Active Electronically Scanned Array (AESA)

Introduction

An important area of microwave engineering is the design of antenna arrays, especially in satellite and mobile communications. A specific type of the phased array antennas is active electronically scanned array (AESA). This type of phased arrays is electronically-controlled array antenna in which the main beam of the transmitted wave can be electronically steered to point into different directions without moving the antenna (without physical/mechanical rotation).

WIPL-D Pro 3D EM solver is a full wave simulation tool based on Method of Moments. It applies advanced techniques to achieve state-of-the-art performances in EM simulations: higher order basis functions, quadrilateral mesh (compared to more popular triangular), highly efficient CPU and GPU parallelized execution, using symmetry for both geometry and excitation etc.

Among other features, specific features make WIPL-D a great choice for AESA simulation. WIPL-D Pro does not require radiation box, so it is extremely suitable for open-domain (radiating) problems. Next, the elements coupling is inherently taken into account so the full wave result includes all possible EM effects. Despite this, the very good approximation for the simulation requirements is to multiply the requirements for a single element of the array with the number of elements. The requirements are mostly dependent on the number of unknown current coefficients. When multiplied with number of elements, the number of unknowns for the single element is an excellent prediction for the required hardware resources and the simulation time. Due to very efficient simulation, WIPL-D Pro has been used to solve problems with hundreds of array elements.

An additional feature which makes AESA simulations even easier is the unique use of asymmetry. Namely, most arrays are geometrically symmetrical, but the feeding is not due to the need to steer the beam into a certain direction. Usually the steering is achieved by setting the appropriate voltages/currents of the feed elements. WIPL-D asymmetry allows to simulate geometrically symmetrical arrays with arbitrary feed voltages. For each symmetry plane, the number of unknowns is reduced around two times. Two significantly faster simulations are carried out and their results combined to achieve the proper array feeding. In the example described later in this document, two asymmetry planes were introduced. Number of unknowns is reduced four times. Next, four calculations were done and their results automatically combined into a full array simulation result.

Simulations Details

The efficiency of the WIPL-D software suite for the simulation of AESA will be elaborated by using 128-element array (16x8 elements). Figure 1 shows top and bottom view. The element of the array is stacked patch antenna. It involves 3 dielectric layers. Each stacked patch is fed by 4 coaxial probes. To achieve proper feeding, two probes are fed while the remaining two are loaded at the end with the appropriate resistors. The feeding voltages of the two active probes can be arbitrary set, which is used to achieve the electronically controlled steering.

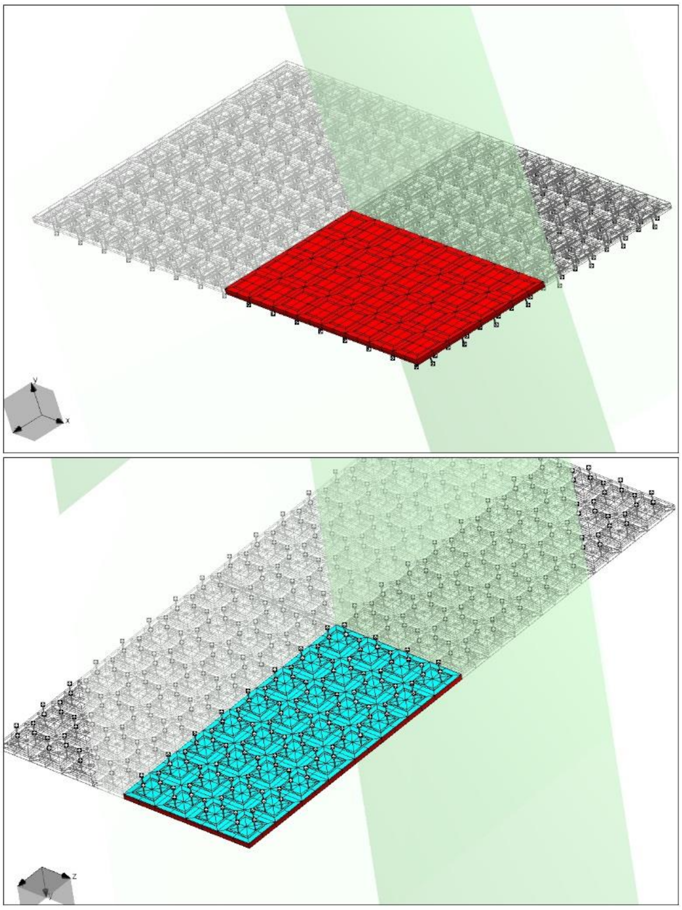

Figure 1. Top and bottom view at the AESA.

