

## Combat Vehicle with GPS Antenna above Real Ground

This application note describes simulation of a radiation pattern of a GPS antenna mounted on a combat vehicle resting on an infinite real ground. The motivation behind the work presented in the application note is to illustrate a reduction in a number of unknowns when a WIPL-D Pro feature *Unused Entities* is used. Furthermore, the application note illustrates that the high accuracy of the results is preserved with a reduced number of unknowns.

The reduction has been achieved by realizing that only objects positioned close to the antenna have significant influence to a radiation pattern. Accordingly, in many simulation scenarios, it is not necessary to simulate the whole structure surrounding the antenna. When using *Unused Entities* feature, the entities that will not be used in the simulation can be selected easily.

In order to demonstrate advantages of WIPL-D Pro with activated *Unused Entities* option, five models of combat vehicle will be simulated and radiation patterns of the antenna compared.

### Combat Vehicle Model

Combat vehicle was modeled using WIPL-D Pro CAD software. This program is especially suited for easy creation of complex 3D geometry models. The models can be either imported from various CAD formats, or created from scratch using built-in primitives. For the particular case of combat vehicle considered in this note, a model has been built using later approach. The model is shown in Figure 1.

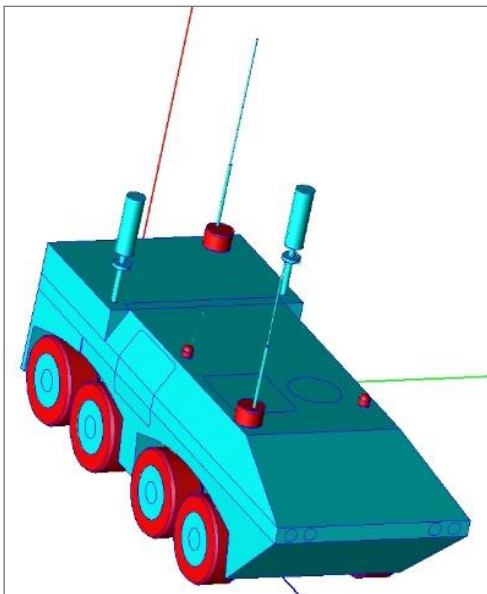


Figure 1. WIPL-D Pro CAD model of the combat vehicle

The antenna which radiation pattern will be calculated, is covered with radome and located on the roof of the vehicle (see Figure 5 for detailed close-up view). Position of the antenna under radome is highlighted in Figure 2 using orange arrow.

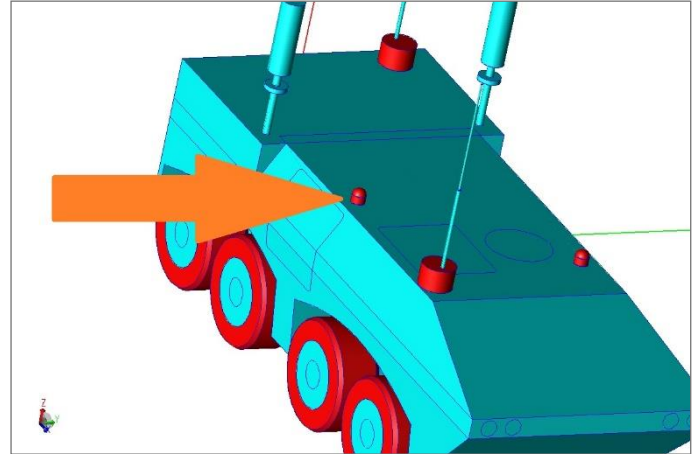


Figure 2. Position of the antenna on the roof of the vehicle

The model created in WIPL-D Pro CAD should be converted to WIPL-D Pro native file format before simulation starts. A conversion to WIPL-D Pro native file format is performed by applying meshing procedure. Meshed model is shown in Figure 3.

