Xarray and Aperture Array Optimisations

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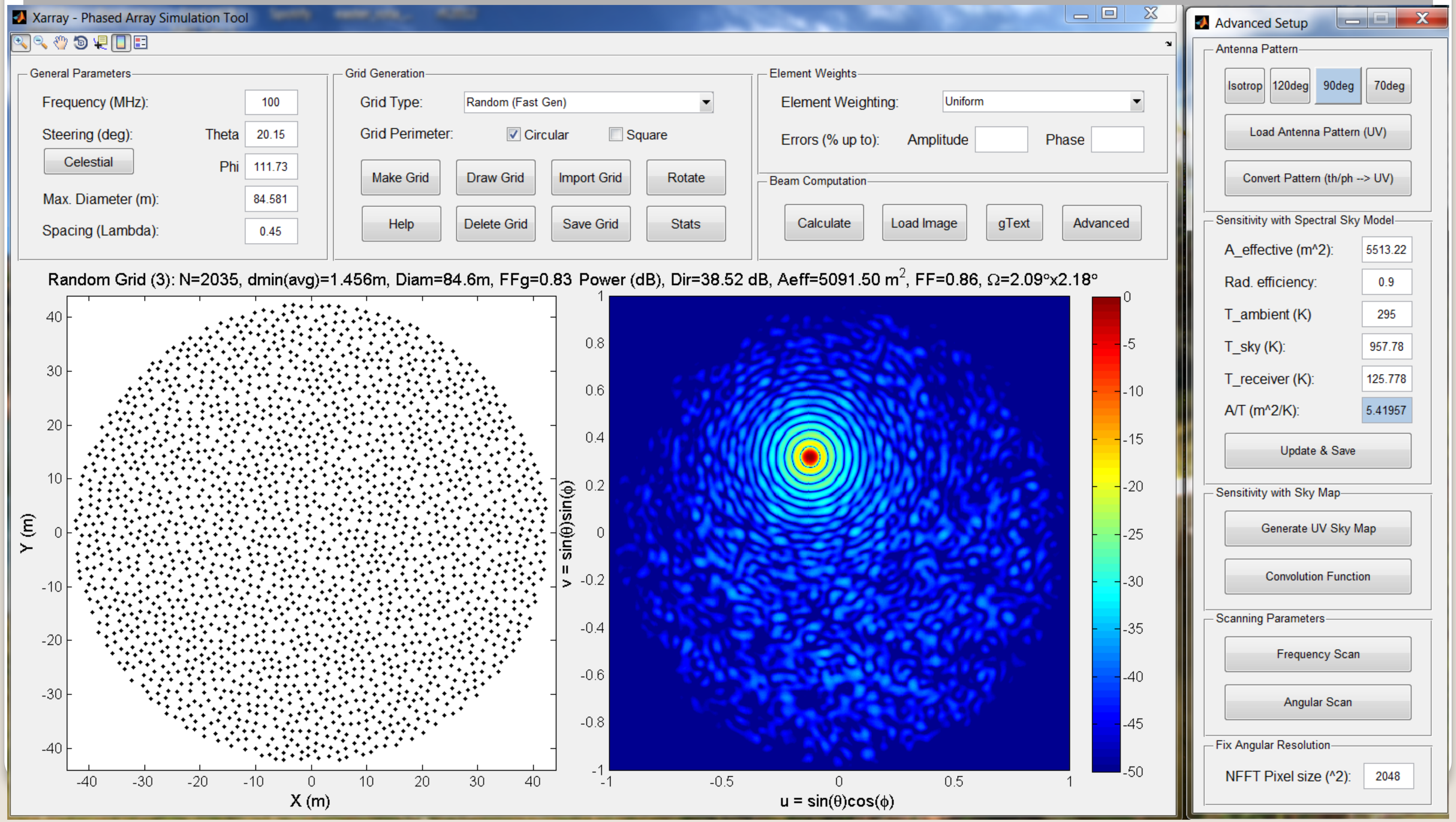
Overview

- AA Configuration design space
- Xarray phased array simulator
- Optimisation Strategy (Thibault Clavier)
- Simulation Efforts
- Future work

Configuration design space

- Sensitivity
  - Depends on diameter, number of elements, and their configuration
- Beam-width (Calibration)
  - We can increase this by either reducing station size or using a tapering function but at the cost of A/T
- Side lobes (Noise suppression)
  - We can reduce this by tapering and irregular configurations like GRS
- Filling Factor (one used figure of merit)

- Xarray - Fast station-level phased array simulator/optimiser based on an irregular 2D-FFT implementation



