Radiation Patterns of On-Vehicle Antenna for Simplified Numerical Vehicle Models

#Tomohito Shoji [1], Mitsuru Muramoto[2], Takashi Hikage[1], Manabu Omiya[3]
[1] Graduate School of Information Science and Technology, Hokkaido University
Kita 14, Nishi 9, Kita-ku, Sapporo, Hokkaido, 060-0814, Japan,
{tomohito.sh@fox49.hucc, hikage@wtemc.ist}.hokudai.ac.jp
[2] Tomakomai National College of Technology
443 Nishikioka, Tomakomai, Hokkaido, 059-1275, Japan, muramoto@gt.tomakomai-ct.ac.jp
[3] Information Initiative Center, Hokkaido University
Kita 11, Nishi 5, Kita-ku, Sapporo, Hokkaido 060-0811, Japan, omiya@iic.hokudai.ac.jp

1. Introduction

On-vehicle antenna characteristics such as input impedance and radiation patterns are affected seriously by the surrounding environment. Therefore, to estimate them accurately, the vehicle body form, glass and in-the-car equipment must be considered in measurements and numerical analysis. However, main storage capacity and computational time are restricted by using PC in calculating [1], [2]. To avoid the problem, the vehicle-body shape is simplified in some case. Experimental measurement is also useful [3], [4]. Generally experiment is a non-straightforward way because it requires a huge electromagnetically anechoic chamber [1] or particular kinds of measurement equipment [3]. On the contrary, the numerical analysis using the high-performance computing (HPC) is recently reported in [5]. It enables us to estimate characteristics of a vehicle-mounted antenna with considering entire vehicle-body shape since it has large amount of main storage capacity and parallel computation. However, developing analysis software is required for HPC because commercial software is not used in HPC.

A complicatedly shaped vehicle-model requires large amount of calculation time and computer's main memory because the vehicle body is much larger than the antenna element. To reduce the computation time, using the simplified numerical models is effective. However, the simplification method of numerical models and their effectiveness are not discussed yet.

In this paper, we clarify differences of numerical results related to simplified numerical vehicle models by applying the FDTD technique [6], [7]. We use an inverted L element for receiving the digital terrestrial television. First, we compare experimental results with computational ones and show the adequacy of the both results. Next, we clarify the influence of model simplification and its effectiveness comparing the computational results each other.

2. Comparison with Experimental Measurement

To prove the adequacy of the computational method, we compare experimental results with computational ones. Figure 1 shows four kinds of numerical vehicle-model prepared for evaluating the effectiveness of model simplification. Model A is a hatchback car of 4,770 mm x 1,800 mm x 1,550 mm in dimension. Model B is the same as model A except the windshield and the hood. Model C is the upper part of model A and model D contains only roof with 300 mm thick. The numerical models shown in Figure 1 consist of perfect conductor. An inverted L element is used and located on the roof at 200 mm apart from rear edge. The antenna is 140 mm in length and its horizontal and vertical parts are the same in length. We use model A to compare experimental results with computational ones. The experimental model is made by copper plate and reduced to 1/10 compared with an actual model. The FDTD method is employed in calculation and the problem space is discretized by 10 mm cube cells. We applied the time step of 1.67×10^{-11} sec, the eight-layer PML absorbing boundary condition and the forty guard cells for computing radiation patterns.

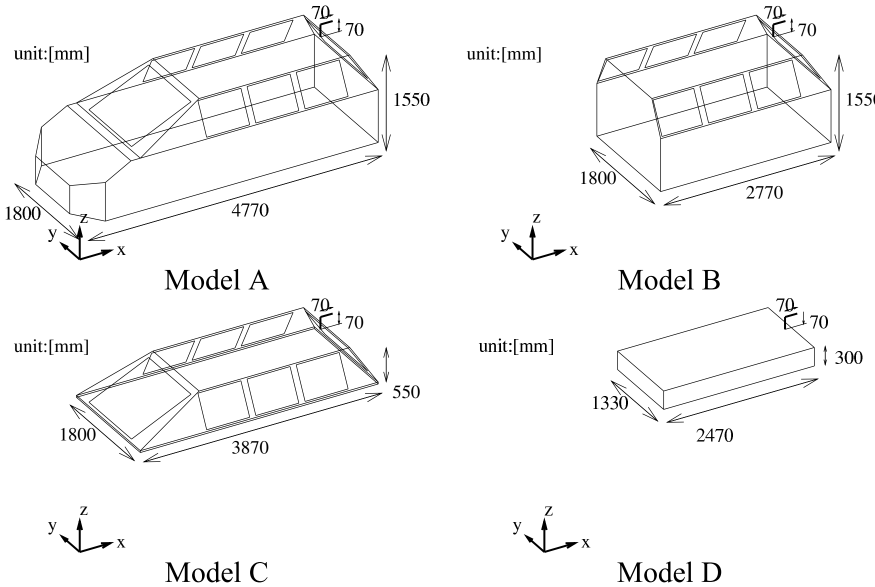


Figure 1: Analytical Models. Model A is an original full model and the others are simplified ones.

