Estimation of the Electromagnetic Fields Excited by a Cellular Phone in a Typical Aircraft Cabin

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Abstract— **The aim of this study is to develop accurate and reliable estimation method of EMF distributions in aircraft that can contribute to numerical EMI assessment technique. Electromagnetic field distributions created by a cellular radio inside a cabin of aircraft are analyzed and propagation characteristics are discussed from the analysis results. We use FDTD technique and a large-scale parallel computing technique to precisely estimate the field distributions inside cabin of Boeing 777-200 aircraft model.**

Keywords— ***aircraft; parallel FDTD analysis; propagation characteristics***

I. INTRODUCTION

In this paper, electromagnetic field (EMF) distributions excited by a cellular radio inside an aircraft are analyzed and propagation characteristics are evaluated based upon the analysis results. Wireless communication devices usage has extended to a wide range of environments such as buses, trains, and aircrafts. Recently, some airlines have begun in-flight voice calls and wireless internet connection services. On the other hand, some paper reported that electromagnetic interference (EMI) to aircraft systems from active radio transmitters is possible [1,2]. The aim of this study is to develop accurate and reliable estimation method of EMF distributions in aircraft that can contribute to numerical EMI assessment technique. In an actual environment, comprehensive measurements cost too much and it is difficult to carry them out precisely. Therefore, we proposed to apply large-scale numerical simulations to examine the EMF excited by cellular radio [3]-[7]. The FDTD technique is a versatile and efficient tool for the solution of Maxwell's equations in complex structures [8]-[10]. In addition, Large-scale parallel computing technique based upon several node partitions of a supercomputer is used because of its memory and speed capabilities [11]. It is able to give us a good perspective within a reasonable computation time. We have used Boeing 777-200 aircraft model and employed the FDTD technique and a supercomputer to estimate propagation characteristics inside the cabin in this paper.

II. FDTD ANALYSIS OF EMF INSIDE AIRCRAFT CABIN MODEL

The FDTD analysis is applied in order to obtain spatial EMF distributions throughout the cabin of an aircraft that contain lossy media. The problem space is quantized by Yee cells. The cell size must be small enough to obtain accurate computed results. Generally, it is less than one-tenth of the minimum wavelength for the analysis. Therefore, the computational memory capacity requires for simulation of large-scale models such as an airplane becomes extremely large. Therefore we employ a supercomputer to estimate the EMF in Boeing 777-200 model. Figs. 1 and 2 show the FDTD model and the cabin configuration used in this study, respectively. Here, an 800 MHz cellular radio simulator is assumed to be placed at the front of the cabin. The dimensions of the aircraft that are taken into the analysis model are as accurate and precise as possible. Because our research interest of this paper is EMF distributions inside the cabin, the wings are not modeled in the analysis. The dimensions of the aircraft model are: length of 52.3 m, width and height of 6.13 m. Tables 1 and 2 summarize the FDTD parameters and the material parameters inside cabin, respectively. The total program space including absorbing boundary condition of perfectly matched layer (PML) is $673 \times 673 \times 5298$ cells. The required computational memory to execute the analysis is about 600 GB. Each node of supercomputer operating individually is able to have its own computational main memory of about 100 GB. Therefore, 6 computational nodes are used to carry out analysis of the EMF in the entire cabin.

III. RESULTS

Figure 3 shows an example of the 2- and 1-dimensional electric field distributions obtained by FDTD analyses. A vertically polarized wave at -10 dBm at 810.05 MHz is radiated from a half-wavelength dipole, located at 1.0 m above the floor in the front of the cabin. The vertical (Ey) and horizontal (Ex) polarized Electric field distributions on the horizontal plane at the height of 1.0 m from the cabin floor are shown in the figure. We confirm that vertical and horizontal polarized field distribution characteristics are similar, though vertical dipole antenna is only set.

Table 1: FDTD parameters

Problem space	673 * 673 * 5298 (x , y , z)
Cell size (cubic)	Δ=1 cm
Frequency	810.05 MHz
Absorbing boundary condition	PML (8 layers)
Number of guard cells	22 (in all directions)
Iteration number	800
Mobile radio	1 / 2 λ dipole antenna
Number of guard cells	22 (in all directions)

Table 2: Materials

Media	ε_r	σ [S/m]
Free space	1.0	0
Aircraft body	-	Perfect electric conductor (PEC)
Seat (metal & pad)	-	PEC
	2.0	3.02×10^{-3}
Cabin partition	-	PEC
Lavatory	-	PEC
Galley	-	PEC
Ceiling luggage rack	-	PEC
Cabin floor	3.5	0.005
Inside panel wall	3.5	0.005
Window	2.26	0.005

