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Estimation of Antenna Characteristics Depending on Numerical Vehicle Models

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1. Introduction

Characteristics of a vehicle-mounted antenna depend seriously on the surrounding environment as well as the antenna structure. To evaluate them accurately, the vehicle body must be considered in calculating. Until now, there are many papers on the analysis [1]–[3]. Most of them use simple approximated models of the vehicle such as a rectangular parallelepiped model, but there are few papers of analyzing the antenna characteristics with the use of complicated-shape models. On the other hand, comprehensive measurements in an actual environment cost too much and it is difficult to carry precisely them out. Relations between antenna characteristics and various kinds of numerical vehicle model have not been cleared yet. From the above, we have to clarify influence of environment for antenna characteristics. Computer simulation is more effective than experimental examination for various testing. Their effectiveness is recognized widely.

In this paper, we clarify differences of numerical results related to the approximated models and the precise ones by applying the FDTD technique [4], [5]. We assume that an antenna element is used for receiving the digital terrestrial television.

2. Analytical Models

Figure 1 shows the analytical models including vehicle body and an antenna. Dimensions of all vehicle models are 4,770 mm x 1,800 mm x 1,550 mm. Model (a) is approximated as one perfect conductor box. The shape of model (b) is vehicle outline. Model (c) is designed considering window glass and vehicle interior space. Additionally model (d) includes polyethylene resin seats and rubber tires. Model (e) is the most precise numerical model in which smooth contours of a real vehicle are considered. Table 1 shows the parameters of media for the FDTD analysis.

Table 1: Parameters of Media

medium	ϵ_r	$\sigma[S/m]$
vacuum	1	0
perfect conductor	0	∞
window glass	5.5	0.003
seat (polyethylene resin)	2.3	0.0
tires (rubber)	3.0	1×10^{-15}

It spends inordinate amount of time to construct a complicatedly shaped vehicle-model such as model (e) by traditional methods. To construct it easily and quickly, we developed a modeling method which uses the 3D-digitizer and a file converter. It proceeds with following steps, (1) assembling a commercially available plastic model, (2) measuring its shape by using the 3D-digitizer, (3) converting

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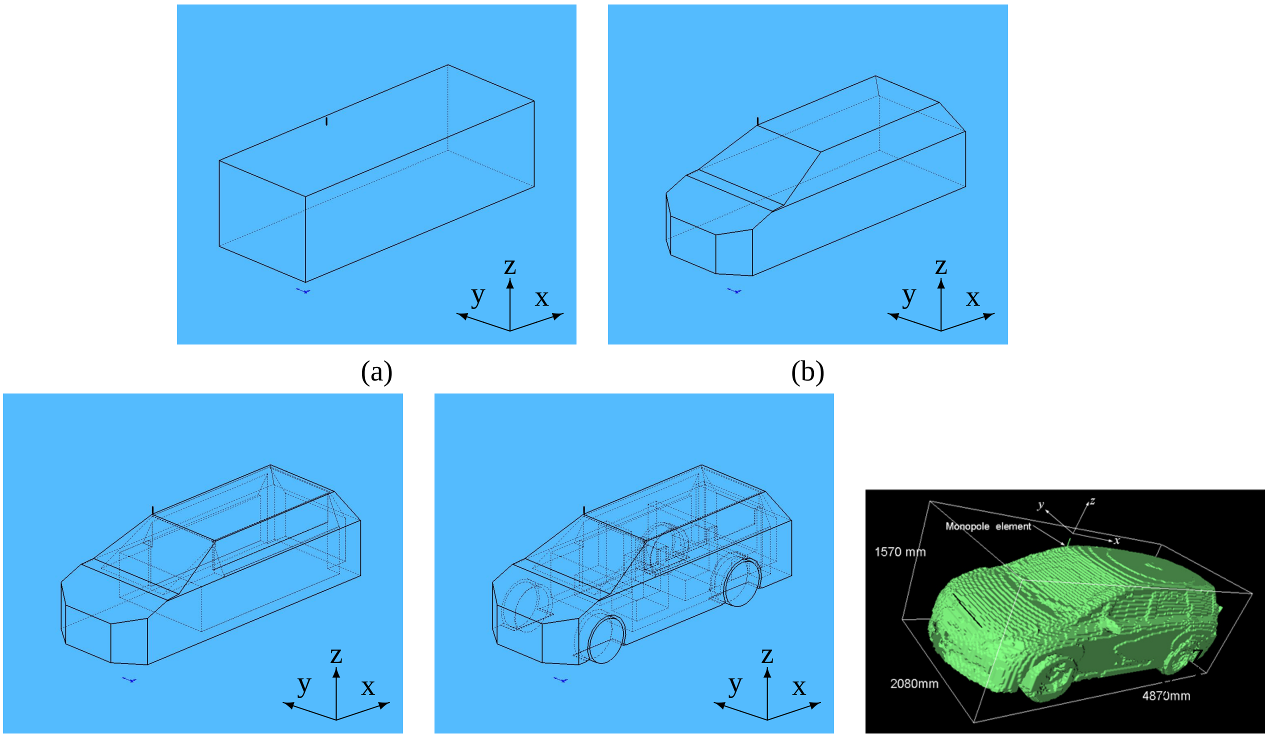

(a) (b)

(c) (d) (e)

Figure 1: Analytical Models

it to the 3D CAD (STL) file format, and (4) converting it into mesh data for the FDTD analysis by using the STL-FDTD mesh file converter.

