstruction Phase

- Divided into two stages
- Stage 1
  - Up to and including Requirements Reviews
- Stage 2
  - Preliminary Design Reviews
  - Critical Design Reviews
  - Production Readiness Reviews
  - Production Ready

Work Break Down Structure

- LFAA Statement Of Work:
  - Derive calibratability requirements from SKA system level requirements for LFAAs
  - Verify that proposed LFAA system design satisfies calibratability requirements
  - Derive station beam requirements from SKA system level requirements for LFAAs
  - Develop station calibration strategy
  - Verify that the proposed station calibration strategy can satisfy the derived station beam requirements using celestial calibration sources available at the SKA candidate sites
  - Provide experimental validation of proposed concepts using LOFAR or AAVS (specifically designed for these purposes)

Other Calibration Related Tasks

- Processing pipelines
- Algorithm development imaging pipeline
- Calibration pipelines
- Aperture Array pipelines

Integrated Task Teams

6.4 SKA.TEL.ITT - SKA Telescope Integrated Task Teams

3 SKA.TEL.ITT - SKA Telescope Integrated Task Teams
- 4 SKA.TEL.ITT.SSP – System Science Performance
- 4 SKA.TEL.ITT.TRD – System Trades
- 4 SKA.TEL.ITT.OPS – Observatory Operations
- 4.SKA.TEL.ITT.CONF - SKA Array Configuration & Topology
- 4 SKA.TEL.ITT.SWE – Software Engineering
- 4. SKA.TEL.ITT.RFI – EMI and RFI Design Policies, Guidelines and Standards

Process

- Extract calibration specific requirements from science (DRM)
- If no specific requirements are defined: make assumptions based on experience
- Define models (simulation or analytical) which show how to meet requirements
- Verify model and validate calibration strategy with prototypes
- Refine model and iterate

LOFAR Practice

- Design Goal:
  - Online station calibration
  - Built in small band correlator
  - Update rate full band: ~7 min.
- Current usage:
  - For “static” calibration table
  - Measured in 24 hours
- Future usage:
  - As designed

Station Calibration

- Necessary or not?
- LOFAR electronics seems to be sufficiently stable at the current level
- Basically gain and phase variations leads to a sensitivity reduction “only”
- The more elements the more the random gain and phase variations average out
- Systematic variations can be calibrated out centrally

Crucial to Know

- Beam pattern as a function of frequency, angle, pointing direction and time
- Model of beam pattern over all variables required including broken elements
- Validation of model required
- Refinement of model necessary for e.g. environmental conditions: rain, sun, …
- Is a celestial source sufficient to use or is an artificial source better for SNR?

Engineering Strategy

1. Design to requirements for affordable cost
2. Use corrections to compensate for variations (e.g. temperature)
3. Use calibration “as a last resort” … which is necessary to keep the designed system affordable for a given budget

Trade-off between cost and performance

Cost of calibration << cost of “the perfect system”

Conclusions

- Calibration work defined all over the system and crucial for AAs in SKA
- Calibration requirements flow from top to bottom and back and forth
- Art is to find the balance between the “perfect system” and a “crappy system” with a giant calibration engine


CHEVROLET
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The End