NEAR-FIELD VALIDATION OF THE ELECTROMAGNETIC MODELS FOR LOFAR LBA-OUTER ARRAY

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Abstract

The characterization in the Far-Field regime of a radio telescope is an essential step to provide accurate astronomical results. This step represents a challenging task for array with large size and operating in a complex environment. Nowadays, several electromagnetic tools capable to simulate array configurations are commercially available. In this paper, the experimental validation of the electromagnetic model implemented in FEKO is shown for LOFAR LBA-outer array in the Near-Field regime. To this end, measurements acquired by means of an UAV-based system have been employed.

Index Terms – antenna characterization, array radiation pattern, electromagnetic model validation, aperture array radio telescope.

I. INTRODUCTION

LOw Frequency ARray (LOFAR) is an International radio telescope consisting of several array stations distributed over Europe [1], see Fig. 1-a). Each LOFAR station is composed of (i) a High Band Antenna (HBA) array working in 120 – 240 MHz frequency band and (ii) a Low Band Antenna (LBA) array working between 30 and 80 MHz. LBA array is in turn composed of 46 antennas distributed within an approximately circular area featuring a diameter of 30 m (known as LBA-inner array) and of 48 antennas again randomly distributed within a diameter of 85 m (known as LBA-outer array). This paper will concern LBA-outer array.

To provide accurate astronomical results, the characterization in the Far-Field (FF) regime of an antenna array (taking into account the coupling effects among antennas and the surrounding environment) is a fundamental step. Commercial tools based on full-wave solvers can be potentially employed for this purpose. However, an experimental verification of the numerical model is recommended in order to assess its accuracy and reliability. A procedure to validate the Electro-Magnetic (EM) model by using a system based on an Unmanned Aerial Vehicle (UAV) has been developed by the authors. Such a system has been employed in several measurement campaigns permitting to characterize both a single embedded element and a full array [2]. In all cases, the agreement between simulated and measured data is better than 0.5 dB.

In this paper, the Near-Field (NF) experimental validation method proposed for LBA-inner array [3] has been applied to the LBA-outer array whose distribution of antennas is illustrated in Fig. 1-b).

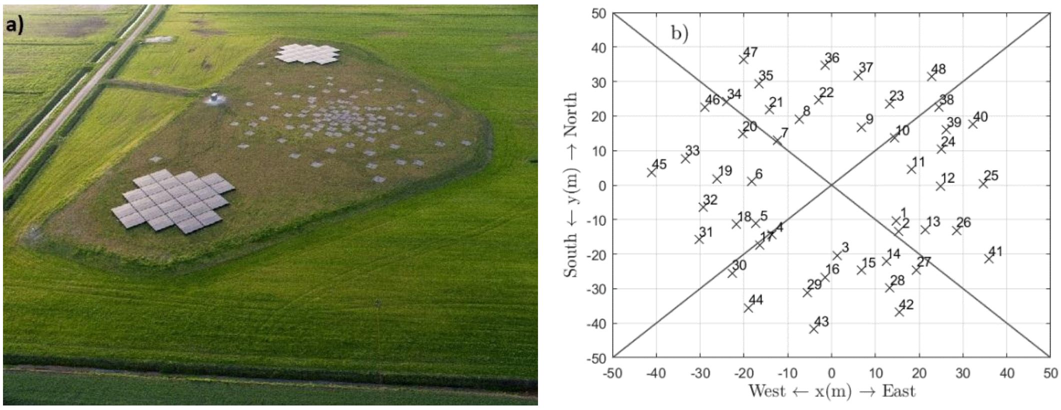

FIG. 1 – a) Picture of a LOFAR station in The Netherlands; b) Distribution of LBA-outer array antennas (ideal UAV trajectories are also indicated as continuous lines).

II. MEASUREMENTS CAMPAIGN ON LBA-OUTER ARRAY

The UAV-based system employed during the measurement campaign on the LBA-outer array, considered hereafter, mounted a horizontal dipole as test source emitting linear polarized signals. LBA-outer antennas under test consist of two orthogonal dipoles featuring dual linear polarization: a dipole oriented along the North-East direction, the other one along the South-West direction. Linear UAV trajectories (height about 100m) were carried out in the E-plane and H-plane for one polarization of the LBA-outer array. Positions of the UAV-mounted source were measured using an on-board differential GNSS system. During each flight, a continuous-wave RF signal is transmitted by the test source and it is received by the antennas under test. Complex voltages received by each antenna are then individually measured by the telescope recording system as a function of the curvilinear abscissa providing a NF scan. The same experimental configuration (including both the UAV and LBA-outer) has been simulated using FEKO, a commercial software tool that performs a full-wave analysis by means of the method of moments.

Simulated NF scans have been evaluated for a decimated UAV position series along the considered trajectory [3].

III. NF EXPERIMENTAL VALIDATION OF THE EM MODEL

In this section, the NF model validation for the LBA-outer array is presented. Measured and simulated NF scan for a linear flight in the array E-plane has been considered for this purpose.

