Simulation and calibration for the SKA AA

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Aim

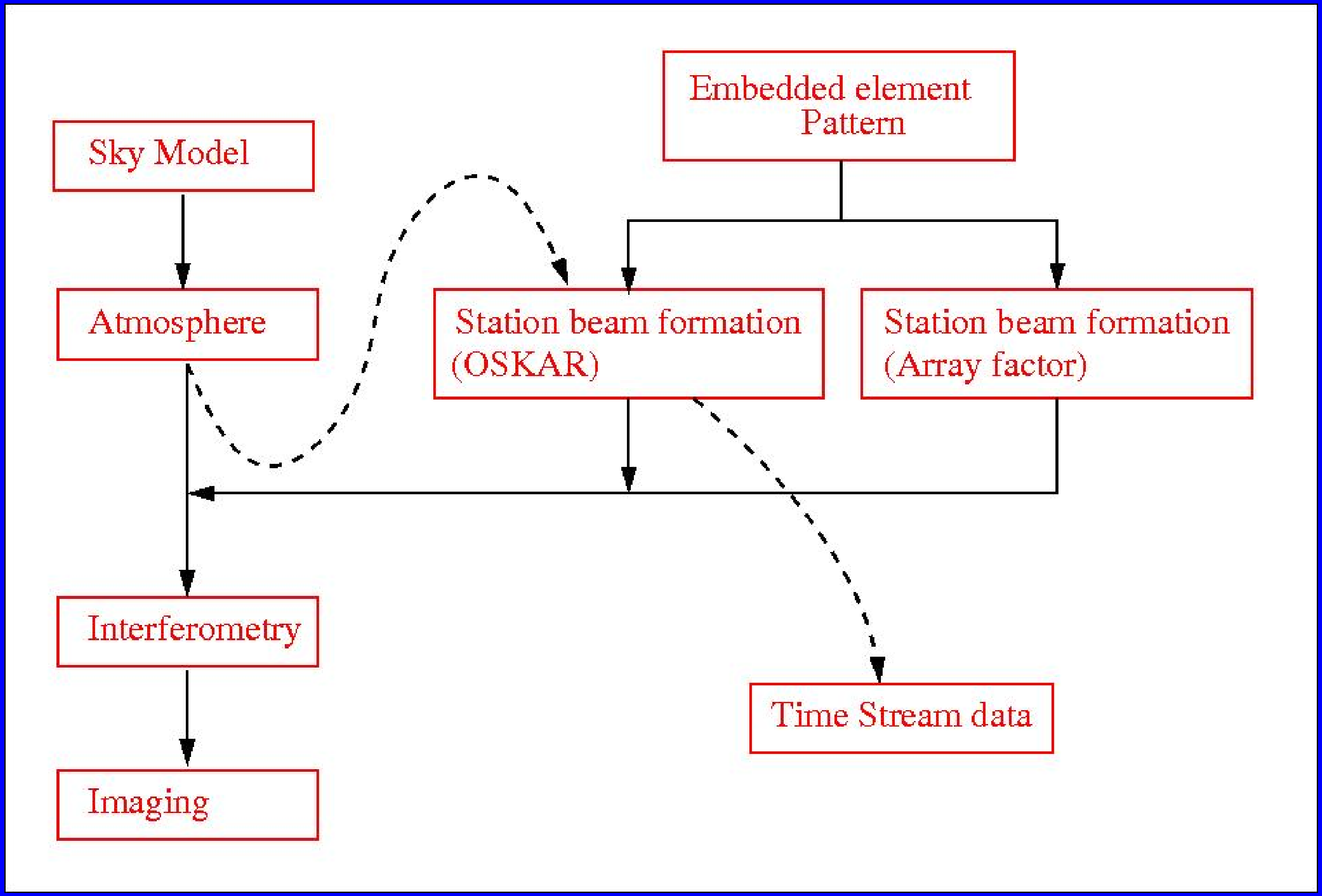
- An overall model for the calibration of the entire AA system.
- Investigate calibration requirements at all sub-system levels

