Vehicle to Vehicle Communication

EM simulations have a significant role in automotive industry. WIPL-D software continuously improves its variety of tools which allow various applications in this growing industry. The range of EM simulations has been extended with introduction of **CAD tools** (allow easy import of CAD files, as well as modeling and positioning of devices in conjunction to complex CAD geometries) and **GPU simulation module** (which extended the range of frequencies where applications can designed and simulated). Furthermore, WIPL-D introduced **Domain Decomposition Solver (DDS)**, a product, which is intended for simulations of electrically very large problems. In this application note, DDS will be used in simulations for *Vehicle to Vehicle Communication*.

WIPL-D Simulations

One of the emerging technologies in automotive industry is vehicle to vehicle communication, as well as general interaction of the vehicles with the environment. The main applications are toll and safety systems, as well as auto pilot and parking sensors systems. This leads to expansion of number of antennas mounted on vehicles.

Typical EM challenge in such cases is design of optimal antenna and positioning it. One of the arising frequency bands is 5.9 GHz. It offers physically small antennas that do not disturb car design. But cars at such high frequencies represent electrically large objects. In that sense unique features offered by WIPL-D software suite allow full wave simulation at these RF frequencies. Among those are higher order basis functions, optimum quadrilateral mesh of CAD models and GPU enhanced simulation. Also, this appears to be a good example for showing capabilities of DDS.

DDS is solver which enables full wave solution of electrically very large structures. It was created to solve structures which would otherwise be impossible to solve using WIPL-D Method-of-Moment solver or solving the structures using WIPL-D MoM solver would require very long simulation time.

The basic idea behind DDS is that the original model is decomposed into a number of groups. A group is composed of a number of neighboring plates and wires. Each group represents a subproject. In the 0^{th} iteration, subprojects are simulated independently and the coupling between them is not taken into account. Solutions of all subprojects are used as macro-basis functions whose weighting coefficients are determined from the condition that mean-square value of the residuum of the original project is minimized. The residuum of the final solution in the 1^{st} iteration can be used as the excitation in the 2^{nd} iteration, and so on. The entire iterative procedure finishes when the total residuum falls below the predefined threshold.

In the following example we demonstrate placing 3 short monopole antennas on generic car model and an advanced scenario where we analyze 2 cars in one simulation.

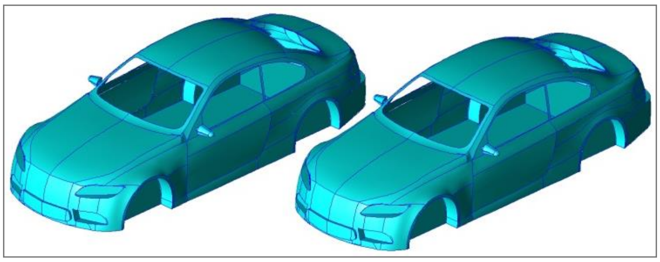
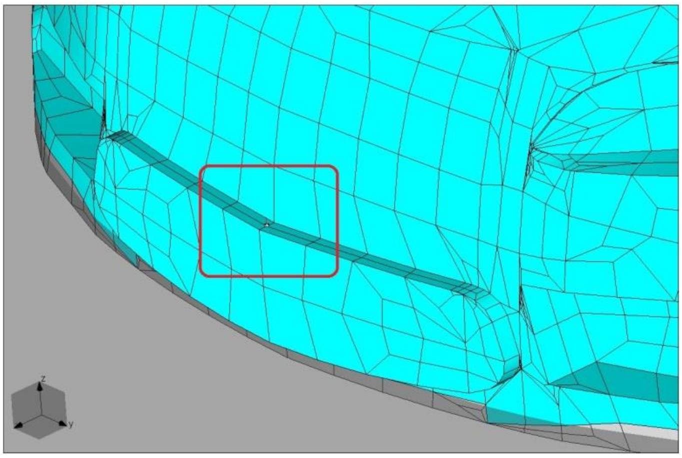
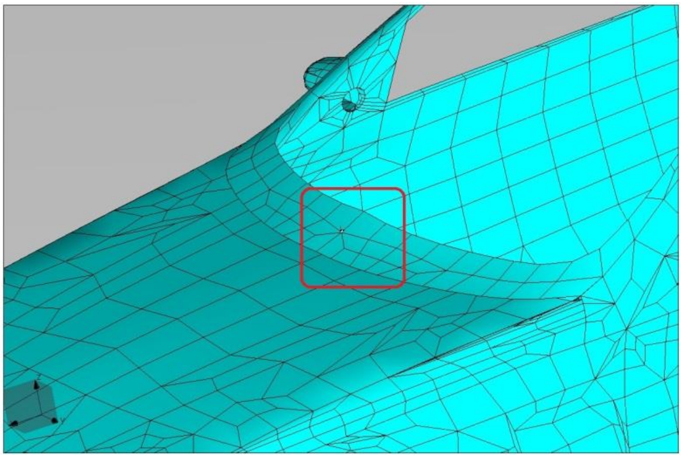


