Measured and Computed In-Vehicle Field Distributions

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***Abstract*— This paper describes an automated in-vehicle field measurement systems that can be used to acquire 3D electric field distribution generated from wireless antenna sources placed within a passenger vehicle. One prototype is made out of metal and another Delrin. Comparisons between simulated and measured 2D field distribution within a simple cavity correlate well at 870 MHz. Measurements made within an actual vehicle using the Delrin positioner shows reasonable correlation with simulations. A short analysis of field measurements at 1800 MHz is performed. Some possible challenges of measurements within an actual vehicle are also discussed.**

I. Introduction

An increasing number of wireless devices are being installed within vehicles [1]. Some of these devices contain transmitters and may introduce electromagnetic compatibility (EMC) problems or present a field exposure threat to the human occupants within the vehicle. Recent introduction of new driver's aids such as on screen real time traffic and pedestrian information to enhance the driver's 'cockpit' experience uses high speed devices which may be affected by transmitters within the vehicle. For some occupations such as the police and people working in the other emergency services, the vehicle may also be considered as a workplace. The European directive 2004/40/EC [2] contains minimum health and safety requirements regarding the exposure of workers to electromagnetic fields which employers in the European union must comply by the year 2012. Hence, it will be critical that on-board transmitters with antennas manufactured and installed within the European community satisfy the required guidelines stated in the directive.

In order to assess potential EMC problems and field exposure risks, information on field distribution within the vehicle may be required. This information may be acquired by means of measurements [3,4] or statistical analysis and performing field simulations [5]. However, each of these methods presents a challenge on its own. Simulations need to be validated using measurements and the accuracy of the measurements may be affected by the measurement equipment perturbing the fields within the vehicle. Measurements also become more complex and tedious when human exposure assessments are required and software simulation may be a more convenient method to evaluate this quantity.

This paper outlines an automated measurement system that can be used to measure fields within the vehicle. Before the measurement system was used for field measurements within an actual vehicle, initial evaluation was performed within a simple rectangular cavity with well characterized field distributions. The measured results are then compared with simulation performed in CST Microwave Studio. Measurements were performed at 870 MHz and 1800 MHz. As analysis of the 1800 MHz measurements are still on-going, only results at 870 MHz will be shown in this paper. Challenges related to measurements within an actual vehicle are also presented.

II. Measurement Setup Within Simple Cavity

An automated field probe positioner which can move in three axis is mounted on the roof of a simple rectangular cavity to acquire field data. The simple cavity is used as it has well characterised field profile which can be easily compare with simulation. An actual vehicle has more complex geometry and correlating simulation and measurements can more difficult. In order to obtain maximum structure rigidity, the first prototype scanning frame was made out of metal and field data were taken within the simple cavity taken at 870 MHz and 1800 MHz. This scanning frame (without the Z axis) is shown in Fig. 1. The metal thickness was kept to the minimum possible thickness of 25 mm and placed close to the roof to minimise changes to fields within the cavity. An isotropic field probe from IndexSAR was connected to a computer using an optical fiber to acquire fields within the empty cavity. Fig. 2 shows the entire scanning frame with the mounted within the simple cavity.

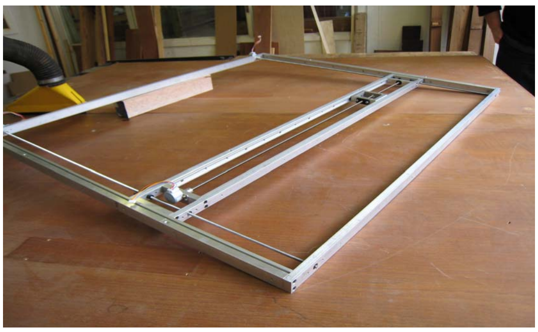

Fig. 1 Metal scanning frame for use at 870 MHz

III. Field Evaluation within Empty Cavity

Two dimensional (2D) cut planes are acquired within the empty cavity at 870 MHz and 1800 MHz. Reasonable agreement between simulations and field measurements were obtained at 870 MHz, as shown in Fig. 3.