At single embedded antenna level, normalized amplitudes of the NF scans have been evaluated for all antennas composing the LBA-outer array. Figure 2-a) shows the comparison between simulated and measured normalized NF scan for antennas 9, 34, and 43 at 32 MHz frequency. Weighted Differences (WDiff) [4] between simulated and measured normalized amplitudes have been computed for each antenna as a function of the curvilinear abscissa (see bottom panel of Fig. 2-a)). The distribution of the WDiff averaged values has been computed in order to summarize the receiving properties of all the antennas. Such a statistical analysis turns out to be a reliable diagnostic tool to verify the overall antenna pattern measurement performance.

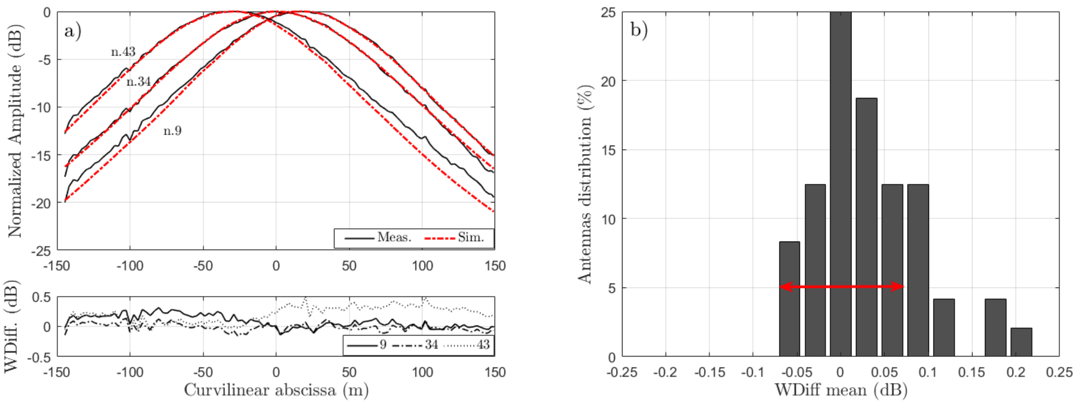

FIG. 2 – a) Comparison between simulated (red curves) and measured (black curves) normalized amplitudes at 32 MHz; b) distribution of the WDiff averaged values at 32 MHz.

The histogram reported in Fig. 2-b) shows a main distribution centred around zero: about 77% of the LBA-outer antennas have the WDiff averaged values inside 0.12 dB (indicated with a red arrow in Fig. 2-b)), whereas only three antennas have the WDiff averaged values outside two times the half width of the distribution.

At full-array level, Figures 3- a) and –b) show the measured and simulated NF scans focused on the zenith direction (corresponding to the LBA-outer array center) at 32 and 70 MHz frequencies, respectively. Individual simulated and measured NF scans have been summed together [3]. The agreement between simulated and experimental data turns out to be really satisfactory, below 0.5 dB as shown in the WDiff panels of Fig. 3.

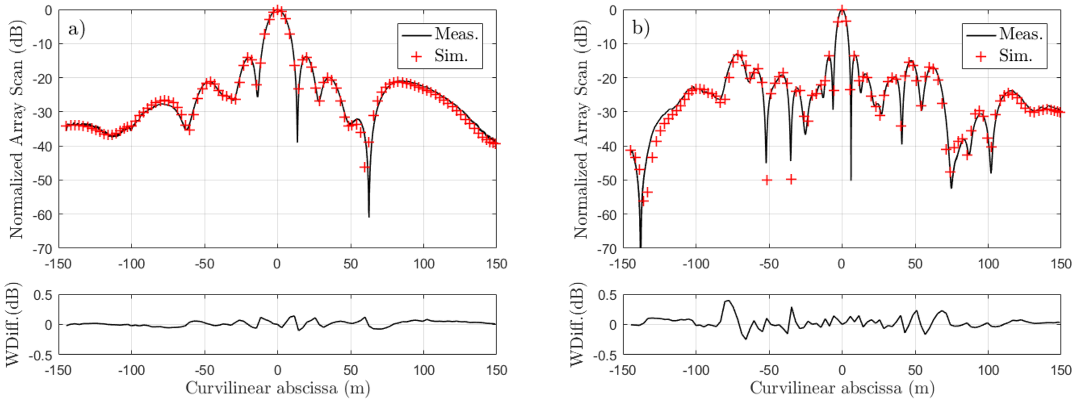

FIG. 3 – Normalized LBA-outer array NF scans at: a) 32 MHz and b) 70 MHz.

IV. CONCLUSION

The UAV-mounted test source makes *in-situ* characterization of radio telescopes based on low-frequency aperture arrays possible. Analysis of the LOFAR LBA-outer array data shows differences between simulated and measured NF scans within ± 0.5 dB both at single antenna and at full-array level. The experimental results have validated in NF regime the EM model, which in turn can be used to predict the FF array pattern.

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