Electromagnetic Field Interaction with Vehicle Cable Harness: An Experimental Analysis

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***Abstract*— The paper presents experimental results obtained as part of the GEMCAR European project using the VERIFY EMP simulator belonging to the Swiss Defense Procurement Agency (Spiez). VERIFY generates a vertically polarized electric field with a rise time of 0.9 ns and an FWHM of 24 ns. The working volume is 4x4x2.5 m 3 and the maximum E-field amplitude is 100 kV/m. Two experimental models for the vehicle and the cable harness were used for the tests. Measurements of electric and magnetic fields within the vehicle, as well as induced currents on the harness were performed, considering two types of illumination (front and side) and different harness terminations. It is shown in particular that the presence of the car could result in an enhancement of the induced current in the wiring system.**

I. Introduction

MODERN cars exhibit complex electrical and electronic systems. As a result, electromagnetic compatibility is becoming an important issue in vehicle engineering (e.g. [1] [2]).

The use of numerical simulation seems to be a powerful tool and a viable alternative for the further study of these phenomena (e.g. [3] [4] [5]). However, a practical difficulty in building simulation models of vehicles is the model complexity. Additionally, the detailed geometry of the car might not be available at the time when modeling is required.

The aim of this paper is to analyze the effect of the presence of a vehicle body-shell, at two levels of complexity, on a simple cable harness installed following an approximate path of the real car cabling. A further understanding of the effect of the geometry of the car and its complexity may lead to simpler simulation tasks and better protections for the on-board electronic equipment.

The analysis is based on experimental results obtained using the VERIFY EMP simulator belonging to the Swiss Defense Procurement Agency (Spiez)[1] . A simple vehicle model (essentially the body shell, with and without all doors) and a simple harness composed of single wires were used for the tests.

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[1]The paper presents experimental 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.

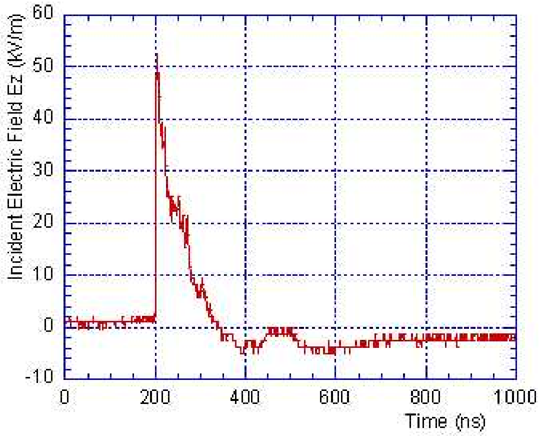


Fig. 1. Electric field (vertical) at the center of the simulator

II. The Experiment

A. Experimental Set-Up

For experimental testing we used the VERIFY (Vertical EMP Radiating Indoor FacilitY), an EMP simulator belonging to the Swiss Defense Procurement Agency (Spiez). VERIFY generates a vertically polarized electric field with a rise time of 0.9 ns and an FWHM of 24 ns. The working volume is 4x4x2.5 m3 and the maximum E-field amplitude is 100 kV/m. A cartography of the E-field produced by the simulator was created by taking several measurements at 1 m above the ground and at squared intervals of 1 m. This grid was used to check the homogeneity of the produced field, by taking the peak value of each sample and representing it in a 3-D plot showing the peak values of Ez as a function of the position inside the working volume.

The incident (vertical) electric field, measured in absence of any test object, is presented in Fig. 1.

For the initial phase of the GEMCAR project, a simple test case was defined comprising the vehicle body-shell (without all doors or glazing) and a simple harness (single conductor with branches and terminations). The x, y and z components of the electric and magnetic fields at various points inside the vehicle as well as induced current along the harness were measured.

