# Array Element Model with Improved Accuracy for LOFAR Radiotelescope

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***Abstract*—This paper discusses the newly araised opportunities for accurate modeling of antenna elements in large antenna arrays. The problem is significant in cases when control of beam pointing side lobes and grating lobe levels is relevant to the correct operation of the antenna array and the analysis of the results.**

## I. Introduction

The LOFAR is European low-frequency antenna array radio telescope, designed and build by are designed by ASTRON, NL. It comprises several remote stations, each one of them consist two antenna arrays – Low frequency array (LBA, 10-90MHz) and High frequency array (HBA, 110-250MHz), so called single stations [5]. These single stations are interconnected with high-speed fiber optics and can operate in as a single station (array) mode or the whole array network mode. The majority of the 52 stations and located in the Netherlands (38), and the rest are stretched across Europe. Employment of antenna arrays instead of reflector antennas for these frequency bands provides multiple benefits as large aperture (base), digital beamforming, noise cancelation, blind spot avoidance et cetera [1].

Figure 1. The core LOFAR array in the Netherlands

For proper operation of the array and correct image resolution, it is essential that exact radiation patterns are known. Since a single array consists of 96 antennas configured in a pseudo random sparse array, the accurate modeling of such large electromagnetic problem and proper calibration of the whole array became a challenge [3];. The present paper presents a newly raised opportunity for such modeling, taking into account the advancements in the electromagnetic CAD simulations.

## II. The Simulation Techinques

The Low frequency element dimensions are displayed on Fig. 2. The antenna consists of twe independent inverted V-shape orthogonal dipoles, each of them providing linear polarization and with proper phase shift – circular [2]. The arm length is approx. 1.38m, tilted at 45deg and the ground plane is a square of metal grid, 3x3m, with size of net 50x50mm.

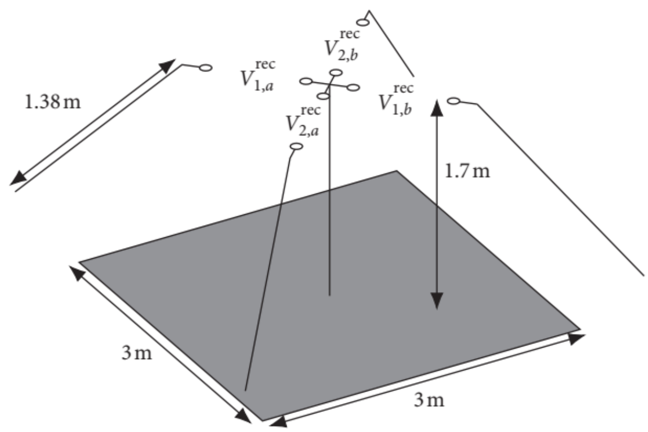


Figure 2. The LBA antenna element dimensions

Simulation of such a simple antenna is not a problem with contemporary numerical techniques, however when the array size rises to 92 elements the analysis became quite challenging. In order to minimize the computational problem, different techniques and approximate solutions are employed. One of the most popular for wire antennas are the codes using Method of Moments. To further simplify the problem, the ground grid is represented as a solid plane.

Direct modeling of the whole array is the most accurate approach, however, depending of array size, wavelength to antenna size and antenna complexity, usually after 10x10 elements, a single machine is not capable to solve the problem (with the current state of electronics), mainly due to memory limitations and processing power. One of the approaches to solve it is to simplify the antenna model, as mentioned above.

The recent development is software EM simulation tools was introduced by Ansys [4]. To solve complex array problems so called Component Array is incorporated in the solver. The novelty of this technique is that each antenna element is solved with high-accuracy FEM solver and the radiated fields are determined on the encompassing box – FeBi (Finite Element Boundary integral) Boundary. This technique allows to model not only the antenna element, but also to account for ground currents, leakage of EM wave behind the ground mesh and antenna active impedances. The greatest benefit is that the FEM mesh is created only of one single element and the fused to the identical mesh of the other elements, saving memory and computational time. Change of the excitation coefficients results in an almost instant pattern update.

