Coaxial Fed Dipole Mounted on F-16 at 1.9 GHz

Simulation of real-life antennas mounted on electrically large platform is often very challenging problem. In such scenarios, the mounted antenna is usually electrically small comparing to overall dimensions of the whole structure. Furthermore, in the model of the antenna, the details which are several dozen times or even several hundred times smaller than wavelength can be found. On the other side, the entire structure can be several hundred times larger than a wavelength. Although such simulations are complex, **the requirements for highly accurate and fast solution** always persist.

In this application note, simulation of an antenna mounted on an aircraft will be presented. The dipole antenna fed by coaxial cable with a balun will be mounted on the fuselage of F-16 aircraft. The dipole antenna represents an antenna which is a part of an IFF (Identification, friend or foe) system. **WIPL-D Pro CAD** and **WIPL-D Pro** software will be used for simulation of this electrically large scenario. Output results, information about application of current expansion order reduction, computer memory requirements and simulation time will be presented. The benefits of using WIPL-D software, especially if combined with WIPL-D *GPU Solver* and features such as *Smart reduction*, will be also highlighted.

MoM Efficiency

WIPL-D Pro, a **3D EM Method-of-Moments (MoM)** based solver, applies **higher order basis functions (HOBFs)**. Thus, WIPL-D is enabled to operate with relatively large meshing elements. The maximum size of meshing elements utilized is 2 wavelengths-by-2 wavelengths. It is possible to combine different orders of current approximation along two axes of a quadrilateral mesh element. This yields to the **minimization of number of unknowns**, even with very elongated mesh elements.

In order to fully exploit capabilities of WIPL-D software, it is desirable to utilize relatively large mesh elements (up to 2 wavelengths-by-2 wavelengths) over flat or smooth model surfaces. At the same time, an accurate representation of model details should be obtained by using fine mesh elements on which low-order basis functions (representing a subset of HOBFs) are applied. Finally, on surfaces of the model which are flat or smooth along one axis and curved along the other, elongated mesh elements become the optimal choice.

Smart Reduction of Expansion Order

Very useful feature intended for antenna placement problems is *Smart reduction*. It is based on **adaptive reduction of current expansion orders** over parts of the model which are distant from the antenna (*Antenna placement reduction*) or in shadow (*Shadow reduction*). By applying the *Smart reduction*, number of unknowns (with computer memory requirement and simulation time) can be dramatically reduced, preserving excellent accuracy. Results after applying both reductions (*Antenna placement reduction* and *Shadow reduction*) will be present in this document.

GPU Solver

Usage of the *GPU Solver* enables the user to perform extremely fast simulation of the models requiring a lot of unknowns. The *GPU Solver* primarily accelerates system matrix solving through usage of graphical processing units (GPUs). The *GPU Solver* is very suitable and very efficient for simulations of electrically large antenna placement problems.

WIPL-D Models

Model of the aircraft is imported from a CAD file by using WIPL-D Pro CAD. WIPL-D Pro CAD represents software which is 3D solid modeler and importer of files supporting various CAD formats. It is a part of the WIPL-D software suite. The dipole antenna with the feeding is modeled from the scratch using WIPL-D Pro CAD and its built-in primitives. The antenna with the feeding is placed on the appropriate position on the aircraft fuselage (Figure 1).

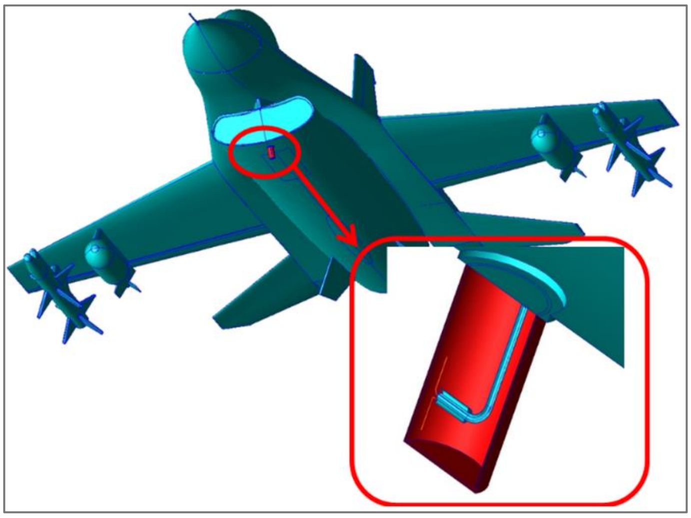

Figure 1. Antenna mounted on air platform – WIPL-D Pro CAD preview

One *Symmetry* plane was applied. That way, the symmetry of the structure was exploted to reduce (half) the number of unknowns and thus, to decrease simulation time.