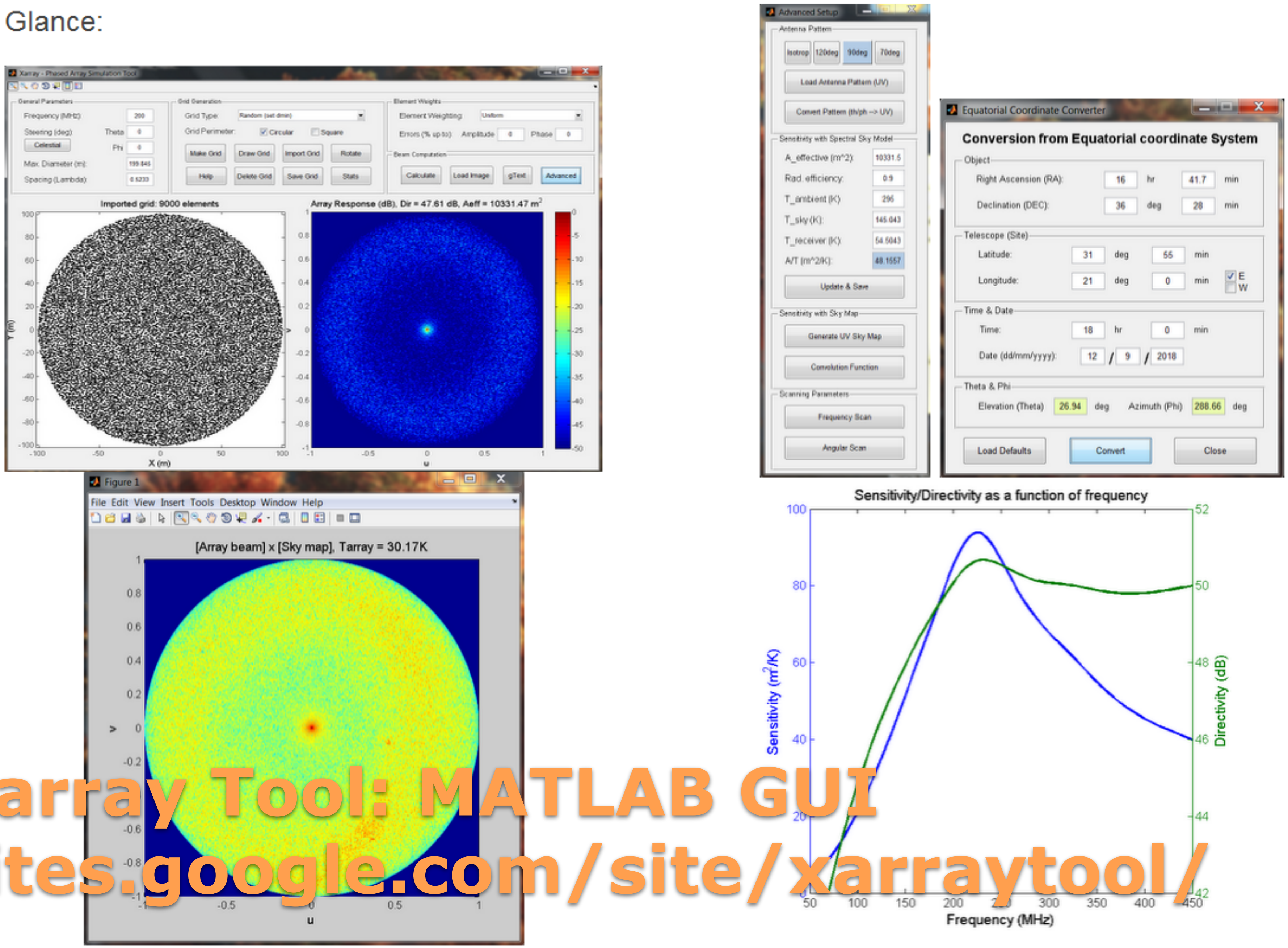
Xarray input parameters

- General parameters: design frequency, steering (spherical or equatorial coordinates), diameter, inter-element spacing
- Type of arrays: regular/triangular, thinned, sparse, concentric rings, random (3 types), golden ratio spirals, spatial tapering
- Grid features: import any, draw/edit, rotation (gradual or full)
- Element weighting: Gaussian, Dolph-Chebyshev, Taylor, percentage errors (amplitude and/or phase)
- Element type: import any embedded pattern, hemispherical, 120°, 90°, 70°

- Scanning in frequency or angle assuming flat or realistic sky brightness distribution (scaled version of Haslam 408MHz map)
- Beam output in FITS format
- Stored parameters: Directivity/Aeff, Tsys, A/T, filling factor, beamwidths, max and mean sidelobe level
- Statistics of XY configuration
- Optimisation parameters (coming soon)
- Beam modelling parameters (future work)