Figure 1. Vehicle to vehicle scenario

The location of three antennas is as in the Figure 2.





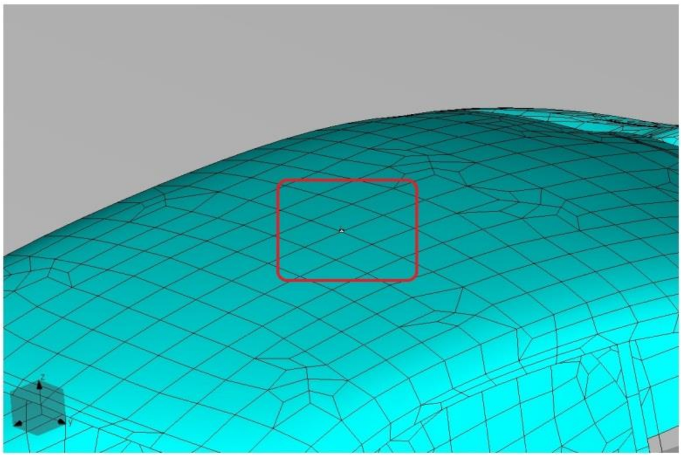


Figure 2. Antennas locations

In the first simulation, we run a single car model with 3 antennas installed. We investigate return loss of the antennas (only antenna #1 has weak return loss due to its mounting) and coupling between antennas.

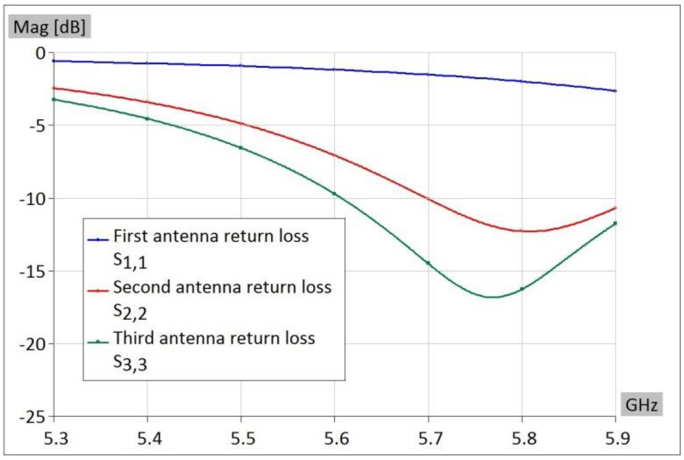


Figure 3. Antennas return loss

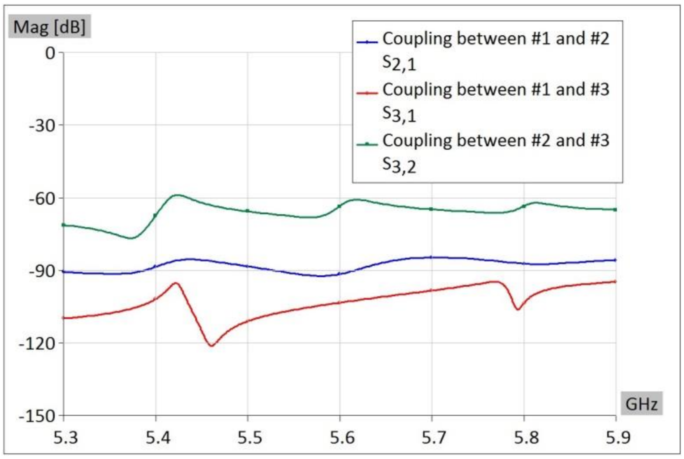


Figure 4. Antennas coupling

Simulation was performed 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 (matrix inversion was performed on GPU cards). Symmetry was applied and problem required **90,000 unknown coefficients** in MoM system matrix. **Simulation time per frequency is around 24 minutes.**

Radiation pattern at 5.9 GHz of the third antenna (mounted on the roof) is shown in Figure 5.