Figure 2 shows the radiation patterns in the *xy*-, *xz*- and *yz*-plane from left to right. The upper three patterns are experimental results at the frequency of 5.3725 GHz and the lower are computational results at 532.75 MHz. Solid and dashed lines show E_θ and E_ϕ, respectively. It is clear from the figure that the experimental results agree well with the computational ones in all patterns.

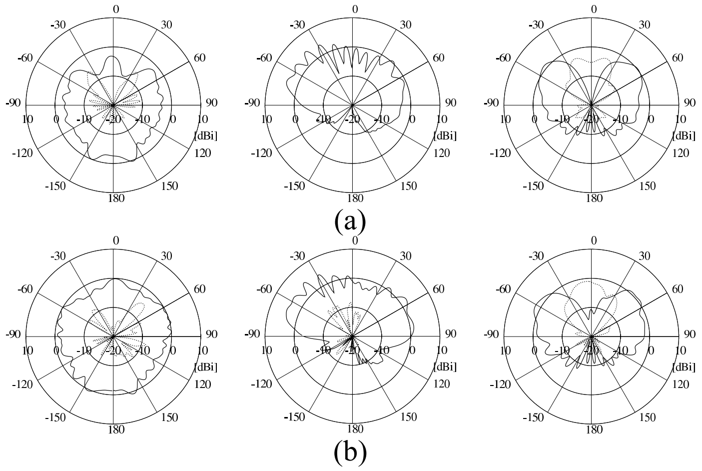
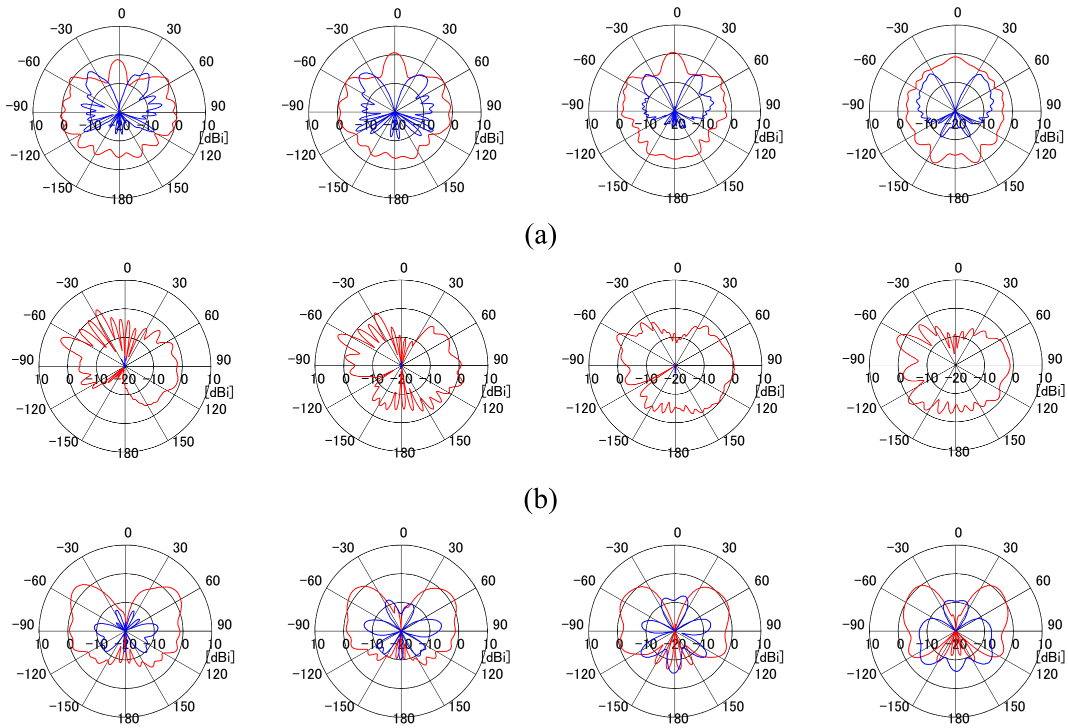


Figure 2: Radiation patterns. Measurement results at the frequency of 5.3725 GHz (a) and computational ones at 5.3725 MHz (b). Solid and dashed lines show E_θ and E_ϕ, respectively.