Additionally, in order to estimate polarization characteristics inside the cabin, a cross-polarization ratio (XPR) histogram is applied. The XPR is defined as the ratio between the power received by the antennas whose polarization is matched to the transmitter polarization and the power received by the antennas whose polarization is perpendicular to the transmitted. Fig. 4 shows the analysis results of XPR histograms for 800 MHz source. The estimation area is horizontal and vertical plane including antenna feeding point inside the cabin except PEC. The x axis and y axis denote the value of XPR and probability distribution, respectively. This figure indicates that the peak of histograms is located near 0 dB. Vertical and horizontal polarizations exist in almost the same level irrespective of antenna polarization direction. The internal wall of the cabin has cylindrical geometry. Therefore, it is thought that direction of polarization was changed greatly by reflecting and scattering inside cabin of the aircraft.

IV. CONCLUSIONS

We estimated EMF distributions excited by an 800 MHz cellular radio inside cabin of Boeing 777-200 aircraft model. The results imply that the large-scale FDTD computer simulation can be considered to be effective for estimating this type of complicated EMF excitation problem. XPR histograms indicate that vertical and horizontal polarizations exist in same level irrespective of antenna polarization direction in the cabin. We intend to conduct other estimations that consider different aircraft models, more radio sources, and different types of transmitting antenna. In addition, measured EMF distributions in an actual aircraft will be compared to simulated values obtained by our large-scale numerical analysis.

ACKNOWLEDGMENT

This work was partially supported by Grant-in-Aid for Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number 24560391. Computations and visualizations were performed using the computer resources provided by the high performance computing system at the Information Initiative Center, Hokkaido University.

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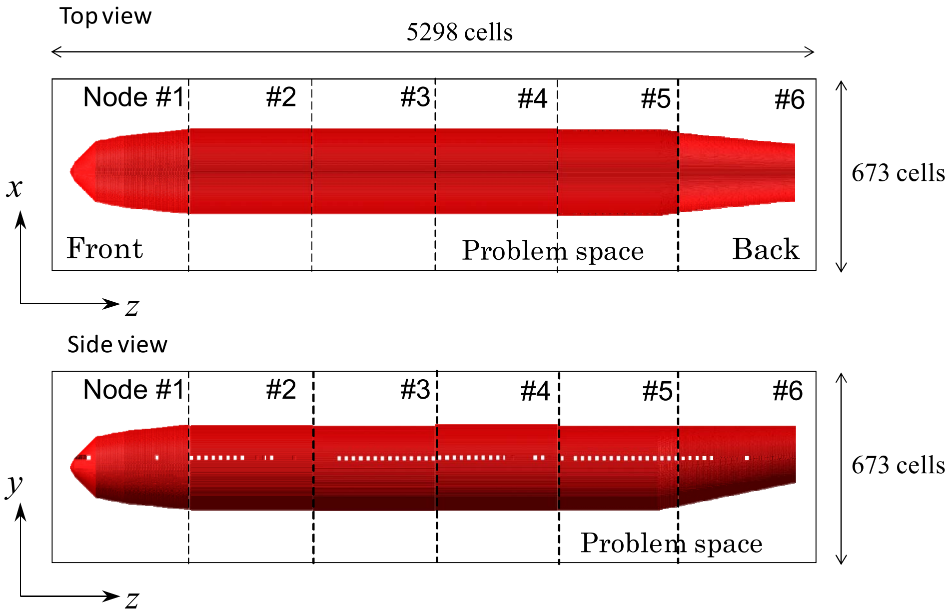

Figure 1: FDTD model for Boeing 777-200 Aircraft. The wings are not modeled in the analysis.