Figure 2 shows the position of the car relative to the antenna for the front illumination case. The eight observation points labeled P1 to P8 for the measurements of the electric and magnetic field are also displayed. All measurements were carried out with the simple test case consisting of the car body-

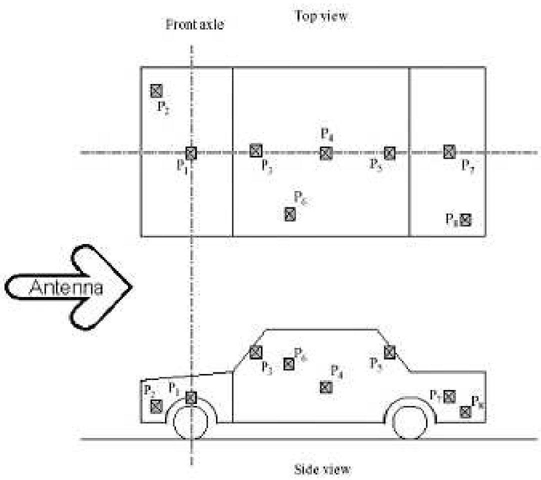
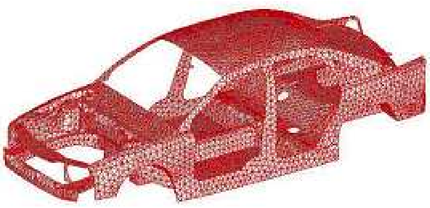


Fig. 2. Measurement points for the electric and magnetic fields



(a) Simple test case vehicle

(b) Medium test case vehicle

Fig. 3. Vehicle models

shell without the doors; the same measurements were repeated with a medium complexity case which this time included the doors (see Fig. 3).

The cable harness was installed following an approximate path of the original cabling of the car but it was composed of single wires with 50 Ω terminations. Current measurements were taken at 4 observation points (see Fig. 4) located at the ends of the branches of the harness.

In addition, measurements of the induced current were also performed using the same cable harness laid over the ground plane in absence of the car.

B. Effect of the body-shell

The incident (vertical) electric field, measured in absence of the car, is presented in Fig. 7(a). Figures 7(b), 7(c) and 7(d) present the 3 components of the electric field measured at the same location (P4), in presence of the medium complexity car (i.e. with all doors installed). It can be seen that the presence

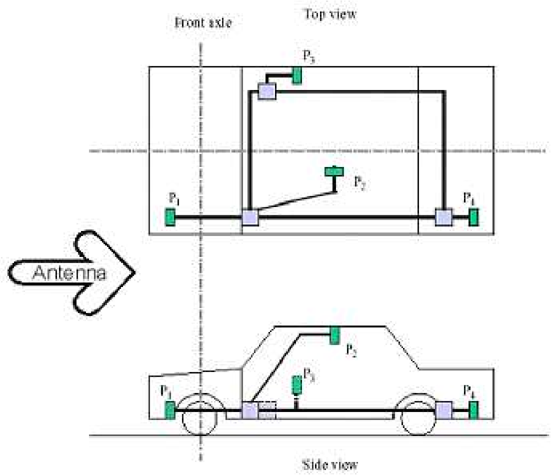


Fig. 4. Measurement points for current at the cable harness

of the vehicle produces a distortion of the E-field. One can observe an attenuation of the magnitude of the vertical electric field (by a factor of about 2.5) and the appearance of horizontal components of the electric field. The horizontal electric fields Ex and Ey exhibit peak values of about 2 kV/m and 8 kV/m, respectively. These values are considerable, especially taking into account that most of the cable harness runs on a trajectory which is parallel to both x and y axes. A similar effect was observed for the same measurement point even when we uninstalled all doors from the vehicle.

The impact of the appearance of horizontal components of the electric field is illustrated in Fig. 6, in which the frequency spectrum of the induced current magnitude is presented for the three considered configurations:

- cable harness laid over the ground plane (with no car),
- cable harness in the simple test vehicle (car body-shell without doors), and,
- cable harness in the medium test vehicle (car body-shell).

