LPDA Immersed into Ice

Introduction

This application notes demonstrates using full wave WIPL-D Pro 3D EM solver for accurate simulation of complex scenario where LPDA antenna is placed below the surface of infinite ice sheet. The antenna is immersed 1m into the ice and points below (into the infinite ice sheet). The simulation requirement is to accurately calculate gain in both front (into the ice) and backward (into air, the radiation toward sky) directions.

The basic abilities of WIPL-D Pro such as: application of modern Method of Moments, Higher Order Basis Functions, quadrilateral mesh compared to traditional triangular allow to have extremely efficient simulation of the antenna itself. The problem requires very low number of unknown coefficients and is easily solved on everyday desktop computers or laptops.

The calculation of radiation above and below ice needs to be done carefully. The simulation has to be split into two separate calculations. The first simulation is the calculation into the ice (forward radiation). It’s based on solving an inverse problem where the antenna is positioned above the ice surface, and air is placed below. Then, the special feature for calculation of reflection coefficient from infinite earth is used to get the calculation into the ice. Number of unknowns is only slightly increased because the antenna is immersed into ice, rather than air (Er=3.2 for ice with losses not included).

The simulation of backward radiation is more complex. In order to get accurate results, a large portion of surface between ice and air (the “clump”) has to be added to simulation. The size of the clump determines accuracy but the simulation is order of magnitude more complex. For this scenario the entire radiation is actually done by clump since the antenna is not immersed in air.

LPDA model

This type of antenna is easily built in WIPL-D Pro by using built in features such as Objects and Symbols. They allow to build the antenna parametrically via predefined primitives, which are later positioned in the proper place. In order to have the most accurate simulation, LPDA is made from metallic plates instead of wires. The antenna is shown in Figure 1.

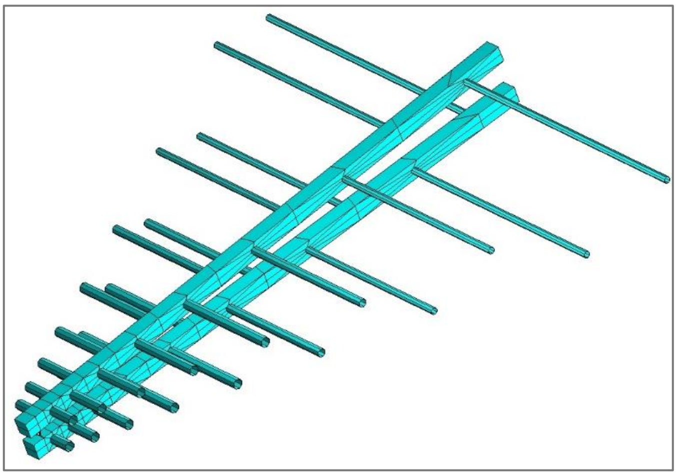

Fig 1 LPDA Antenna

The LPDA simulation in free space requires 2,200 unknowns in air and 3,300 in ice. The simulation Is done on everyday PC in a couple of seconds.

Radiation into Ice (Forward)

Radiation into ice is obtained by placing the LPDA above z (x0y) plane. The antenna is placed into air, but the Er of air is changed to 3.2. Then the second domain is specified as infinite earth below z plane, with Er=1 and negligible losses. The feature where radiation pattern is calculated as if infinite earth is placed in –z half space is turned on. The advantage of this approach is that number of unknowns remains the same: 3,300 as for the antenna itself. Radiation pattern is shown in Figs 2-3.

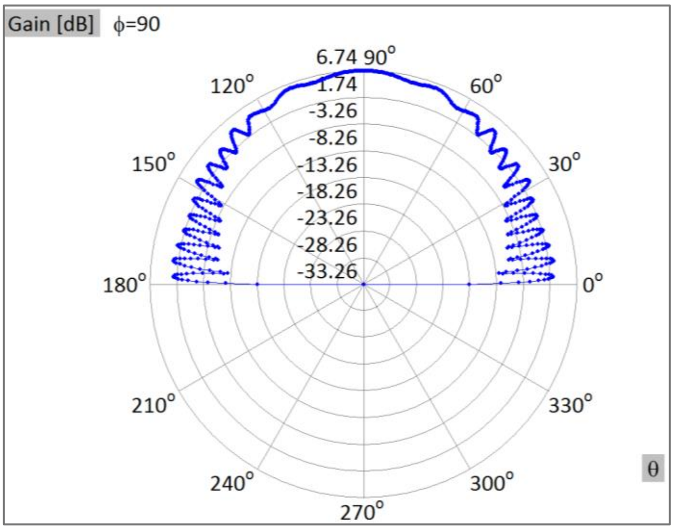

Fig 2 LPDA radiation into the ice Phi=90 degrees

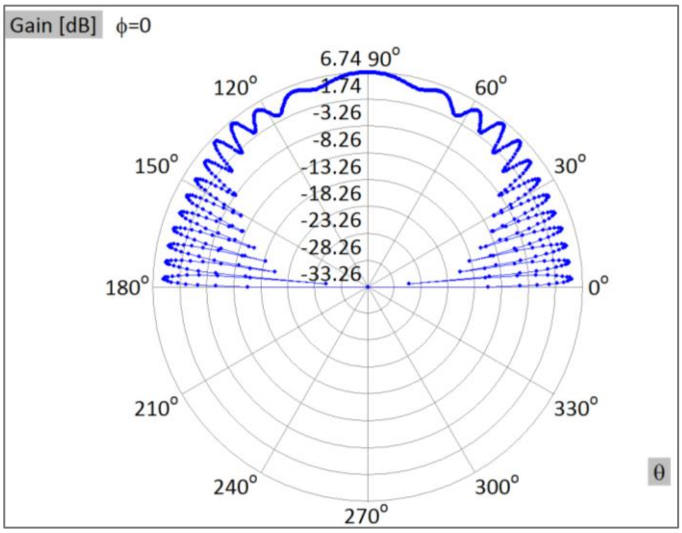

Fig 3 LPDA radiation into the ice Phi=0 degrees

Radiation into Air (Backward)

Radiation into air is obtained by placing a large clump.