— Provide feedback and comment on specs

Focus

- Phase I AA is the initial priority
- Also take forward Phase II considerations

SIMULATION OUTLINE



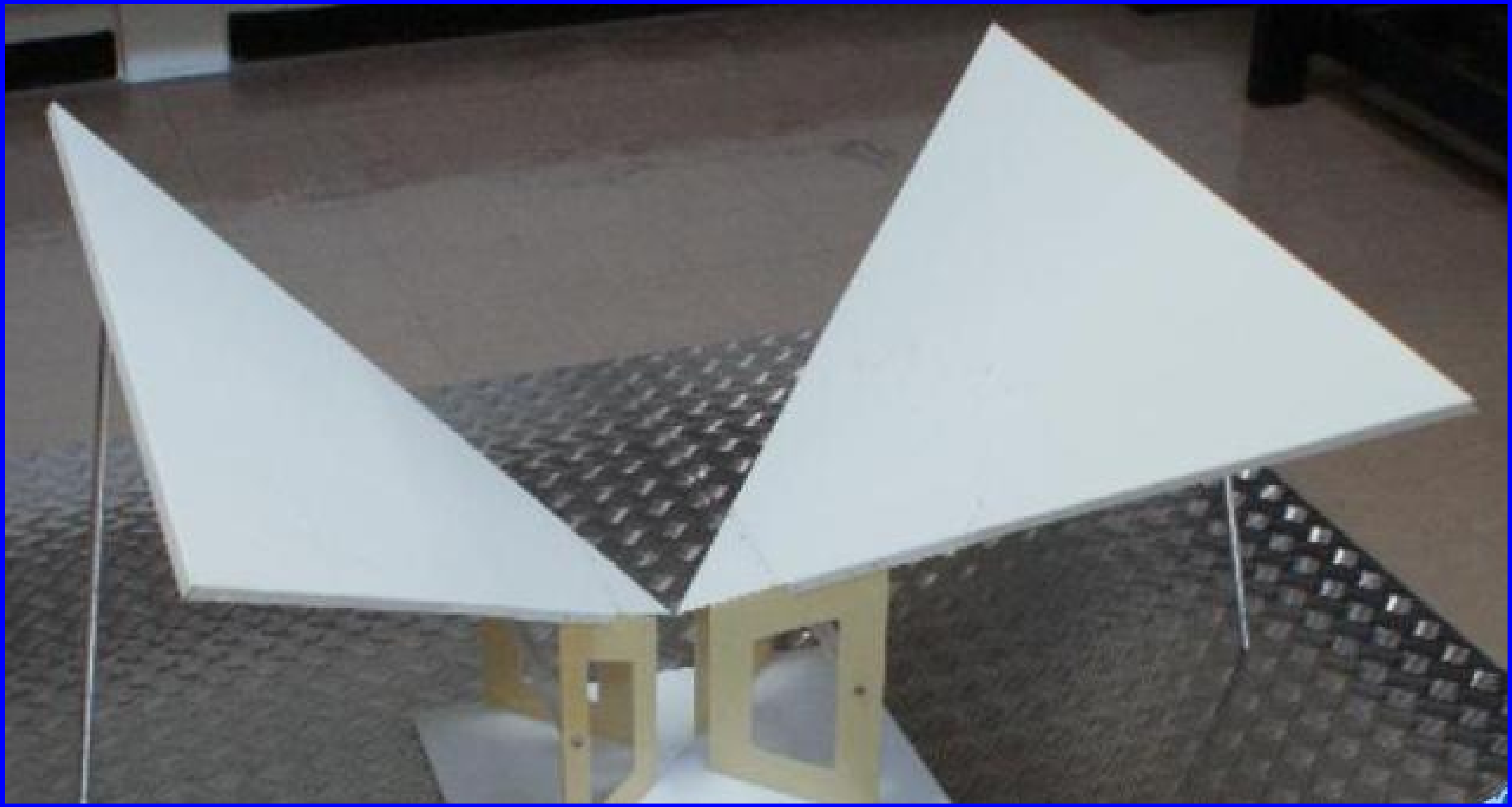
Sky Model

- Initially concentrate on total intensity
- Construct sky model through linear superposition from different contributions.
- Within inner area of primary beam put down Poisson sources according to radio source count
- Spherical harmonic representation of galaxy
- Bright sources in far sidelobes
- Consider effects of sources coming above horizon

