Effects of Vehicle Furnishings on Performance of Aperture Mounted Multi-Band Conformal Automotive Antenna

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***Abstract*— The effects of vehicle furnishings on the performance of a planar multi-band window mounted automotive antenna are discussed. Simulated and measured antenna performance together with field distributions within the vehicle cabin at 900 MHz and 1800 MHz shows the importance of including sufficient cabin furnishings in an electromagnetic model.**

I. Introduction

Conformal antennas are being increasingly used on cars. Most are printed on glass areas where their performance may be affected by the resonant nature and furnishings within the vehicle. Electromagnetic simulators such as FEKO, CST Microwave Studio and CST Micro- stripes are currently used by automotive antenna engineers to predict installed performance of conformal antennas prior to the product being manufactured [1]-[3]. However at higher frequencies bands (e.g. mobile-phone, Bluetooth, and Hiper-lan), some vehicle furnishings are often omitted in simulations because of limits on computer memory and processing power.

Past studies have shown that electric field distribution within a vehicle cabin may be disturbed by inclusion of dielectric components at frequencies above 1 GHz [4]-[5]. There is also noticeable scattering from metallic vehicle furnishing even at the lower FM frequencies [6]. Currently, there is little published literature that describes how interior cabin furnishings can affect the performance of window mounted antennas at frequencies near mobile phone bands. This information can perhaps be useful for optimising antenna placement location and with availability of vehicle internal field distribution data, appropriate field mitigation techniques may be used to limit human exposure to electromagnetic fields.

Using a highly simplified cabin model, this paper presents a comparison between the performance of a multi-band antenna operating at 900 MHz and 1800 MHz with and without interior vehicle-like cabin features. The antenna will be mounted in all four apertures. The apertures are representative of windows of an actual vehicle. Although observation in this paper is done using only a highly simplified model, the work reported herewith are on-going and results presented will be incorporated for future study on antenna performance and field mitigation techniques within an actual sedan vehicle.

II. Antenna and Cabin Model

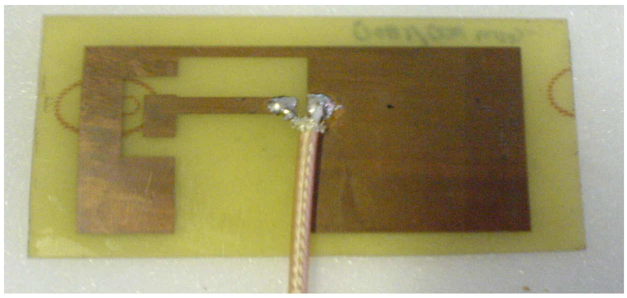

Fig. 1 Planar Multi-band Antenna operating at 900 MHz and 1800 MHz

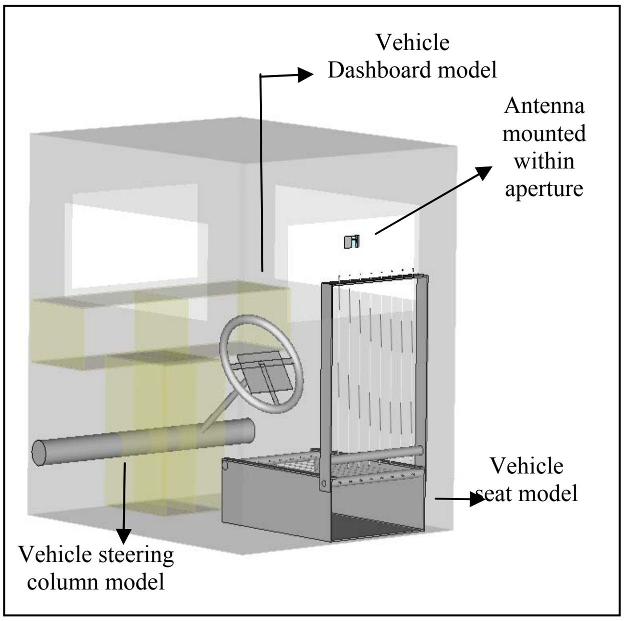

Fig. 2 Highly simplified cabin model with vehicle-like feature

A multi-band antenna [7] shown in Fig 1 is used for evaluating the effects of furnishing on antenna performance. The antenna operates at both 900 MHz and 1800 MHz. When printed on a flexible Mylar sheet the antenna can be mounted onto a vehicle's glass window. Glass panels are not used on the simple cabin model in this study. Hence the antenna elements are printed onto a 0.8 mm thick FR4 substrate measuring 67 mm x 37 mm. The antenna is placed sequentially in both vertical and horizontal polarisation, 50 mm from the top edge in all four apertures of the simple cabin model as shown in Fig. 2. The simple cabin measures 1200 mm (L) x 1000 mm (W) x 1200 mm (H) and is made out of aluminium sheets. The furnishings in the cabin; i.e. seat, dash board and steering column can be easily removed for evaluating antenna performance with and without cabin furnishings.