The STL file format describes any model by assembling triangular shapes in various sizes. In consideration of this knowledge, this converter sets ϵ_r and σ of the media to mesh-cells included in a circumscribed rectangular parallelepiped shape of each triangular shape shown in Figure 2. To raise the precision of numerical model, the converter divides a big triangle into small ones before considering a circumscribed shape.

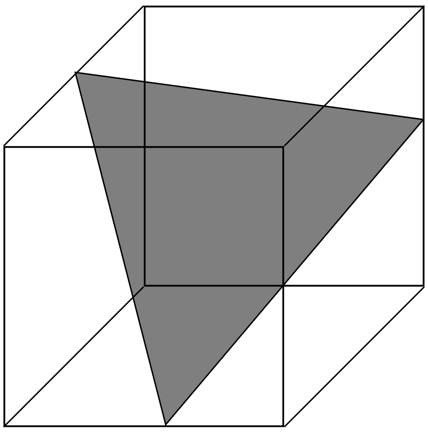

Figure 2: Circumscribed Rectangular Parallelepiped Shape of Triangular Shape

We analyzed a monopole antenna in the beginning because it is the most fundamental element and its characteristics are well-known. The length of the monopole antenna is 120 mm and its position is the front-right side edge of the roof. We calculated its impedance characteristics and estimated its radiation patterns at the frequency of 537.25 MHz. We applied the eight-layer PML absorbing boundary condition, twenty guard cells for calculating the impedance characteristics, and one hundred guard cells for estimating radiation patterns.

3. Numerical Results

Figure 3 shows input impedance characteristics of each model. They are computed using the time domain data of 16,384 time-steps. The FDTD analysis takes about 40 minutes for each model. Figure 4 shows radiation patterns of each model. They correspond to the results after 11,200 time-steps FDTD calculation. The FDTD analysis takes about 110 minutes for each model.

Models (a) and (b) are similar in the input impedance characteristics, but they are different from each other in the radiation patterns of xz-plane. We expect it due to the presence of front-part of vehicle. Although Model (b) has smooth curve, model (c) has ripples in the input impedance characteristics. And model (c) differs clearly from model (b) in the radiation patterns. We expect that the cause is reflection and diffraction in the vehicle interior space. Models (c) and (d) are similar in the input impedance characteristics and the radiation patterns. Hence the interior parts such as the seats and the tires affect little in the input impedance characteristics and the radiation patterns. Models (d) and (e) are similar in the input impedance characteristics, but they are different from each other in the radiation patterns.

4. Conclusion

We developed the modeling method which uses the 3D-digitizer and the file converter to construct a complicatedly shaped vehicle-model easily and quickly. We intend to improve the method in the future. And we presented the differences of the antenna characteristics between the precise vehicle models and the approximated ones by numerical simulations using FDTD method. It became clear that the exact characteristic was obtained only when we considered the inner air space of the vehicle. It was also shown that the interior parts affected little the input impedance characteristics and the radiation patterns. However, the radiation patterns of the most precise model are clearly different from the others. We intend to investigate a cause of the difference and analyze other kinds of antenna element.

Acknowledgments

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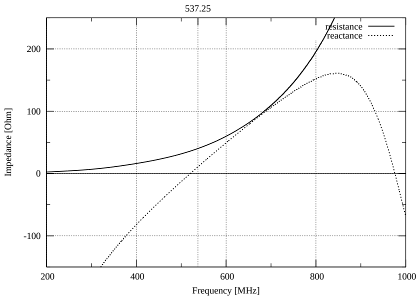
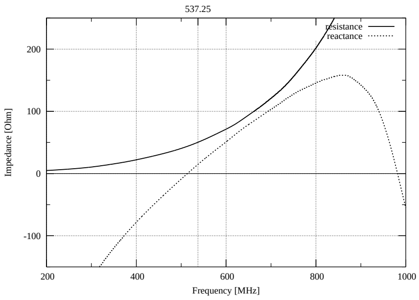
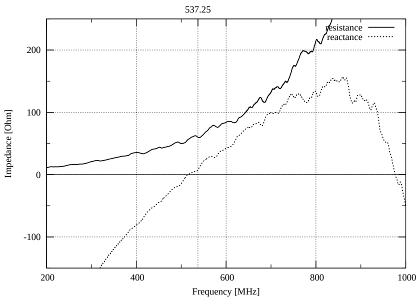