Atmosphere

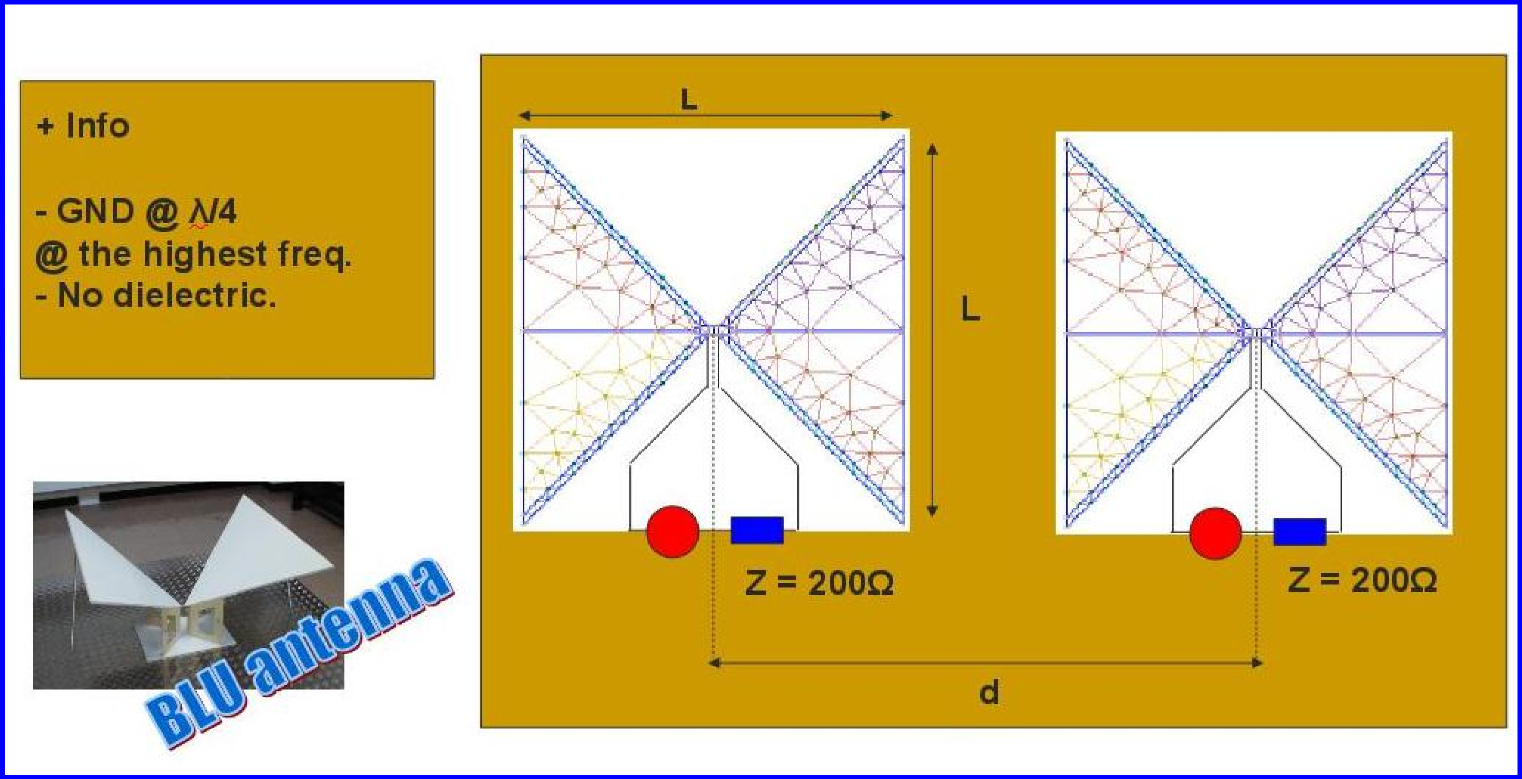
- Initially consider a simplistic model to account for ionosphere (A. Scaife)
- Function of time, geometry and frequency
- Antenna based phase screen
- Can be applied directly as a multiplicative factor to each station beam

ANTENNA ELEMENT: BLU ANTENNA



- Eloy de Lera Acedo and Nima Razavi-Ghods
- Bow-tie Low-frequency Ultra-wideband antenna
- 70–450 MHz
- Low profile and differential feeding
- Good matching at the high end of the band
- No dielectric