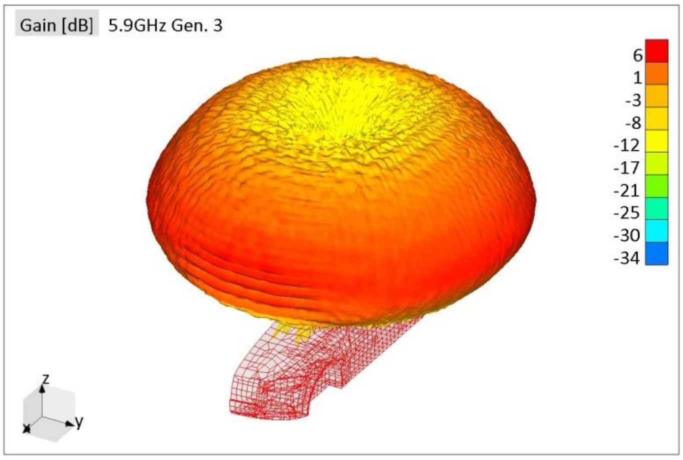


Figure 5. Third antenna radiation pattern

The final scenario includes 2 vehicles and 6 antennas in total. No symmetry can be applied so total **number of unknowns is 364,262**.

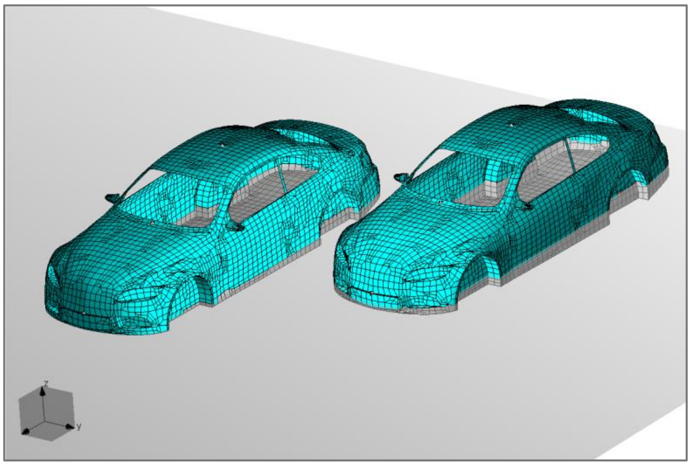


Figure 6. Scenario final model

The EM simulation is now extremely challenging. Simulation time on the previously described desktop is **4.6 hours**. Number of unknowns was reduced by putting bottom of cars and parts insignificant for EM simulation in the **shadow region**, where number of unknowns is significantly lowered.

Number of unknowns was also reduced via **antenna placement reduction**, which means orders of current approximation are lowered on parts away from antennas. All the previously described features are automated. As the last possibility to spare unknown coefficients, parts of the model were selected manually (back side of the car, interior side of vehicle doors etc.) and reduction was put specifically on these parts. Such modification requires user intervention and understanding of EM simulation.

Similar simulations were performed on the mentioned desktop machine using DDS. The complex scenario (with two vehicles) was investigated and appropriate radiation patterns are presented (Figure 9 and Figure 10). In this case, the first DDS iteration was sufficeint for obtaining an accurate result. DDS simulation times are shown in Table 1.

