EMF Excitation Dependency on the Boundary Condition Due to Mobile Radios - Parallel FDTD Analysis on the Radio Environment in a Train Carriage -

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1. Introduction

Electromagnetic field (EMF) distributions inside a train carriage caused by the cellular radios of the passengers are analyzed and effects of their electromagnetic interference (EMI) on implantable cardiac pacemakers are evaluated based upon the analysis results. Since portable radios may be used almost everywhere, accurate and reliable estimations of EMC in various environments including special conditions are required. Spaces surrounded with conductive surfaces, e.g. train carriages and cars, are typical environments requiring assessment. Here, we refer to this kind of environments as a semi-echoic environment (SEE).

The authors have already reported the results of both precise computer simulations and experiments using 800 MHz and 2 GHz transmitters in an actual train carriage [1]. We employed the FDTD technique [2] and a supercomputer to estimate the EMF distributions excited inside train carriages. Moreover, large-scale parallel computing based upon several node partitions was used because of its memory and speed capabilities. It could give us a good perspective within a reasonable computation time [3]. In Addition, a simplified histogram estimation method for electric field strength in whole area of the train carriage were employed to deal with the complicated electromagnetic field (EMF) distributions. It allowed the EMI risk to pacemakers by cellular radio transmission to be quantitatively evaluated. The obtained results implied that FDTD computer simulation could be used for estimating complicated EMF excitation problems in SEE precisely. Those results confirmed that excessively high EMF, high enough to affect the normal functions of the pacemaker, did not occur inside the train carriage beyond the safe distance of 22 cm [4], the safety specification for pacemaker users. In the above investigations, we assumed the inside surface of train body to be made of perfectly conductive walls in the FDTD analysis because of considerations for really serious case. Admittedly, the inner surface of the carriage body is covered by non-metallic materials.

This paper discusses effects of thin lossy dielectric plates used for inner surface of the carriage. We use a typical train carriage now in active service in Japan, and 800 MHz band cellular radio simulators. We examine the EMF histograms of inner space of train carriage when the inside surface of the body is covered by plastic panels made from polypropylene. The realistic and complicated situations wherein humans occupy a train carriage are also examined.

In the following sections, the configurations of FDTD analysis for the EMF of the train carriage are described. Section 3 shows the analytical results of the EMF excited in the train carriage. Finally, a brief summary of this paper is provided in the last section.

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2. The train carriage model and Parallel FDTD configurations

A typical train carriage examined in this paper is represented schematically in Fig. 1. The dimensions of the carriage are length of 17,500 mm, width of 2,780 mm and height of 2,200 mm. The FDTD analysis is employed in order to obtain spatial electric field distributions throughout the inner space of the carriage. The details of the FDTD analysis configurations are summarized in Table 1. Here we also employ a supercomputer to analyze the EMF in the train carriage. To achieve a precise computation, spatial resolution is set to 1 cm^3. The FDTD problem space is divided into some regions to be adopted parallel computation by using a supercomputer. In this paper, six numbers of computational nodes are used to carry out the FDTD analysis of the train carriage. In this case, the computational memory required to calculate the whole inner space of the carriage model is 30.18 GB.

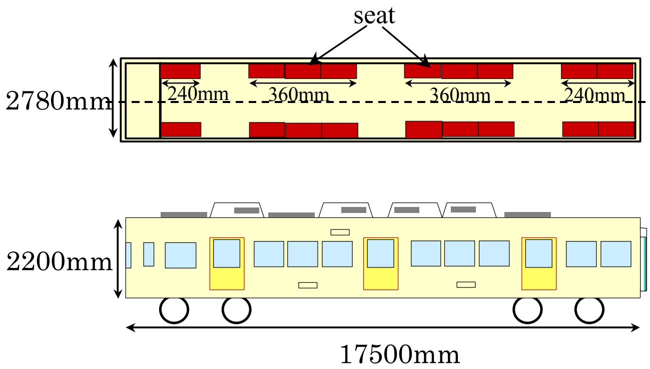

Fig. 1. Typical train carriage.

In the actual train, the effect of the loss by the passenger body cannot be disregarded. Then, to examine the realistic and complicated situations wherein humans occupy a train carriage, we apply a homogeneous human phantom model in the FDTD analysis.

Fig. 2 shows two types of the geometry of the carriage body. The model on the left hand side is a conservative model that is all metallic body. And the other is metallic wall covered with poly-propylene (PP) plates at the inside surface of the carriage body. In both of models, the thickness of the metallic body is kept at 100 mm.

Table 1. Parameters for FDTD analysis.

