MODELING OF THE PENETRATION OF AN ELECTROMAGNETIC FIELD INSIDE AN AUTOMOBILE USING A PARALLEL VERSION OF NEC

A. Rubinstein[1], F. Rachidi[2], B. Reusser[3]

[(1)] École Polytechnique Fédérale de Lausanne, EPFL-LRE, 1015 Lausanne, Suisse
E-mail: abraham.rubinstein@epfl.ch

[(2)] As (1) above but E-mail: Farhad.Rachidi@epfl.ch

[(3)] Swiss Defence Procurement Agency, Spiez, Switzerland. E-mail: Beat.Reusser@gr.admin.ch

ABSTRACT

This work presents preliminary results obtained in the frame of the GEMCAR project (Guidelines for Electromagnetic Compatibility modeling for Automotive Requirements). The paper presents experimental results obtained using the VERIFY EMP simulator belonging to the Swiss Defense Procurement Agency. The VERFY simulator generates a vertically polarized electric field with a rise time of 9 ns and a FWHM of 24 ns. The working volume is 4x4x2.5 m3 and the maximal electric field amplitude attains 100 kV/m. A very simplified model of a car (essentially the body shell) and a simple cable harness composed of single wires has been used for testing. Measurements of electric and magnetic fields inside the car as well as induced currents in cables were performed considering two types of illumination, front and side. The experimental results are compared to numerical simulations obtained with a modified version of the Numerical Electromagnetics Code (NEC), which was parallelized using sophisticated numerical techniques especially adapted to modern supercomputer architectures. By using this version of NEC, we have been able to run models consisting of more than 24.000 segments.

INTRODUCTION

The paper presents preliminary results obtained as part of the GEMCAR project. GEMCAR (Guidelines for Electromagnetic Compatibility Modeling for Automotive Requirements) is a three-year European project with the aim of producing a freely available guideline for the numerical modeling of automotive electromagnetic compatibility.
The automobile industry has been undergoing an increase in on-board technology. Modern cars exhibit navigation systems, high-tech entertainment devices, and computer-controlled optimization of fuel injection, brakes, etc. As a consequence, the study of the EMC phenomena in automobiles becomes indispensable [1-4]. This process generally involves the production of a prototype, the execution of immunity tests, changes in design, and the construction of a new modified prototype. The goal of the GEMCAR project is to minimize this test-error-modification-test to a minimum, by taking the biggest possible part of the immunity tests to computer simulation. The use of more advanced computing tools and of highly optimized mathematical routines that fully take advantage of the new processor architectures allows the study of very complex structures at a reasonable price.

MEASUREMENTS

For experimental testing we used the VERIFY (Vertical EMP Radiating Indoor FacilitY), an EMP simulator belonging to the Swiss Defense Procurement Agency. The VERFY simulator generates a vertically polarized electric field with a rise time of 9 ns and a FWHM of 24 ns. The working volume is 4x4x2.5 m3 and the maximal electric field amplitude attains 100 kV/m.
Fig. 1 shows a typical waveform of the electric field generated by the simulator in the absence of the test object.
For the initial phase of the GEMCAR project, a simple test case was defined comprising the vehicle bodyshell (without doors or glazing) and a simple harness (single conductor with branches and terminations). Electric and magnetic fields at various points inside the vehicle as well as induced current along the harness were measured. Fig. 2 shows the vertical component of the electric field measured at the center of the vehicle.

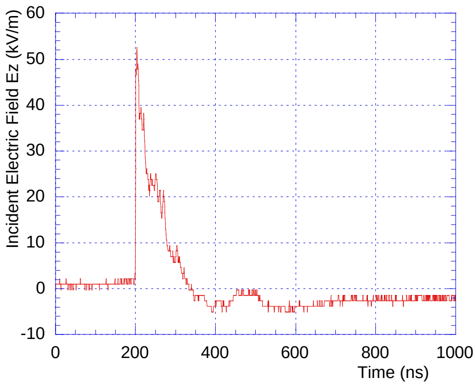

Fig. 1. Electric field (vertical) at the center of the simulator.

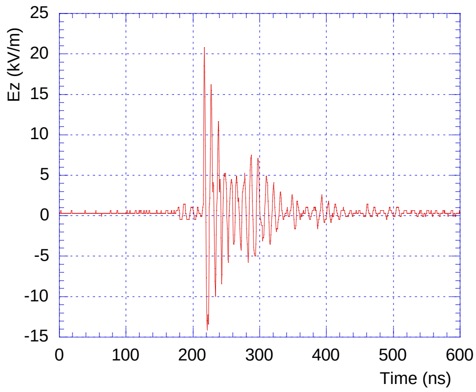

Fig. 2. Vertical component of the electric field measured at a point at the center of the vehicle for a frontal illumination.