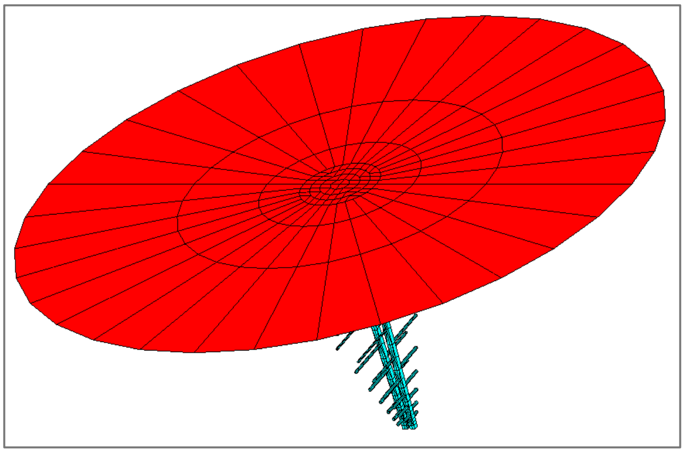

Fig 4 LPDA below Clump

The results depend on size of the ground clump taken. If the clump size is increased, the results converge. Results for different number of unknowns (different clump size) are presented in Figs 5-6. In this scenario, the LPDA is below the ice surface. The current distribution along the mesh elements of the LPDA is not taken into account for calculation of far field. In that sense, only the mesh of clump is used to get the radiation. The frequency of interest is 1 GHz. The LPDA is 720 mm long, with span of the longest radiating elements around 750 mm. The clump radius simulated varies: 150, 300, 600, 1200, 2400, 4800 to 6000 mm. Increasing the clump radius dramatically increases the number of unknowns, since it is proportional to clump surface.

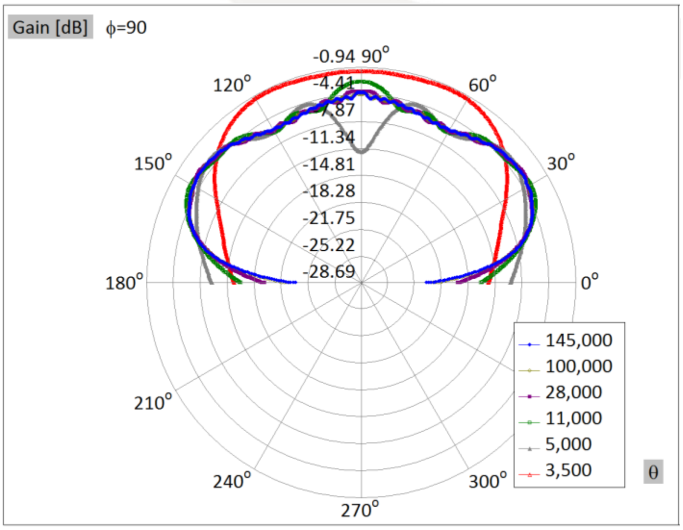

Fig 5 LPDA radiation into the air Phi=90 degrees

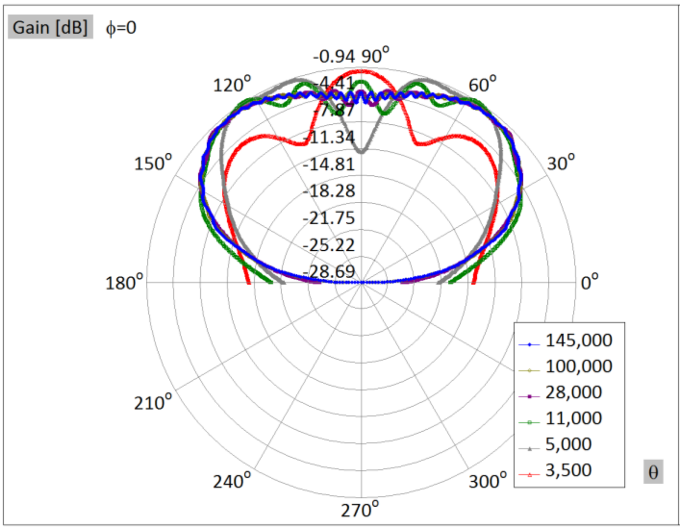

Fig 6 LPDA radiation into the air Phi=0 degrees

Conclusions

The results indicate that it is possible to calculate radiation of the LPDA antenna into the infinite ice without adding additional complexity to the simulation of the LPDA itself. However, for calculation of the backward radiation, large clump needs to be taken into account. The accuracy of simulation is determined by the clump size. Excellent results are obtained even with 28,000 unknowns, while the perfect accuracy is achieved with 100,000. Simulations for large size clump should be performed with everyday workstations equipped with inexpensive CUDA capable GPU cards (such as GTX1080). Single GPU card is sufficient even for the most accurate simulation. Simulation time varies from just a couple of seconds for LPDA in free space (or with minimum clump size) up to 1h for the most demanding simulation (largest clump size to confirm the simulation convergence).