Due to the fact that the array is geometrically symmetrical, the simulation involves two asymmetry planes. Thus, we actively simulate only one quarter of the structure, while the voltages of the elements which are not simulated are simply set via the Generators table. Such scenario also allows to run a single simulation and then later apply the appropriate generator voltages for different steer angles. Once the EM simulation, where coupling between elements is carried out, the excitation can be set arbitrarily.

WIPL-D allows two ways of geometry modelling. In a classic way, the user can manually make a single array element and then use Copy manipulation to generate the remaining elements. There is also a second approach where WIPL-D Pro CAD tool is used. This tool performs automatic mesh into a simulation ready model. The input can be CAD file for import (such as IGES, STEP etc.), or the user can model the element of the array on his own. After the mesh, the user gets simulation ready EM model with the optimum mesh.

This EM simulation consists of four sub-simulations (as described above). Each of the sub-simulations requires about 59,500 unknowns. The recommended hardware platform for this sort of simulation is a regular desktop PC with as many CPU cores as possible (quad core or more recommended), as much RAM (4 GB and more recommended) and at least one cost-effective CUDA enabled GPU card.

In this case the project was simulated using: Intel® Core™ i7-7700 CPU @ 3.60GHz 3.60 GHz, with 64 GB RAM and one Nvidia GeForce GTX1080. In WIPL-D, matrix filling is usually performed using CPU. Here, both, matrix fill and matrix inversion were performed using given GPU card. In this specific case, the constellation of hardware exploited ensures minimal simulation time.

Basically, any modern desktop configuration can be converted into a simulation-ready WIPL-D workstation by adding a single inexpensive GPU card or by having more CPU cores. The GPU approach is easier and more affordable. In our case, the simulation lasts about 64 minutes (4 sub-simulations, each one taking about 16 minutes). The chosen steering direction achieved by setting the generator voltages is 45 degrees.

In the case where the entire array would be simulated, the problem would require over 250,000 unknowns. Such simulation in WIPL-D would take much longer and would require a workstation with several GPU cards. Such a simulation would be hardly possible in any other commercially available EM solver.

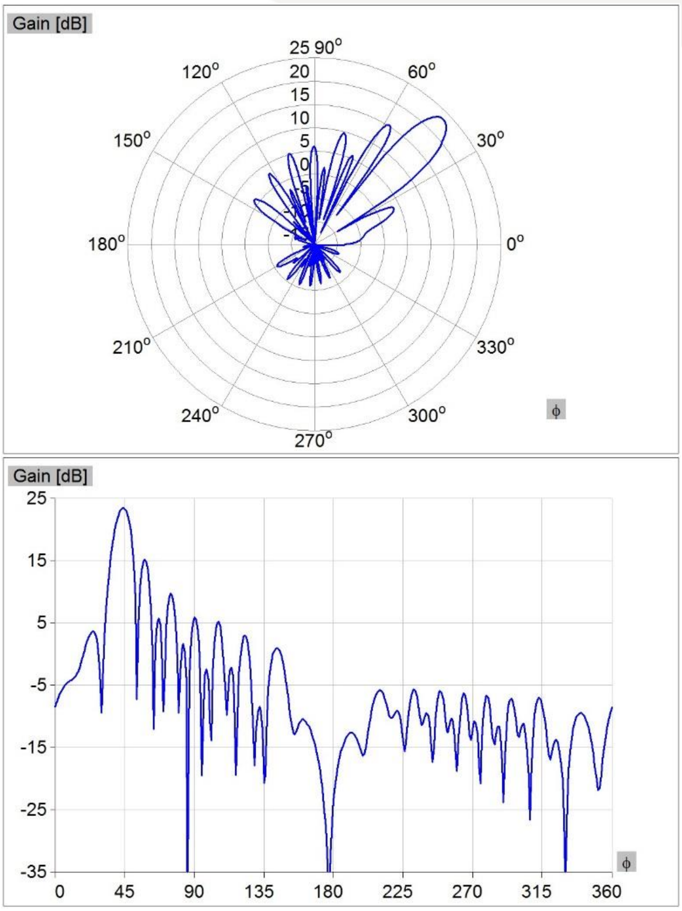

Figure 2. Simulated radiation pattern