3GC-II Workshop: Beam modeling

Albufeira, Portugal, 2011

Workshop overview by Isak Theron

Jan Noordam

- Station/dish beam shapes are not identical
- Need to know the beams
- Difficult to distinguish between beam shape and sky model uncertainties
  - Limit the ability to do pointing correction
- Difference between actual beam and model must be smooth
- How do we get the beam shape?

Jan Noordam

- Open loop
  - Use theoretical model
  - Measure once, e.g. on a bright source
- Closed loop
  - Continuously measured, using sources in field
  - Time, frequency and polarisation
  - Almost an improved self-cal
  - *This is the only way that can deliver*
  - *Need parameterised beam models, but still do as good as possible with the actual beam*

Tony Willis

- Dishes define life of a telescope
- Selection of the SKA dish from the options (If we can select, we can also optimise)
- Three classes of dishes
  - Prime focus with 3rd axis, e.g. ASKAP
  - Offset Gregorian, e.g. ATA
  - Prime focus equatorial, e.g. WSTR
- Need to provide a process of selection
  - Simulation with MeqTrees

Tony Willis

- Select a sky model
- Select which effects to include
- Define the test array
  - Size, and number of dishes
  - Frequency and number of channels
- Simulate and calibrate (blind) data
  - Provide feedback to dish designers
  - Beam movement with frequency
- Report how to weigh the various issues

Walter Brisken

- EM simulations are complex
- Final geometry unknown
  - Tolerances, fine detail, etc.
- Why model beams?
  - Do trade-offs, e.g. A_e and T_{sys}
  - Understand observed defects, e.g. polarisation
- Work with (complex) voltage beams
- Overview of modelling techniques

Walter Brisken

- Cassbeam software
  - Geometrical optics
  - Full polarisation
  - No diffraction
- GRASP 9 analysis (by Bruce Veidt)
  - Physical optics, PTD extension
  - Very efficient dish analysis
  - Adding small features, e.g. struts very costly

Walter Brisken

- Prime focus beam ripple
  - Associated with beam broadening
- Keep optical path free of scatterers
  - Use shapes that are easy to model
- Can image through beam nulls
  - Move with frequency
  - Do we want variation
- Side-lobes are polarised
- Defined circular pointing measurements?

Marianna Ivashina

- Use numerical beam patterns
- Expanded again i.t.o. analytic ones
- Use shifted elements as basis function
- Small number needed
- For reflectors, expand the feed pattern

Overview of beam modelling

- Ben Mort
  - OSKAR – imports EM beam simulations
- Stefan Wijnholds
  - APERTIF
  - Derive beam specification from SNR requirement
  - Balance beam errors against other errors

Christophe Craeye

- Determine beam from a cylindrical mode expansion of a known aperture distribution
  - Fourier transformed to form beams
  - Radial dependency
    - Fourier Bessel series (go to zero at edge)
    - Zernike series
      (orthogonal if on an infinite plane, but not required)
  - Relatively few modes
    - Derived from required angular extent
    - Zernike Bessel functions better for small number
      - Could be used as basis functions for beam calibration

Christophe Craeye

- Determined AA station beams
  - Mutual coupling correction for < λ/3 elements
  - Use constant element pattern
  - Cannot scan too low
    - Smooth degradation
  - Solve for the difference between computed and measured beams
  - Fitted with 120 modes?

Peter Williams

- Showed beam patterns of ATA
  - Fairly consistent between dishes
  - Shroud needed for tipping performance
- Beam offset (angle between X and Y beams)
  - Measured in HEX pattern
  - Vary with time
- Gain and leakage correction
  - 7 parameters
  - Averaged for all antennas

Isak Theron

- Overview of modelling techniques
- Overview dish design
  - Parameter trade-offs
  - Shaping and spill-over shielding extension
- Interpolating complex values must reflect the physics
- Frequency interpolation on components of dish pattern
  - Main reflector, sub-reflector, feed

Future

- Extend Tony's system characterisation plan
  - To be done for MeerKAT options investigation
    - MeerKAT layout
    - Need to determine optimal pattern θ-stepping
    - Define model sky
  - Pipeline that takes pattern and output quality
- Careful consideration of the phase slope
  - Process above
  - 14.5 GHz prime focus/offset Gregorian patterns
  - Mechanical solution

Future

- Determine 2x2 parameterised beam model
  - Basis functions for calibration expansion
    - Spatial distribution and how to interpolate
    - Frequency interpolation
  - Starting coefficients from theoretical beams
  - Dishes: Combine Christophe and Isak's ideas
    - Phase dependence as a function of frequency
    - Zernike Bessel expansion of main aperture
    - Diffraction coefficients / small aperture distribution for sub-reflector basis functions