Reduction of Unknowns Over Electrically Large Scatterers

Calculation of monostatic scattering from electrically large metallic objects\aircrafts is often required by a scientific, military, or an engineering working groups. With state-of-the-art 5th generation coated stealth aircrafts coming into play for RCS simulations, computational resources required are increasing rapidly. The increase is due to the presence of a single or multilayer dielectric coating leading to a significantly higher complexity of the aircraft viewed as an electromagnetic structure. Following the same line of reasoning, it is obvious that a pure metallic scatterer represents a computationally less demanding EM problem. However, **the simulations of a large, pure metallic scatterer** are not obsolete and **still require significant attention**. This is because of older but still widely used airplanes of the 4th generation, helicopters, missiles, and metallic spheres which are in fact still used for various calibrations and verification of the results.

This application note deals with the metallic aircrafts, in particular with the calculation of related monostatic RCS at 2.00 GHz. The aim is to demonstrate utilization of WIPL-D software for RCS calculation with a special attention given to a reduction of a number of unknowns. The high accuracy is preserved as the calculated RCS is almost unaffected by the reduction. The reduction will be performed by decreasing *Reference frequency* to 87.5% of initial value resulting also in a decrease of required number of unknowns and consequently the simulation time. **Such reduction is simple, fast, and straightforward to use.** The quality of results after performing the reduction will be confirmed by comparison of RCS with model simulated with higher number of unknowns.

WIPL-D Pro CAD, a full wave **3D electromagnetic Method-of-Moments (MoM) based software** will be used for simulation of the models throughout this application note.

WIPL-D Models of Metallic Aircraft

The demonstration model of airplane in WIPL-D Pro CAD is shown in Figure 1. The model is symmetrical, so only a half of the aircraft will be simulated.

The aircraft will be simulated with three different reference frequencies. Setting the first reference frequency to 87.5% of operating frequency should result in a reduced number of unknowns. The second reference frequency, which is set to equal to the actual operating frequency yields a default number of unknowns. Finally, the third reference frequency is set to 110% of operating frequency and therefore requires an increased number of unknowns. It will be considered to produce the most accurate results among the three cases. The models of aircraft obtained by meshing the aircraft at three frequencies are shown in the Figure 2.

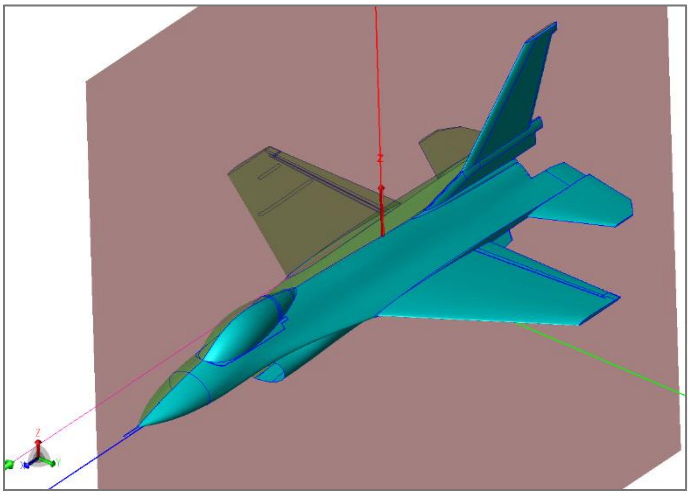

Figure 1. Metallic aircraft in WIPL-D Pro CAD

As it can be seen from Figure 2, the differences in meshing are relatively hard to notice. However, they do exist and are shown in the magnified areas of the left aircraft wing. The models shown in Figure 2 will be further referred to as 87.5%, 100%, and 110% models, respectively.

Simulations and Results

The airplane was simulated at frequency of 2.00 GHz while meshing of the aircraft is performed at three different frequencies. This means that reference frequencies in each of three models took following values:

- Model 87.5% - *Reference frequency* is 1.75 GHz
- Model 100% - *Reference frequency* is 2.00 GHz
- Model 110% - *Reference frequency* is 2.20 GHz

The RCS is calculated at 1801 equidistant directions in phi=0 cut. In coordinate system used in WIPL-D Software, direction in theta = 90 degrees points toward z = Inf. The default meshing from WIPL-D Pro CAD is changed in such manner that curvatures are meshed with tolerance of 45 degrees while maximum patch size is defined as 1.83 x wavelength.

The first group of the simulations was performed in order to find the optimal settings of numerical kernel parameter *Integral accuracy*. The simulations were performed at *Reference frequency* set to 2.00 GHz (100%). According to the results presented in Figure 3, and engaged computer resources listed in Table 1, it can be concluded that optimal value of *Integral accuracy* for this particular case would be *Enhanced 2*. Actually, *Integral accuracy* set to *Enhanced 1* also produce very good result. However, since number of unknowns will be decreased in the next step, we intentionally used higher value of *Integral accuracy* (here, *Enhanced 2*).