Fig. 2 Simple rectangular cavity used for field measurements at 870 MHz and 1800 MHz

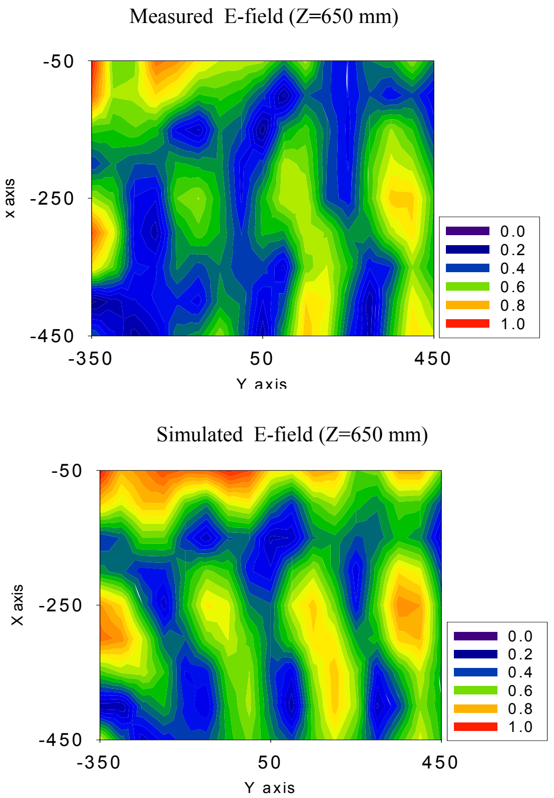

Fig. 3 Comparison betwen measured and simulated field measurements at 870 MHz in the simple cavity

However, field comparisons between simulation and measured field distributions do not correlate as well when similar measurements using the metal frame were performed at 1800 MHz. This was expected as an initial test using two simple probes placed at arbitrary locations within the cavity shows that the cavity resonance was affected and significantly more scattering were observed at the frequencies above 1.2 GHz, when the scanning frame was inserted into the empty cavity. The transmission parameter between the two probes is shown in Fig. 4.

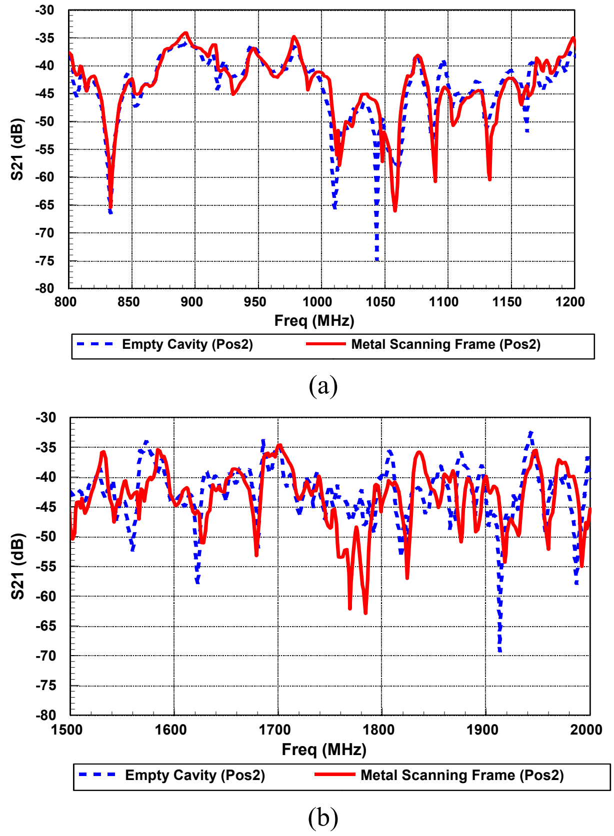

Fig. 4 Transmission measurements between two probes showing cavity resonances and scattering at:

(a) 800 MHz to 1200 MHz (b) 1500 MHz to 2000 MHz

IV. Field Evaluation within Actual Vehicle

In order to carry out future measurements at 1800 MHz, another automated probe positioner of similar structure but larger in size is used to obtain 2D cut planes within an actual vehicle (Volvo S80). It is manufactured from 10mm x 25mm Delrin to maintain the structure rigidity of the scanning frame. The Delrin used has a dielectric constant of 3.4 and loss tangent of 0.004. The measurement apparatus are shown in Fig. 5. Field measurement at 870 MHz when compared to simulation performed in CST microwave studio is shown in Fig. 6. In this case, the difference is more obvious between measured and simulated E-field results. However on closer examination, there are still some similarities in the location where high field level occurs and considering that the measurements were taken in an actual vehicle. The correlation seems reasonable.