Table 1. Iterations and appropriate simulation time

Model	*Iteration*	*Simulation time [minutes]*
Complex scenario with two vehicles	1^{st}	30 (0^{th} + 1^{st})
Complex scenario with two vehicles	2^{nd}	19.6

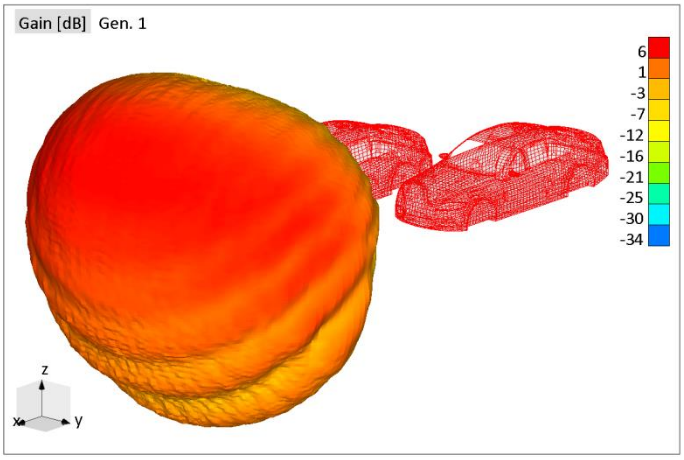


Figure 7. First antenna radiation pattern (complex scenario)

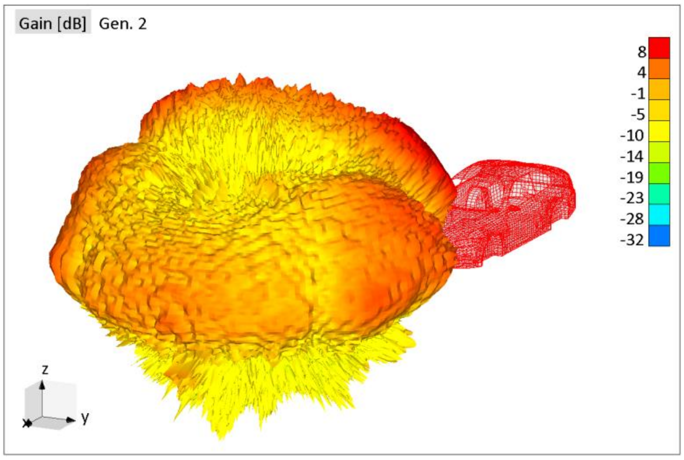


Figure 8. Second antenna radiation pattern (complex scenario)

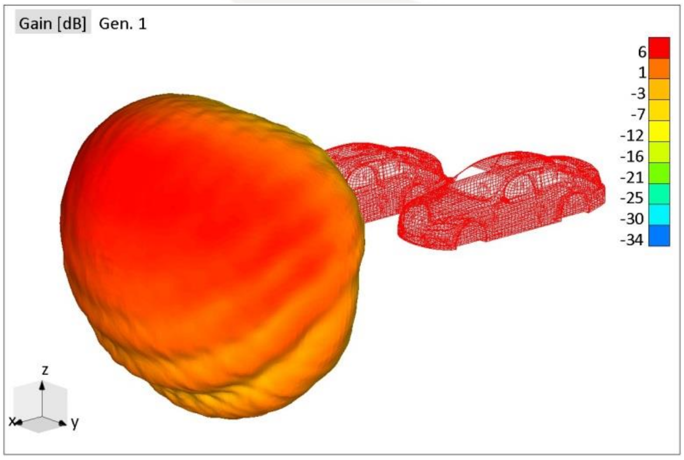


Figure 9. The first antenna radiation pattern (complex scenario) obtained using DDS

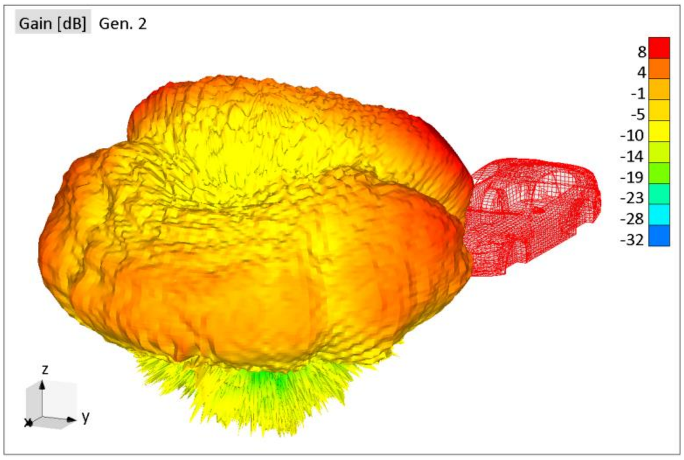


Figure 10. The second antenna radiation pattern (complex scenario) obtained using DDS