3. Radiation Patterns and Current Densities

Figure 3 shows radiation patterns in the *xy*-, *xz*- and *yz*-plane at the frequency of 537.25 MHz. The patterns from left to right correspond to models A, B, C and D, respectively. Red and blue lines show E_θ and E_ϕ, respectively. The radiation patterns of models A and B approximately consistent in all measurement planes. This is because the rear part of vehicle is an important part for determining radiation patterns. The radiation patterns of models A and C approximately consistent in the *yz*-plane, although the lower part of radiation pattern of model C is expanded in the *xz*-plane because only the upper part of vehicle is considered in model C. The radiation patterns of models A and D approximately consistent in the *yz*-plane. In the *xy*-plane pattern of model D, the hollows in the directions of ±30° are vanished and its gain is decreased. It is because the hollows in the directions of ±30° are generated by the rear window aperture and the surrounding pillars. Hence, in the evaluation of radiation pattern, the apertures of windshield and pillars must be considered [1].

Figure 4 shows the current densities on the vehicle body surface at the frequency of 537.25 MHz. It is reveal from these figures that the current intensity is high on the metal roof for all models and the range of high current intensity is limited around the antenna. Furthermore, the current on the pillars is also large. As a result, model C is considered to be a candidate of simplified vehicle model for estimating radiation patterns of on-vehicle antenna.



(c)

Figure 3: Radiation patterns at the frequency of 537.25 MHz in the *xy*- (a), *xz*- (b) and *yz*-plane (c). The patterns from left to right correspond to models A, B, C and D, respectively. Red and blue lines show E_θ and E_ϕ, respectively.

4. Conclusion

The paper studies the vehicle model simplification related to characteristic evaluations of vehicle-mounted inverted L antenna. First, Experimental results are compared with computational ones to prove the adequacy of the method. Next, it is clarified from computing radiation patterns for four types of numerical model that the structure of roof and pillar must be considered.

Acknowledgments

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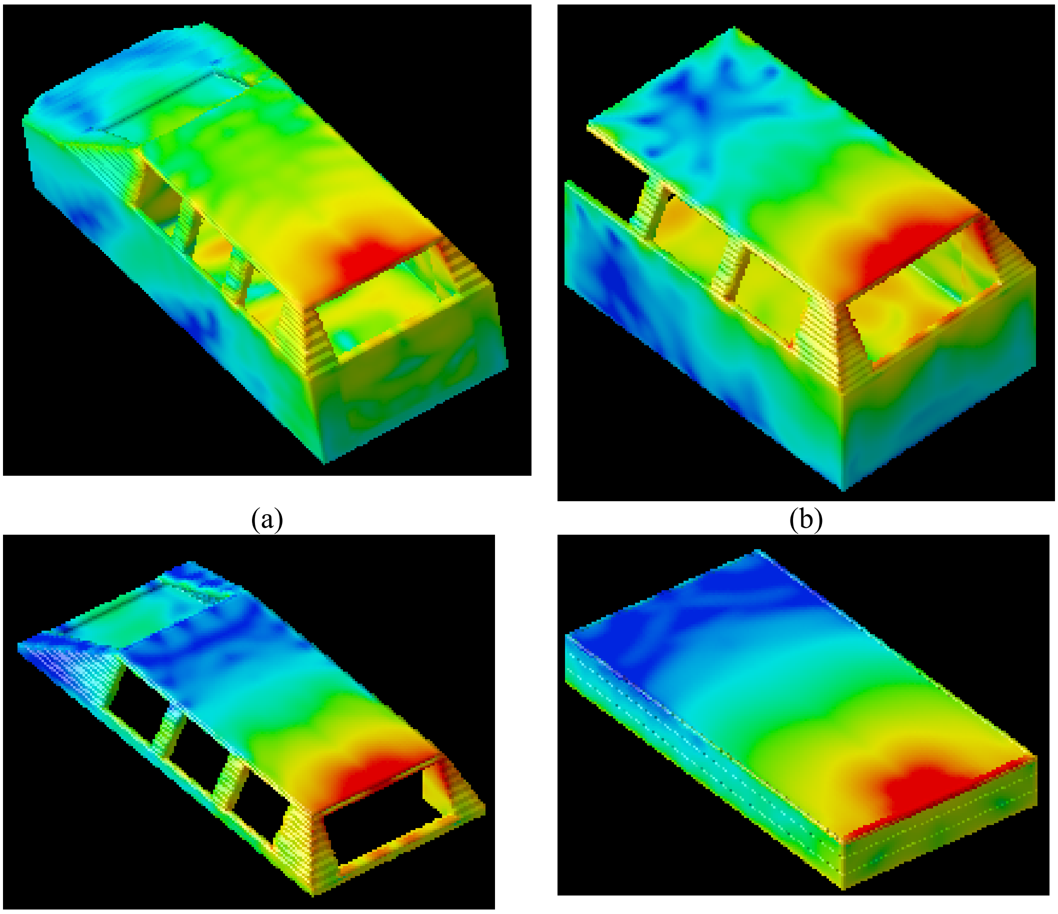

(a) (b) (c) (d)

Figure 4: Current Densities on the vehicle body at the frequency of 537.25 MHz.

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