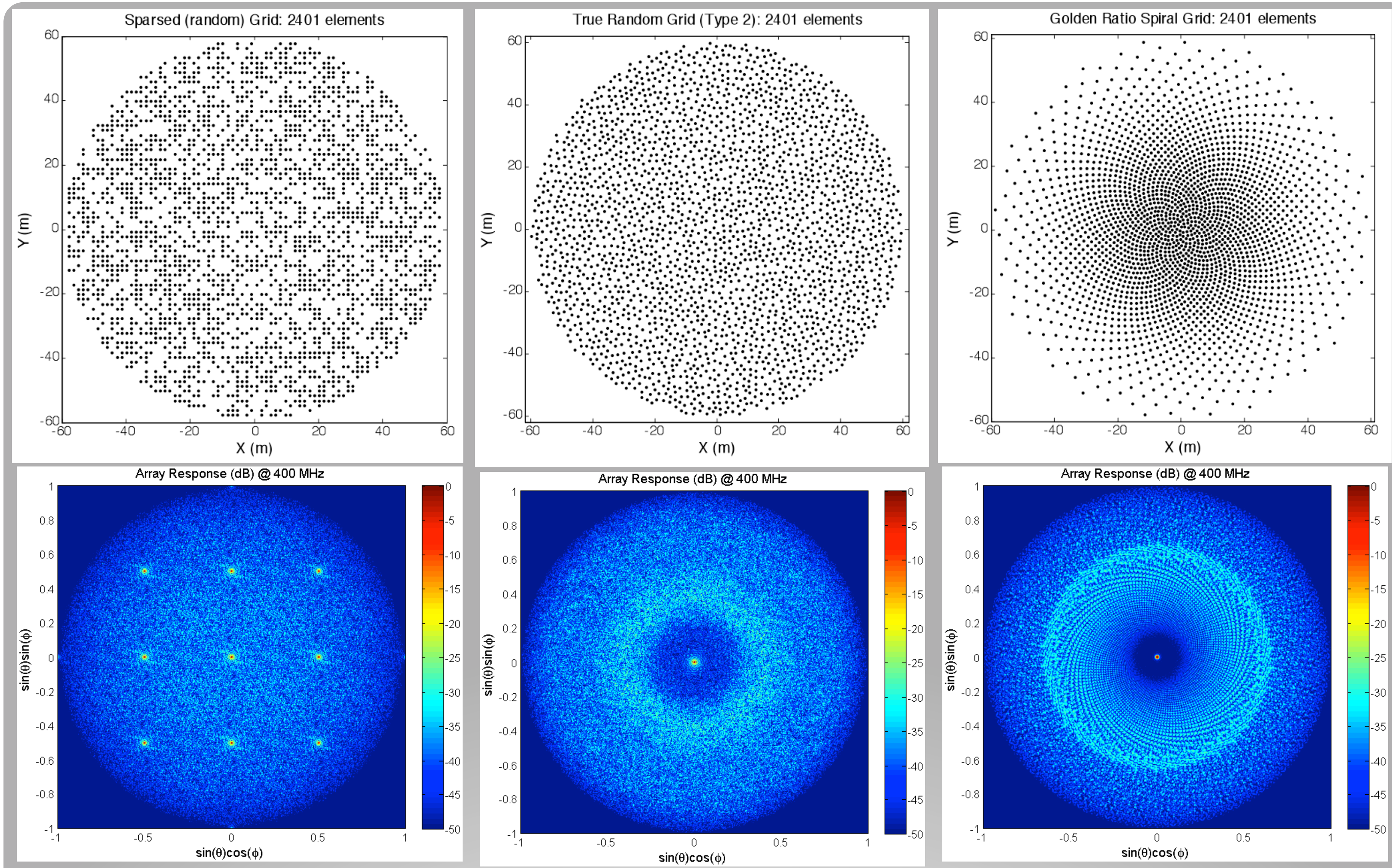
Xarray output parameters

Xarray at a Glance:

