RCS Simulation of Fighter Airplanes

WIPL-D Software suite offers a great set of tools for full wave electromagnetic (EM) simulation of real life geometries at high frequencies. WIPL-D Pro CAD enables import of extremely complex geometries from all popular CAD files (this allows using models created in tools specialized for mechanical engineering), validation of models, and easy simplification of details obsolete for EM simulation itself. This product also includes in-house developed mesher which performs subdivision of complex geometries into generalized quadrilaterals which serve as input for numerical kernel. The meshing is automated and extremely efficient to allow precise modeling of details, curvatures and small features while the requirements for EM simulation are kept as minimal as possible.

After a proper quad mesh is created, WIPL-D Pro allows EM simulation in most efficient manner available among commercial tools. WIPL-D kernel allows mesh elements (quads) of size 2 wavelengths by 2 wavelengths due to unique higher order basis functions (current expansion on mesh elements is a polynomial of 8^{th} degree for 2 wavelengths edge). The number of unknown coefficients to be stored in Method of Moments (MoM) matrix is minimal and it can be estimated as 30 unknown coefficients per lambda square for metallic surfaces. The tool encompasses many features to further decrease number of unknowns but preserve the accuracy, which leads to even less demanding EM simulation. WIPL-D also offers very efficient CPU and GPU simulation on inexpensive hardware platforms. WIPL-D support team has many years of experience in simulation of complex EM problems and it offers it services to users as part of regular technical support process.

F16 Simulation

One of the most complex applications of EM codes for RCS problems are fighter airplanes because of their size, complexity and high frequencies used for manufacturing of devices in this field.

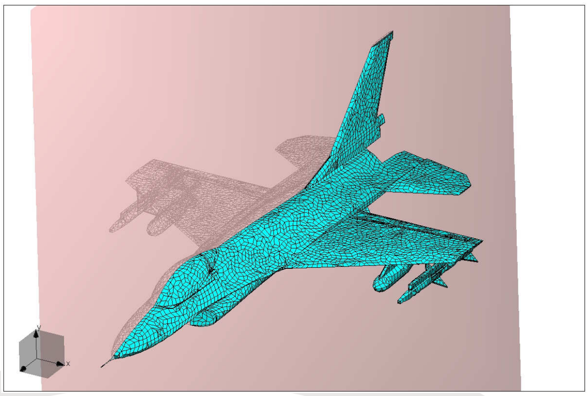

Figure 1. F16 fighter airplane

We will illustrate the efficiency of WIPL-D code by using simulation of monostatic RCS of F16 fighter.

Fighter length is 15.06 m, wing span is 9.96 m. the simulation is performed at 2.4 GHz which makes airplane 120 wavelengths long. Without any reduction for the number of unknowns, simulation requires 246,346 unknown coefficients.

The most efficient manner to simulate extremely large EM models is to use hardware platforms enhanced with GPU cards. This simulation was performed on the following workstation:

CPU Intel Core i7 930 @2.8GHz, 24 GB RAM, Win 7 Professional 64-bit, 3 GPU cards GeForce GTX480, 7 hard-disk drives with I/O speed about 100 MB/s.

RCS was performed as monostatic. Symmetry of the structure was used to half the number of unknowns. Incident wave lies in the symmetry plane and number of directions for the entire span of angles in this plane is 1800. Simulation time is 22449.35 seconds (6.2 hours).

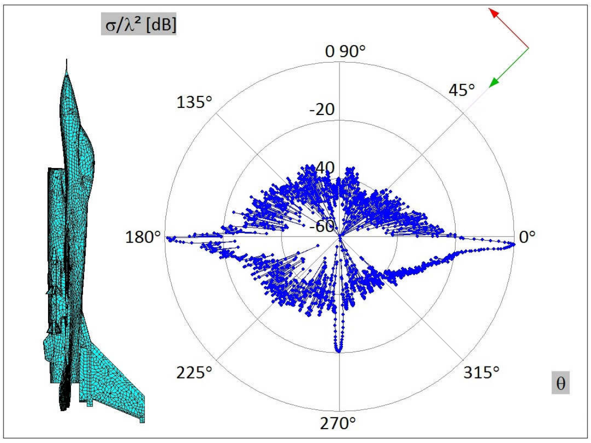

Figure 2. F16 monostatic RCS

In order to illustrate what the number of unknown coefficients means for the simulation of this airplane and how it influences the final simulation time, Table 1 shows the data of interest at four different frequencies.

Table 1. Scalability of the problem

Frequency [GHz]	No. of unknowns	Simulation time [sec]
0.1	8642	190.16
0.3	18267	289.08
1.0	73969	3135.87
3.0	348212	71035.54

F35 alike Fighter Simulation

This challenging model can be used to demonstrate the efficiency of techniques for reduction of number of unknowns without impacting the accuracy.

The first simulation is bistatic RCS at 1.5 GHz. Fighter is 15.7 m long with wing span of 10.7 m. That makes it 78.5 wavelengths electrically long. Simulation requires 100,133 unknowns without any reduction.

