Full-Wave EM Simulation in Automotive at 24 and 40 GHz

Introduction

Electromagnetic (EM) simulations have a significant role in automotive industry. WIPL-D software continuously improves its variety of tools which allow various applications in this 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 be designed and simulated). One of typical applications would be mounting collision radar onto a car front bumper at high frequencies.

Radar Antenna Mounted on Automobile

One of typical applications in automotive industry would be usage of full wave EM simulator to accurately predict radiation pattern of radar antenna mounted on car front part. Frequencies of interest for such application are usually very high, typically in GHz area. Since car dimensions are extremely large at such frequencies (measured in wavelengths), an EM simulation becomes very demanding.

WIPL-D software suite offers unique features that allow simulation of problems at much higher frequencies than in other commercially available full wave 3D EM solutions. First of all, WIPL-D uses quads as mesh elements, rather than triangles. This halves the required EM problem size, which is measured in unknown coefficients ("unknowns") required to determine current distribution on the model ("EM solution"). In addition, WIPL-D Pro 3D EM solver uses higher order basis functions (HOBFs) on quadrilaterals, rather than polynoms of first order. This allows having quadrilaterals of larger size (up to 2 wavelengths for polynomial order 7), which reduces number of unknown coefficients between 3 and 10 times, compared to low order EM simulators. Thus, the applicable range of frequencies for EM solutions is dramatically extended.

In recent years, the challenges of EM simulation have been even more demanding. In such cases, WIPL-D Pro software suite has been improved so that very large problems can be solved approximately, with very small loss of accuracy. Number of unknown coefficients on model parts which are far away from the antenna can be significantly reduced since such elements do not significantly contribute to radiation pattern. This feature is called **antenna placement reduction**. Also, number of unknowns can be reduced on model parts which are not directly illuminated by the antenna and such feature is called **shadow reduction**.

During the last decade, the most dominant technology in EM numerical computations is simulation on **clusters and GPU cards**. WIPL-D Pro offers simulation on very **affordable workstations** comprising of regular PC with one or several high computation graphic cards of latest generation. This allows simulation of problems up to 500,000 unknowns in one day on very cheap hardware platforms. **WIPL-D Pro** also offers module for import of CAD files, called **WIPL-D Pro CAD**. By using this module, realistic geometries can be imported and used for EM simulations. Such geometry is shown in Fig. 1.

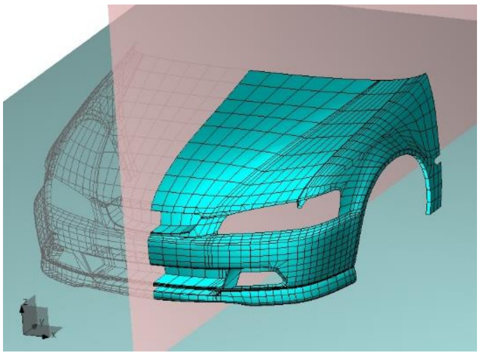

Figure 1. Realistic car shell

By using all the features described above, a demanding scenario will be set and simulated in WIPL-D software suite. A dipole antenna is placed in front of the car front bumper, symmetrically so that number of unknown coefficients is halved and simulation time is reduced. The car shell and magnified area where dipole antenna is positioned are presented in Fig. 2. The dipole antenna is half wavelength long dipole placed quarter of wavelength in front of the front bumper.

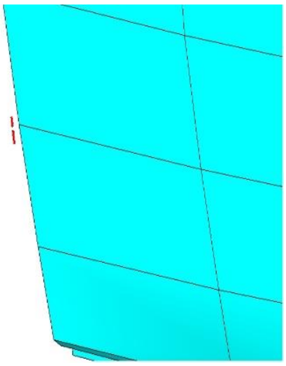

Figure 2. Dipole antenna in front of bumper

The first result presented is radiation pattern calculated at 24 GHz (Fig. 4). **Number of unknowns is successfully reduced** to 119,000 unknowns by using antenna placement and shadow reduction as shown in Fig. 3.

