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Electromagnetic characterization and modeling of SKA1-LOW stations for design and calibration

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The Square Kilometre Array (SKA) [1] is the largest and most powerful radio astronomy project at meter and centimeter wavelengths in the world today. The SKA will be divided into two main instruments, a high frequency instrument in the Karoo radio reserve, South Africa and a low frequency aperture array instrument (SKA1-LOW) at the MRO (Murchinson Radio Observatory), Western Australia. The SKA1-LOW (50-350 MHz) will consist of 512 aperture array station each with 256 antenna elements (known as SKALA antennas). This super interferometer will be the largest of its type and faces multiple design challenges to meet the demanding SKA requirements. A consortium of universities is carrying out the design work across the globe and it is known as the Aperture Array Design Consortium (AADC).

In this presentation we will describe the efforts on developing an electromagnetic simulation tool to characterize the response of the aforementioned stations in an environment where mutual coupling could dominate the instrument's response. We will discuss the different concepts behind the numerical method itself (Method of Moments, Macro Basis Functions, harmonic-polynomial modeling, [2]) and our findings regarding the effects of mutual coupling in several scenarios (beam forming, nulling, etc.). We will also discuss how the effects of mutual coupling on array patterns can be accurately modeled [3], near the main beam and beyond and how such models can support calibration algorithms. We will illustrate the impact of the effects of mutual coupling in the interferometric process.

The numerical method known as HARP, developed by Université catholique de Louvain, in collaboration with the University of Cambridge, has now been validated against both measurements and other commercial codes and it has both proven its accuracy and its computational efficiency. In a nutshell, thanks to a series of pre-calculations totally independent from array configurations, it can provide all the embedded element patterns of a SKA station problem 3 orders of magnitude faster (about 1000 times) than commercial software.

[1] The Square Kilometre Array, www.skatelescope.org.
[2] H. Bui Van, J. Abraham, M. Arts, Q. Gueuning, C. Raucy, D. Gonzalez-Ovejero, E. de Lera Acedo, C. Craeye, `` Fast and Accurate Simulation Technique for Large Irregular Arrays,'' submitted to IEEE Trans. Antennas Propag., Feb. 2017, available on Arxiv.
[3] H. Bui Van, E. de Lera Acedo, C. Craeye, ``Main beam modeling for large irregular arrays : The SKA1-LOW telescope case,'' "Experimental Astronomy,'' Vol. 44, p. 239-258, Nov. 2017.