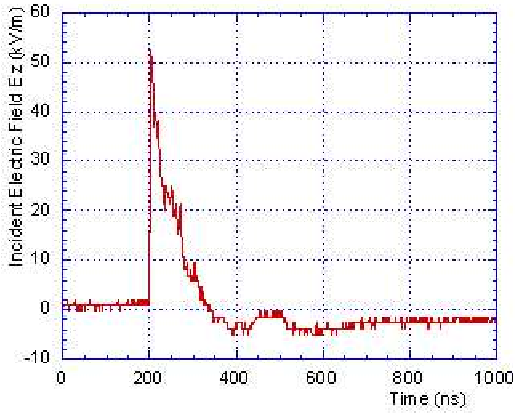
It can be seen that, despite the attenuation of the vertical electric field, the presence of the car may enhance the magnitude of the induced current over a wide frequency band for the simple and medium complexity cases.

C. Effect of the doors

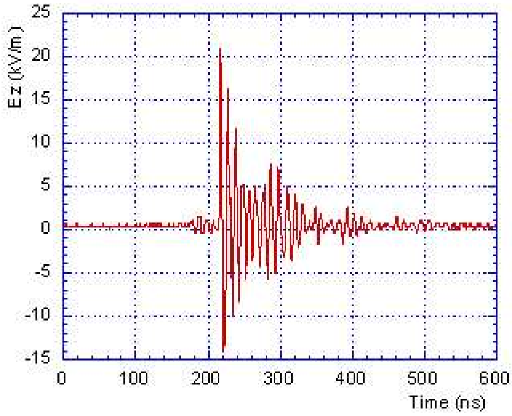
The current measurements at the four observation points (see Fig. 4) for a frontal illumination, with and without the doors are compared in Fig. 7. Although at low frequencies, the presence of the doors results in a reduction of the magnitude of the induced currents, we notice an enhancement of some of the resonances appearing at frequencies of a few tens of MHz. This same effect was observed for the side illumination as well.

As a possible explanation for this phenomenon, we might consider the fact that, as the car becomes more complex (i.e. the doors are installed), its effect on the deformation of the incident electric field increases.

The presence of a more voluminous metallic structure may have an even higher effect of enhancement on the creation of



(a)



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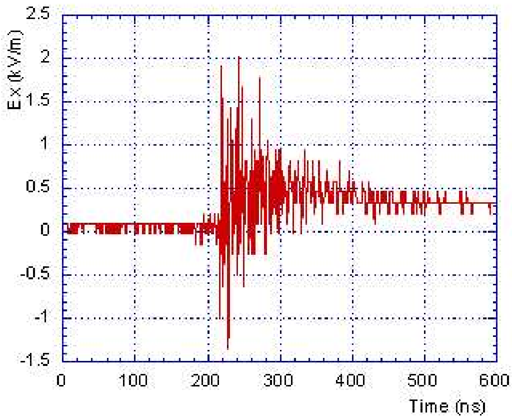
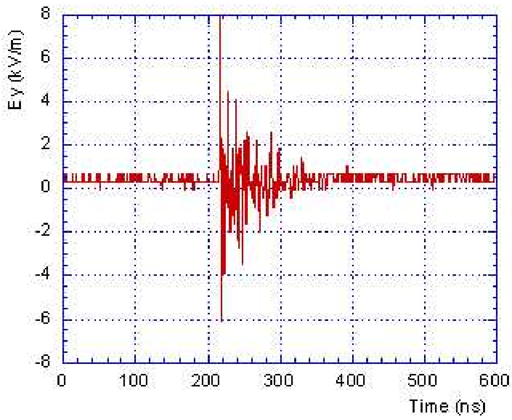


(c)



(d)

Fig. 5. Vertical electric field in the absence of the car (a) and z, x and y components of the electric field inside the car for the same measurement point (b, c, and d)