Cell size (cubic)	Δ=10 mm
Total problem space	338×330×1810 cells
Number of guard cells	22 (in every directions)
Absorbing B. C.	PML (8 layer, M=3)
Time step	Δt = (1/(Max2 x Freq.)) Max2=76 for 800 MHz
Iteration	450 (800 MHz)
Required memory	30.18 GB (5.03 GB x 6-node)
Train model	Body: PEC or PEC+PP polypropylene (PP): ε_r=2.25 and $\sigma=10^{-3}$ Window glass: ε_r=5.0 and $\sigma=10^{-7}$ Seat: ε_r =1.0 and $\sigma=10^{-7}$

In the next section, EMF histograms of the inner space of the carriage are calculated. We discuss about the differences between properties of EMF due to a single metallic wall and additional PP panels located inside the carriage body. Here a half-wavelength dipole antenna is used as 800 MHz band cellular radio in the FDTD analysis.

3. Results

To estimate the percentage of the same strength area for whole inside plane of the train carriage, we have proposed to use field histograms. The relative field strength normalized to a reference value is used. In this paper, the reference value of the field strength is determined from the experimentally obtained maximum interference distance for the 800 MHz band cellular radio (PDC) [5].

First, we examine the EMF in the case of only a Tx antenna exists and no passenger is in the carriage. Fig. 3 depicts an FDTD model. One transmitter operating at 800 MHz is set up at the height of 1,570 mm from the floor. Fig. 4 presents three results for the cases, without PP panel, with 10 mm PP panel and 50 mm PP panel, which are derived from analysis of EMF distributions. The height of estimation plane is same as the Tx antenna location. From the figure, the amplitudes of the electric field in the cases of metallic wall with the 10 mm PP panel and without PP panel are almost same properties. Though, the EMF value in the case of metallic wall with 50 mm PP panel becomes about 1 % smaller than the others. We have confirmed that the simulation results for 800 MHz source coincide well with the experimental results measured along the actual carriage [1,6].

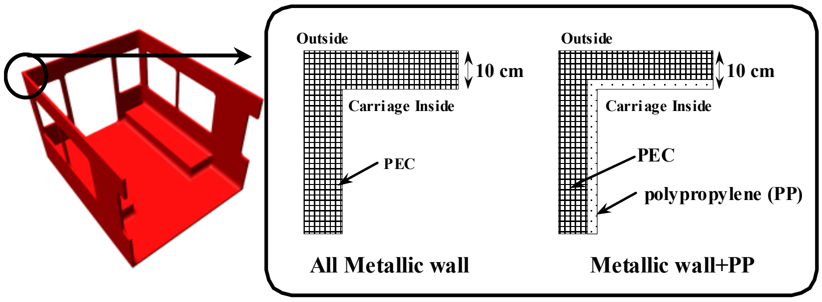

Fig. 2. Two types of carriage body structures.

Figs. 5 and 6 show an FDTD model and calculation results for one transmitter and 120 passengers existing in the train carriage. We assume eighty-four standing passengers and thirty-six sitting passengers. The former consists of twenty-four passengers of 1,500 mm tall, thirty-six passengers of 1,600 mm tall, fifteen passengers of 1,700 mm tall and nine passengers of 1,800 mm tall. The transmitter is positioned at the height of 1,270 mm from the carriage floor. Also, the height of estimation plane is same as the height of the settled Tx antenna. As shown in Fig. 6, the intensities of EMF in both cases are the almost same. The same conclusion is derived from the evaluations with and without passengers.

4. Summaries and Conclusions

This work sets out to estimate the EMF dependency on the boundary conditions in the train carriage. We assumed the carriage body, which was made of metallic wall and inside polypropylene panel, and estimated EMF distributions excited in the carriage due to 800 MHz band mobile radio by using the FDTD technique based on parallel computation. Although the EMF amplitudes are slightly different in the histogram, the properties of the EMF distributions are almost the same as the case of the metallic carriage.

Finally, these results suggest that the EMF strength inside the train carriage does not exceed the EMF reference value.

Acknowledgements

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References

[1] T. Hikage, T. Nojima, S Watanabe and T. Shinozuka, "A STUDY ON IMPLANTABLE CARDIAC PACE MAKER EMI FROM CELLULAR RADIOS IN SEMI-ECHOIC ENVIRONMENTS," 2004 International Symposium on Electromagnetic Compatibility, 3B2-2, pp. 565-568, Jun. 2004.

[2] Taflove, Computational Electromagnetics, Artech House, Boston, 1995.

[3] M. Omiya, K. Munakata and T. Hikage, "Design of Slot Antennas and Arrays Using the FDTD Technique and a Parallel Supercomputer," The 19th Annual Review of Progress in Applied Computational Electromagnetics, pp. 539-544, Mar. 2003.

[4] "Guidelines on the Use of Radio communication Equipment such as Cellular Telephones -Safeguards for Electric Medical Equipment-," EMC Conference Japan, Electric Medical Equipment Study Group, 1997.

