An Outdoor Antenna Metrology Facility for Candidate Square Kilometre Array Antennas

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***Abstract* — The Square Kilometre Array (SKA) will be the largest radio telescope ever built operating at multiple frequency bands. The lowest band, SKA-low, covers 70 - 450 MHz and consists of sparse aperture arrays. The International Centre for Radio Astronomy Research (ICRAR) is investigating conical spirals as one candidate antenna for SKA-low. These large (~1 m) low frequency antennas are characterized using a quick and efficient procedure called the 'car-park' pattern measurement method. To verify the viability of the method, the characteristics of scaled conical spiral antenna prototypes, measured in both the car-park and an anechoic chamber, are compared in this paper. Initial indications confirm the reliability of the car-park measurement method and, by extrapolation, its suitability measuring full-sized antennas.**

Keywords – SKA; Radio astronomy; Antennas; Metrology

I. INTRODUCTION

The Square Kilometre Array (SKA) will be the world's largest radio telescope. The operating frequency of the SKA will comprise of three bands [1]. The lowest band operates from 70 to 450 MHz [2] and consists of sparse aperture arrays (SKA-low) using phased array technology. The Aperture Array Verification Program (AAVP) is an international collaborative undertaking the development of the SKA-low. International Centre for Radio Astronomy Research (ICRAR)/Curtin is an active member of the AAVP. Under this collaboration, ICRAR/Curtin undertakes the design and prototype development of very wideband aperture arrays; this includes the antenna and the associated RF components. Each single element in the array needs to cover the required frequency range (70 – 450 MHz).

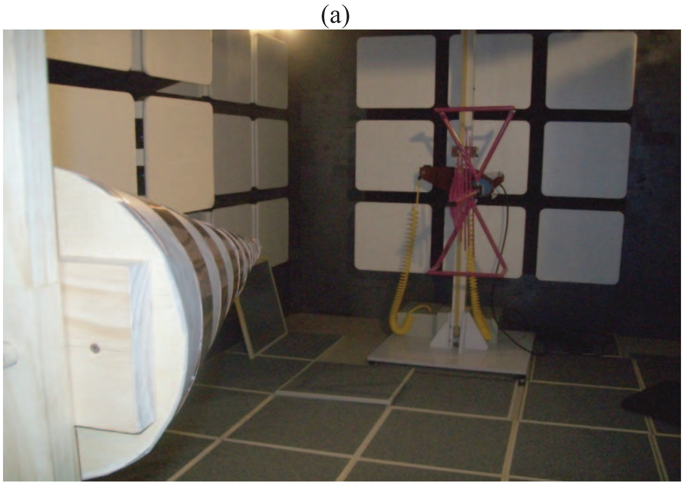
Conical spirals, belonging to the frequency independent class of antennas [3], have many features which may make them suitable for the SKA-low. One useful feature is their relatively small footprint compared to dipole variants. This physical characteristic is of utmost practical importance, especially for a low frequency wideband array, where the wavelength is large (~4.2 m). The compact physical size, relative to dipole alternatives, reduces the minimum separation between array antennas and improves the filling factor at higher frequencies. In terms of broadband behaviour the spiral exhibits constant beam-widths, consistent and linear impedance behaviour, low ellipticity (enabling polarization purity over the wide frequency band) [4] and low mutual coupling [5] in an array configuration. The higher gain of the antenna, relative to dipoles, implies fewer elements to meet target sensitivity requirements.

Fig. 1. Photograph of: single (LHS) and dual polarised conical spirals

Fig. 2. Photograph of wooden mast, for the antenna under test, with manual rotation

Characterising spiral (and other) antennas at SKA-low frequencies is essential. Indoor measurement of these, physically large, low frequency antennas is onerous. An alternative arrangement is necessary. The alternative method is the 'car-park' measurement method. The car-park is a term to define temporarily used wide open space, which is devoid of potential sources of reflection. A first car-park test system is set up at ICRAR to assess its viability. To verify the achievable accuracy, radiation pattern of scaled prototypes (see Fig. 1) of conical spiral antenna are measured at an anechoic chamber and those results compared with the car-park measurements.