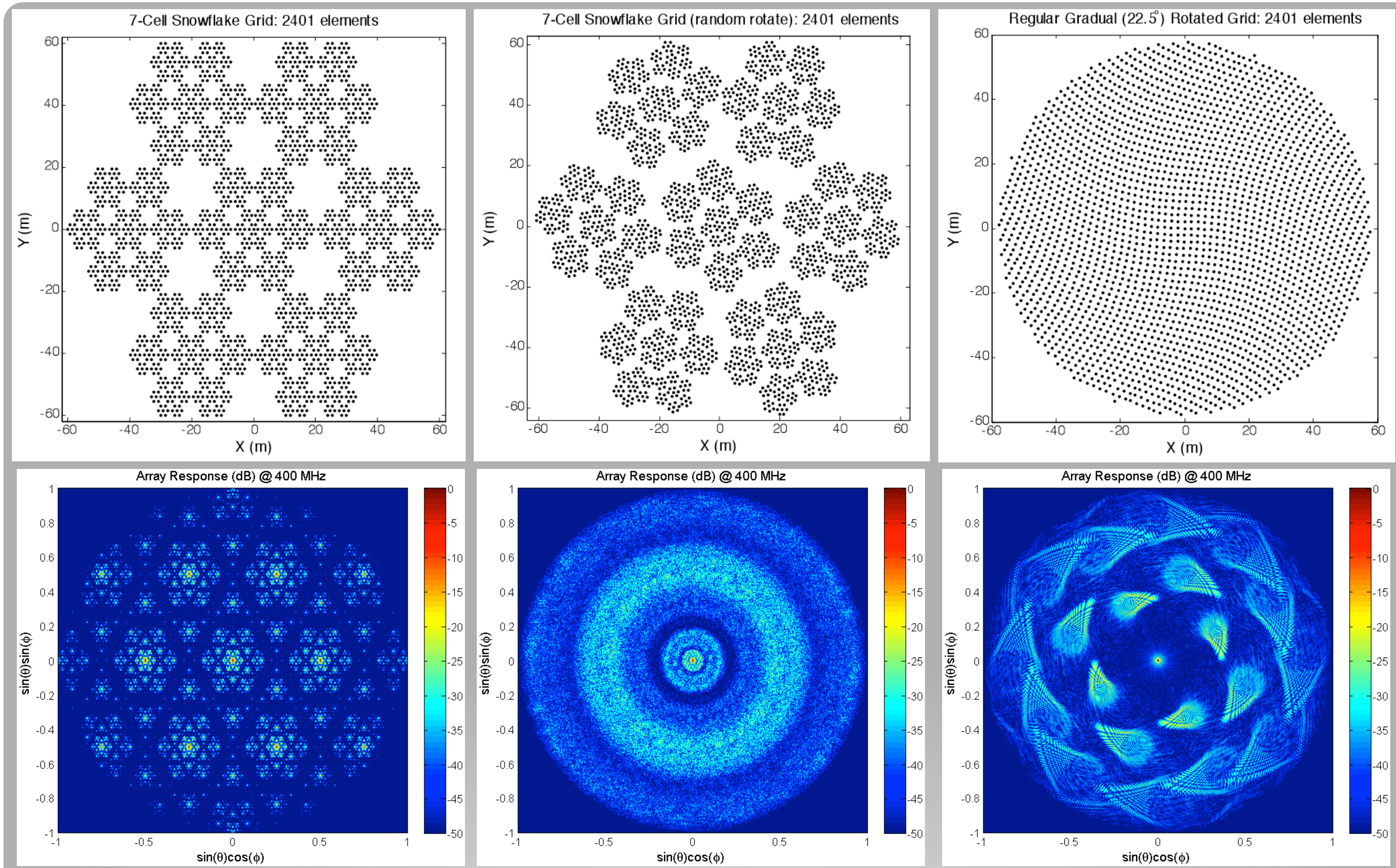


Xarray Tool: MATLAB GUI

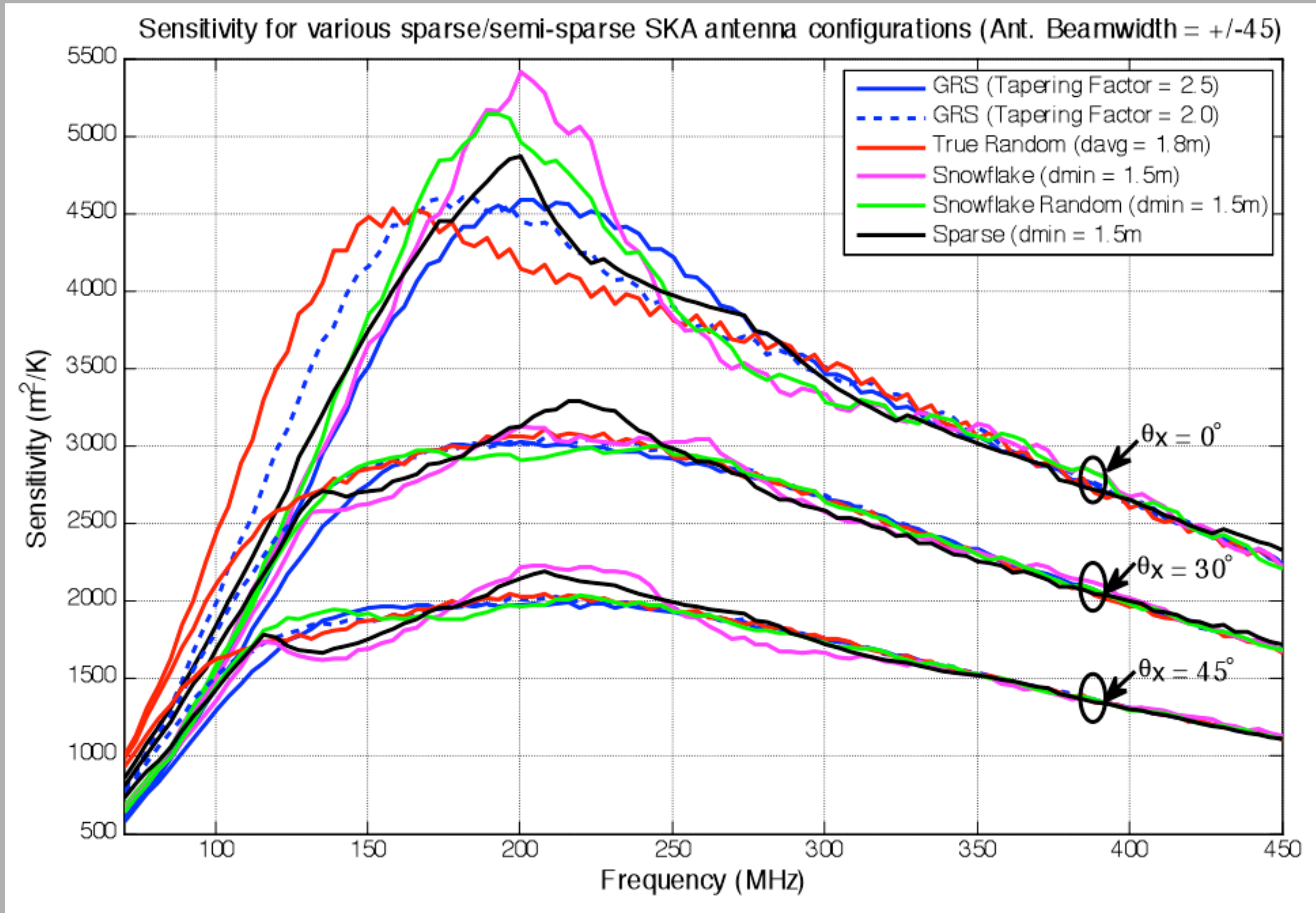
sites.google.com/site/xarraytool/



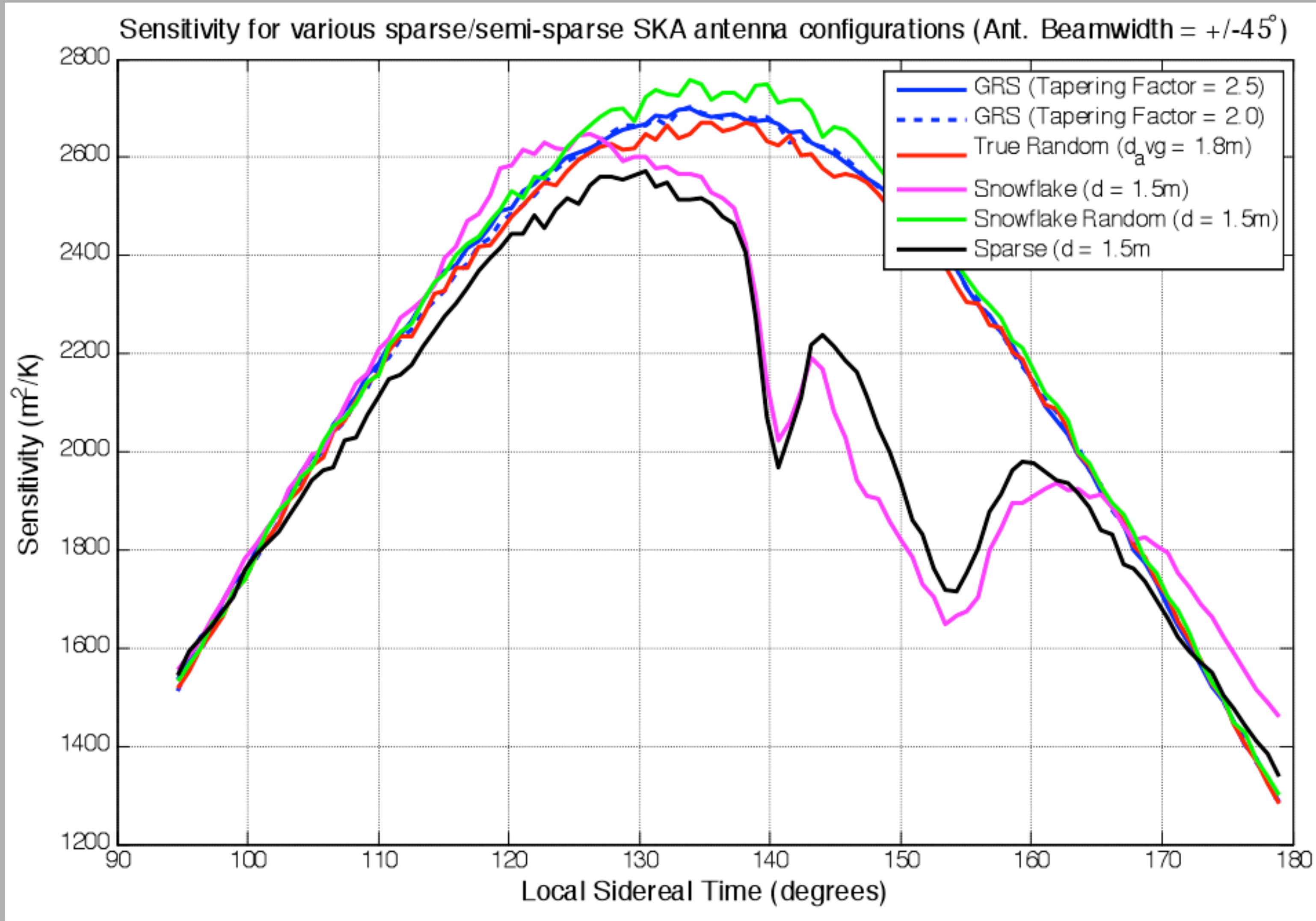
Possible Geometries for AA-Low



Possible Geometries for AA-Low



