3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Computational Electromagnetics for low frequency radio telescopes

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1 Extended Abstract

Computational Electromagnetics includes both integral equation-based methods (the Method of Moments, MoM), and differential equation-based techniques, in particular the Finite Difference Time Domain (FDTD) method and the Finite Element Method (FEM). After many years of development since their introduction in the 1960s, simulation codes implementing these techniques are mature and in widespread use [1].

For low frequency (typically VHF band) radio astronomy, aperture arrays are the current technology of choice. (An aperture array in radio astronomy terminology is a receive-only phased array with a direct view of the sky). This includes LOFAR, the LWA, the MWA, and SKA-Low. All of these comprise arrays of highly-conducting metallic wire elements. These include “droopy” dipoles (LOFAR low band), bowties (LOFAR high band and MWA) and log-periodic dipole arrays (SKA-Low). “Stations” comprise arrays of a number of these - varying from 16 dual-polarised bowtie antennas (MWA) to 256 DP LPDAs (SKA-Low). The overall radio telescope will comprise a (potentially large) number of stations.

A full-wave MoM model of an SKA-Low station can easily require several million degrees of freedom, and application of an accelerated method of some or other type is essential to compute the required embedded element patterns (EEPs) [2, 3]. The Multi-level Fast Multipole Method (MLFMM) is a key simulation tool for such problems. Work continues on alternate approaches to fast solvers. A number of these are based on the concept of characteristic basis functions. An early example of this in radio astronomy is [4]. A specific application to SKA-Low is HARP [5]. Another is the Domain Green’s function approach [6]. Unfortunately, in its original form, the DGF is not well suited to the computation of EEPs; work is currently in progress on this.

This paper will review the current status of CEM methods (in particular, the MoM and associated fast methods) for simulating low-frequency aperture arrays.

References

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