[5] "Results of investigation into the effect of electromagnetic waves on medical equipment," Association of Radio Industries and Businesses (ARIB), Mar. 2002.

[6] Yuki Sumi, Takashi Hikage, Toshio Nojima, Manabu Omiya, Soichi Watanabe and Takashi Shinozuka, "ESTIMATION OF THE EMF IN ACTUAL TRAIN CARRIAGE USING THE PARALLEL FDTD METHODS," International Conference of Antennas and Propagation (ISAP) 2004, 1C2-4, pp. 137-140, Aug. 18, 2004.

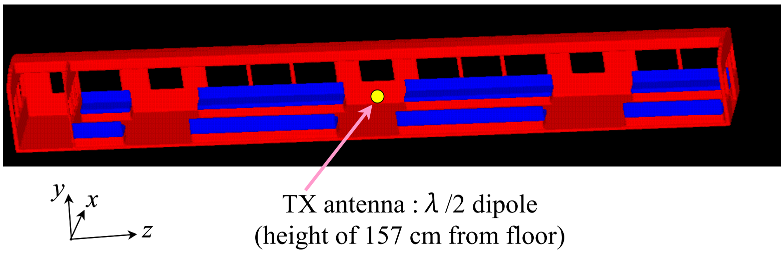

Fig. 3. FDTD model without passenger.

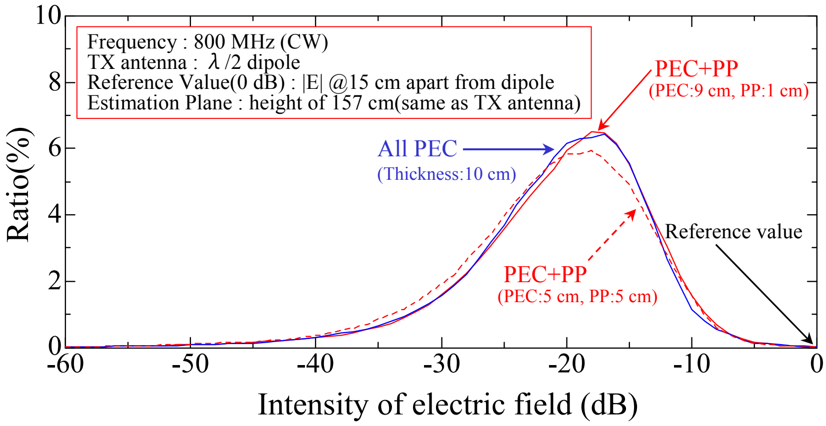

Fig. 4. EMF histograms (empty train carriage) .

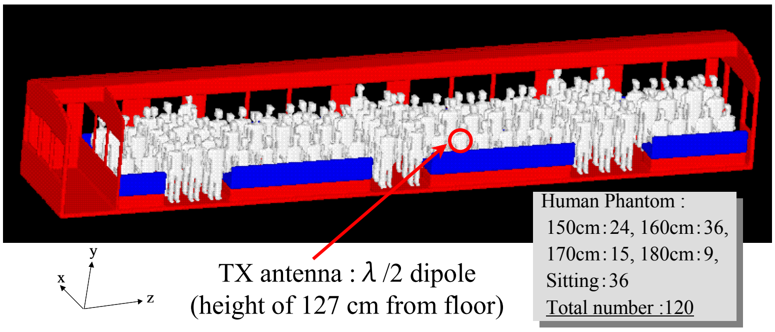

Fig. 5. FDTD model with 120 passengers.

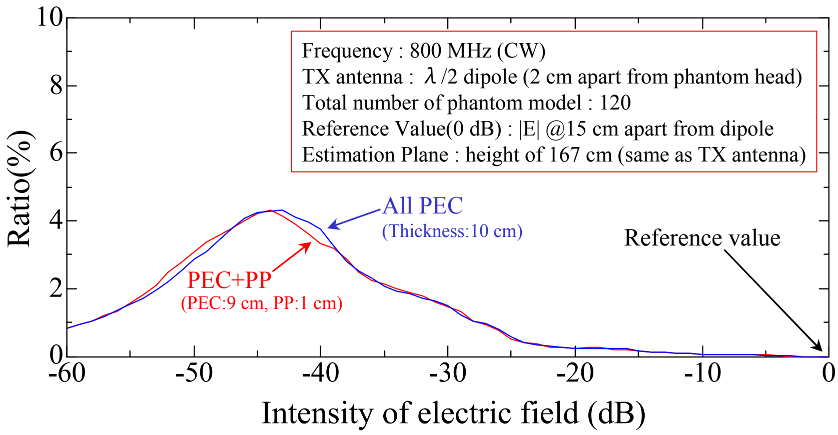

Fig. 6. EMF histograms (existing 120 passengers).