Example: A_{eff}/T_{sys}

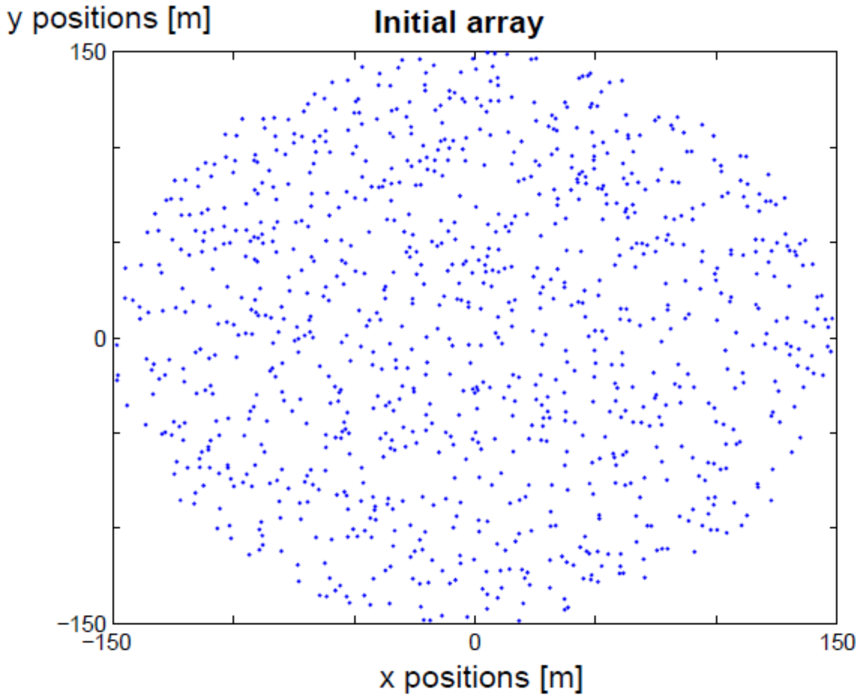


Example: A_{eff}/T_{sys} vs. scan

AA element optimisation

by Thibault Clavier

The Master's Thesis focusses on the design of one station



The random array is a possible configuration

Question	How to modify the positioning of a given array to improve its performance ?

The objective is to minimize a weighting of the side lobes

Constraints	Main beam width is fixed to w_{mb}
	Minimal distance between antennas is δ

