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EXPERIMENTAL VALIDATION OF TIME-DOMAIN ELECTROMAGNETIC MODELS FOR FIELD COUPLING INTO THE INTERIOR OF A VEHICLE FROM A NEARBY BROADBAND ANTENNA

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Abstract: Numerical electromagnetic models based on a typical automotive immunity measurement scenario have been built from a vehicle manufacturer's CAD data and compared with corresponding measurements on a complete vehicle. The simulations were carried out in time-domain using the TLM and FDTD techniques. Despite the many limitations of both the numerical models and the measurements, the models are found to provide a satisfactory representation of the measured field coupled into the passenger compartment.

INTRODUCTION

Modelling automotive immunity test scenarios is a particularly challenging activity. Not only is the vehicle both geometrically complex and electrically large at the frequencies of interest (to 1 GHz in current legislation, although some manufacturers already test up to 3 GHz), but the measurements also employ a broadband antenna placed in very close proximity (~ 1 m) to the vehicle. In addition, the most common test environment is a semi-anechoic chamber. The use of idealized plane waves and simple antennas to excite the system model is therefore unsuitable for automotive applications. Consequently, an automotive immunity model intended for experimental validation must include details of the source antenna as well as the vehicle geometry.

EXPERIMENTAL MEASUREMENTS

The measurement configuration used here was based on standard automotive immunity test arrangements [1]. A complete vehicle was placed in MIRA's large semi-anechoic chamber (with a working volume 22 m x 10 m x 8 m) and illuminated from the front and side using a "biconilog" antenna. This device is essentially a log-periodic dipole array augmented with a pair of "bow-tie" elements in order to obtain improved low frequency performance. The bandwidth was 20–1000 MHz.

The antenna and chamber were calibrated as specified in [1], by recording the power required to generate an electric field of 50 V/m in the empty chamber at a reference point that is specified in relation to the vehicle geometry. This point is located 0.8 m behind the front axle, on the longitudinal axis of the vehicle at 1 m above the ground plane. The antenna was positioned with the feed point at a height of 1.2 m, at a distance of 2.5 m to the front or side of the reference point. The calibration data is used to estimate the power needed to generate the required "threat" field during vehicle measurements. In standard measurements, this allows deviations in the functional performance of the vehicle to be referenced to the corresponding field at the reference point in the empty chamber. In this work, the electric field strengths measured at selected points within the vehicle were similarly normalized using the field at the reference point for the empty chamber. Thus, the measured relative field strength represents the resulting field at the measurement point under a notional threat of 1 V/m at the reference point. This approach may also used [2] to produce computed field results that can be directly compared with results from measurements without the need to model the antenna source characteristics in detail, and to reduce the impact of systematic errors. For the antenna used in this work, comparison of such results derived from measurements in the semi-anechoic chamber with a variety of simulations for an infinite ground plane [3] indicate that chamber resonances are present in the measurements below 100 MHz.

Electric field measurements were made at selected points in the passenger compartment using isotropic field probes. Reproducible positioning of the probes was achieved by mounting the probes on a thin wooden board that could be reliably located between the armrests in the front and rear of the vehicle relative to readily identified fixed points. This allowed the field measurement points to be located from vehicle CAD data, and also ensured that they could be easily reproduced in the course of measurements. The measurements were made under illumination from the front and side of the vehicle, for both horizontal and vertical antenna polarizations. Separate calibration results were used to normalize the data for each of the four antenna illumination configurations.

NUMERICAL MODELS

Time-domain methods are particularly suitable for EMC applications, because of the need for broadband results. For large and complex systems, methods based on structured meshing (using hexahedral cells) offer many advantages, including more frugal use of memory than unstructured meshing methods and the ability to accommodate additional surfaces without increasing the memory needed. The main disadvantage for vehicle applications is the resulting "stair-cased" approximation of curved surfaces. The results reported here were generated using two such time-domain, structured meshing techniques: FDTD [4] and TLM [5]. These models employed ONERA's "ALICE" FDTD code [6] and the "Microstripes" TLM solver [7] from Flomerics.

