RF Antenna Coupling on Realistic Platforms

Introduction

WIPL-D Software suite encompasses several simulation techniques, but emphasize is always on accuracy. Thus, the default simulation tool is WIPL-D Pro, a frequency-domain Method of Moments (MoM) based code. The kernel of the tool enables very accurate full wave electromagnetic (EM) simulation of arbitrary 3D structures. Owing to application of numerous sophisticated techniques, very large structures are simulated on ordinary PC computers or inexpensive workstations.

Among all, 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. Thus, for the same representation of current distribution, HOBFs typically require 3-10 times less unknown coefficients. 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 via various features (both basic and advanced).

One of the unique features is the usage of quadrilateral mesh instead of triangular one. This further reduces required computational demands. WIPL-D Pro has the modeler where the user is in full control of mesh (user can also use numerous built-in elements) while WIPL-D Pro CAD offers automatic quadrilateral mesh. The tool includes several mesh methods, but the default one is in-house developed direct quad mesher which results in EM simulation ready models adapted for WIPL-D Pro MoM implementation. Such mesh (even in case of real life platforms with huge number of both small and large details) yields again the minimum requirements.

However, the simulation of real life platforms (such as aircrafts, ships, cars etc.) at RF frequencies would not be possible with modern and affordable GPU technology. Inexpensive GPU cards can be added to existing desktop computers and allow simulation of models with hundreds of thousands of unknown coefficients (up to 500,000 currently in reasonable time).

At the end, a very common engineering problem is to place the antenna on a large realistic platform. WIPL-D offers a feature to automatically reduce order of current expansion on parts of the model insignificant for EM results. The feature is called smart simulation and it can be based on placing the part of the structure in the shadow, or using the antenna placement reduction. It is based on adaptive reduction of current expansion order over parts of the model which are distant from the antenna. This way, the number of unknowns is reduced, while very good accuracy of calculated radiation pattern or coupling between multiple antennas is preserved. The usage of features requires very little user intervention. Only the Integral Accuracy parameter is increased to Enhanced 1 or Enhanced 2, based on the applied reduction level.

Simulations

One of the common engineering problems is the coupling between antennas which use the same or different frequency band and are located in different positions on the realistic platform. For the demo example, we will choose the fighter aircraft F35. Fighter is 15.7 m long with wing span of 12.3 m. That makes it 78.5 wavelengths electrically long at 1.5 GHz. Simulation requires around 92,000 unknowns without any reduction. The simulation frequency is chosen in such a manner that all simulations fit into 100,000 unknowns WIPL-D Premium license. All simulations can be solved on regular desktop PC enhanced with single inexpensive CUDA enabled GPU card in under 1 hour. The aircraft is symmetrical. User can choose between symmetry and asymmetry in the model, depending on the position of the antenna. If the antenna is placed asymmetrically (outside of symmetry plane), each simulation is run twice. First the symmetry plane is replaced with PEC and then with PMC, and results are combined.

Applicability of antenna placement reduction heavily depends on position of the antennas. The most challenging scenario is when several antennas are scaterred at the aircraft surface. We have chosen to place one antenna on top near the cockpit, and the other antenna on the bottom near the tail. That way the majority of surface must be included into simulation, which corresponds to the scenario with multiple antennas spread on the surface. The aircraft came in as a CAD file imported into WIPL-D Pro CAD and meshed properly for WIPL-D MoM simulation. The antenna locations are shown in Figure 1.

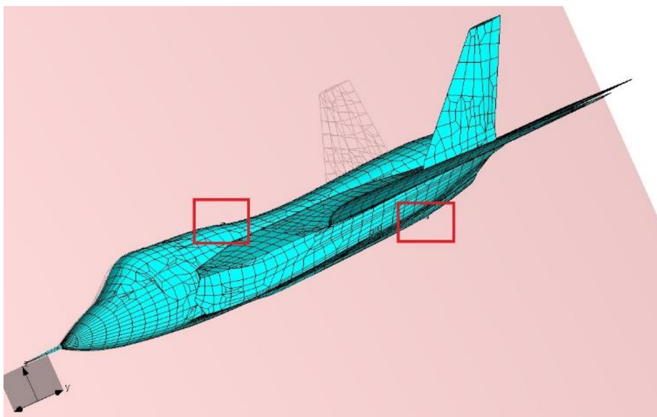

Figure 1. Positions of antennas on F35

The antennas are simple quarter wave wire monopoles matched at 1,100 and 1,400 MHz. Typical return loss at the matched frequency is -15 dB. The frequency is chosen in such a way that simulation is carried out between 1 and 1.5 GHz. The detail of the antenna is shown in Figure 2.

