Antenna Placement on Electrically Large Platforms

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

MoM is one of the full-wave simulation techniques (MoM, FEM, FDTD,...). It is a source-domain discretization technique unlike FEM and FDTD which are field-domain discretization techniques. Hence, MoM is not prone to error accumulation due to wave propagation through meshed field-domain. Also, it demands far less memory and time resources for open-region problems. For example, in case of coupling between two distant antennas, FEM and FDTD would demand a large number of cells to calculate the fields in the region between the antennas. When using MoM, the distance between the antennas doesn't influence neither the resources nor accuracy.

Current distribution is approximated by known basis functions defined over mesh cells, multiplied by unknown coefficients that need to be calculated during simulation. The efficiency of MoM simulation is directly dependent on the type of basis functions applied.

WIPL-D software applies very sophisticated higher order basis functions (HOBFs). 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 explicitly set increasing or decreasing of the default orders of approximation over certain model parts or in the entire model.

Table 1. Application of HOBFs.

Meshing and basis functions	Unknowns/λ^2 - metal	Unknowns/λ^2 - dielectric
Triangular meshing, rooftops	150	300
Quadrilateral meshing, HOBFs (WIPL-D Pro)	32	64

Table 2. Application of HOBFs - examples.

Structure	Number of unknowns	Memory requirement
Parabolic reflector with 40λ apertures	10,000	0.8 GB
Military helicopter at 520 MHz – 25λ long	20,000	3.2 GB
Fighter at 1.39 GHz – 55λ long (one symmetry plane used)	30,000	8 GB

Direct Solution & Out-of-core Solver

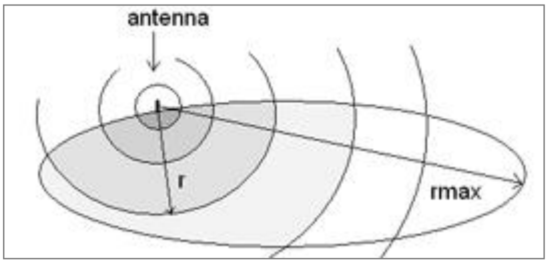
Direct solution based on LU decomposition is the most accurate solution technique used in WIPL-D Pro. When there is not enough RAM for the incore solution, out-of-core solution can be used instead. The out-of-core solver employs the PC hard drive for matrix storage during calculations. This causes a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

Exploiting CPU and GPU Capabilities

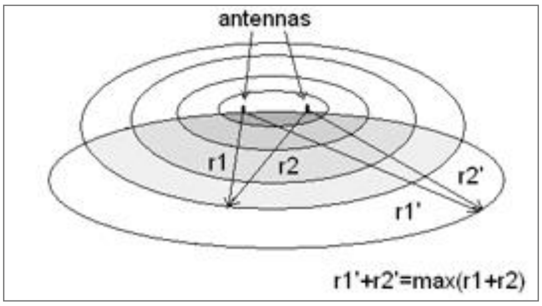
The WIPL-D suite offers highly efficient parallelization on all modern CPU/GPU platforms. Matrix fill-in is greatly speeded up if inexpensive multithread desktop PCs are used. For electrically small and moderate problems, the CPU technology is more than sufficient for the matrix inversion. For electrically large problems, the suite relies to WIPL-D GPU solver. It allows solving electrically huge problems by using affordable nVidia CUDA enabled GPU cards. Using even a single GPU card can turn regular desktop PC into a powerful WIPL-D workstation.

Smart Reduction of Expansion Order

The feature intended for antenna placement problems is “smart reduction”. 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 3-10 times, while very good accuracy of calculated radiation pattern or coupling between multiple antennas is preserved.

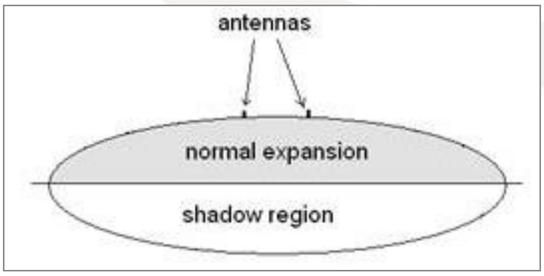


Gradual decrease of expansion order with the increase of distance from the antenna



Gradual decrease of expansion order – two antennas

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.