After completing CAD model, model of the antenna and air platform was meshed by using in-house developed mesher. The result of the meshing process is presented by capturing WIPL-D Pro *Preview* window (Figure 2). Size of meshing elements on flat and smooth surfaces is set to be slightly lower than 2-by-2 wavelengths. Meshing elements over the small details of the structure are smaller. Cylindrical parts over the antenna are meshed using elongated quadrilateral elements. Such meshing elements enabled us minimization of number of unknowns over the entire model.

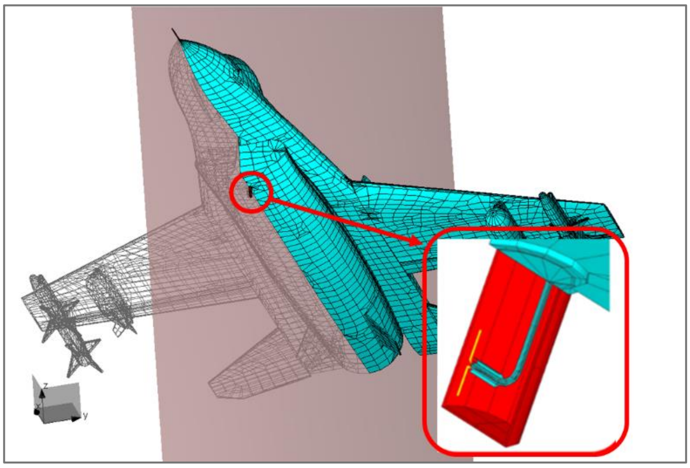

Figure 2. Meshed model of the antenna mounted on air platform - WIPL-D Pro preview

As it was stated above, *Smart reduction* features were applied. Usage of *Shadow* reduction is visualized in Figure 3 by displaying grayed mesh plates.

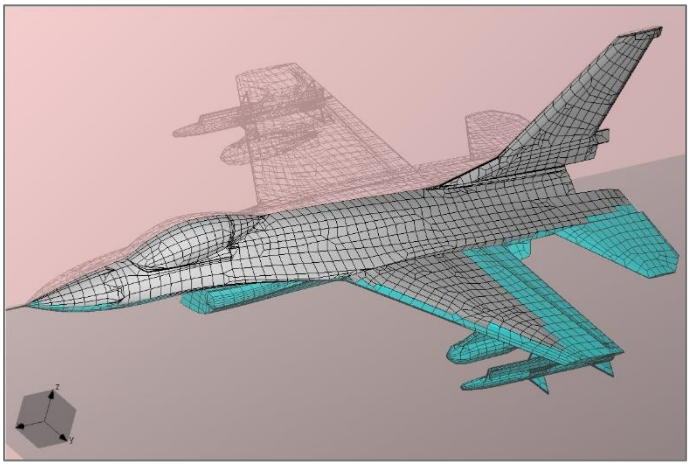

Figure 3. The antenna mounted on the air platform. *Shadow* reduction can be noticed - WIPL-D Pro preview

Results and Simulations

The models were simulated from 1.7 GHz to 2.1 GHz at 5 frequency points. Such a low number of frequency points is possible due to built-in powerful interpolation algorithm. For example, it is extremely important when simulation requires the S-parameters in a frequency band, especially at radio frequencies.

S_{11}-parameters and radiation patterns are calculated and presented. S_{11}-parameters are displayed in Figure 4. The compared radiation patterns are displayed in Figure 5. 3D radiation pattern at 1.9 GHz is displayed in Figure 6.