Although the FDTD and TLM models aim to represent the same system, the numerical representations in fact differ for a variety of practical and operational reasons. In the FDTD model for the antenna, the dipole elements were represented using thin wires. For the TLM model, however, it was found to be more practicable to use solid bars. The FDTD vehicle model was based on a geometrical model that had been simplified and reduced to single surfaces, augmented with simplified models for the seat frames and steering gear. The TLM model was constructed from original vehicle CAD data using specialized meshing tools, and thus included both the inner and outer surfaces of structures such as the doors.

VALIDATION RESULTS

The antenna models were also "calibrated", as in the experimental work, and the results used to normalize the computed coupling. The resulting relative electric field predictions could then be compared with the corresponding measurements. Sample results, taking account of the measurement uncertainties, are shown in Figs. 1-2, for two different illumination configurations. The low frequency measurements (below 100 MHz) are corrupted by chamber effects that are not represented in the models, but at the higher frequencies both models generally give results that are within the estimated error bounds of the measurements.

CONCLUSIONS

Despite the many approximations and limitations of both the simulations and the measurements, the TLM and FDTD models are found to provide a satisfactory representation of the measured field coupling. The quality of the two models is not markedly different, indicating that the heavily simplified geometry used for the FDTD model can still yield satisfactory predictions for the field coupled into the interior of the vehicle.

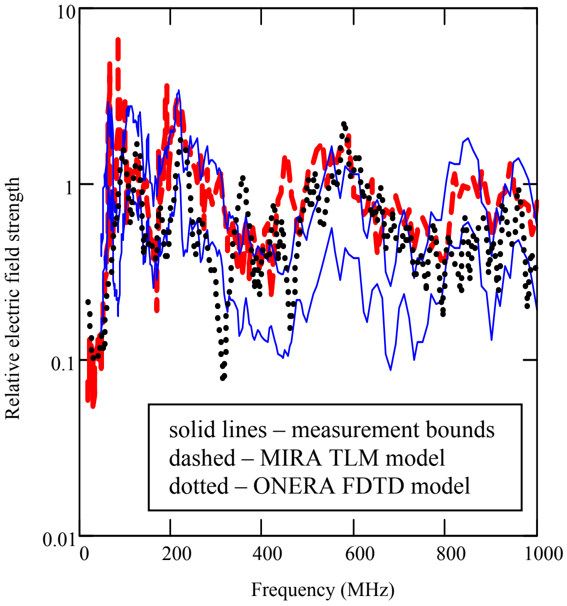

Figure 1: Electric field at front left-hand monitoring point: vertical polarization, front illumination

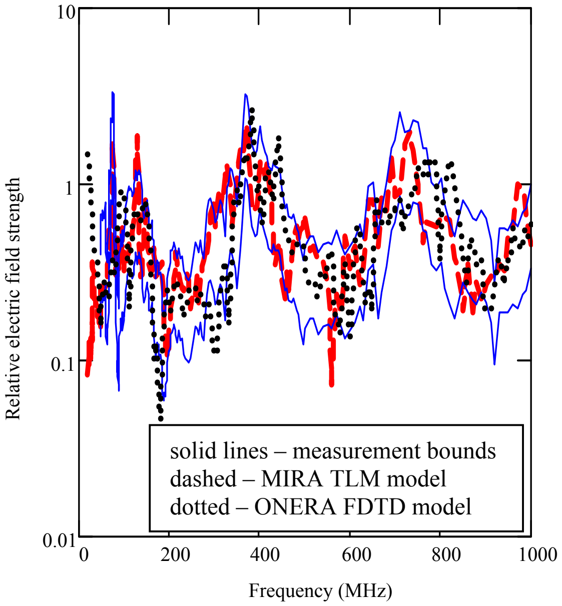

Figure 2: Electric field at front left-hand monitoring point: horizontal polarization, side illumination

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