In general, **if electrically large models are simulated, it is always recommended to set *Integral accuracy* at least to *Enhanced 2*.** Also, it is worth noticing that simulation time data from Table 1 (and later from Table 2) do not contain the time required to mesh the airplane, which is about 6 minutes for the most demanding model - the model with 110% reference frequency.

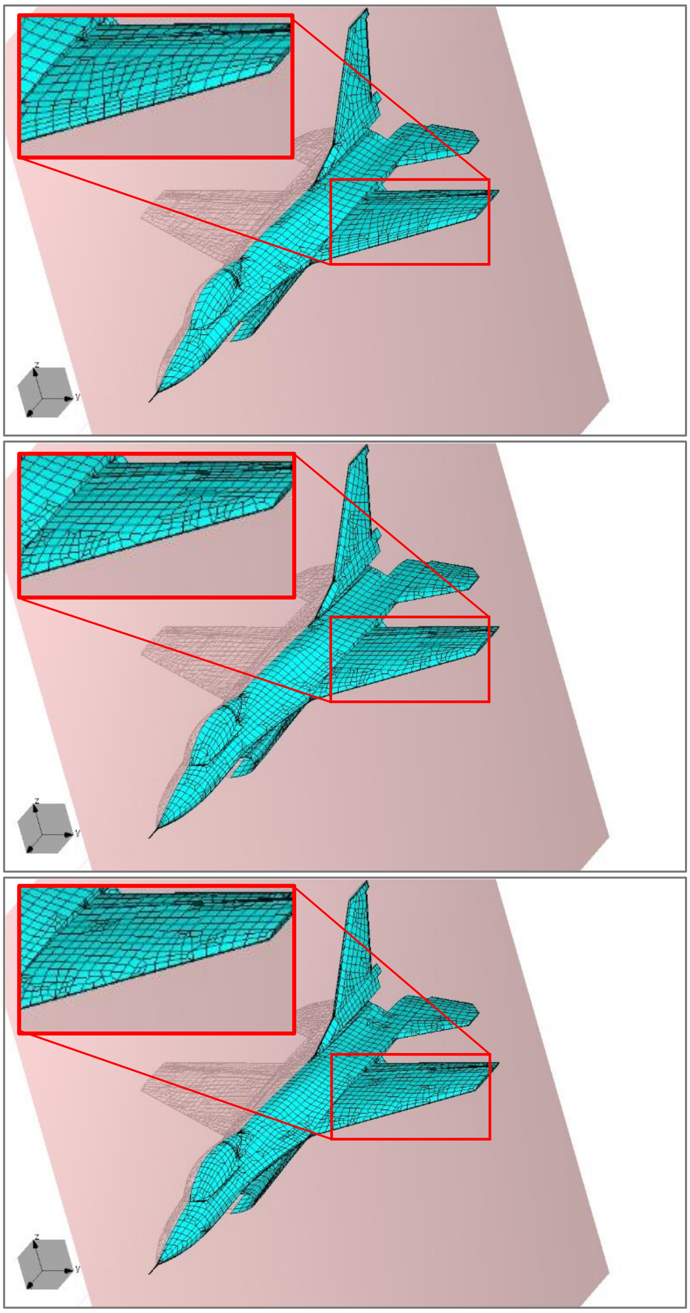

Figure 2. Meshed models of the metallic aircraft at 87.5%, 100%, and 110% of reference frequency which is equal to 2.00 GHz (from top to bottom). WIPL-D Pro preview

Table 1. Number of elements, number of unknowns, and simulation times required for aircraft simulation with Reference frequency of 100%

Integral accuracy	Number of elements	Number of unknowns	Simulation time
Normal	8,114	144,661	25 mins
Enhanced 1	8,114	144,661	28 mins
Enhanced 2	8,114	144,661	30 mins
Enhanced 3	8,114	144,661	37 mins

