CSIRO - Australia Telescope National Facility

Some general antenna considerations for LF-SKA, and why the "magic-carpet" concept could be a "dingo".

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11 February 1999

1. *Introduction*

In this discussion document, the antenna principles underpinning some of the concepts discussed in Ref 1 for the LF-SKA are extended to illustrate the potential difficulty of achieving constant collecting area, and hence the practical realisation of the "magic-carpet" concept. Applications to the "randomised" antenna-element approach to array-station design, and the trade-offs that need to be considered, are briefly discussed.

2. *Some Basic principles (see also Ref 1):*

For LF-SKA, the astronomers are calling for:

a) Constant collecting area (10^6 m^2)

b) Constant sky viewing angle (100°)

c) Wideband coverage (10:1), say 150-1500 MHz

d) Dual polarisation

It has been generally assumed that these desires can be achieved through the use of some form of planar-array (or "magic-carpet"). Because antenna engineers see such a concept as out-of-the-ordinary, a compromise solution which could satisfy (b), (c) and (d), but not (a) was proposed to stimulate thought and discussion (See Ref 1). In this reference, a particular element performance (gain 10dB, beamwidth (HPBW) 55°) was chosen to illustrate the compromise between instantaneous sky-coverage and number of antenna elements, together with the mean sidelobe level for an array-station when the elements are arranged in a "randomised" fashion. The characteristics of the antenna element used in this first study has now been extended by considering antenna elements of different gain, and hence HPBW; see Table 1. (Note: Ae is the effective collecting area of a single element). The highest-gain element corresponds to the one used in the first study. This element and the one with an HPBW of 75° would need to be mechanically steered to meet the specification (b). The lowest gain element having a symmetric pattern (HPBW 100°) would not need to be steered, and would be a candidate for the "magic-carpet". (How one realises such an antenna with a 10:1 bandwidth and dual-polarisation is another question).

3. *The "Magic-carpet" concept:*

This leads us to the "magic-carpet" concept, which is interpreted to mean a planar surface, which has a constant absorbing collecting area, constant (primary element) sky viewing angle and wideband coverage, ie it meets all the astronomers' desires (a) to (d) above.

Let us consider an element, which meets the 100° HPBW criterion across the 10:1 frequency band. To be "carpet-like" the elements should be spaced approximately $\lambda/2$ at the maximum frequency. This alone will put severe restrictions on the element size and its overall performance. As the frequency decreases, the element spacing (in wavelengths) reduces, and all the horrific effects that antenna array engineers quietly warn us about come into play. Incidentally, these deleterious effects actually probably help to maintain constant collecting area (albeit with very low efficiency!).

I think this illustrates that the concept of the "magic-carpet" could well be a "dingo".

4. Design factors for a "randomised" element configuration for the Array-station

If we revert to using "randomised isolated" elements for the array-station (see also Ref.1) Table 1 can be used as input into a design optimisation study which considers the following key factors:

- Trade-off between number of elements per array station and the instantaneous sky-coverage, including costs for antennas, LNA etc, time-delaying system, and any associated mechanical drives;
- Consideration of the impact on cost and performance of breaking an array-station into a number of "concentrators".

5. Conclusion

It would appear that 3 out of the 4 astronomers' desires could be met by using "randomised" widely spaced elements. The elements should have constant beamwidth (and hence gain) across the 10:1 band. This then raises a very critical question for the astronomy community to ponder on: What is the collecting area versus frequency characteristics, which would be the most desirable compromise for all useful astronomy observations. If a relatively large collecting area is required at the higher frequencies, it may be desirable to add additional high-frequency elements interspersed with the elements covering the complete bandwidth, for example.

6. Reference

Bruce MacA Thomas, "An evolutionary approach to the development of the "Square Kilometre Array", and related generalised antenna layouts and concepts, particularly for a low-frequency facility covering the approximate frequency range 150 - 1500 MHz", ATNF Technical Document 39.3/087, 22 January 1999.

LF-SKA: Basic Antenna Characteristics

General Antenna Type	HPBW	G (dB)	Ae/λ^2	No. per Array Station*
Dipole	[80°]	2	0.13	-
Symmetric	100°	5	0.25	20,000
Symmetric	75°	8	0.50	10,000
Symmetric	55°	10	0.80	6,250

* Ae for Array station = 2×10^4 m^2 @ 150 MHz

$$G = \frac{35{,}000}{(HPBW)^2} ; Ae/\lambda^2 = \frac{G}{4\Pi}$$