Fig. 3 shows a meshed view of the simple cabin model and the area within the cabin for marked for internal field evaluation. To keep the antenna model simple, a single-band dipole with a bazooka balun is used instead of the multi-band antenna. The dipole source is placed in the aperture furthest away from the steering wheel. The 2D field distribution (900 mm x 400 mm) within the cavity is measured using an Indexsar e-field probe mounted on an automated probe positioner. The same area within the cavity is measured with and without interior furnishings.

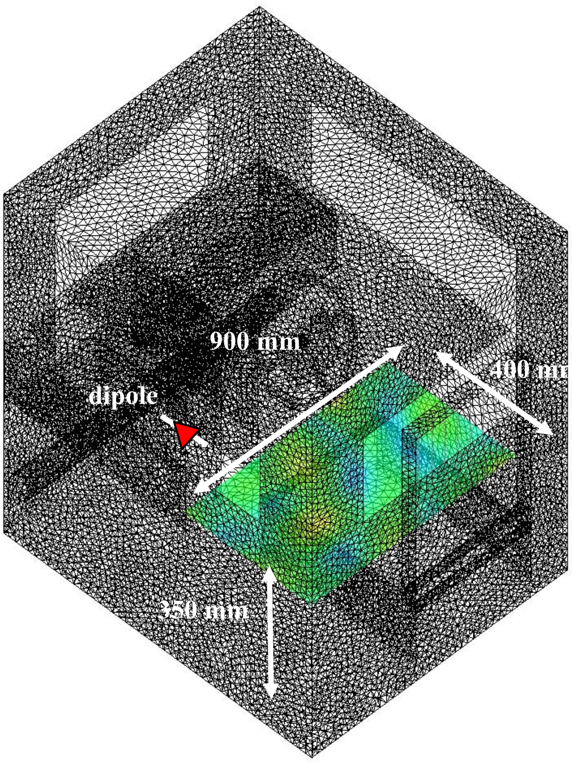

Fig. 3 Field measurement area within model cabin.

III. FIELD DISTRIBUTION

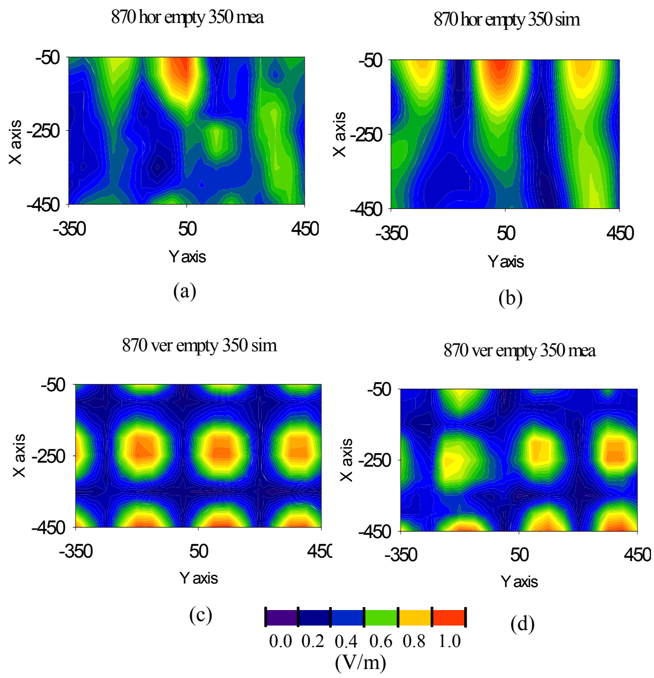

Fig. 4 Comparison between measured and simulated field distribution for empty cavity at 870 MHz

(a) & (b) horizontal polarization (c) & (d) vertical polarization

Electric field strength measurements and simulations were performed using the model shown in Fig. 3 at 870 MHz. Further investigations at 1800 MHz are not shown in this paper as work is still in progress. Simulations were carried out using two electromagnetic simulation software; CST Microwave Studio and FEKO. As both software produce comparable results [8], only results obtained from CST Microwave Studio will be shown in this paper.