BOWTIE ELEMENT OPTIMISATION

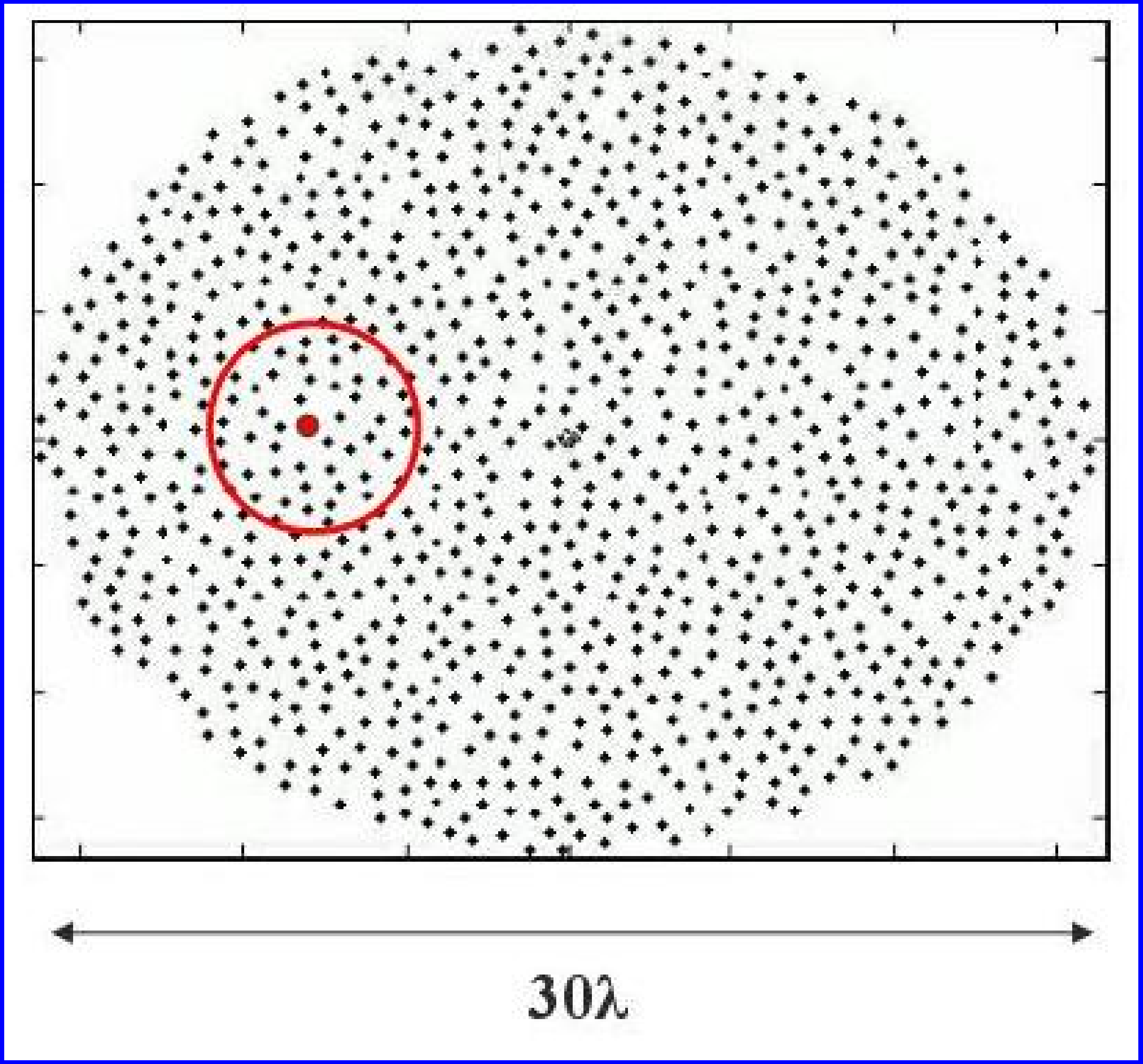


- Infinite array simulations
- Optimise bowtie sensitivity
  - — inter-element spacing
  - — antenna size
  - — arm tilt angle

ARRAY CHARACTERIZATION: EFFECTS OF COUPLING

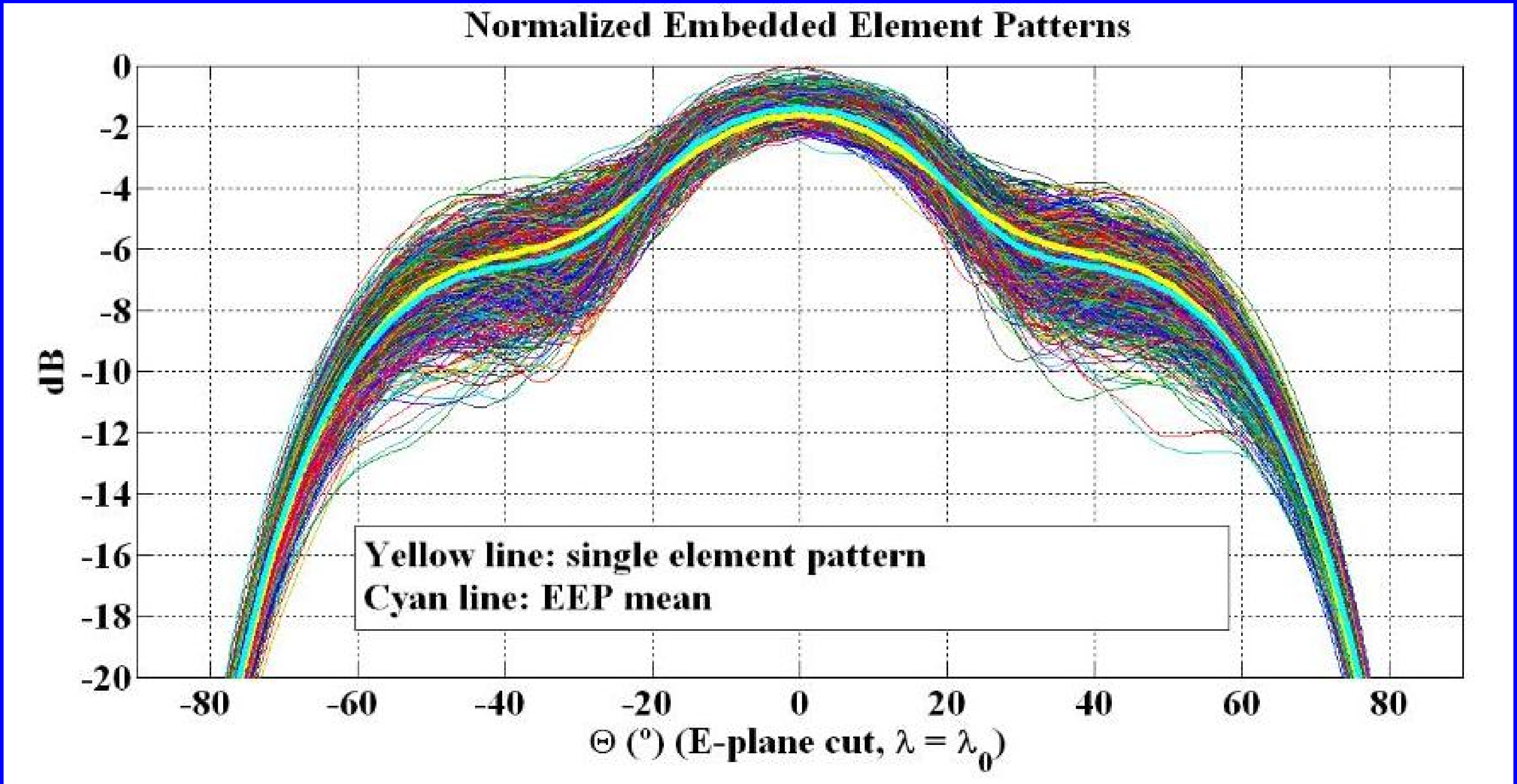
- Antenna elements very strongly coupled
- Simulation of coupling
  - — Uses compact set of macro basis function approach
  - — Issues: sparceness; configuration; frequency channel bandwidth; ...
  - — Collaboration with Christophe Craeye (UCL)