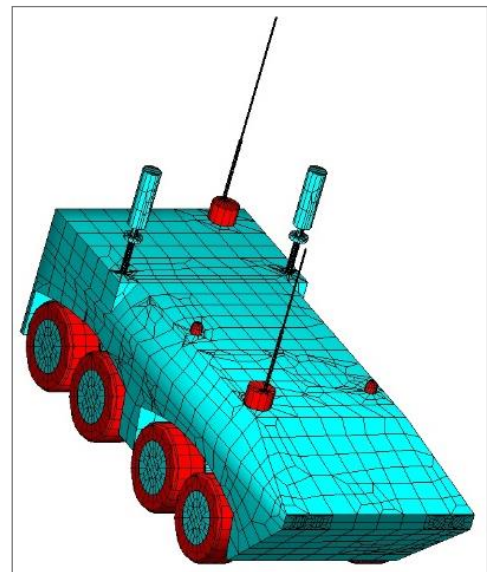


Figure 3. Meshed model of combat vehicle in WIPL-D Pro

In WIPL-D Pro software, materials being used for various parts of a model can be visually identified, since parts modeled with the same material can be presented in the same color. In the particular case of combat vehicle model, the two dielectrics can be identified in Figure 4. The air, colored in magenta, has been used to model tires. The other dielectric material is presented in dark blue. Parameters of the dark blue material are  $\epsilon_r = 2$  and  $\epsilon_i = -0.002$ , and it has been used for radome of GPS antennas and for a cylindrical cover for basis of two FM antennas. The real ground in  $z = 0$  plane (not shown in the figures) has been used in this model. The electrical parameters of the real ground are  $\epsilon_r = 10$  and  $\sigma = 0.001$ .

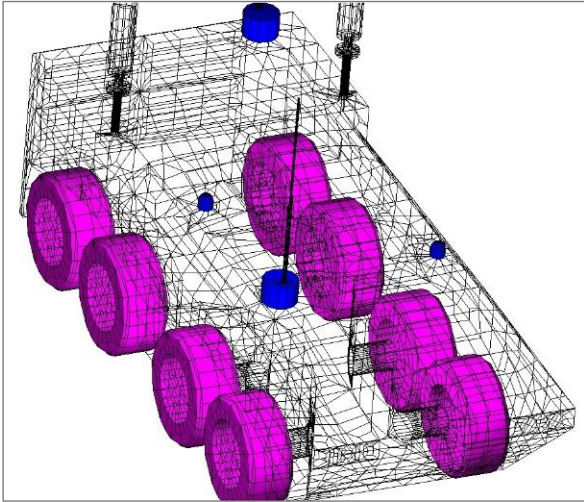


Figure 4. Different dielectric materials used in the model of combat vehicle

### GPS Antenna Model

Antenna operating in the GPS band is shown in Figure 5. Two dipoles have been placed perpendicularly above a metallic cylinder and fed with signals in quadrature. The antenna is covered with a dielectric radome. A transparency feature has been applied to the radome to illustrate entire antenna construction in the figure.

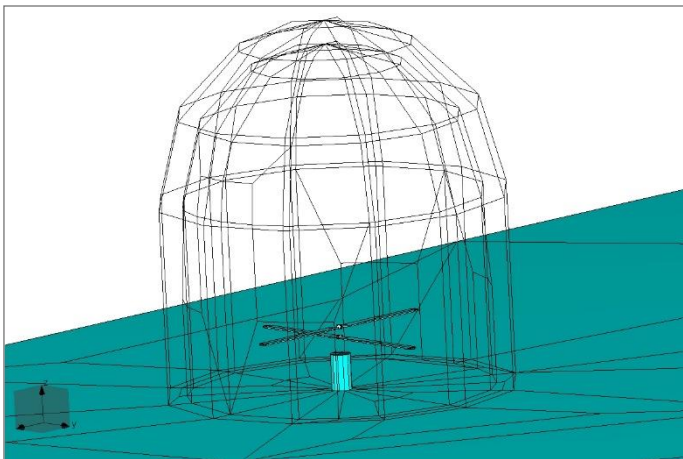


Figure 5. GPS antenna on the roof of the vehicle

### Applying *Unused Entities* Feature

In order to reduce simulation time and minimize utilization of the other computational resources, WIPL-D Pro feature named *Unused Entities* has been applied. In Figures 6-9, high versatility of the feature is demonstrated. In each of the figures entities colored in yellow will not be included in the simulation. For example, in Figure 6, only a small part of the vehicle near the antenna will be simulated. A larger area of the combat vehicle has been included for the model presented in Figure 7, even larger area in Figure 8, while the largest, but still reduced vehicle model is presented in Fig. 9

