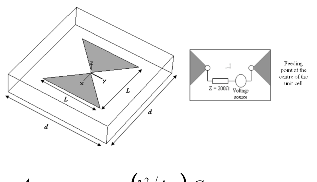
SKA-AAlo design study and simulation tool

The SKA relies on the use of very large phased array antennas. Furthermore, the SKA community is considering the use of non-periodic sparse configurations instead of the classical regular arrays to cover the sub 500 MHz band. The University of Cambridge is working towards the design of a sparse array of bow tie antenna elements to cover the SKA-AAlo band (70-450 MHz). The noise and sensitivity analysis of the unit cell of a periodic array have resulted in the design of an ultra-wideband element, the BLU antenna[1]. Studies of array configurations have been made in order to understand the effect of the array grid in the noise of the system, and therefore in its sensitivity[2]. A simulation tool is proposed to reduce the computational cost associated to solve the full EM problem in such arrays[3].

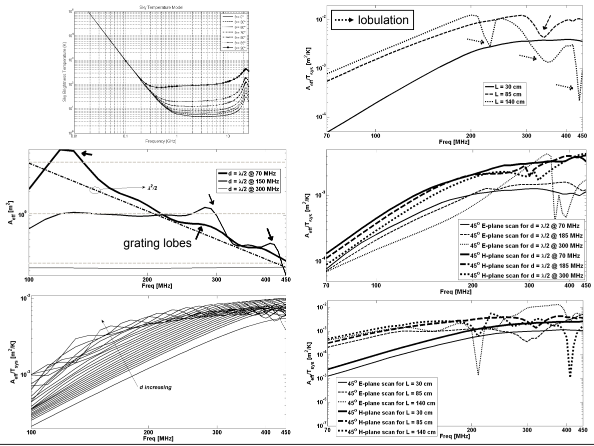
1 Sparse arrays and the BLU antenna



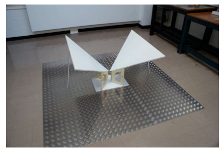
$$\frac{A_{eff}}{T_{sys}} = \frac{\left(\lambda^2/4\pi\right) G_{cell}}{\eta_{rad} \cdot T_{sky} + \left(1-\eta_{rad}\right) \cdot T_{amb} + T_{LNA}}$$

Idealized amplifier parameters

F_{min}	R_n	Z_{opt}	Z_{amp}
0.2	10 Ω	200 Ω	200 Ω



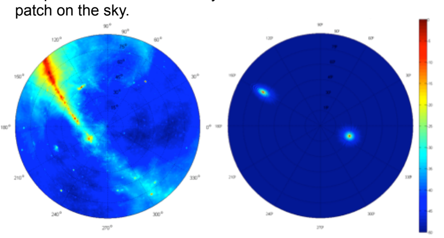
BLU antenna
(*Bow-tie Low-Frequency Ultra-wideband antenna*)



- Sparser arrays (large *d*) show a better sensitivity across the band, due to the influence of the Sky noise at lower frequencies.
- Larger elements suffer from the presence of multiple lobes, affecting the sensitivity. The reduction in sensitivity for a smaller element can be compensated by using more elements or larger spacing distances *d*.
- Tilting the arms of the antenna reduces the system noise (Improved antenna impedance across the band) – results not shown –.
- A design covering the SKA-AAlo with a scan range of +/- 45° is achieved.

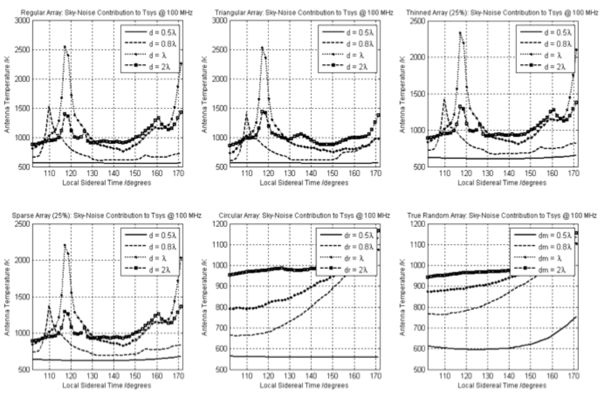
2 SKA-AAlo non-regular grids and real sky contribution to T_{sys}

Array factor based simulations were also carried out to analyse the real sky contribution to system temperature for various AA-lo antenna configurations composed of 10,000 elements. Six potential geometries were evaluated (regular, triangular, sparse random, thinned, circular, and fully random), with four minimum inter-element separations of 0.5λ, 0.8λ, 1λ, and 2λ. Array Temperature was then analysed as the beam tracked a cold patch on the sky.



Sky (Haslam) Lat = 28.59S, Long = 115.45E Date: 01/01/2020, Time 19.33h

Triangular Lattice Beam 10,000 elements, d = 0.8λ

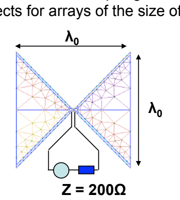


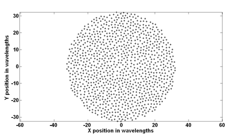
As expected, the results were fairly dependant on the region been scanned. Here it is apparent that grating lobes play a significant role for any arrays with a regular structure and in this category, the simulations showed the 1λ arrays were worst than 2λ. Although the positions of the grating lobes corresponded, their beam-width did not, leading to a much wider beam pointed to the galactic plane for the 1λ case.

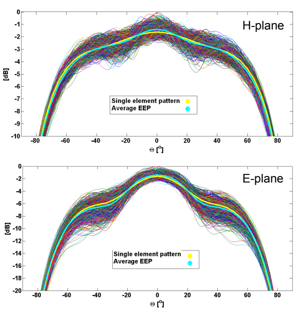
However, both circular and random arrays performed much better at larger spacings.

3 SKA-AAlo simulation tool

- Based on Method of Moments + MBFs (CBFs) and the interpolation technique presented in [1] by D. González-Ovejero and C. Craeye, where the computation of interactions between MBFs is carried out by interpolating exact data obtained on a simple grid. It will allow us to study specific non-regular configurations including all mutual coupling effects for arrays of the size of an SKA-AAlo station (>10,000 elements). More about the method in [2].







- The example on the left is for a 1,000 elements circular random array. The plots show the embedded element patterns.
- The current specifications of the software for a standard laptop are:
  - Pre-process (computing data to interpolate): 37 min.
  - Computing 1,000 EEPs: 1000x36 s = 10h (if all the EEPs are needed).
  - Only 17.8 MB of contiguous memory is required.
  - Sparse matrices: Simulation time reduced to 1h.
  - Requires more contiguous memory: 1.77 GB

[1] D. González-Ovejero and C. Craeye, "Fast computation of Macro Basis Functions interactions in non-uniform arrays," in Proc. IEEE AP-S Soc. Int. Symp., San Diego, CA, Jul. 2008.
[2] D. González-Ovejero, E. de Lera Acedo, N. Razavi-Ghods, and C. Craeye, "Fast mbf based method for large random array characterization," in Proc. IEEE AP-S Soc. Int. Symp., APS-URSI'09, North Charleston, SC, 1-5 June 2009.

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SEVENTH FRAMEWORK PROGRAMME

PrepSKA SQUARE KILOMETRE ARRAY

CAVENDISH ASTROPHYSICS

UNIVERSITY OF CAMBRIDGE