Analysis of Conformal Automobile Antennas, Theory and Experiment

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1. Abstract

Intelligent Transport System (ITS) has been required to integrate many types of antennas on an automobile. As a consequence of this trend, theoretical or sub-scale analysis for low cost prediction of antenna characteristics is increasingly used [1]. This paper examines relations between a theoretical testing and a sub/full-scale measurement for development of automobile FM conformal antennas.

2. Introduction

The objectives of this study are to predict and measure the automobile conformal antenna performances at the FM band (88-108 MHz) in the United States. Input impedance characteristics and gain pattern characteristics in both polarizations were reviewed. A general purpose method of moments (MoM [2][3]) computer code (the Electromagnetic Surface Patch code version 5 (ESP5)) was used for a theoretical analysis. In a sub-scale analysis a metallic 1/30-scaled model was used. These characteristics were examined and compared to those of a full-scale antenna on a test vehicle.

3. Theoretical and Experimental Approaches

A conformal tapered gap antenna [4] and a 1986 Chevrolet Cavalier were chosen as a test antenna and a test vehicle, respectively, for our analysis. The antenna was mounted on a backlite of the vehicle and had a coupling with the heater-grids to improve antenna characteristics.

In a numerical analysis, the antenna and the body of the vehicle were modeled using perfectly electrically conducting (PEC) wire-grids whose radius was 1 [mm] for the ESP5 (figure 1). The ESP5 can calculate the input impedance of the antenna in the presence of the vehicle body, and also the gain patterns of the antenna for both azimuth and elevation cuts. Cable losses and losses due to impedance match were not included in the model.

In a sub-scale experiment, the metallic 1/30-scaled model was used as the test antenna and the vehicle. For a ground plane effect this model was mounted on a circular metallic disk with 1.2 [m] diameter. As a reference experiment the full-scale antenna was implemented on the vehicle. The full-scale vehicle was mounted on a rotating pedestal where the rotation angle and speed could be controlled in an open range (figure 2).

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4. Comparison of Results

We performed antenna measurements between 50-150 [MHz] covering the FM band. Figure 3 shows plots of the return loss (S_{11}) in Smith chart. Figure 4 shows plots of the S_{11} amplitude [dB] (upper figure) and phase [degree] (lower figure). The solid line shows the full-scale measurement results and the dashed line shows the ESP5 results. The dot line shows the sub-scale measurement results. The measurements were calibrated to 50 ohms at the feed point of the antenna in all cases.

Figure 5 shows plots of the azimuth gain patterns in vertical polarization (V.P.) and horizontal polarization (H.P.) of the antenna in dB at one of the FM frequencies (104.9 [MHz]). All gains were normalized to the reference antenna such as 75 [cm] vertical monopole mounted at the center of the top roof of the test vehicle. In the figure, the outer circle is 10 [dB] and scale is 10 [dB/div]. The azimuth angle at 0 degree is the front of the vehicle and it rotates counter-clockwise (CCW). In the same way as the input impedance figures, the solid line shows the full scale measurement results and the dash line shows the ESP5 results and the dot line shows the sub scale measurement results.

The impedance results for the different cases were essentially the same. All of them had resonance around a center frequency of the FM band. Typical values of the S_{11} were below –5 [dB] in the FM band. The gain results for the different cases also had the same values essentially. They had the same peaks and nulls at the same directions.

For the accuracy of the numerical and the sub-scale analysis, we found that gaps of the vehicle body were very important. These gaps effect the impedance match and the gains. The gaps are located between body components such as main body frame, doors, wheel gaps, a trunk hatch, an engine compartment cover and so on.

5. Conclusions

We have presented the theoretical and sub-scale models for analysis of automobile conformal antenna. The effectiveness of the theoretical and the sub-scale modeling for the prediction of the antenna characteristics were shown.

6. References

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[2] R. Harrington, *Field Computations by Moment Methods*. New York: MacMillan, 1968

[3] J. H. Richmond, ”Radiation and Scattering By Thin-Wire Structures in a Homogeneous Conducting Medium”, *IEEE Trans. Antennas Propagat.* Vol. AP-22, p. 365, March 1974.

[4] J. G. Heston, et al, ‘MM Wave/Fir Twin Slot Antenna Structures,’ *IEEE AP-S Int. Symp. Digest.*, pp. 788-790, May 1990.