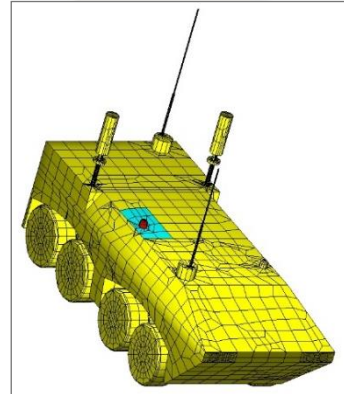


Figure 6. *Unused Entities* (1)

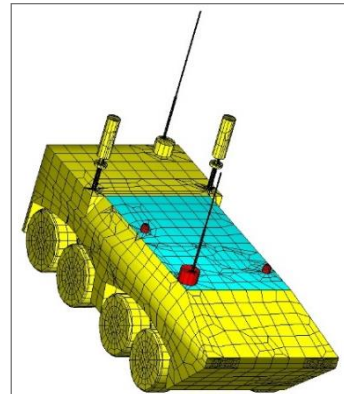


Figure 7. *Unused Entities* (2)

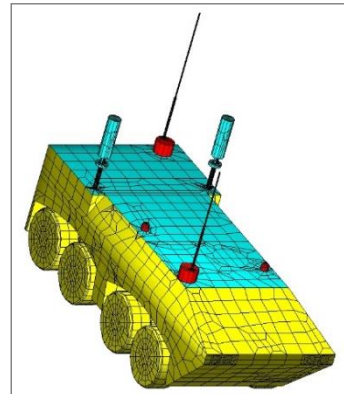


Figure 8. *Unused Entities* (3)

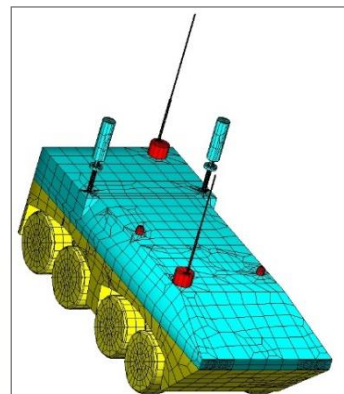


Figure 9. *Unused Entities* (4)

The model without *Unused Entities* feature applied has been presented in Figure 3.

### Simulations

All models of the vehicle will be simulated at 1500 MHz in AGAT (All Generator At Time) operation mode. This means that the dipoles from Figure 5 have been excited at the same time.

The simulations are carried out on a desktop computer, Intel® Xeon® CPU E5-2650 v4 @2.20 GHz, 2 processors, 256 GB RAM and 4 GPUs Nvidia GeForce GTX 1080 Ti. CPU is used for matrix fill, while GPU is used for matrix inversion.

Numbers of unknowns, occupied computer memory and simulation time are presented in Table 1. Simulation time is a sum of three intervals: time spent in matrix filling, time spent in matrix inversion and time spent in calculation of radiation pattern. In any simulation scenario, time required to calculate a radiation pattern is negligible compared to both, matrix filling time and matrix inversion time.