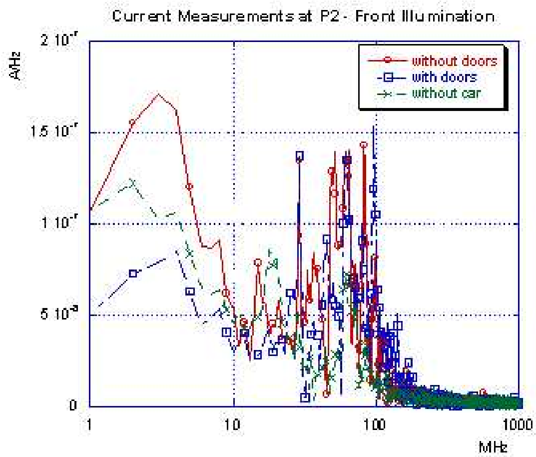


Fig. 6. Measurement points for current at the cable harness

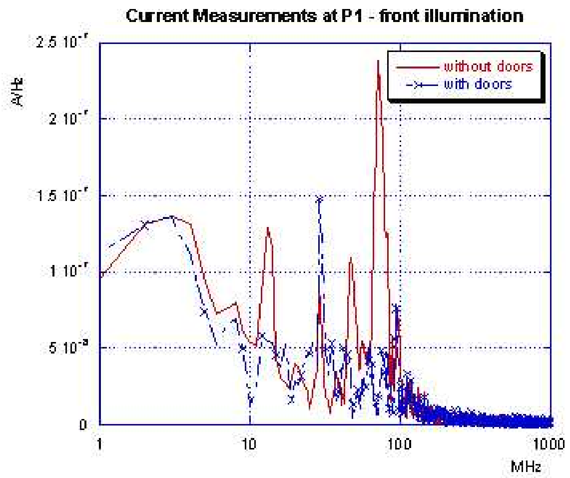
the horizontal components of the electric field. From another point of view, a more closed metallic structure may facilitate the propagation of the signal inside the body-shell, and induce or enhance some resonances that depend on the modified geometry, once the doors installed.

D. *Position of the observation point*

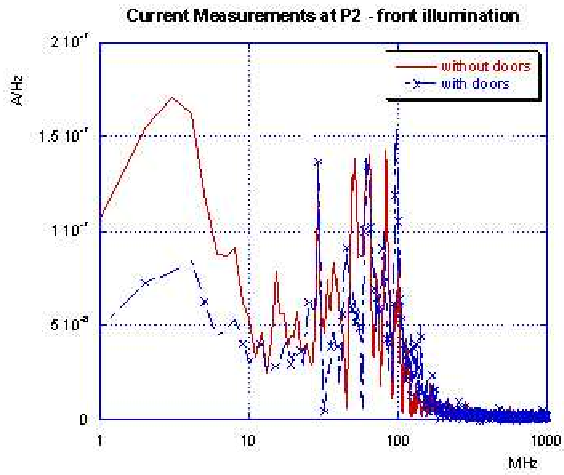
Fig. 8 presents the four current measurement points for a front illumination and for the simple test case. One can observe that P1, the closest point to the antenna among the measurement points, exhibits the maximum peak resonance occurring at about 70 MHz. On the other hand, the medium complexity case (Fig. 9) shows the opposite behavior, having the highest resonance peak at P4 (f $\approx$ 30 MHz), the point inside the luggage compartment. One possible explanation for this could be the fact that, the absence of all doors and, in particular, the hood, makes P1 more vulnerable to the direct interaction with the incident field. Once the doors installed, the more complete body-shell may facilitate the propagation of the incident field towards the luggage compartment where the effects of the smaller cavity result in enhanced resonances at certain frequencies.

III. Conclusions

Experimental results obtained as part of the GEMCAR European project were presented. The data were obtained using the VERIFY EMP simulator belonging to the Swiss Defense Procurement Agency (Spiez). Two simple vehicle



(a)



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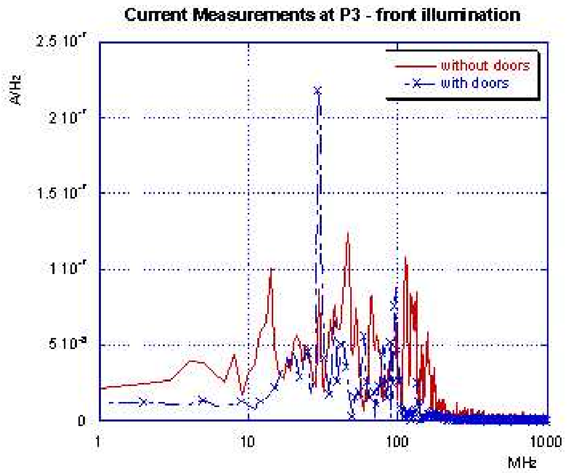