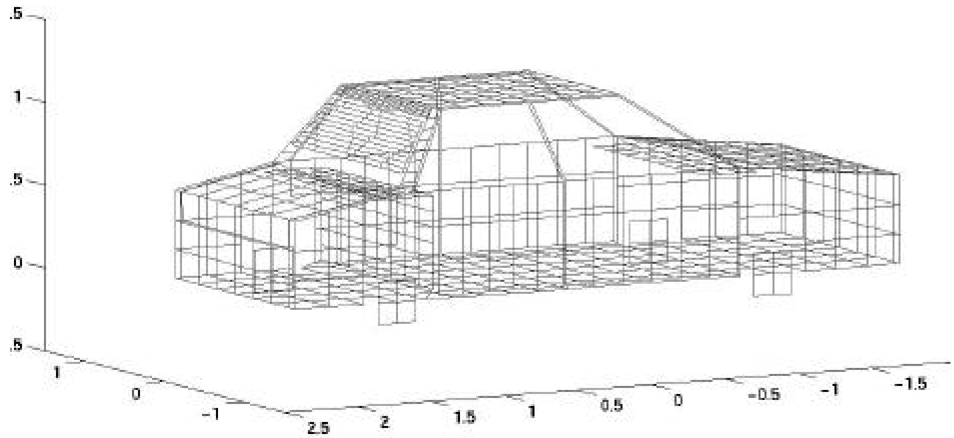

Figure 1, Wire-Grid Model for MoM code (ESP5)