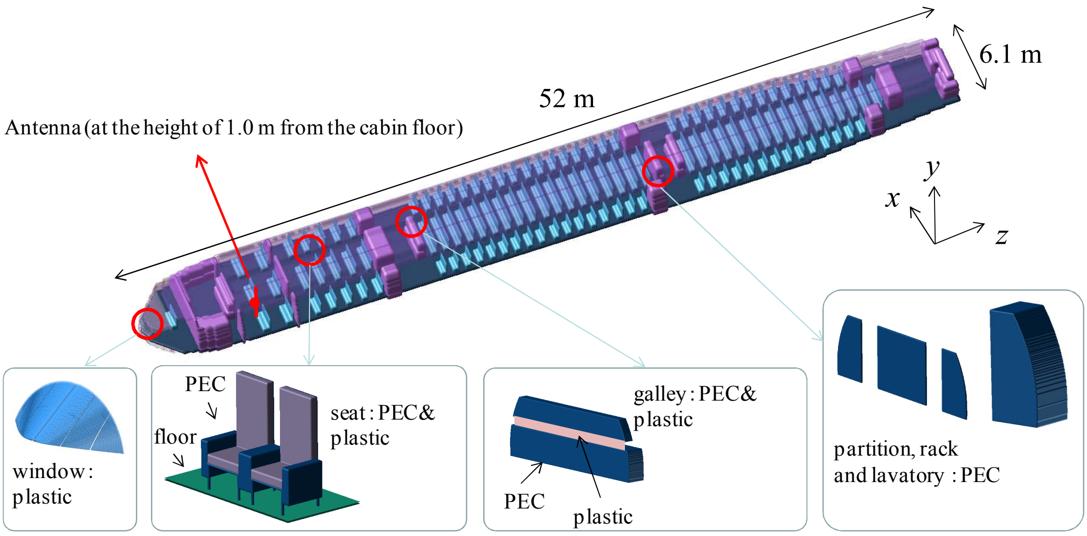

Figure 2: Cabin configuration

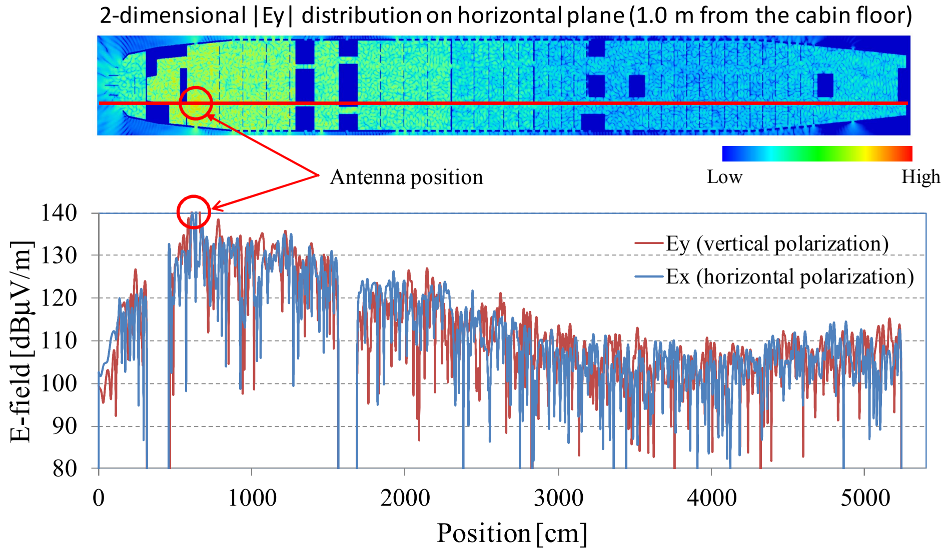

Figure 3: EMF distributions inside the cabin on the horizontal plane at the height of 1.0 m from the floor.

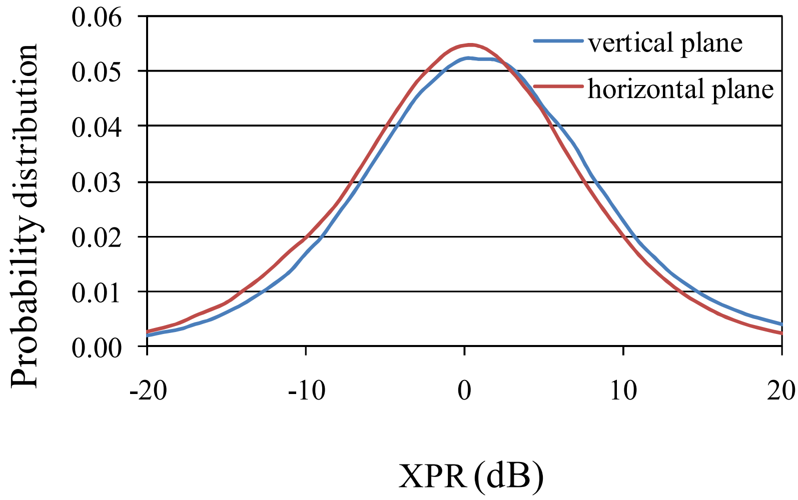

Figure 4: Cross-polarization power ratio (XPR) histogram inside cabin (horizontal plane including antenna feeding point and the vertical plane including antenna position)