Array Characterization



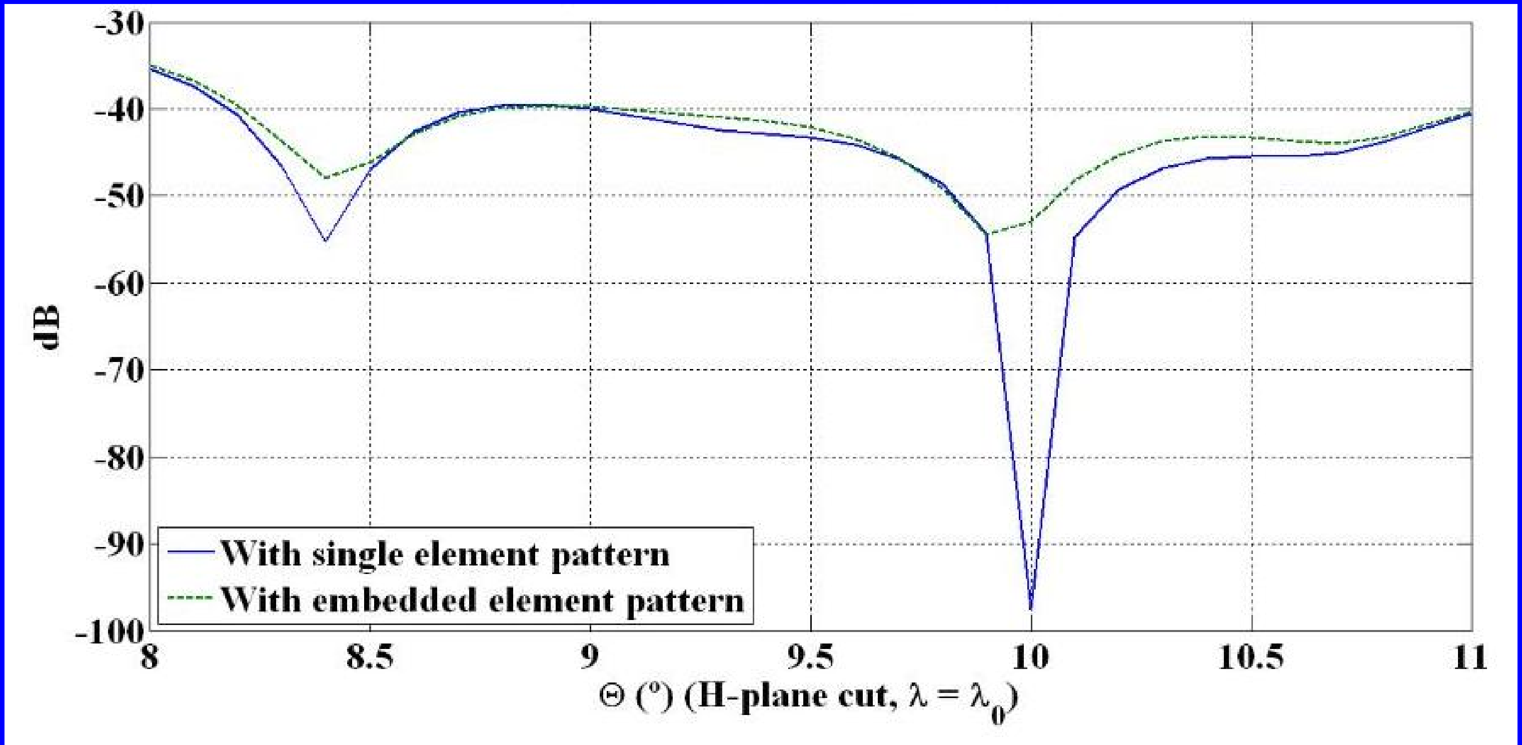
- Radius of influence approximation; interactions between MBF only within this region
- System solved for whole array using sparce matrix solver