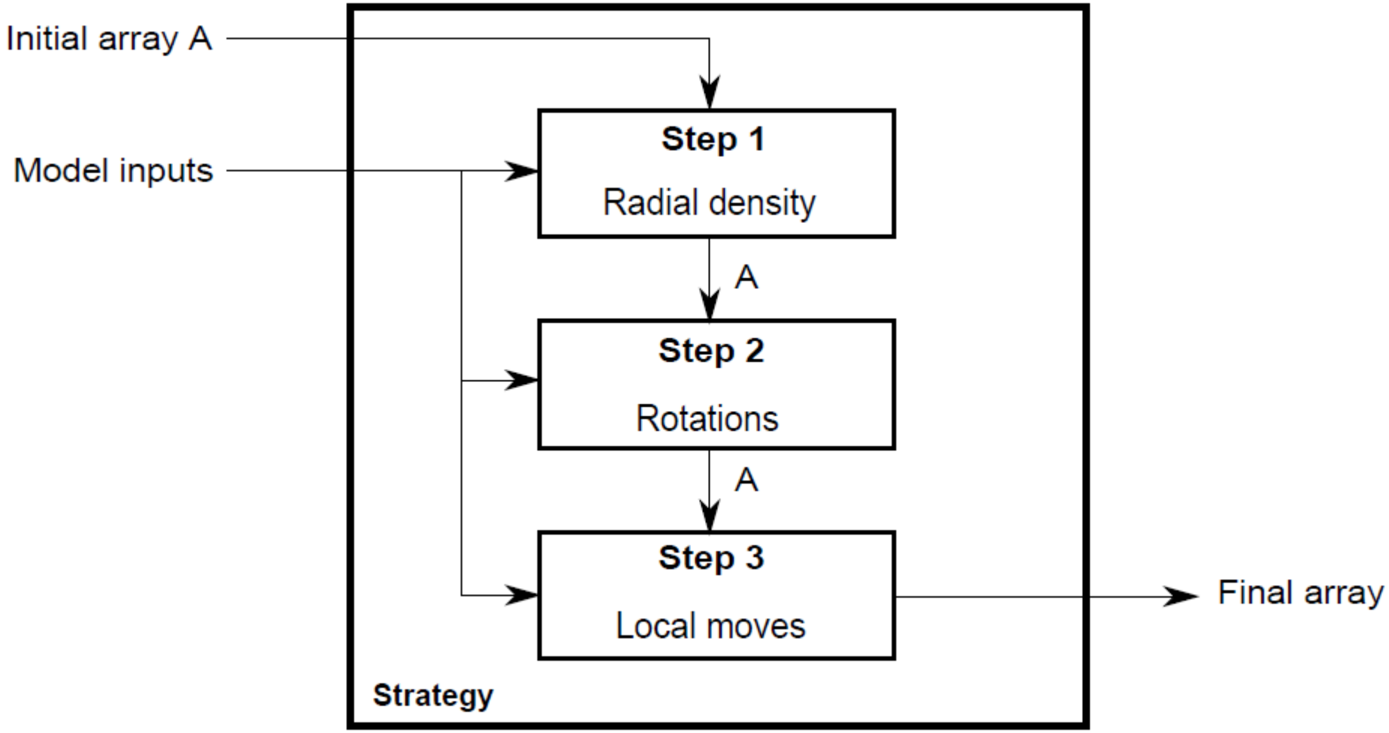
Cost function

$$\min_{x_n, y_n} \left[\int_{\mathcal{U}} \left(W_e(u_x, u_y) \, |R_A(u_x, u_y)|^2 \right)^p du_x \, du_y \right]^{1/p}$$

where p measures the importance of high peaks
W_e is a weight function on $\mathcal{U}$

- Use l_p norm to optimise for a defined array and interferometric weighting function W_e

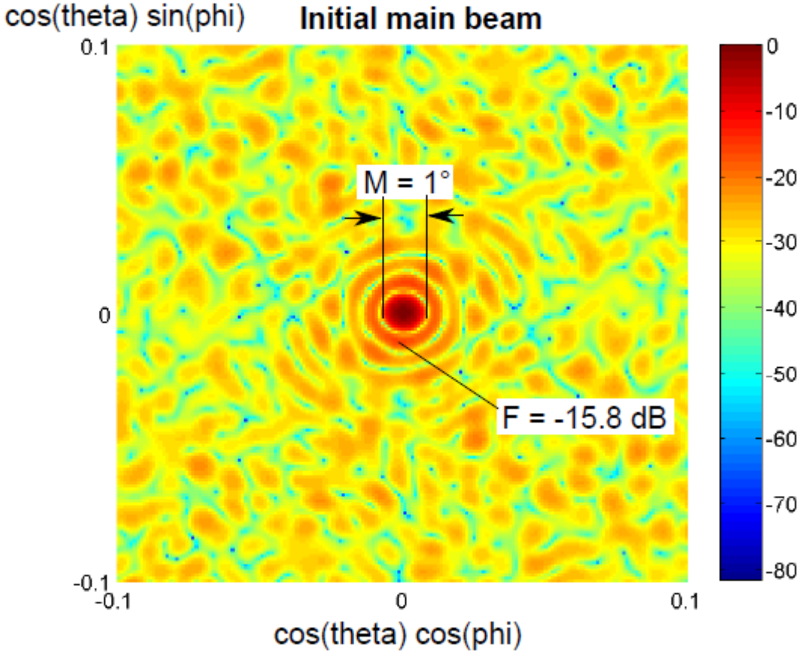
The optimization strategy consists of three steps

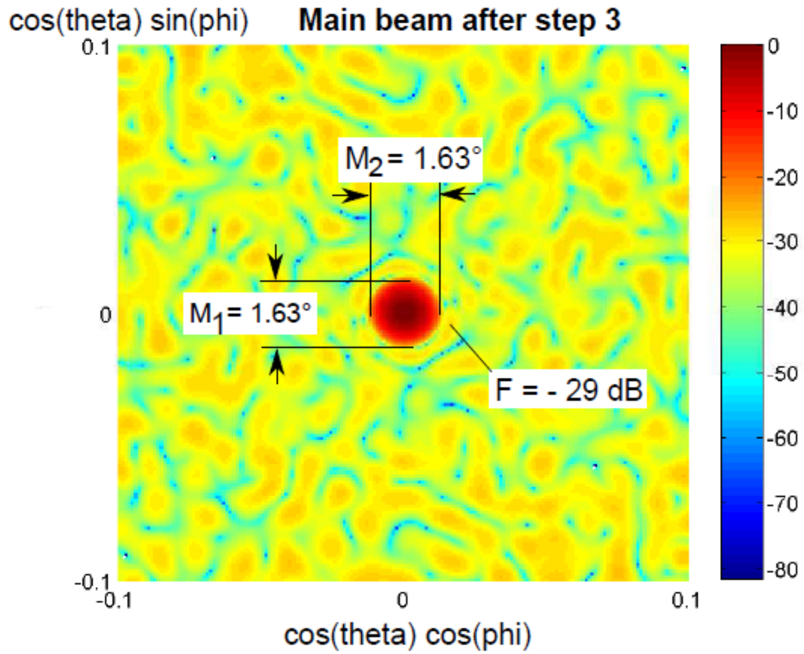


The model inputs are the required main beam width w_{mb}, the minimal separation δ, the parameters p and e

