Estimation of the Electromagnetic Fields Distribution due to Mobile Radio in a Typical Aircraft Cabin Using Large Scale FDTD Analysis

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1. Introduction

In this paper, electromagnetic field (EMF) distributions excited by mobile radio inside an aircraft cabin 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 allowing in-flight voice calls. 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 mobile radio [3]-[5]. The FDTD technique is a versatile and efficient tool for the solution of Maxwell's equations in complex structures [6]-[8]. In addition, Large-scale parallel computing technique based upon several node partitions of a supercomputer is used because of its memory and speed capabilities [9]. 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 aircraft cabin in this paper.

2. FDTD analysis of EMF in 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 requirs to analyze 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 aircraft cabin configuration used in this study, respectively. Here, a 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 6.12 m. Tables 1 and 2 summarize the FDTD parameters and the material parameters inside cabin, respectively. The total program space including absorbing boundary condition is 673*673*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 aircraft cabin.

3. Results

Fig. 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 (E_y) and horizontal (E_x) 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.

Additionally, in order to estimate polarization characteristics inside aircraft 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 in 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. In aircraft cabin, it is a multi-reflection environment and the internal wall is a cylindrical geometry. Therefore, it is thought that polarization direction is changes greatly by reflecting and scattering inside aircraft cabin.

4. Conclusions

We estimated EMF distributions excited in aircraft cabin due to 800 MHz mobile radio. 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 aircraft cabin. Other estimations those consider the different position or more number of antenna sources or different type of transmitting antenna will be conducted. Additionally, measured EMF distributions in an actual aircraft will be compared to simulated values obtained by our large-scale numerical analysis.

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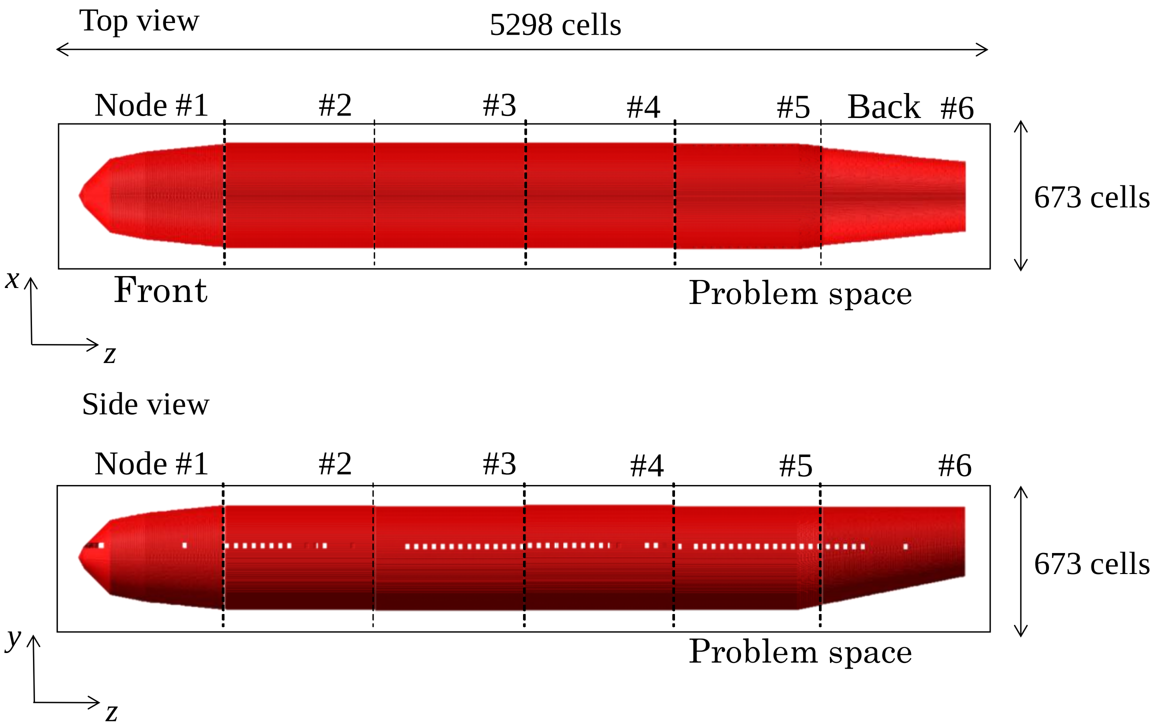

Figure 1: FDTD model for Boeing 777-200 Aircraft. The wings are not modeled in the analysis.