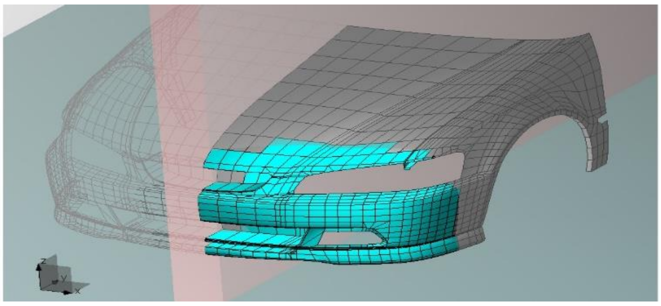

Figure 3. Shadow reduction

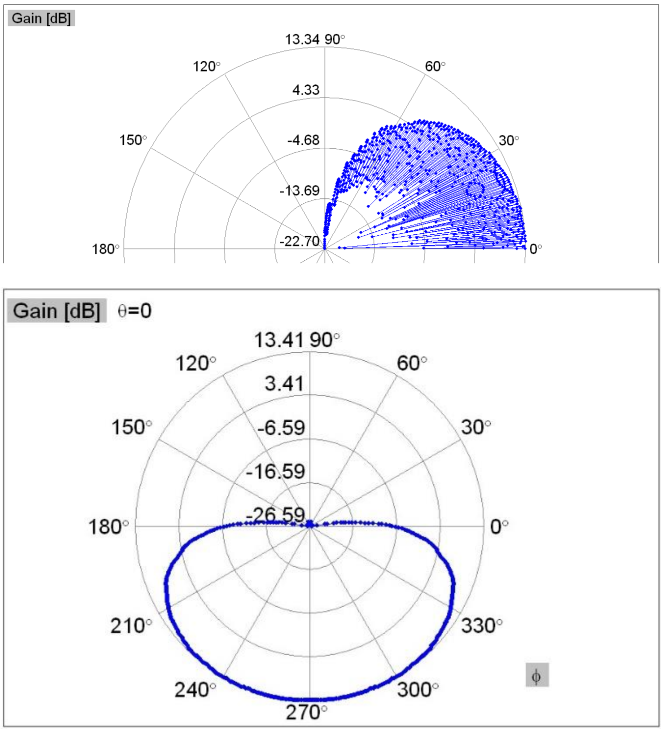

Figure 4. Pattern in two principle planes at 24 GHz

Fig. 5 illustrates the size of the problem, showing the final mesh of the structure where mesh elements are 2 wavelengths large.

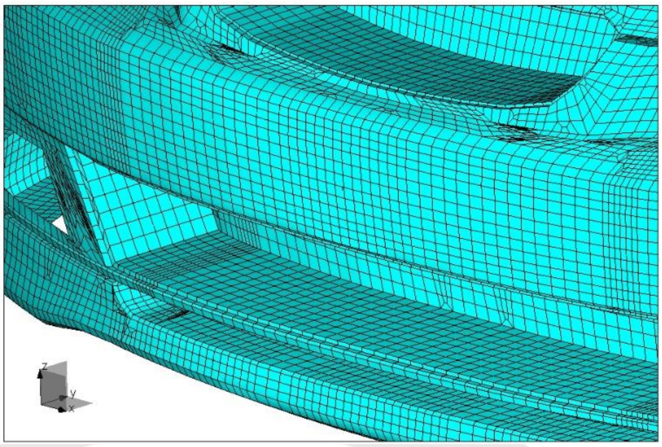

Figure 5. Final mesh at 40 GHz

The EM simulation was performed on the following hardware platform: Intel® Xeon® Gold 5118 CPU @ 2.30 GHz (2 processors) with 192 GB RAM and four NVIDIA GeForce GTX 1080 Ti GPU cards. Simulation was next performed at 40 GHz which yielded in 295,000 unknowns. **The simulation times are 1,107 and 12,644 seconds**.

To compare two results, we present a magnified area with small elevation angles (between zero and 10 degrees) in Fig. 5. As expected, number of minimums in radiation pattern is approximately 2 times larger at 40 GHz than at 24 GHz.

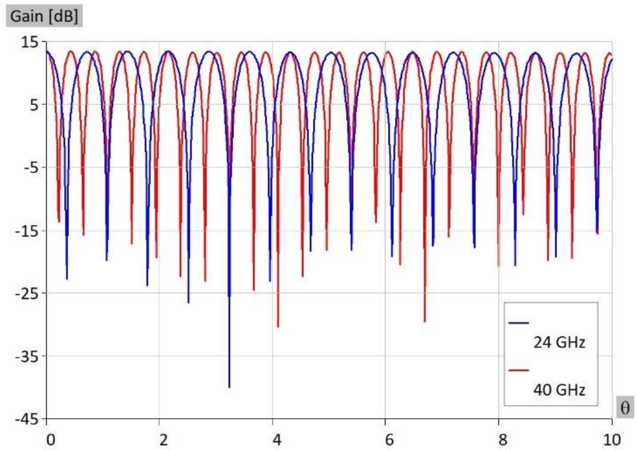

Figure 6. Comparison of pattern for small elevation angles for 2 operating frequencies

Conclusion

This application note describes the use of WIPL-D software suite for full-wave EM simulation of automotive applications at 24 and 40 GHz. Simulation at such high frequencies would not be possible without use of numerous unique features, distinguishing the WIPL-D products from other available products in the competitive EM simulation market. The EM model in question is **a realistic car shell model**, imported to WIPL-D Pro CAD. The model is next repaired and meshed.

Among them, the most relevant are quad mesh, higher order basis functions, customized in-house quad mesher optimized for HOBFs, **efficient reduction of number of unknowns without compromising accuracy, fast simulation on inexpensive GPU/CPU platforms**.

The EM simulation have been carried out at moderate hardware platform, including two multi-thread CPUs and four inexpensive CUDA enabled GPU cards. The app note shows low simulation times (measured in minutes or hours) and scaling of simulation time when the frequency is increased from 24 to 40 GHz. The radiation pattern at low elevation angles is verified by comparing placement of minimums at the two frequencies.