With the dipole source placed within the empty cavity in both vertical and horizontal polarisations, Fig. 4 shows that although the field distribution are not identical, there is good agreement between measured and simulated results. The field distribution plots in Fig .4 were all normalised to its highest field strength level, i.e. Red on the legend shows highest field strength. In both vertical and horizontal polarisation, standing wave caused by the resonant nature of the cavity can be observed. The regions of high field distribution provide useful information when determining where a transmitter/receiver should be placed within a vehicle. It should be noted that when model furnishings are placed within the empty cavity, there are more field distribution variations between simulated and measured data. However in both cases, simulated results show a high level of agreement with measurements in relation to the position where hotspots (higher field regions) are located within the model cabin.

Using the simplified model, the above results are useful as they provide some knowledge on the level of uncertainty between simulated and measured results. This should provide confidence when performing simulation on models of increasing complexity such as the CAD model of an actual vehicle.

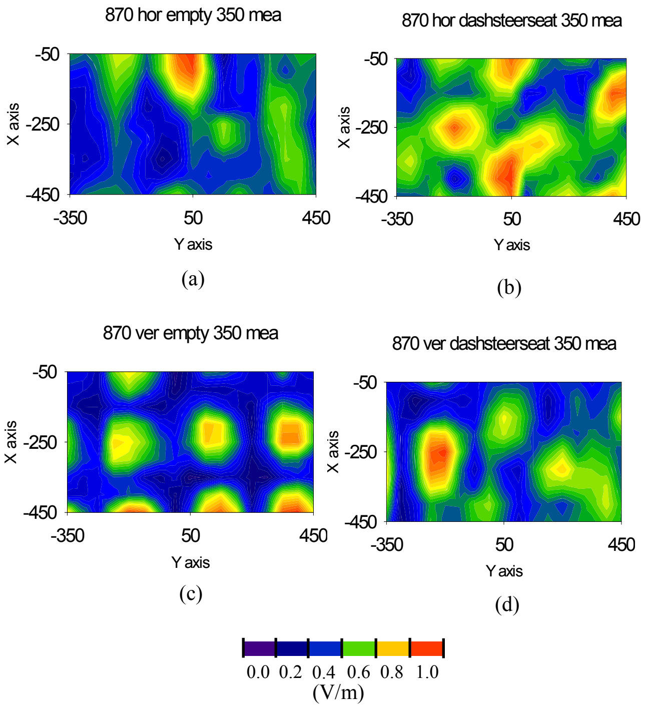

Fig. 5 Comparison between measured field distribution for cabin with and without model furnishings at 870 MHz

(a) Empty cavity (b) With furnishings - Horizontal Polarisation

(c) Empty cavity (d) With Furnishings – Vertical Polarisation

In Fig. 5, the field strength distribution within an empty cavity is compared to a cavity populated with model furnishings at 870 MHz. Changes in field distributions are observed in the entire cavity volume when furnishings are introduced. The changes are evident for both vertical and horizontal orientations of dipole source. When interior furnishings are placed into the cavity individually, it is observed that there are only small changes to field distributions when the dashboard made out of Acrylonitrile butadiene styrene (ABS) plastic is placed into the cavity. It is expected that the metal parts of the furnishings will cause a more significant change in field distributions within the cavity. The inclusion of the steering wheel model does not significantly change the field profile within the cavity for horizontal polarisation. However there is significant field redistribution for vertical polarisation where the clear mode structure of the empty cavity has been changed by the steering wheel. When only the seat was included, then the field distributions changed quite significantly - particularly for vertical polarisation, and is likely to be due to the large metal structure scattering the field.

The results show that internal field distribution within a vehicle can change significantly when furnishings are included. If an antenna is mounted on window apertures, this may affect antenna performance. The following section will describe changes to radiation patterns of a multi-band antenna when mounted within the aperture of the model cabin.

IV. Antenna Performance

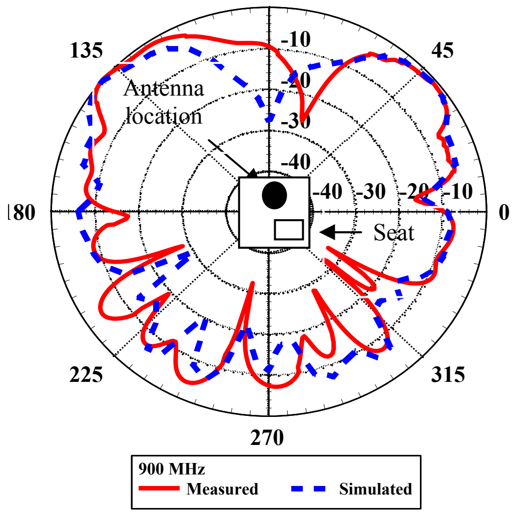

Fig. 6 Comparison between simulated and measured radiation patterns for cabin model without furnishings

This section concentrates on the measurement of radiation patterns with the antenna installed on the apertures of the cavity. Antenna far-field radiation patterns were obtained and should not be confused with internal field measurements performed in the previous section. The antenna is installed sequentially on all four apertures of the cavity and the measurements repeated with and without interior furnishings. In order to measure the radiation characteristic, the cabin model is placed onto a turn- table within an anechoic facility. The ground of the anechoic facility is not lined with absorbing materials but has materials very similar to that of a road surface.

