Antenna Placement Reduction Applied to Frigate Warship

WIPL-D Pro is a frequency-domain Method-of-Moments (MoM) based code which enables very accurate EM simulation of arbitrary 3D structures. Owing to application of sophisticated techniques, very large structures can be simulated on PCs or relatively inexpensive workstations.

This application note will be used for presenting *Smart reduction*, a WIPL-D Pro feature. The feature will be investigated on the model of a frigate warship. Results obtained after four applications of reduction of current expansion order will be compared with result obtained after simulation of full model. The quality of results, computer memory required and simulation times will be compared and discussed. Efficient usage of reduction utilized within WIPL-D Pro model will be highlighted.

MoM Efficiency

WIPL-D software applies very **sophisticated higher order basis functions** (HOBFs) on a quadrilateral meshing. This means that basis functions are higher order polynomials instead of simple linear (rooftop) functions. Hence, in case of equal number of HOBFs and rooftops defined over a surface, HOBFs are capable of expressing more dynamic current distribution. Owing to this efficiency, significantly larger structures are quickly simulated on relatively cheap PCs. Application of HOBFs is entirely automatic, although the user can increase the accuracy of approximation.

Smart Reduction of Expansion Order

The *Smart reduction* is a feature which is very suitable for antenna placement problems. It is based on adaptive reduction of current expansion order over parts of the model which are distant from the antenna or in shadow. Applying *Smart reduction*, the **number of unknowns can be significantly reduced**, while very good accuracy of calculated radiation pattern or coupling between multiple antennas is preserved. Furthermore, regions of the platform regarded by the user to be in shadow are additionally treated. Expansion orders on all patches in shadow are decreased uniformly, in addition to the distance-to-the-antenna factor.

Decreasing expansion orders usually requires increasing *Integral accuracy*, a WIPL-D numerical kernel parameter. After convergence studies, *Integral accuracy* parameter applied in the frigate models is set to *Enhanced 2*.

Model Description

Model of the frigate warship, shown in Fig. 1, is **117 meters long**, and **12.6 meters wide**. The ship is placed above a PEC plane which models the influence of the sea. A monopole antenna is placed on the top of 24 meters high communication tower (Fig. 1). The simulation frequency is 240 MHz, which makes the frigate about **94 wavelengths long**.

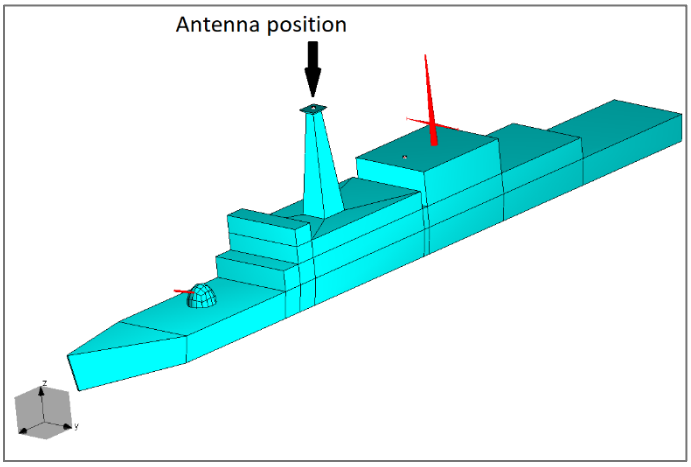

Figure 1. Frigate model in WIPL-D Pro.

Simulations and Results

The frigate model without any reduction, requires **86,894 unknowns.** This is equivalent to 56.3 GB of memory. The complete simulation without order reduction, using a multithreaded WIPL-D Pro 3D EM solver, takes about **1.44 hours**, or **14.7 minutes with GPU**.

Time savings due to smart reduction of expansion order depend on the antenna position on the warship. In case of the antenna location on the top of the communication tower (Fig. 1), the number of unknowns can be reduced significantly while maintaining an acceptable accuracy of radiation pattern results. As the number of unknowns decreases, so does the simulation time, as shown in the Table 1.

PC used for the frigate simulations is Intel® Core™ i7-7700 CPU @ 3.60 GHz, with 64 GB RAM and 1 GPU card NVIDIA GeForce GTX 1080.

Table 1. Number of unknowns, computer memory required and simulation time

Number of unknowns	Memory [GB]	CPU simulation time [min]	GPU simulation time [min]
86,894	56.3	86.5	14.1
64,147	30.7	37.0	8.6
51,844	20.0	20.3	5.4
40,125	12.0	10.1	3.3
33,564	8.4	6.3	2.4

Conclusion

The number of unknowns was **decreased about 2.5 times** (the computer memory requirement was **decreased about 6.7 times**), while the simulation time was **decreased about 14 times (about 6 times with GPU)** without significant discrepancies of the calculated radiation pattern.