Decrease of expansion order in the shadow region

Case Study

λ/2 dipole is placed along the *y* coordinate axis, above a large platform representing a payload fairing. The axis of the fairing is along the *z*-axis of the coordinate system. The fairing length is 8.66 meters, while the largest cross-section diameter is 2.9 meters. Simulation frequency is 2 GHz, which means that fairing length is about 58 λ.

With one symmetry plane applied, the model requires 44614 unknowns (rigorous MoM). Thus, 15.2 GB of memory would be needed for simulation.

By applying "smart reduction" and one shadow region, memory requirements are significantly diminished. Three different sizes of the shadow region were tried (figure to the right).

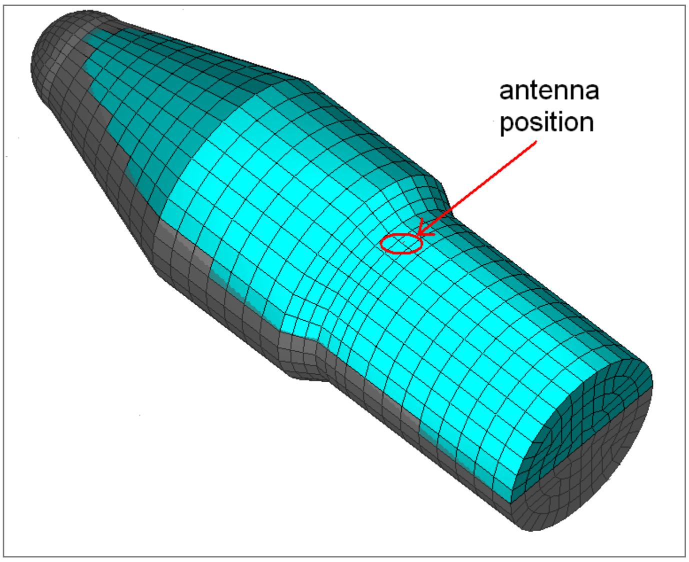
All the results show excellent agreement. With as few as 5000 unknowns, discrepancies occur at side-lobes with levels lower than 25 dB relative to the gain. At that point, the model employs 9 times less unknowns than the one with default formulation, occupying about 80 times less memory.

All four simulations were done on a regular desktop PC with a Intel Core 7700 CPU at 2.66 GHz (standard desktop quad core PC). The simulation details are given below.

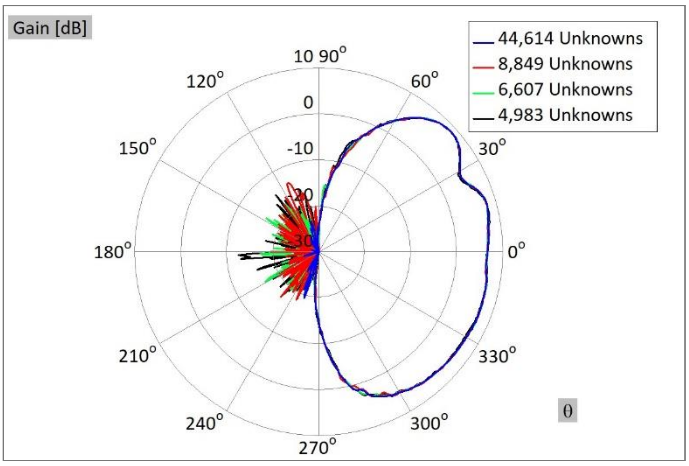
Number of unknowns, required RAM and simulation time for the various reduction levels.

Number of unknowns	Required memory [MB]	Simulation time [s]
44,614	15,186	736 (132*)
8,849	597	12
6,607	333	7
4,983	189	5

*Simulation time has been speeded up by using an inexpensive GPU technology (nVidia GTX 1080) and the WIPL-D GPU solver for the matrix inversion phase.



Payload fairing model



Radiation pattern – plane perpendicular to the dipole antenna axis