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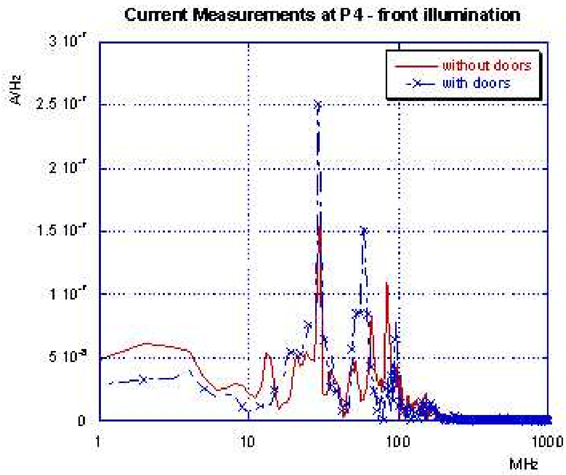

(d)

Fig. 7. current measurements at the four observation points for a frontal illumination. Effect of the doors

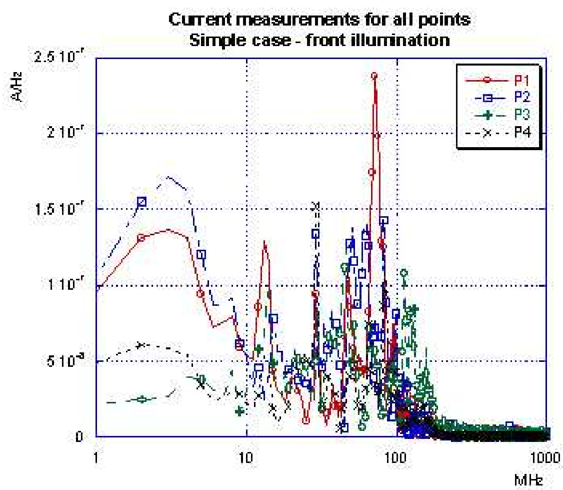

Fig. 8. All current measurement points for the car without doors. Front illumination

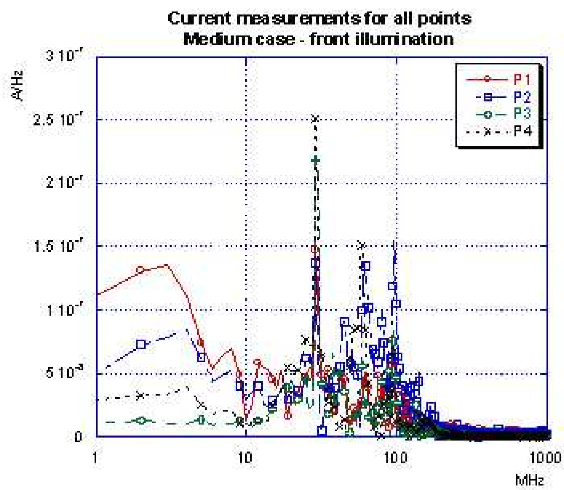

Fig. 9. All current measurement points for the car with doors. Front illumination

models and a simple harness composed of single wires were used for the tests.

It was confirmed that the vehicle body-shell does not represent a perfect shield, isolating cabling and electronic equipment installed from the action of external incident electromagnetic fields. The observation of experimental data shows in particular, that the presence of the car may result in an enhancement of the induced current in the wiring system. In fact, the interaction of electromagnetic fields with the cable harness installed in the vehicle is a very complex problem, which requires significant quantities of data for further observation. The use of numerical simulation seems to be a powerful tool and a viable alternative for the further study of these phenomena.

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