**Table 1. Number of unknowns, occupied memory and simulation time for simulated models**

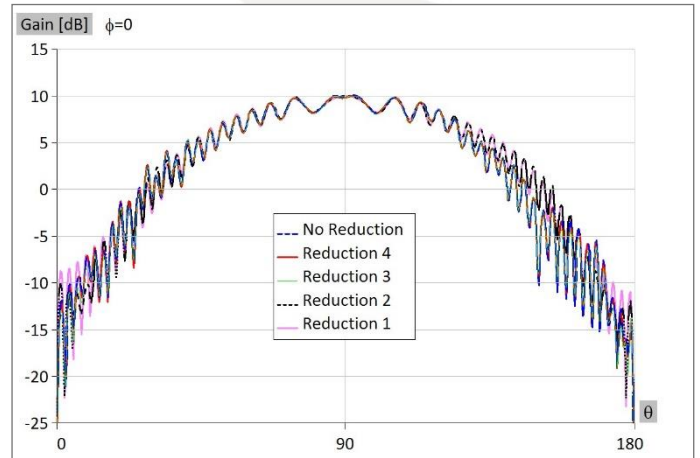
Model	Number of unknowns	Memory [GB]	Simulation time [sec]
Reduction 1	3,235	0.078	4
Reduction 2	17,166	2.195	20
Reduction 3	33,232	8.228	51
Reduction 4	49,930	18.574	102
No Reduction	170,058	215.469	1432

### Results

After inspecting convergence of the results, it has been verified that WIPL-D Pro accurately simulates models of the combat vehicle with default simulation settings.

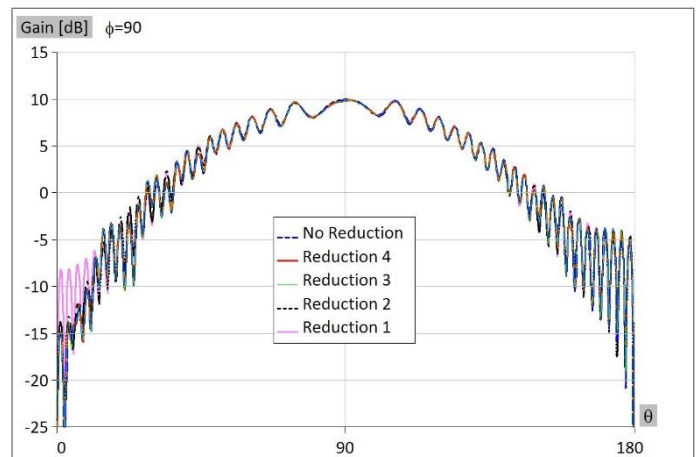
Radiation pattern results for applied different reductions in Phi = 0 plane and above the real ground are presented in Figure 10 (in WIPL-D, Theta = 0 angle refers to xOy plane).

In order to show that levels of reduction influence the results in other directions, model of the GPS antenna was simulated for Theta = 45 Degrees. A comparison of calculated radiation patterns in Theta = 45 plane is presented in Figure 12.

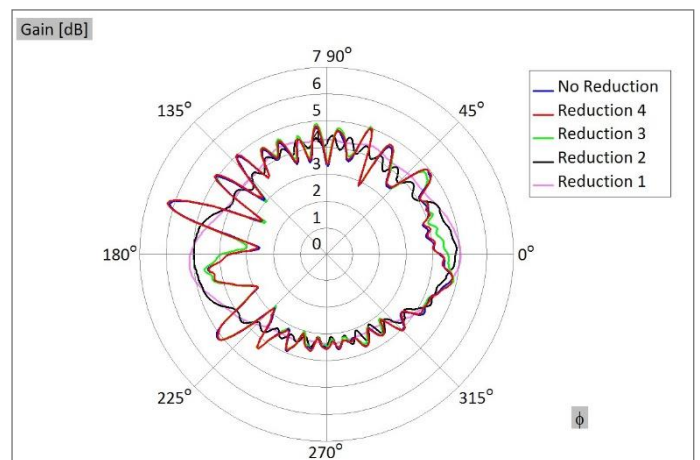


**Figure 10. Radiation pattern in Phi = 0 Degrees plane**

Results obtained for radiation pattern in Phi = 90 Degrees plane with different model reductions are presented in Figure 11.



**Figure 11. Radiation pattern in Phi = 90 Degrees plane**



**Figure 12. Radiation pattern for Theta = 45 Degrees**