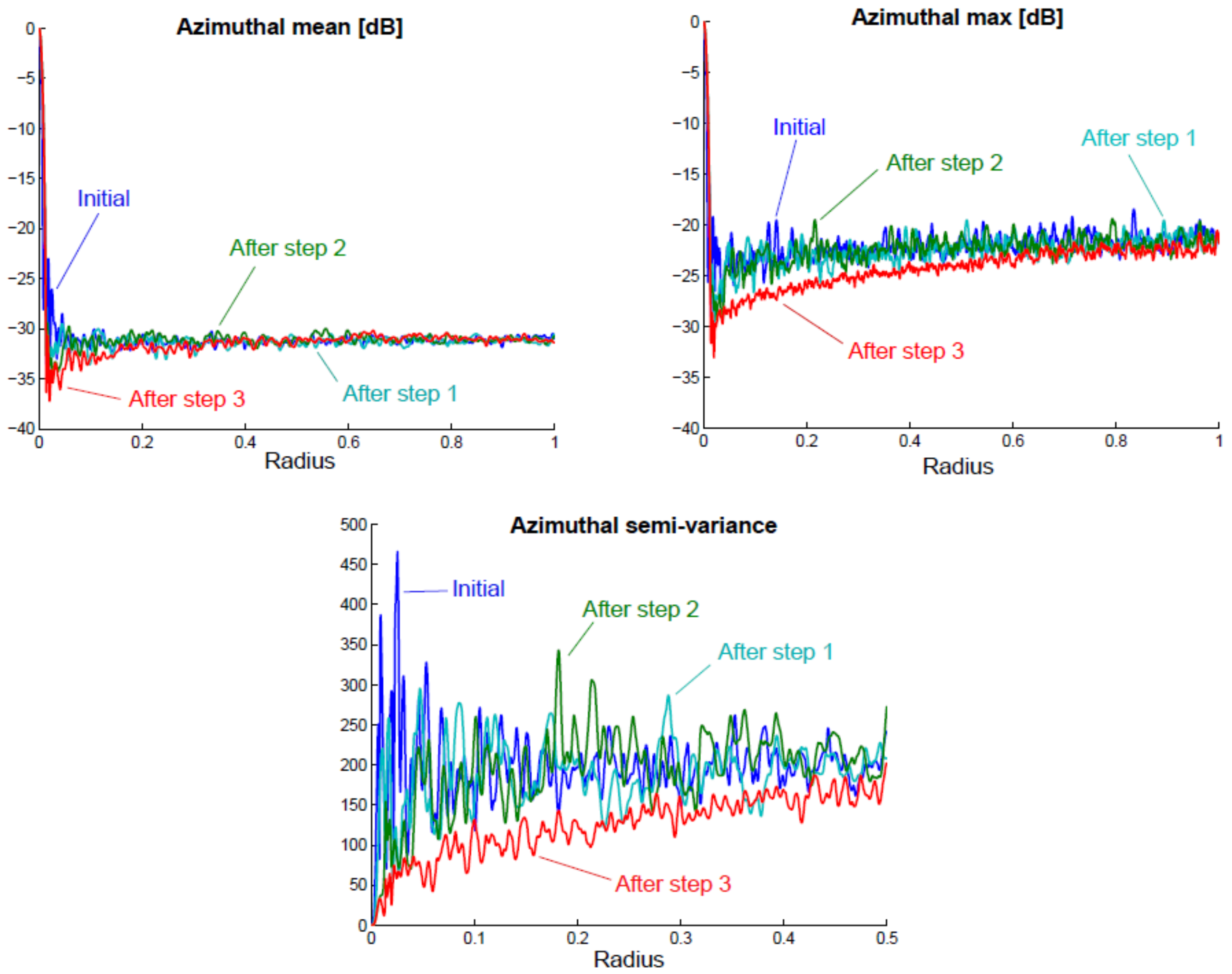
The main beam width is morphed

$$w_{mb} = 1.64^\circ$$





The statistics show a marked improvement on the side lobes



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- MBF-MOM (element and station level characterisation)
- Xarray (station level)
- AA optimiser (station + interferometric level)
- OSKAR2 (interferometric level)

Still to come…

- Comparison tools to be developed: figures of merit need to be defined and an assessments carried out.
- How does this link with calibration assessment?

AA simulation effort

Hard questions

- What is defined by a "good" station beam
  - Define better metrics!
  - Fix beamwidth, low sidelobe or localised sidelobes through optimisation
  - How calibratible is it?
- High FF core station design: ~850m sea of elements and their practical considerations (how to change elements, paths through elements, physical perimeters and coupling between elements)

- Define a useful programme for station beam optimisation – work with UCL
- Update Xarray to incorporate compact representations of main beam and first few sidelobes.
- Utilise more accurate simulations of the station beam based on MBF approach (collaboration with UCL)
- Use computational framework for SKA simulator (OSKAR2) to evaluate antenna configurations and develop comparison tool (ongoing work with Oxford)

Future work and collaborations

Thank You.