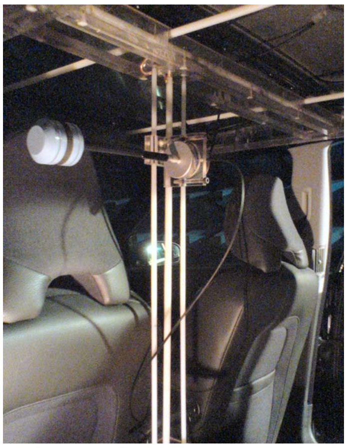

Fig. 5 Scanning frame mounted on the roof of a vehicle

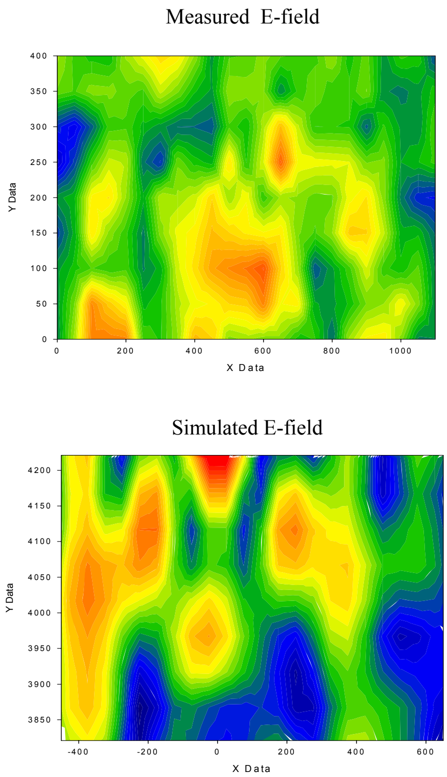

Fig. 6 Comparison between measured and simulated field measurements at 870 MHz in an actual vehicle

However, at 1800 MHz, the correlation between measured and simulation E-field using the Delrin scanning frame is still poor. An electric field fluctuation analysis similar to the one described in [3] is performed using the Delrin material. 1.4 dB of field difference at 1800 MHz was obtained at distance less than 250mm from the surface of the Delrin material. The analysis shows that the Delrin with a dielectric constant of 3.4 and a thickness of 25mm can still introduce considerable disturbance to the electric field. A material with lower dielectric constant and thickness will be required.

V. Challenges of Field Evaluation within an Actual Vehicle

As shown in the previous section, the comparison between simulated and measured fields within an actual vehicle is seen to be more challenging. The following list some problems that may affect the accuracy of the measurements:

- Probe positioning within the vehicle is tricky. The scanning frame has to be levelled on a slanted roof.
- If an inappropriate material is used to make the moving parts of the scanning frame it may introduce field disturbance for measurements above 1.2 GHz.
- Although CAD data was available, there were difficulties in adjusting the front seats in the real test vehicle to match the CAD model.
- Adequate rigidity in the positioner's vertical arm was required to hold the probe in place.

VI. Conclusions

Comparison between simulated and measured fields within a simple cavity and an actual vehicle are presented. Good agreement is obtained within the simple cavity but there is less correlation when the automated measurement system is used in an actual vehicle and at higher frequencies. Some possible challenges of measurements within an actual vehicle are discussed. Future work will focus on lowering the field disturbance using a different structural design and material for the scanning frame.

VII. Acknowledgment

The work outlined above was carried out as part of SEFERE (see www.sefere.org), a collaborative research project supported by the UK's Technology Strategy Board (contract reference TP/3/DSM/6/I/15266) and Engineering and Physical Sciences Research Council (grant reference EP/D033187/1). The project consortium includes MIRA Limited (coordinator), ARUP Communications, BAE Systems Limited, Harada Industries Europe Limited, Jaguar Cars, University of Sheffield, UK National Policing Improvements Agency and Volvo Car Corporation (Sweden).

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