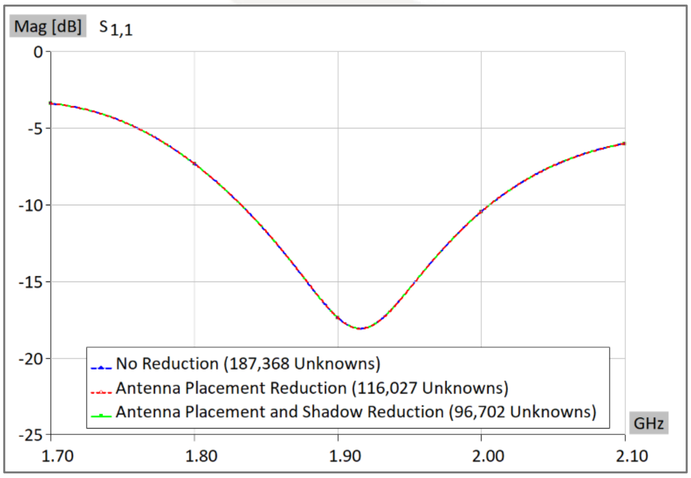

Figure 4. S_{11}-parameter of the IFF system antenna

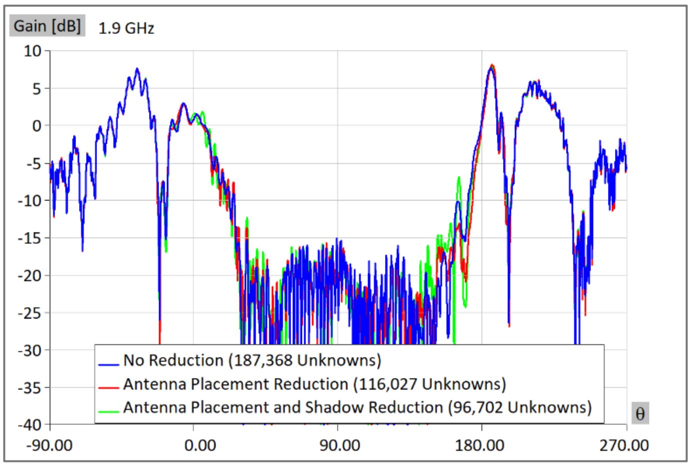

Figure 5. Compared radiation patterns

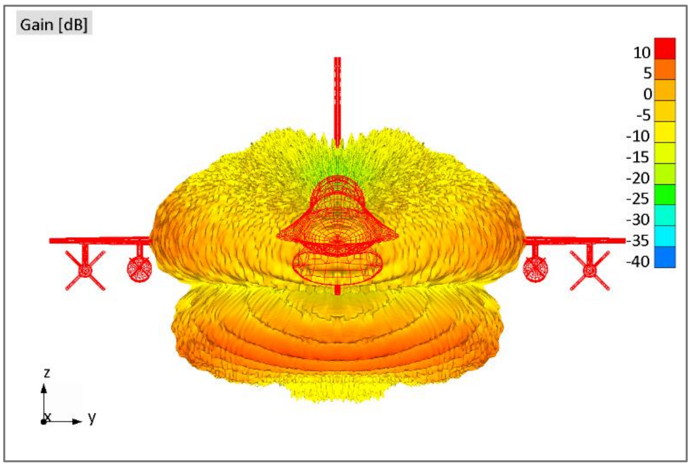

Figure 6. 3D Radiation pattern of IFF system antenna

Model of the antenna mounted on aircraft platform was simulated on **computational platform** Intel® Xeon® CPU E5-2650 v4 @ 2.20 GHz (2 processors) with 256 GB RAM and four inexpensive GPU cards NVIDIA GeForce GTX 1080 Ti. Matrix fill-in was performed on CPU while matrix inversion was performed on GPU. Simulation time mainly consists of time required for matrix fill-in and matrix inversion.

Number of unknowns, computer memory required and simulation times at one frequency, for simulated models are shown in Table 1.

Table 1. Number of unknowns, computer memory required and simulation time per frequency

Reduction	Number of unknowns	Memory [GB]	Simulation time per frequency [mins]
No Reduction	187,368	262	52.5
Antenna Placement	116,027	100	13.6
Antenna Placement and Shadow	96,702	70	9.8

Conclusion

Three models of a dipole antenna with a balun which is covered with dielectric radome and mounted on the F-16 aircraft fuselage were simulated using WIPL-D software. The first model was simulated without any reduction applied. The second model was simulated with *Antenna placement reduction*. Finally, the *Antenna placement reduction* and *Shadow reduction* were applied to the third model. Various output results with the computer requirements were presented. CPU was used for matrix fill-in, while GPU was used for matrix inversion.

Bearing in mind that this model represents antenna placement scenario, all the **simulations were performed very fast**. Especially, with both reductions applied, the results are obtained very fast using GPU card. This means that, for example, during the design process, the antenna designer can successfully **experiment with various design variables in relatively short amount of time**.

The results presented in this application show us that WIPL-D can **successfully simulate electrically large platforms** (approximately 105 wavelengths length) **with dielectric involved**, especially if methods of reducing number of unknowns were properly applied. Also, WIPL-D software can **successfully handle discrepancy between size of model details and size of the entire structure**. The length of the aircraft is about 15 meters (105 wavelengths), while the diameter of inner coaxial conductor of antenna feeder is only 3.16 mm (approximately 45 times smaller than wavelength).

Finally, maybe the most important conclusion is that the **properly applied reductions** (Figure 4 and Figure 5) **give us almost the same results as the model without any reduction applied**. In the other words, even in such demanding models, significant speeding up the simulation can be enabled without losing accuracy.