EMBEDDED ELEMENT PATTERN

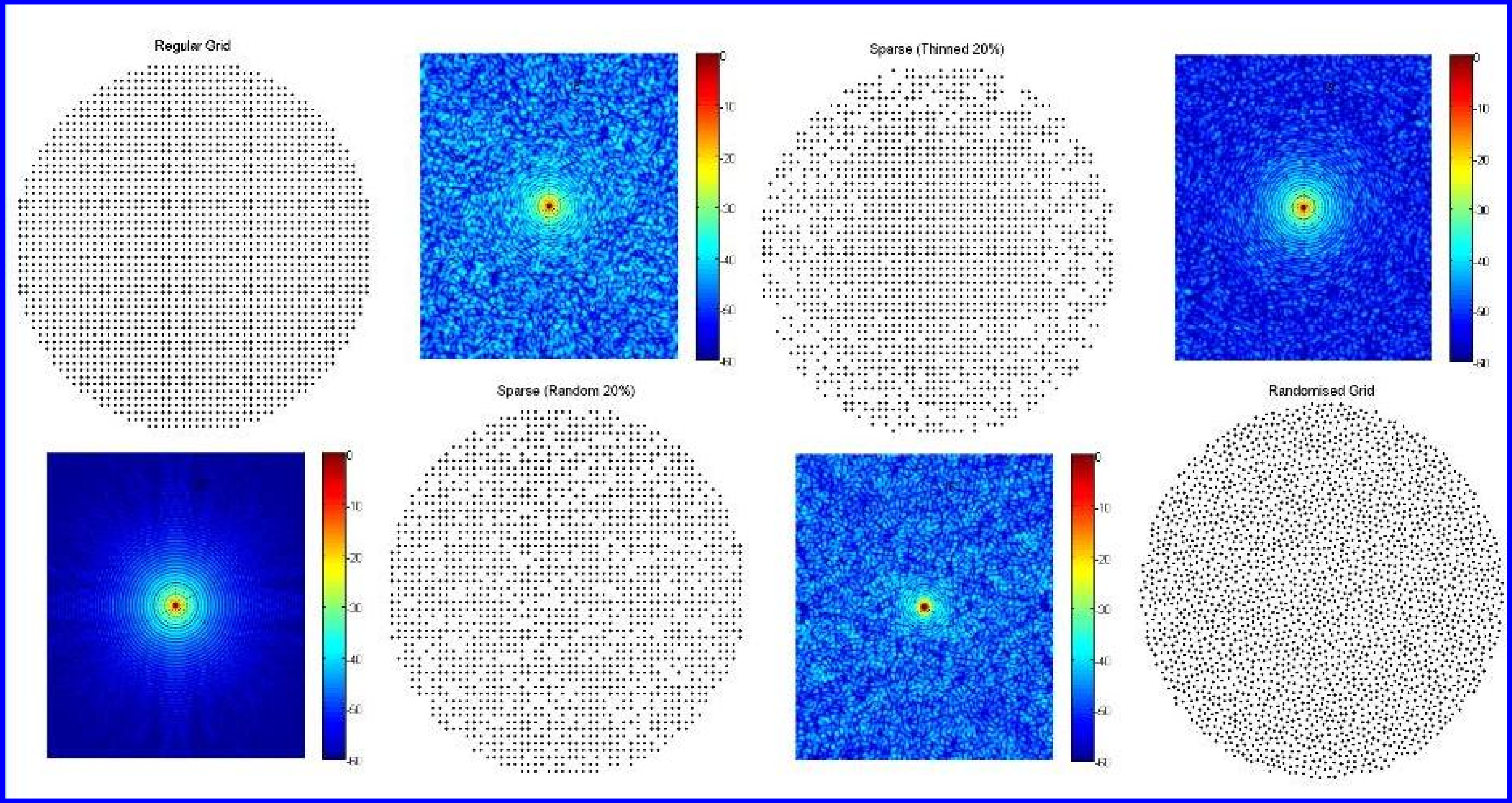


- 1000 elements
- 1 hour run time
- 1.5 GB contiguous memory

Effect of embedded element pattern



BEAM FORMATION: ARRAY FACTOR

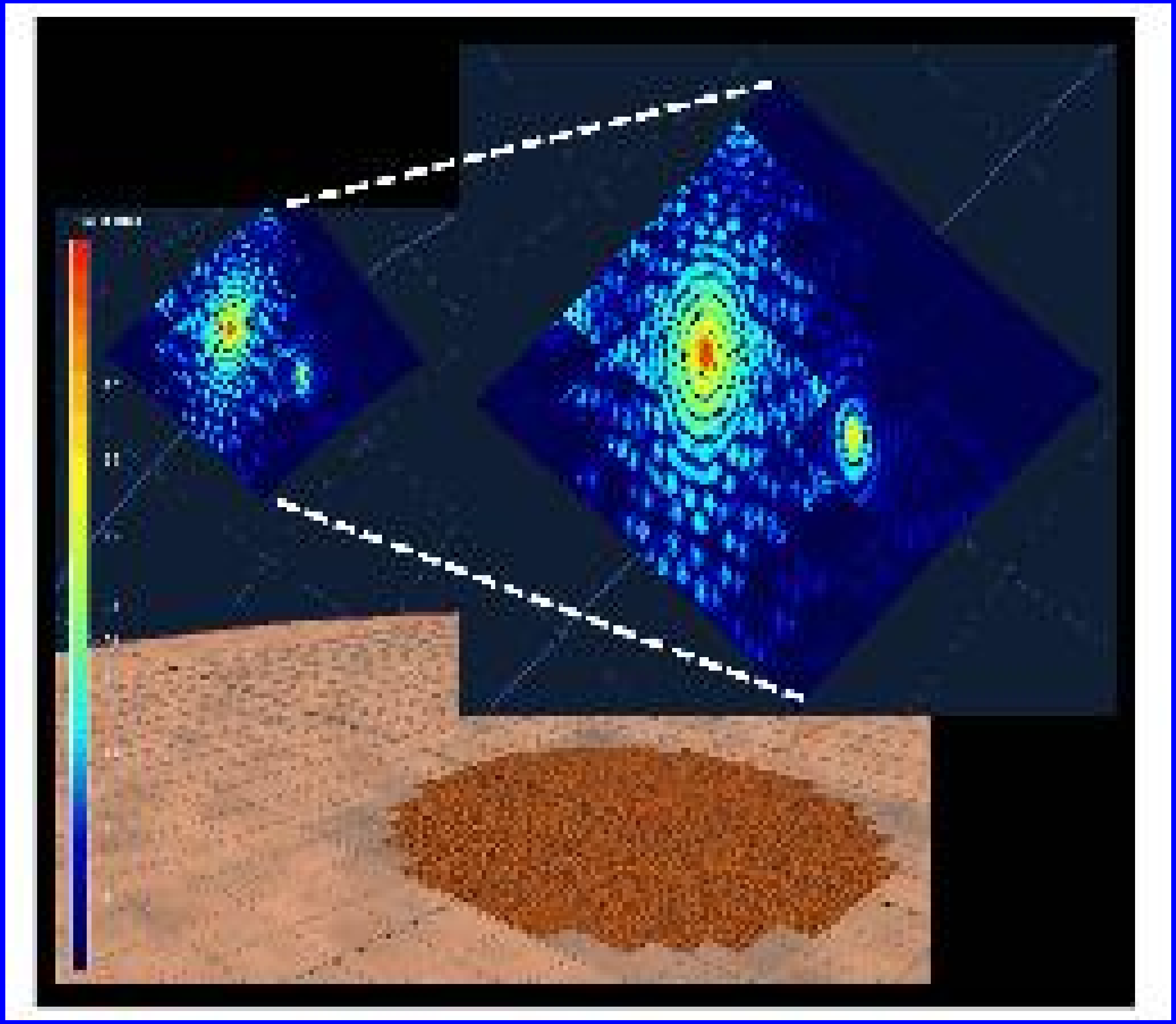


- Attempt to speed station beam simulation by considering Array Factor and mean embedded element pattern
- Array Factor: station configuration; convolutional gridding; FFT; interpolation.
- Interpolation of beams between different pointing directions and frequencies.