The radiation pattern in the transverse plane, perpendicular to the ship bow-stern axis, is shown in the Figure 2 for different degrees of smart order reduction. Angle θ is measured from the xOy plane up, so θ=90° corresponds to the monopole antenna axis (towards the sky).

The shape of the radiation pattern doesn't change as the number of unknowns is decreased, while some discrepancies occur for θ>65°. However, calculations are still stable and give a very good estimation of the EM behavior of this structure.

In case of the maximum order reduction, a **94 wavelengths long** frigate is modeled by **33,564 unknowns** and **simulated in around 6.3 minutes, or only 2.4 minutes with GPU**.

The presented data lead us to conclusion that properly used *Smart reduction* feature can decrease both computer memory requirement and simulation time, whether GPU Solver is used or not. Finally, this means that WIPL-D user, if properly applies WIPL-D features, can efficiently utilize computer resources, thus **saving financial budged** intended for computer hardware.

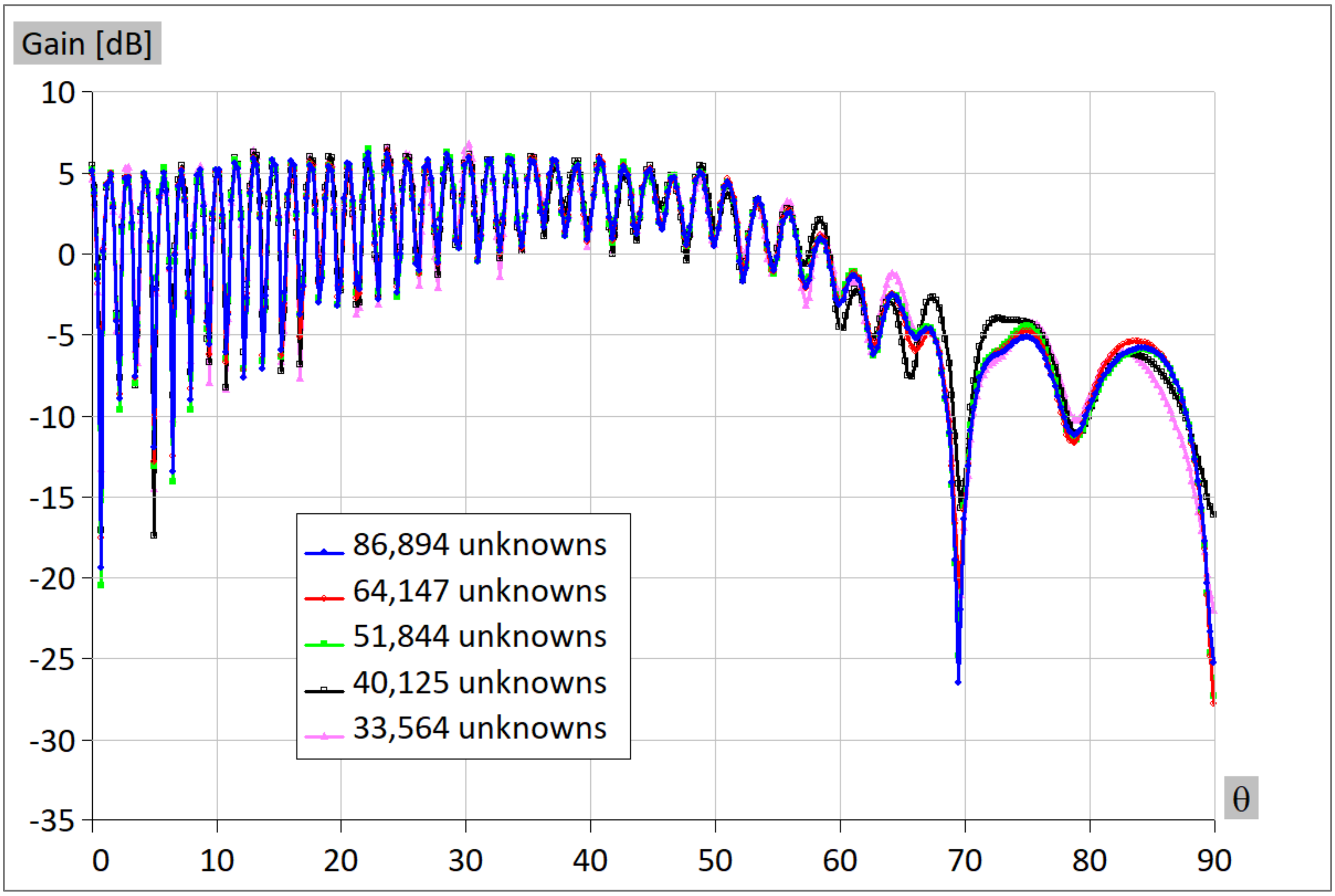

Figure 2. Influence of appropriate smart reduction on radiation pattern