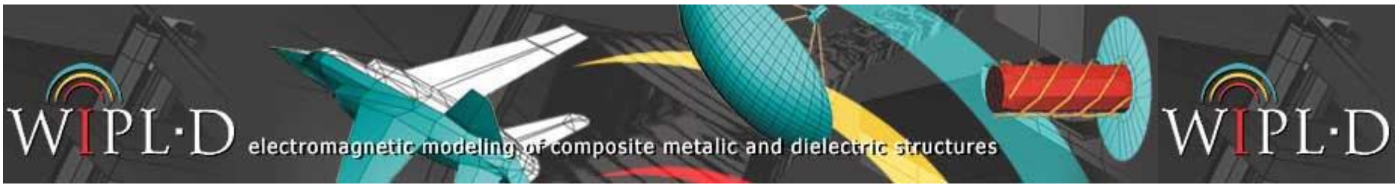


Simulation of a Frigate Warship Model on a PC

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 are simulated on PC computers or inexpensive workstations.

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 cheap PCs than by using other methods/solvers. Application of HOBFs is entirely automatic, although the user can increase the accuracy of approximation.

Direct Solution & Out-of-core Solver

Direct solution based on LU decomposition is the default solution technique used in WIPL-D Pro. When there is not enough RAM for the incore solution, out-of-core solution can be used instead. The out-of-core solver employs the PC hard drive for matrix storage during calculations. This causes a small increase in simulation time, usually up to 20% of the incore solution time.

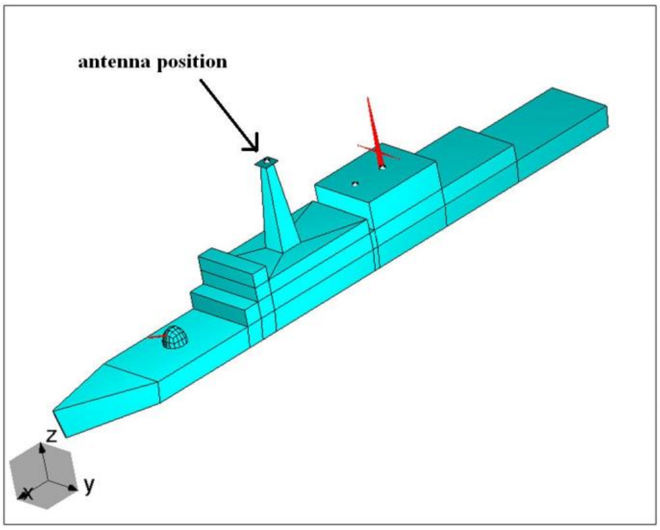
Smart Reduction of Expansion Order

This feature is especially 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. This way, the **number of unknowns is reduced 2-10 times** depending on the model, while very good accuracy of calculated radiation pattern or coupling between multiple antennas is preserved.

In addition, 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.

Model Description

Frigate warship model is **117 meters long**, and **12.6 meters wide**. The ship is placed above a PEC plane that models the influence of the sea. A monopole antenna is placed on top of a 24 meters high communications tower. The simulation frequency is 240 MHz, which makes the frigate about **94 wavelengths long**.



The full model, without any symmetry planes, **requires 86,894 unknowns**, which is equivalent to 56.3 GB of memory. This requirement is not easily met by any workstation on the market. However, so much RAM is not needed for this simulation. Applying the out-of-core solver, the hard drive can be used as storage during computations, which makes almost any PC a powerful simulation environment.

The frigate model was simulated on a PC containing:

- Intel Core ™ i7 CPU 950 @ 3.07 GHz,
- 24 GB RAM,
- 1 GPU card Nvidia GeForce GTX 590.

The complete simulation without order reduction, using the out-of-core solver and a multithreaded WIPL-D Pro 3D EM solver, **takes 8.39 hours, or 1.12 hours 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, 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 below.

Number of unknowns	Memory [GB]	CPU simulation time	GPU simulation time
86894	56.3	8.39 h	1.12 h
64147	30.7	3.88 h	31 min
51844	20.0	1.6 h	11.4 min
40125	12.0	45 min	6.4 min
33564	8.4	26.6 min	4.7 min

The number of unknowns was **decreased about 2.5 times** while the simulation time was **decreased about 16 times** 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 below 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 electromagnetic behavior of such a large structure.

In case of the maximum order reduction, a **94 wavelength long frigate** is modeled by **33584 unknowns** and **simulated in around 26.6 minutes, or only 4.7 minutes with GPU**.