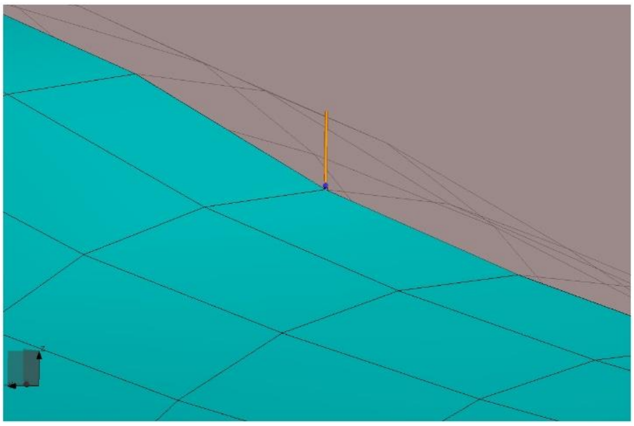

Figure 2. Placing a wire monopole to aircraft surface

The return loss is not of interest, but due to electrical size of the platform and the fact that antennas are spaced apart, -15 dB loss remains almost unchanged when antenna is mounted on the aircraft (presented for 1,100 MHz antenna in Figure 3).

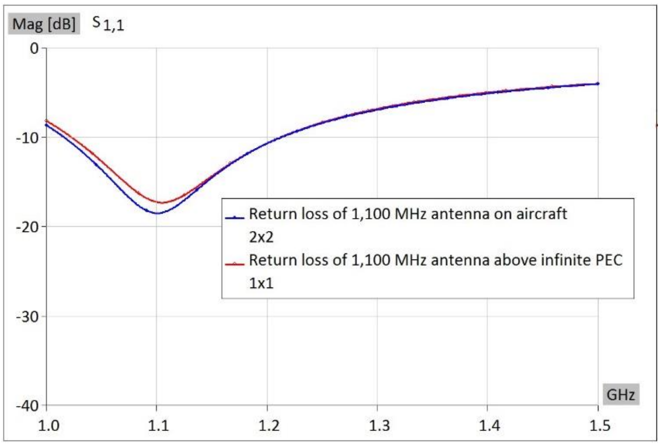

Figure 3. Return loss for mounted antenna

Next, we demonstrate the efficiency of the simulation. 80 lambda aircraft requires only 92,000 HOBF unknowns. By using inexpensive GPU technology, the example is solved in 1,770 seconds per frequency point on the following configuration: Intel Core i7-7700, 4 Cores, @3.60GHz, Nvidia GTX 1080.

Despite the worst-case scenario, antenna placement reduction still can be applied (with smaller unknowns saving). The recommended values which usually do not affect the simulation accuracy at all are 20% and 40%, while 60% and 80% usually yield excellent accuracy.

Table 1. The influence of antenna placement reduction for the worst-case scenario.

Reduction	Number of unknowns
Full model	92 178
Antenna placement 20%	87 868
Antenna placement 40%	82 806
Antenna placement 60%	77 507
Antenna placement 80%	72 533

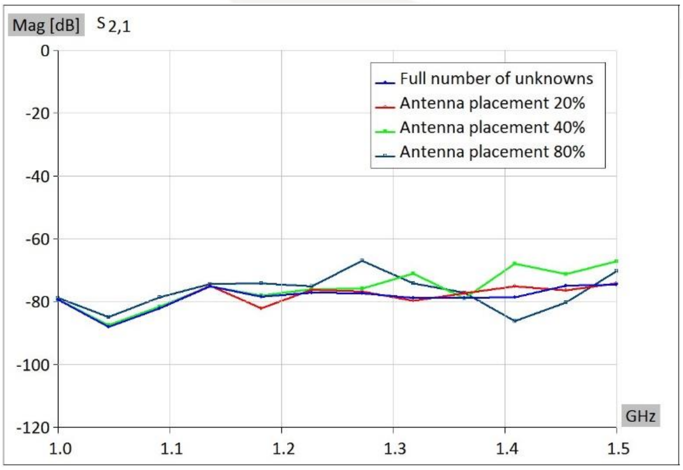

Figure 4. Influence of antenna placement reduction

The antenna placement reduction shows a modest reduction in terms of number of unknowns for the particular problem. If antennas however are placed on the same part of aircraft, say one on top and other on bottom half near the tale, the reduction yields values as in Table 2.

Table 2. The influence of antenna placement reduction for the near locations scenario.

Reduction	Number of unknowns
Full model	92 178
Antenna placement 20%	85 587
Antenna placement 40%	78 316
Antenna placement 60%	71 107
Antenna placement 80%	64 618

The effects are more pronounced when frequency increases. The only required setting is to apply increased Integral Accuracy (in Edit, Options). The safest recommendation is to use Enhanced 2 in all models, although in general smaller reduction requires lower Integral Accuracy level.

Although increasing the accuracy improves the effects of antenna placement reduction, number of unknowns generally rises as the square of frequency. In that sense, simulations become impractical even at two times larger frequency. WIPL-D offers solution in WIPL-D Domain Decomposition Solver (available in v13 and later).

WIPL-D DDS constructs macro BFs (MBF) which cover larger surfaces (than typical BFs). The method is iterative and it converges toward MoM solution by employing correctional currents between iterations. In each iteration, it determines weighting coefficients for MBFs in a way to minimize difference with respect to MoM matrix. The tool also applies antenna placement regime. Particularly, DDS is oriented towards electrically large problems. It needs less memory and significantly less CPU time. The method is suitable for inexpensive CPU platforms, especially with multicore CPUs. Its accuracy cannot be compared with rigorous MoM, but from engineering point of view it can provide sufficient accuracy in CPU time unreachable to MoM.