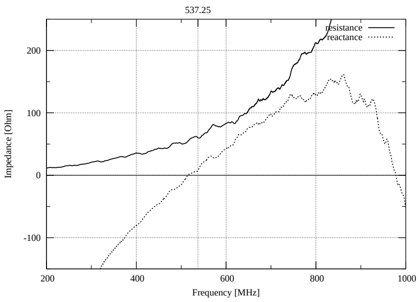
Model (a)



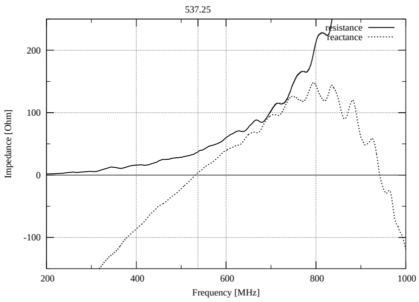
Model (b)



Model (c)

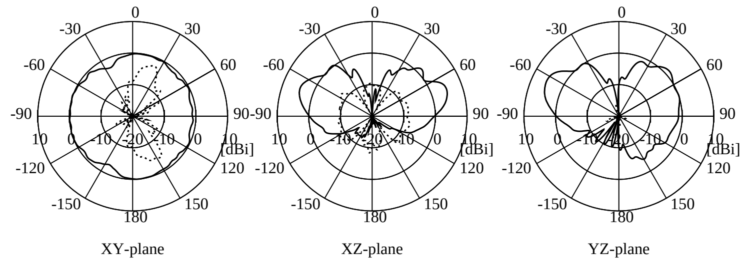


Model (d)

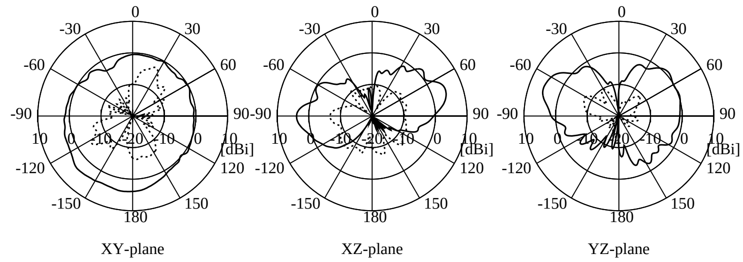


Model (e)

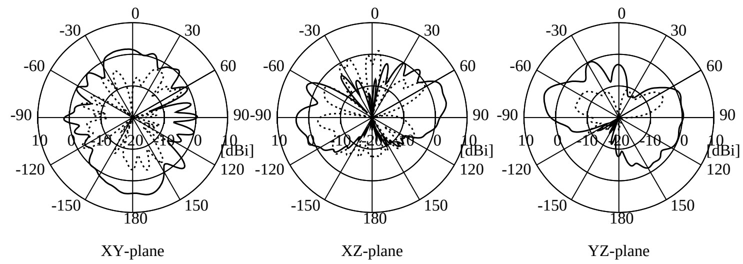
Figure 3: Input impedance characteristics



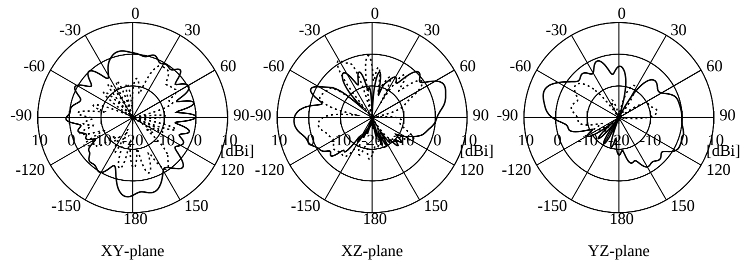
Model (a)



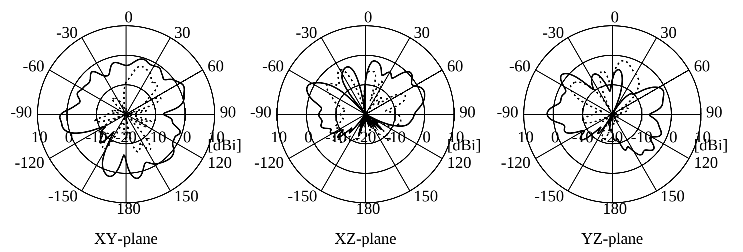
Model (b)



Model (c)



Model (d)



Model (e)

Figure 4: Radiation patterns at 537.25 MHz