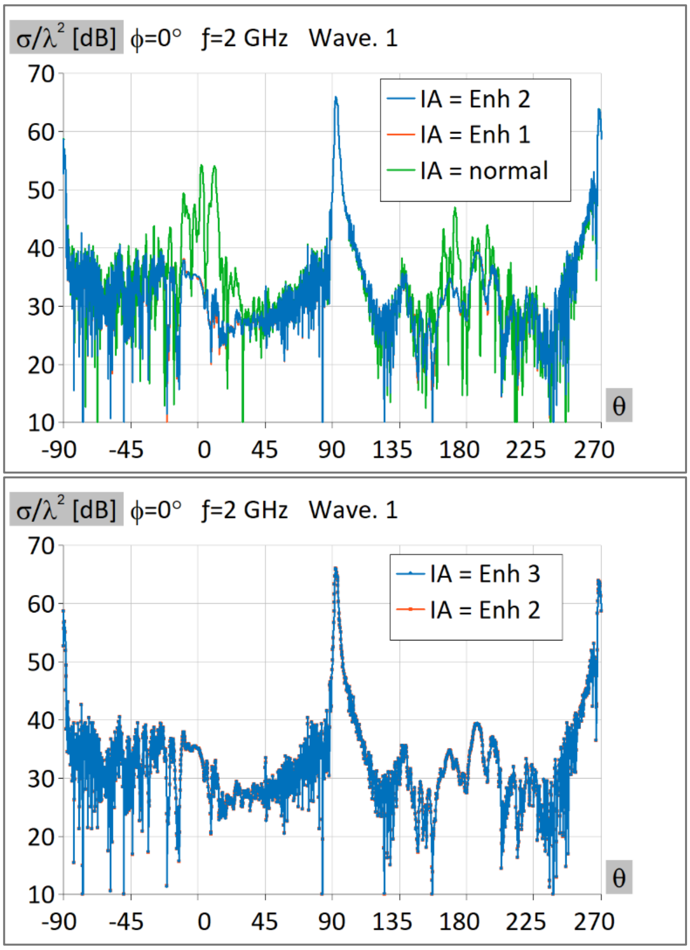

Figure 3. Scattering results for various *Integral accuracy* for model with *Reference frequency* of 100%

In the second step, reference frequencies are varied while *Integral accuracy* is fixed to previously selected *Enhanced 2*. This step should enable comparison of the results focusing on the changes occurring as a consequence of applying reduction. The comparison of the results is shown in Figure 4. It should be noticed that the result with the reduction applied (87.5%) is very similar to the remaining two results (100%, 110%).

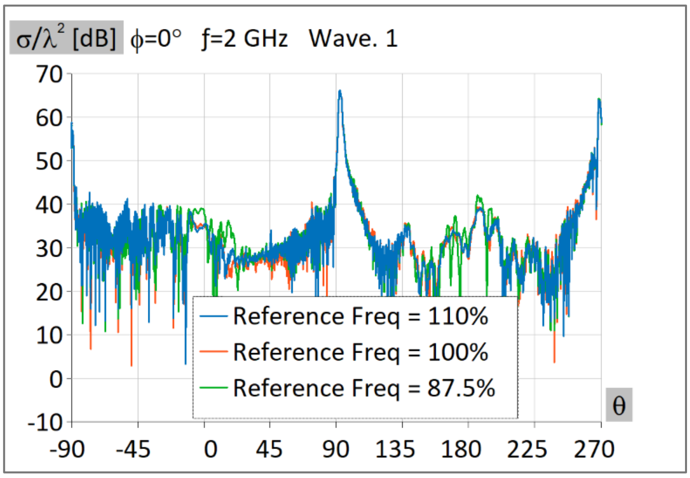

Figure 4. RCS for varied *Reference frequency* parameters

Variations of number of elements, number of unknowns and related simulation times as *Reference frequencies* varies are listed in Table 2.

Table 2. Number of elements, number of unknowns, and simulation times required for aircraft simulation with varied *Reference frequency* parameter

Reference frequency	Number of elements	Number of unknowns	Simulation time
87.5%	7,278	118,611	19 mins
100%	8,114	144,661	30 mins
110%	9,621	172,706	48 mins

The simulations were performed using a workstation with the hardware specification given in Table 3. GPU cards are used for matrix inversion.

Conclusion

This application note outlined utilization of WIPL-D Pro CAD, which is a full wave 3D electromagnetic Method-of-Moments (MoM) based software, in simulations of **monostatic scattering from electrically large metallic aircrafts**. Actually, this simple, and fast reduction was presented. The reduction encompassed decreasing *Reference frequency* parameter to 87.5% of initial value.

The aim of application note was to present the **benefits of implementing a reduction** of number of unknowns when working with WIPL-D. The calculated RCS is almost unaffected with the reduction while number of unknowns and simulation time and are both reduced. The result obtained with parameter *Reference frequency* set to 87.5% of a default value is indeed calculated with **reduced computational resources retaining the high accuracy.** In spite of very large electrical size of the structure all the results were calculated in relatively short amount of time. In addition, the workstation used for the calculations was an affordable desktop PC empowered with GPU cards.

The presented reference frequency settings can be successfully applied to many realistic scenarios such is calculating RCS of a 4th generation fighter aircraft.

Table 3. Workstation used for the simulations

Hardware	Description
Processor	Intel® Xeon® Gold 5118 CPU @ 2.30GHz 2.30 GHz (2 processors)
RAM	192 GB
GPU	2 GPU cards: NVIDIA GeForce GTX 1080 Ti