(a)



(b)

Fig. 3. Photos of (a): car-park test range set up and (b): anechoic chamber set up.

II. Measurement Set Ups

A. *Car-park measurement*

For a typical car-park measurement, two antennas are placed horizontally on masts. The Electro-Magnetic (EM) response of the Antenna-Under-Test (AUT) is measured by rotating a wooden mast (shown in Fig. 2) along with the AUT. The source is a calibrated antenna which has a well understood response over the frequency range of interest. Absorbing foam is used to attenuate the reflections from the ground.

In the case shown in Fig. 3a, a spiral antenna operating from 280 to 1300 MHz is used as the AUT. For an antenna of a given size (D) at wavelength (λ), the distance (R) between the source and the antennas is given as $R \geq 2D^2/\lambda$ [6]. To avoid ground reflections, the minimum height (h) from ground is given as $h = 4D$ [6]. The diameter of the AUT is 295 mm. At the highest frequency of 1500 MHz, the minimum distance R = 0.87 m. The separation used for the test set up is 6 m. The minimum height over the ground is similarly calculated, at 250 MHz, as 1.18 m. The closest to this requirement, on the mast, is at 1.27 m and hence AUT and source are mounted 1.27 m above ground. The wooden mast, with the AUT, is rotated manually with a 5 degree azimuth angle resolution.

The source is an EMCO model 3147 log periodic antenna [7] and data is collected using an Agilent CSA spectrum analyser. The spectrum analyser generates 256 frequency points over the measured band of 250 – 1500 MHz.

It takes one hour for two people to set up the antennas and source. The measurement takes 3 hours for both the polarisations. The measurements are repeated over several days to demonstrate the repeatability of this method.

B. *Anechoic chamber measurement*

The same AUT, used for car-park measurement, is utilised for the anechoic chamber measurement (as shown in Fig. 3b). The distance between the AUT and the source is 3 m. This is the maximum distance that can be achieved in the chamber. The AUT and the source are kept 1.27 m above the ground. The AUT, mounted on a wooden mast, is again rotated with a 5 degree resolution for the azimuth angle. The source antenna used is bilog antenna (Schaffner CBL 6141a X-wing) [8]. An HP EMI receiver is used for data collection. The receiver generates 401 frequency points over the measured band of 250 – 1500 MHz.

III. Results and Discussion

Figs. 4, 5 and 6 show normalized radiation pattern measurements of the AUT obtained from both the test set ups. It should be noted that the frequency data points of the receivers do not always overlap. However, the slowly varying nature of the AUT beam patterns allowed a good comparison of the measured radiation patterns from the two test arrangements.

The radiation patterns obtained from the two test set ups show similar characteristics. In particular, the main lobe of the radiation patterns agrees quite well. However, there are some differences, especially in the back lobe. In Figs. 4 and 6, the radiation pattern obtained from the car-park measurement shows a greater dip, at +120 and -120 degrees respectively, compared to the pattern from the anechoic chamber measurement. In Fig. 5, the pattern from the anechoic chamber measurements has a greater dip at -120 degrees.

The antenna prototype has construction errors particularly at the feed point. The feeding is physically asymmetric leading to tilting of the beam in the antenna radiation pattern. The effect of the asymmetric feeding increases with frequency. In

Fig. 6, at the higher operating frequency of 809 MHz, the tilting of the main lobe is noticeable. Both methods of measurement showed the shift in main lobe direction validating the measurement process and showing the importance of making real field measurements to validate the construction and electrical feed network.

