Evaluation of Aircraft Cabin- to-Exterior Propagation Characteristics for 4.4 GHz-band WAIC Systems using a Large Scale FDTD Analysis

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Abstract—The aim of this study is to develop an accurate and reliable method for estimating propagation characteristics inside and outside aircraft cabin so as to advance radio link design of WAIC systems. This paper uses FDTD method and a large-scale parallel computing technique to estimate propagation characteristics from aircraft cabin to exterior mounted antenna of WAIC installed on an aircraft model (Airbus 320-200). EMF distributions created by a 4.4 GHz wireless transmitter inside cabin are analyzed and propagation characteristics are determined from the analysis results.

Keywords—Wireless Avionics Intra-Communication (WAIC); aircraft; propagation characteristics; large-scale FDTD analysis

I. INTRODUCTION (HEADING 1)

Recently, a system that substitutes wireless system for wire harness communicating devices of improving safety performance such as emergency lighting and barometric pressure sensor has been proposed to reduce aircraft cabin operation cost. AVSI (Aerospace Vehicle Systems Institute) has been considered using wireless communication standard WAIC (Wireless Avionics Intra-Communication) for this system and has been proposed to use frequency band from 4.2 GHz to 4.4 GHz [1]. To realize high speed and reliable wireless communication, designing a wireless line is important considering the propagation characteristics inside and outside the aircraft cabin. However, to perform comprehensive measurement under actual circumstances is difficult from the viewpoint of labor cost.

Therefore, the authors conducted a large-scale simulation using a supercomputer based on the FDTD method [3, 4], and reported on the attenuation characteristics of electromagnetic field intensity and the polarization dependency about WAIC system [10, 11] in the aircraft cabin. Electromagnetic waves that radiated from antenna inside the aircraft cabin is multiple reflecting by the surrounding metal wall surface, and leak out through multiple windows. Moreover, these electromagnetic waves combine with reflection wave from blades outside the aircraft cabin, therefore, the electric field distribution becomes complexly. For this reason, highly accurate evaluation of electric field intensity (received electric power) at the installation position of the external reception device is important subject in a wireless line design of the WAIC system between the inside and outside aircraft cabin. In this paper, the authors estimate propagation characteristics from the transmit antenna that is 4.4 GHz-band WAIC system installed inside the center of the aircraft cabin to near the tip of the external main wing considering height dependency of the evaluation points.

Fig. 1. Aircraft cabin model

TABLE I. TABLE TYPE STYLES

<table>
<thead>
<tr>
<th>Cell size [mm]</th>
<th>Δ = 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cells</td>
<td>3625 × 2449 × 7525</td>
</tr>
<tr>
<td>Frequency [GHz]</td>
<td>4.4</td>
</tr>
<tr>
<td>Absorbing boundary condition</td>
<td>C.P.M.L(10 layers)</td>
</tr>
<tr>
<td>Antenna</td>
<td>λ / 2 dipole; Input 100 mW</td>
</tr>
</tbody>
</table>

II. NUMERICAL ANALYSIS MODEL OF NARROW BODY AIRCRAFT CABIN AND FDTD ANALYSIS PARAMETERS

Figure 1 shows the outline of a numerical model constructed based on the structure and dimensional data about Airbus 320-200 that is a narrow body aircraft cabin. Table 1 summarizes the FDTD analysis.
parameters. The analysis space are discretized with 5 mm cubic voxel. 
Figure 1 shows the green solid line is the magnetic wall. Thus, we can 
analyze in half region using symmetry. Moreover, the green dotted line 
is the absorption boundary as C.P.M.L of ten layers. We decide a 
sinusoidal wave of 4.4 GHz as an excitation source. In addition, 
repetition counts in FDTD analysis are set 6000 periods considering 
convergence. We set a transmit antenna (λ/2 Dipole antenna) with input 
power of 100 mW. This antenna is installed vertically polarization at 
1.0 m above the floor in the aircraft cabin.

III. SIMULATION RESULTS

We evaluate the propagation characteristics of WAIC frequency 
band electromagnetic waves that radiate from transmit antennas instal 
le in the aircraft cabin. In this paper, Figure 2 shows, the transmit antenna 
isis placed at a height of 1.0 m above the floor of aircraft cabin, evaluation 
points 1, 2 and 3 are located at a distance of 15 m from the transmit 
antenna outside the aircraft cabin (+ x axis direction) at 0.5 m, 1.0 m, 
1.5 m from the floor. Further, the electric field intensity values in the 
region of about one wavelength (70 mm × 70 mm) are set as the electric 
field intensity of each evaluation point around each point.

![Fig. 2. Transmit antenna and height of evaluation points](image)

Figure 3 shows two-dimensional field intensity distribution (xy 
plane) that obtaine from the analysis results. Black dotted lines indicate 
the location of the aircraft cabin that is outside the evaluation plane. 
Height pattern is appears due to interference between the direct wave 
that radiate from the transmit antenna installle inside the aircraft cabin 
and reflecte wave from the wing. The ranges of electric field strength at 
evaluation points 1, 2, 3 are 75 ± 3 [dBµV/m], 72 ± 6 [dBµV/m] and 69 
± 3 [dBµV/m]. These show electric field strength varies of difference 
depending on the height of evaluation points.

![Fig. 3. Two-dimensional electric field distributions at transmit antenna installation position](image)

IV. CONCLUSIONS

In this report, an example of the propagation characteristic 
evaluation of 4.4 GHz band WAIC system between inside and outside 
the aircraft cabin was shown. The authors evaluated propagation 
characteristics from the transmit antenna that is 4.4 GHz-band WAIC 
system installed inside the center of the aircraft cabin to near the tip of 
the external main wing by using two-dimensional electric field 
distributions. From these results, To design the radio line is important 
considering the dispersion of the electric field intensity with regard to 
the installation position of the external WAIC system. From now on, 
we are going to analyze the propagation characteristics, when we 
change the parameter such as the type of antenna, installation position 
and polarization characteristics.

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