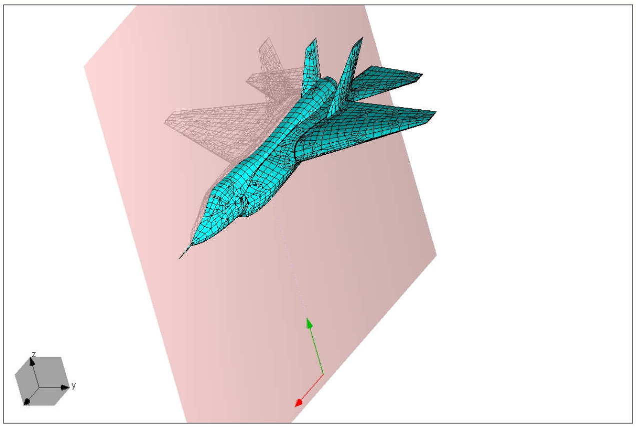

Figure 3. Fighter - bistatic RCS

Since the incoming wave is placed below the airplane, we can place the entire upper surfaces of the airplane in the shadow region and reduce number of unknowns on it. In addition we can reduce referent frequency used for determining level of current expansion (between 1st and 8th order) on quads for 30% (from 1.5 GHz to 1.05 GHz). After this, number of unknowns reduces to 43,203 (almost 60% reduction). Simulation time without reduction is 4,112 seconds (1800 directions) while reduced models runs only 494 seconds (8 times speed up).

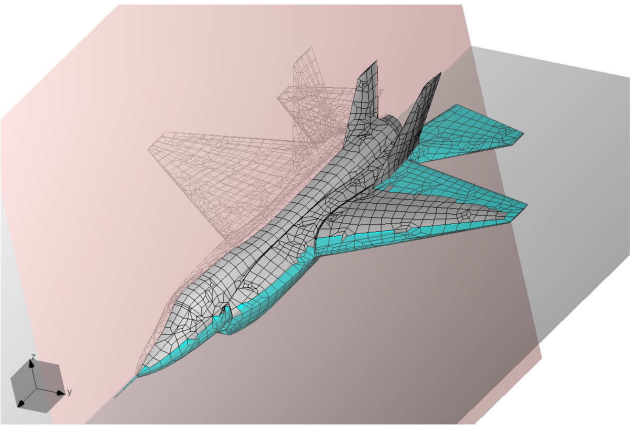

Figure 4. Fighter after applying the shadow – bistatic RCS

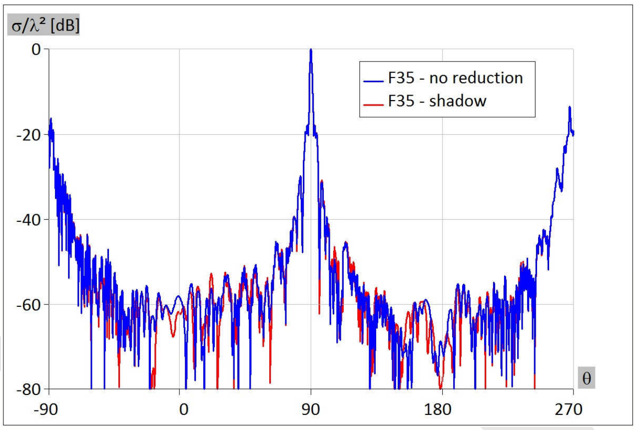

Figure 5. Influence of shadow reduction

The most challenging simulation is monostatic RCS at 4 GHz. Required number of unknowns is 569,550 and it can only be reduced by reducing referent frequency to 3.5 and 3 GHz. This yields 455,446 and 346,880 unknowns while simulations times are 98, 46 and 22 hours, starting from the most complex model. Number of directions is 3600. Electrical size of the model (length) is 210 wavelengths.

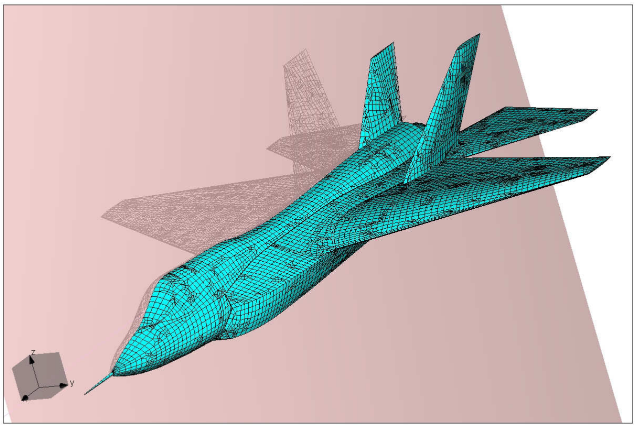

Figure 6. Fighter monostatic RCS at 4 GHz (dense mesh)

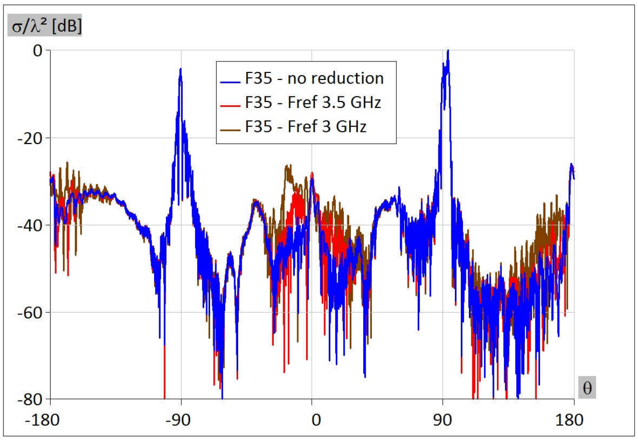

Figure 7. Influence of reduction at 4 GHz

Just like in the previous example, Table 2 illustrates how the same model of this airplane can be used for simulation at different frequencies and how that influences the simulation time.

The configuration used in this case is CPU Intel Core i7 950 @2.8GHz, 24 GB RAM, Win 7 Professional 64-bit, 3 GPU cards GeForce GTX480, 7 hard-disk drives with I/O speed about 100 MB/s.

Table 2. Scalability of the problem

Frequency [GHz]	No. of unknowns	Simulation time [sec]
0.1	4080	69.36
0.3	10645	130.98
1.0	49659	1299.41
3.0	323289	57399.44