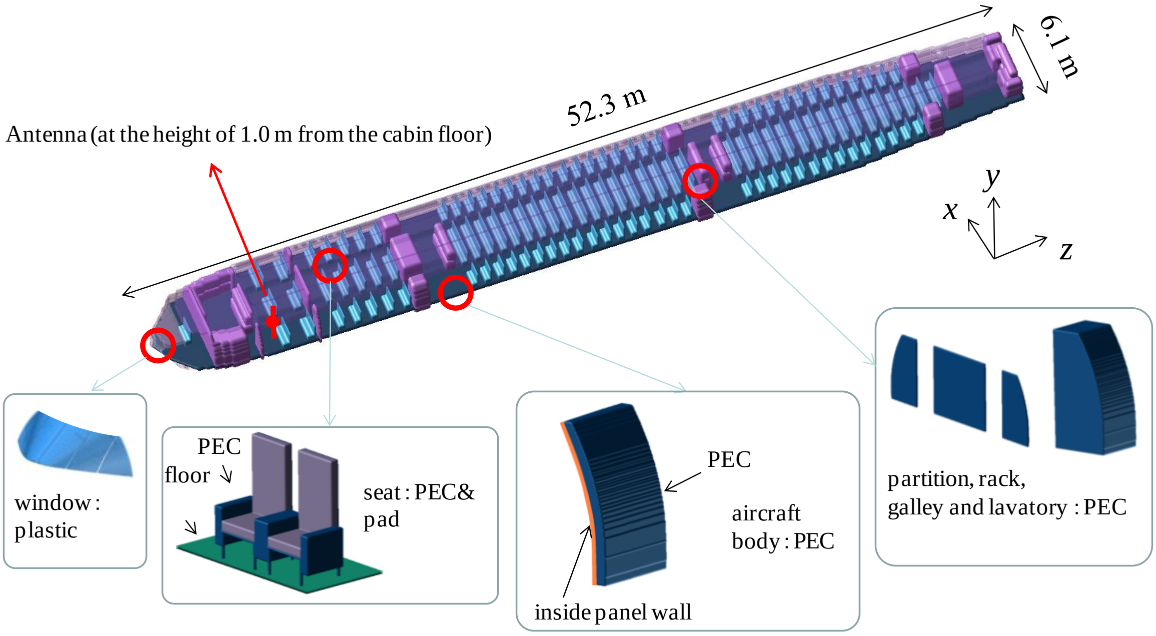

Figure 2: Cabin configuration

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)
Iteration number	800
Antenna	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	-	∞ (PEC)
Seat (metal & pad)	-	∞ (PEC)
	2.0	$1*10^{-3}$
Cabin Partition	-	∞ (PEC)
Lavatory	-	∞ (PEC)
Galley	-	∞ (PEC)
Ceiling luggage rack	-	∞ (PEC)
Cabin floor	3.5	$5*10^{-1}$
Inside panel wall	3.5	$5*10^{-1}$
Window	2.25	$3*10^{-4}$

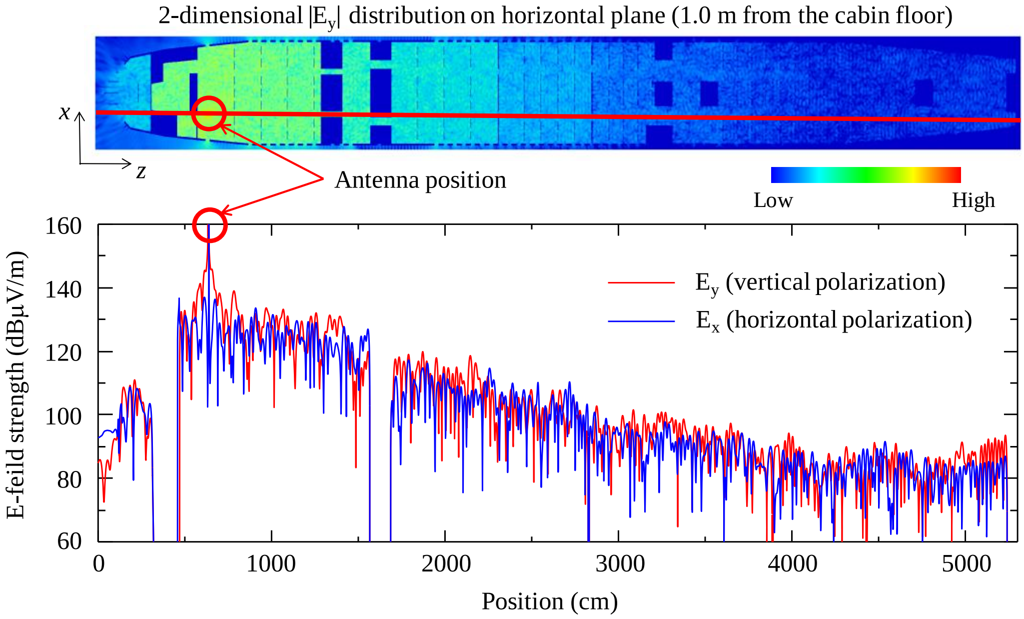
2-dimensional $|E_y|$ distribution on horizontal plane (1.0 m from the cabin floor)

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

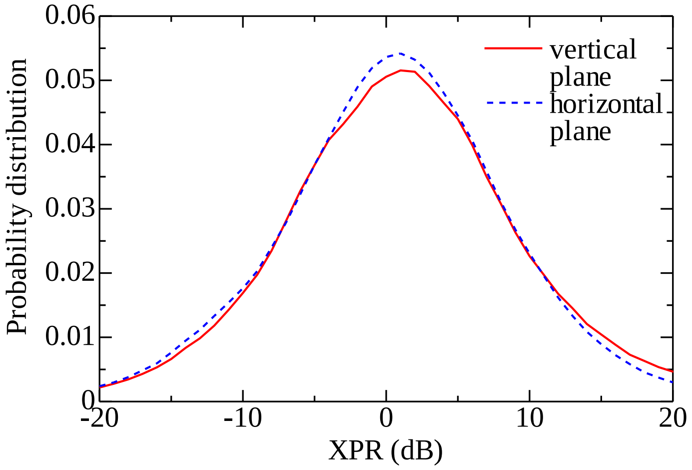

Figure 4: Cross-polarization power ratio (XPR) histogram inside cabin (horizontal plane including antenna feeding point and the vertical plane including antenna position)