Fig. 6 shows a comparison between measured and simulated radiation pattern at 900 MHz for the antenna installed within an aperture on the model cabin. The plot is normalised to the highest received power so they can be compared on the same plot. Although the radiation plots are not totally identical, simulation predicted the nulls to be in close vicinity to the measured pattern. There may possibly be small experimental errors when placing the model cabin on the turn-table and in the alignment of the transmitting antenna with the cavity. Similar measurements were performed at 1800 MHz and similar good agreement between measured and simulated radiation patterns is observed. .

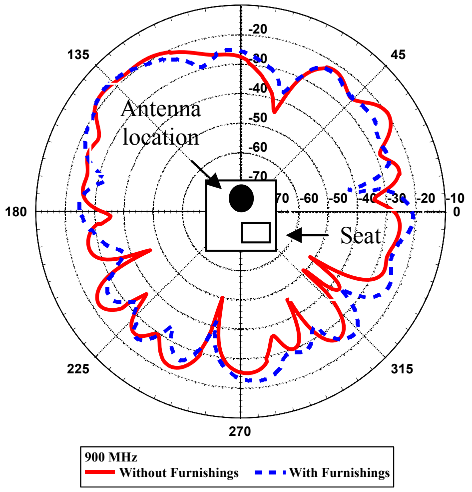

Fig. 7 Comparison between measured radiation patterns for cavity with and without interior furnishing at 900 MHz

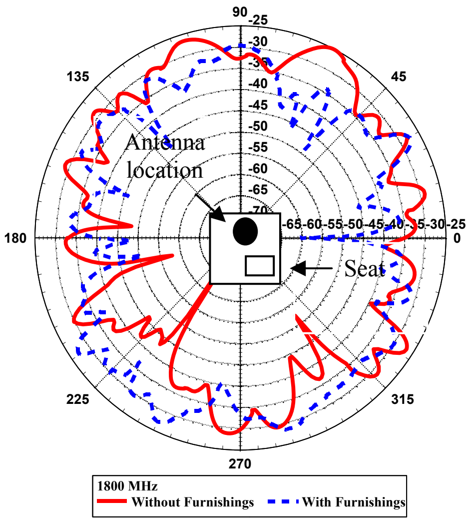

Fig. 8 Comparison between measured radiation patterns for cavity with and without interior furnishing at 1800 MHz

Comparing the radiation plots when the cavity and is empty and when populated with furnishings, it could be observed in Fig. 7 that although there are changes in internal field distributions at 900 MHz, there are very small changes to radiation patterns. However, the effect of furnishings on radiation pattern is much greater at 1800 MHz. This is shown in Fig. 8. Simulated results show changes in internal field distribution when furnishings are added to the model cabin. The difference between the absolute averaged receive power at 900 MHz for the cavity with furnishing and without furnishing is 0.87 dB. The setup with furnishings has a higher averaged received power. At 1800 MHz, this difference is 0.76 dB, with the setup with furnishing receiving lower averaged power compared to when it was without furnishings. Further analysis for antenna placed in different apertures shows that the changes are dependent on the antenna placement location relative to the cabin furnishings. The observation here gives a general overview of the changes that can be observed between a vehicle model with and without furnishings. A more detailed statistical analysis of the difference in radiation patterns will be useful for comparing models which are more complex in the future.

V. Conclusions

The effects of vehicle furnishings on the performance of a planar multi-band window mounted automotive antenna are discussed. Measured field distributions and antenna radiation pattern compare well with simulated data and can be useful in future comparison work. Internal cabin field distributions changes at both 900 MHz and 1800 MHz when furnishings are added to the model cabin. This has introduced small changes to radiation patterns at 900 MHz but more visible changes to radiation patterns can be observed at 1800 MHz. The return loss of the antenna is also affected by the resonant nature of the model vehicle cabin. The results show the importance of including sufficient cabin furnishings in an electromagnetic model.

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