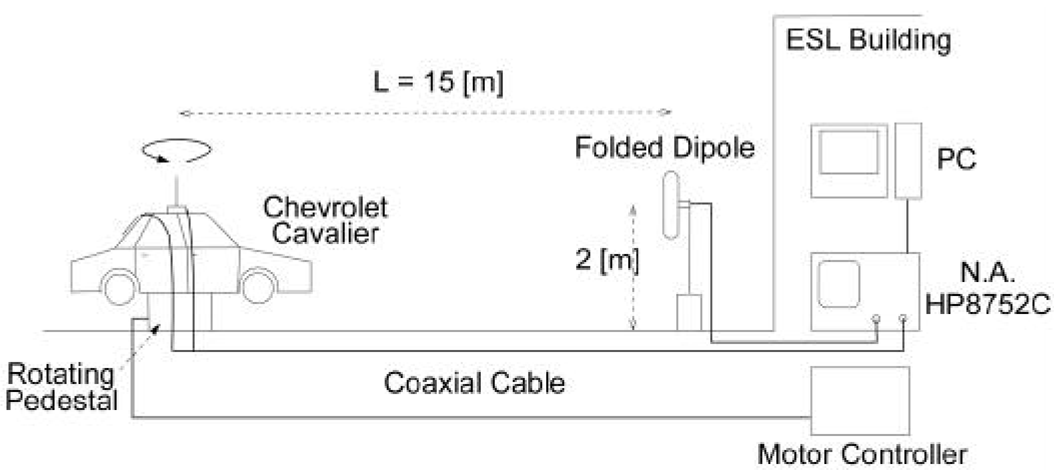

Figure 2, Full Scale Gain Pattern Experiment Setup

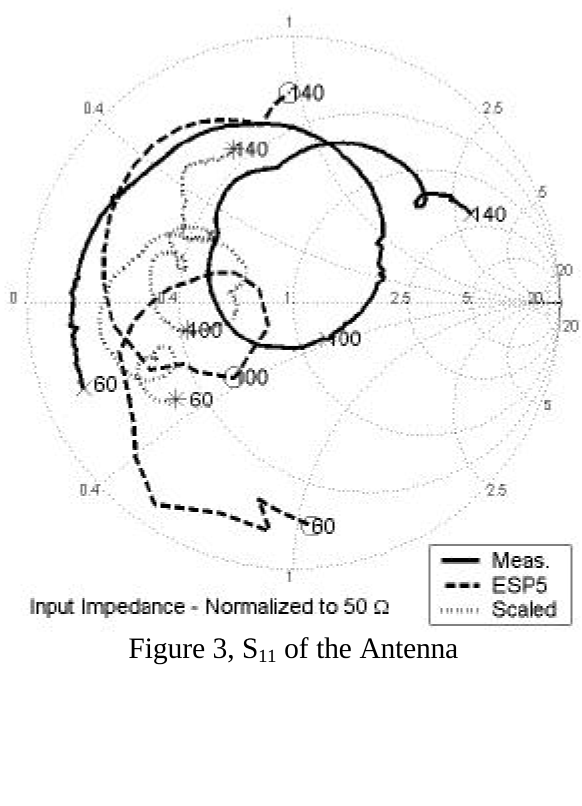

Figure 3, S_{11} of the Antenna

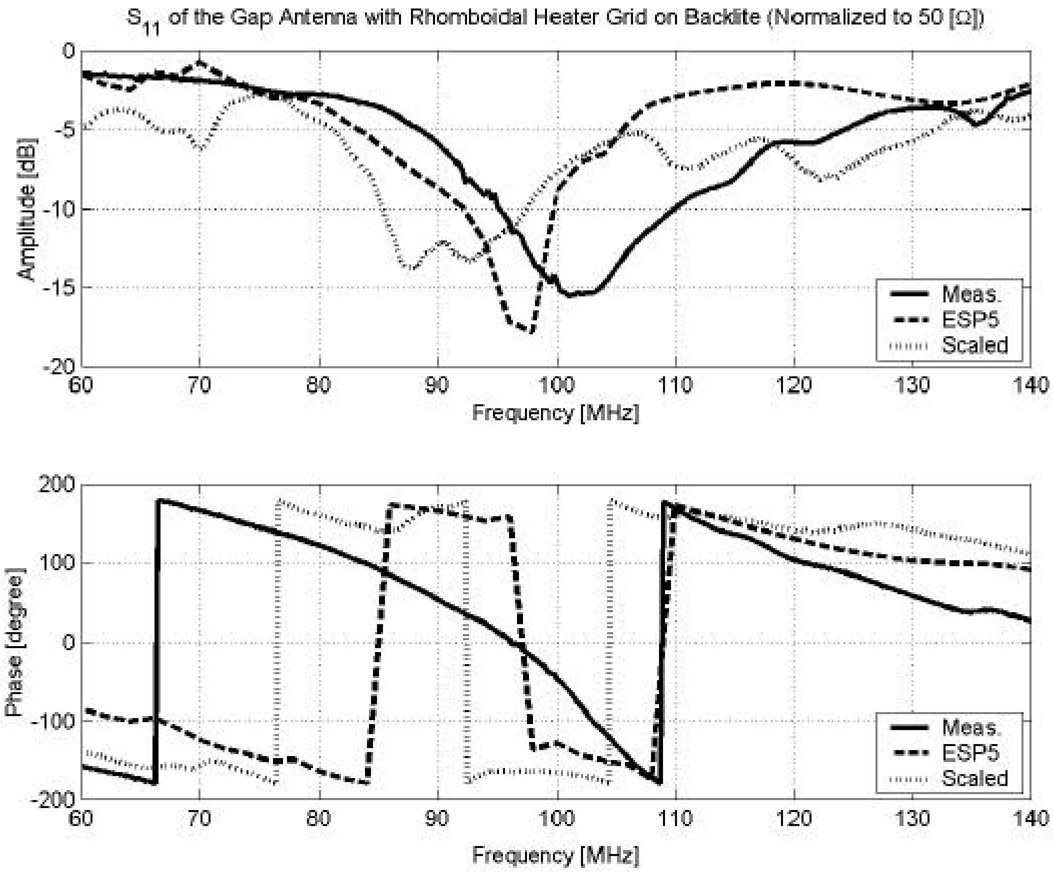

Figure 4, S_{11} of the Antenna (Amplitude and Phase)

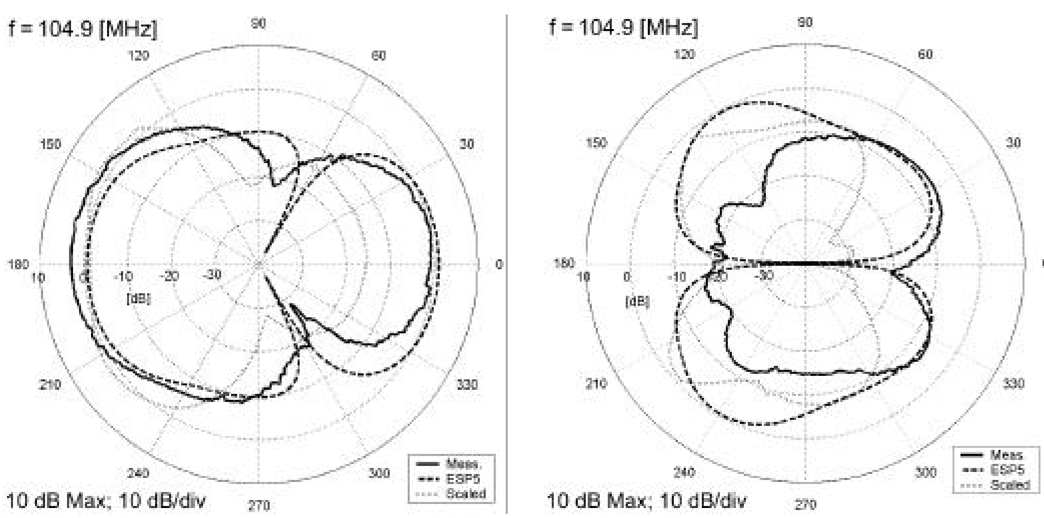

Figure 5, Azimuth Gain Patterns (V.P.(left) and H.P.(right))