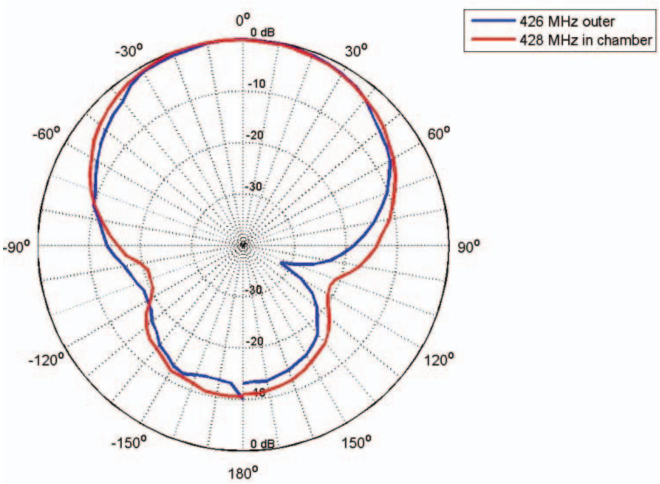


Fig. 4. Radiation pattern of AUT at 426 MHz and 428 MHz for car-park and chamber set up respectively.

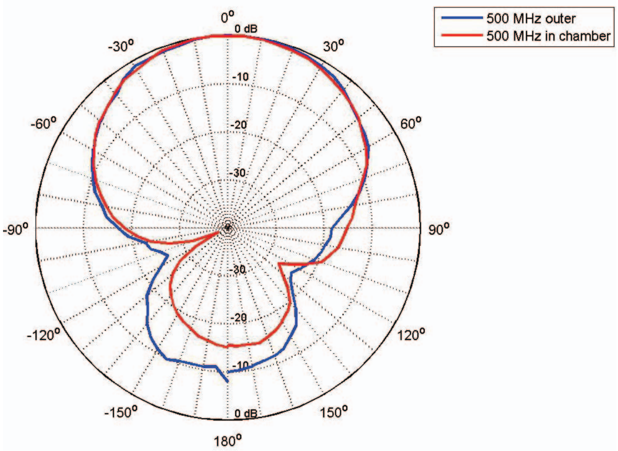


Fig. 5. Radiation pattern of AUT at 500 MHz for both car-park and chamber set up.

Significant information regarding the radiation pattern can be obtained from the outdoor test range, making it suitable for testing antennas which are too large for indoor measurements. However, the outdoor set-up will have to be done with bigger masts to mount the antennas further away from the ground. The full scale antennas will also require a sturdier mount which can cope with the heavier weight.

The SKA-low antennas will be in the order of 1 m for an operating frequency range of 70 – 450 MHz. Assuming the antenna dimension to be 1.3 m, the minimum separation for the source and AUT is 5 m. The minimum mount height, to reduce ground reflections, is 5.2 m.

IV. Conclusions

The car-park method is a quick, efficient and repeatable procedure for measuring antenna radiation patterns. This method will be useful for testing the large low frequency antennas for SKA-low frequency band. These measurements are useful in determining antenna performances and the associated fabrication errors which will be used in optimizing the antenna geometry profile and feeding network.

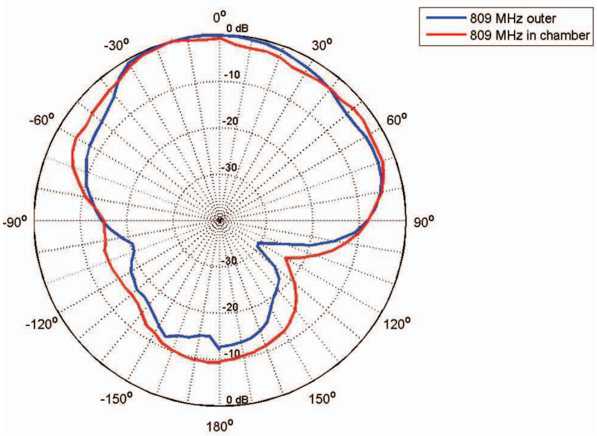


Fig. 6. Radiation pattern of AUT at 809 MHz for both car-park and chamber set up.

V. Future Work

Full scale (70-450 MHz) single and dual polarised log spiral antennas will be constructed and tested using the next version of the car-park measurement set-up. The next version of the car-park test set-up will include 6 m masts, to reduce ground effects, and will be able to measure SKA-low antennas over the complete bandwidth. This future arrangement will be at a rural WA site and will be an important asset in the measurement and development process of the low frequency antennas for the SKA.

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