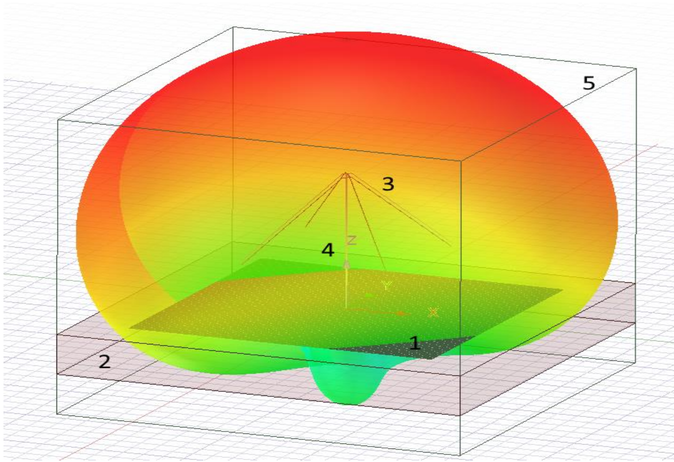


Figure 3. The LBA antenna element model with radiation pattern

The array element model (Fig. 3) consists of 1- Ground plane, modeled as a gird, 2 – Soil, with its permittivity and conductivity properties, 3- The Dipole arms and 4 - The plastic pipe that supports the dipoles, 5- Radiation box (the solution volume). The single element antenna is simulated on 4 core, 4.6GHz machine with 32GB of RAM. Simulation time took 10minutes. Computed radiation pattern is added to the physical model, indicating gain between 6.3dBi (Red) and -5.5dBi (green).

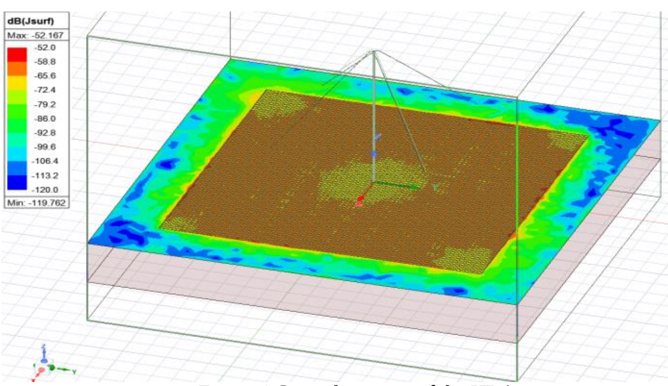


Figure 4 Ground currents of the HBA

The Fig. 4 displays the ground currents, induced by the antenna in the soil. The currents inside the soil block is also simulated, however for the sake of clarity, just the surface is color coded. This solution gives opportunity not only to accurately represent the array, but also to determine the size of the simulation space (radiation box), beyond which the contribution of the ground currents would be negligible (i.e. to minimize the solution volume).

Given the models above, a simple component array, 5x5 element is created, where inner 3x3 elements are the actual array and the boundary components doesn't have an active antenna (soil only, Fig. 5).

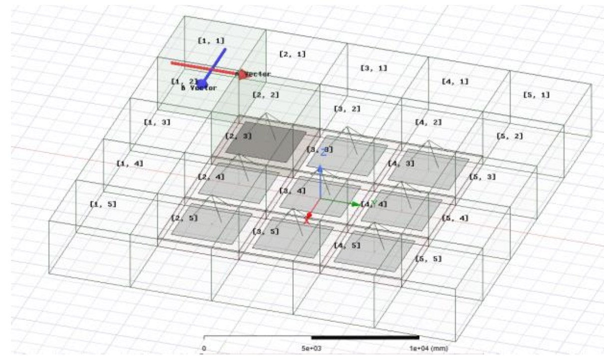

Figure 5. Ground currents of the HBA

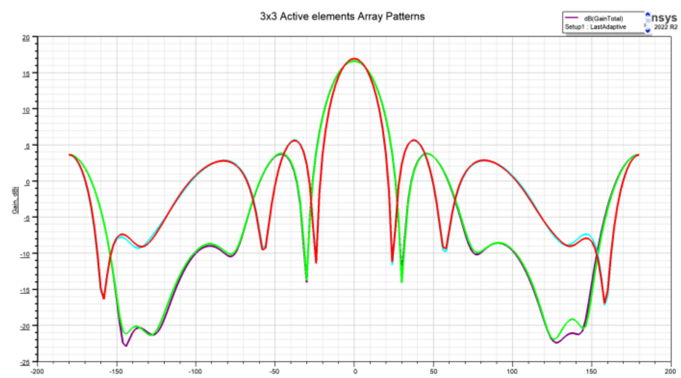


Figure 6. Array pattern with 3x3 active elements

Given the models above, a simple component array, 5x5 element is created, where inner 3x3 elements are the actual array and the boundary components doesn't have an active antenna (soil only, Fig.5) and its pattern is presented on Fig. 6 (red line). For comparison, with green line is the pattern of the same array, modeled with flat ground and no soil. Computational time on the same computer was 3h15'. The simulations and results show that new opportunities for accurate array design are presented with component array technique.

## Acknowledgment

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