NUMERICAL SIMULATIONS AND COMPARISONS WITH EXPERIMENTAL RESULTS

The Numerical Electromagnetics Code [5] is a user-oriented computer code based on the method of moments and written in FORTRAN for the analysis of the electromagnetic response of antennas and other metal structures. It has been widely used for radio communications testing as well as antenna design with great success. With its ability to represent models by means of wires, the code should also allow the simulation of very complex 3D structures.
Because of the complexity of the geometrical information of a car, the original version of NEC is not capable of handling such model. Electrically large structures are impossible to fit in memory and even using the out of core solution, embedded into the code, simulation times and disk spaces attain unpredictable values.
NEC has been optimized and parallelized for this purpose [6]. Using this version of NEC on the Swiss-T1 and Eridan parallel supercomputers belonging to the Swiss Federal Institute of Technology, we've been able to run very complex models of the car containing up to 24.000 segments (see Fig. 3).
Fig. 4 shows a comparison measurement/calculation for the vertical component of the electric field at the center of the car for a front illumination. We can see that simulation results show a satisfactory agreement with the measurements. The differences may be explained by the fact of having used a CAD file of the car as the source of production of the NEC input file. The creation of this file has been done by the decomposition of triangular patches into segments with dramatic differences in segment lengths that impede the proper application of the modeling guidelines stated in the NEC manual. Another consequence of the non-uniformity of the segments is the difficulty of assigning an appropriated radius to the elements, which is probably the most important source of inaccuracy of the simulation.
There is also a certain incertitude associated with the definition of the positioning of the observation points. The sensors actually measure the field over a finite volume located close to the observation point. Finally, the applied field is not a completely uniform plane wave.

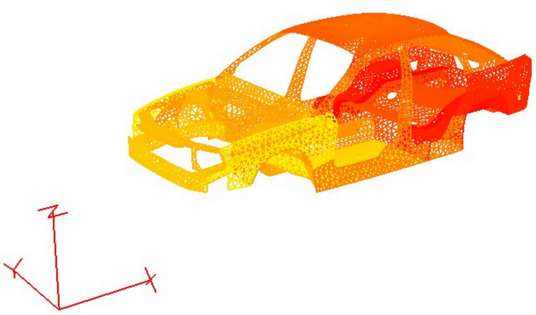

Fig 3. NEC mesh of the car

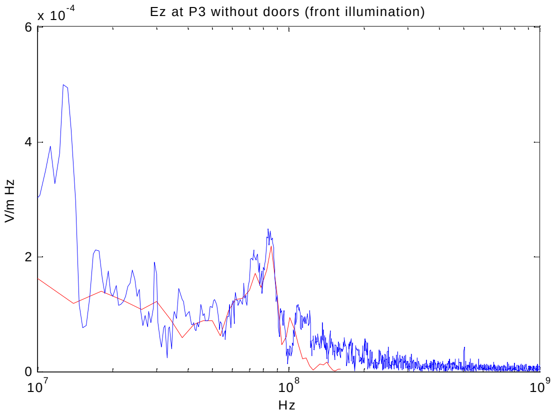

Fig 4. Electric field inside the vehicle. Comparison between simulation (dashed line) and measurement (solid line)

CONCLUSIONS

The paper presents experimental results obtained using a very simplified model of a car illuminated by an EMP simulator. The electromagnetic field was measured inside the car. The experimental results are compared with numerical simulations obtained using a parallel version of NEC. Despite all measurement uncertainties and the strong simplification of the car model, the results of the simulations show a good agreement with the measurements.

Acknowledgments - This work was carried out as part of the GEMCAR project, a collaborative research project supported by the European Commission under the competitive and Sustainable Growth Programme of Framework V (EC contract G3RD-CT-1999-00024) and by the Swiss Federal Office for Education and Science (Grant No. 99.0377). The consortium acknowledges the assistance of Volvo Car Corporation (Sweden) for permission to use vehicle CAD data in the project.

REFERENCES

[1] F. Canavero, J-. C. Kedzia, P. Ravier and B. Scholl, “Automotive EMC: Numerical simulation for early EMC design of cars”, in *4th European Conference on Electromagnetic Compatibility*, (Brugge, Belgium), Tutorials pp. 32–39, 11–15 September 2000.

[2] P. Young, “Future trends in EMC testing of automotive systems”, in *IEEE Seminar on Electromagnetic Compatibility for Automotive Electronics*, pp. 1-5, 1999.

[3] A. Ruddle, D. Ward, A. Williams and A. Duffy, “Objective validation of automotive EMC models”, in *1998 IEEE International Symposium on Electromagnetic Compatibility*, Volume 1, pp. 475-479, 1998.

[4] N. Jennings, “EMC modelling of cable installations”, in *IEEE Colloquium on EMC and the Motor Vehicles*, pp 4/1-4/9, 1992.

[5] G. Burke and A. Poggio, “Numerical electromagnetics code - method of moments”, Livermore CA: Lawrence Livermore National Laboratory, Report No. UCID-18834, 1981.

[6] A. Rubinstein, F. Rachidi and M. Rubinstein, “Development of an Optimized Parallel Numerical Electromagnetics Code (NEC) and Its Implementation on the Swiss-T1 and Eridan Parallel Supercomputers”, *Annual Review of Progress in Computational Electromagnetics*, Monterey, 18-22 March 2002.