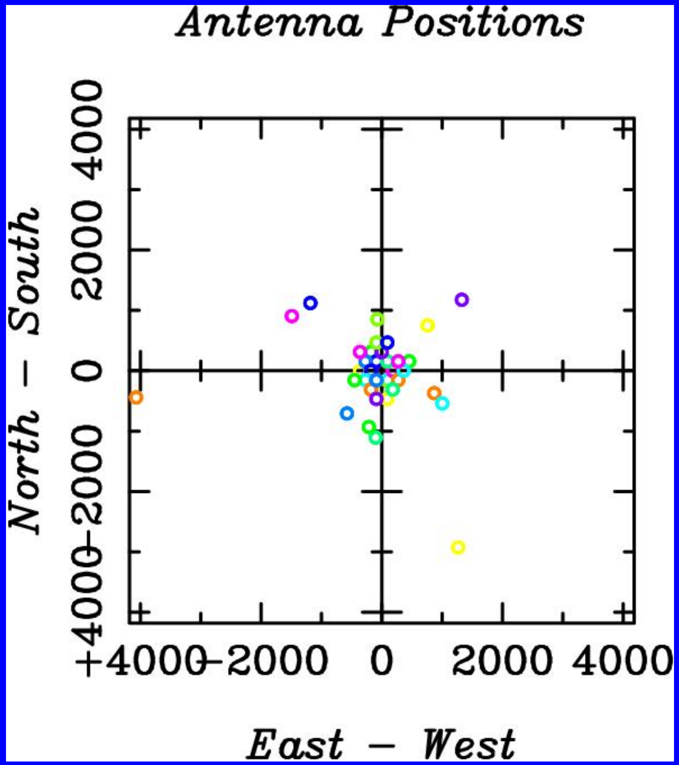
STATION BEAM FORMATION: OSKAR

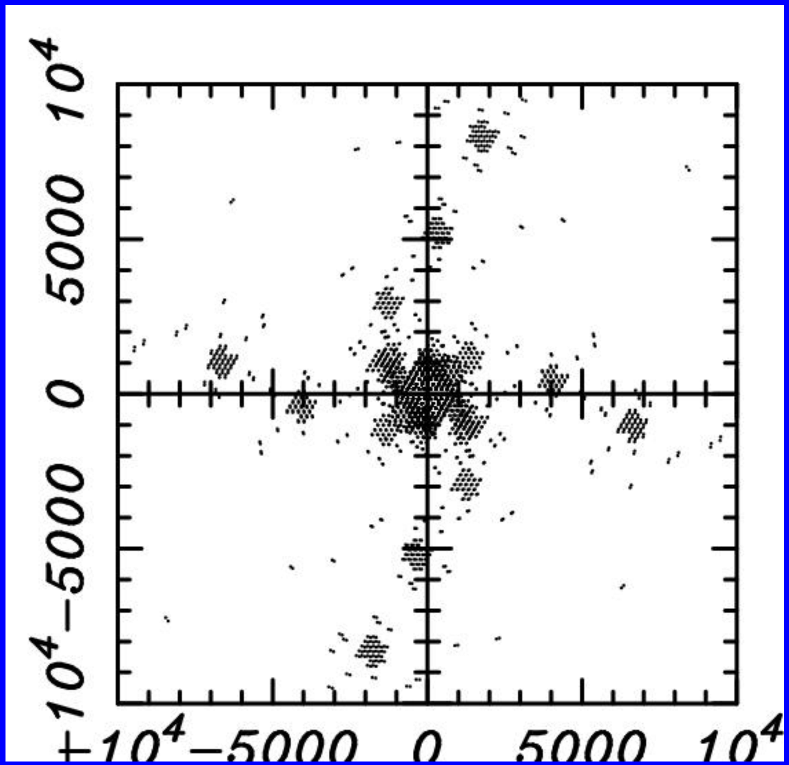
- Oxford OeRC: Stef Salvini, Ben Mort, Fred Dulwich
- A complementary beam forming analysis package
- A tool to investigate:
  - — hierarchical beam forming issues
  - — processing design structure
  - — digitisation issues
  - — weights during beam forming
- Has the capability of simulating station time stream data
- Adapt to import imbedded element patterns

STATION BEAM FORMATION: OSKAR



INTERFEROMETRY





- Input from sky model, atmosphere and station beam work here
- Initially concentrate on Phase I

— 50 stations around 300 MHz, compact configuration (R Bolton)

INTERFEROMETRY

- Wide field interferometry

— Formulate problem in wavelets basis (McEwen and Scaife 2009)

- Primary beam issues

— Each has different randomised element configuration

— Station beams change as track source across sky

⇒ Every baseline will have its own individual PB at each time step

— Convolve with aperture illumination function in transform space rather than multiplying by primary beam on sky?

- Apply ionospheric effects directly to station beams
- Apply time average and bandwidth smearing effects
- Add random noise to visibility (model for $T_{sys}(\nu)$)

Key Questions

What level of calibration is required at every stage?

- Goal: achieve 80 dB dynamic range
- Element level
  - — Physical accuracy of elements: size, shape, position and rotation
  - — LNA issues: variation over time and across station; loss of an element
  - — What magnitude is a negligable error in the analogue chain for gain and phase?
  - — Accumulation encompasses all electronic and temeperature effects
- Digitisation
  - — Required ENOB and ADC performance
  - — Filter performance and ADC sampling rate (aliasing)
- Beam formation
  - — Element coupling effects
  - — Bandpass changes
  - — Sample bit count at various stages through processing chain

KEY QUESTIONS (CONTINUED)

- What minimum system level does calibration need to done to?

  — Element? Tile? Station?

- Is calibration specific hardware e.g. noise source required?

- Is overall calibration problem computationally tractable?

→ Address with a combination of simulation and theory and testing against measurement

  — Scaled BLU array at 1.4–9 GHz

- What part does polarisation performance have on dynamic range (wide field issues)