Analysis of Radio Altimeter Interference due to Wireless Avionics Intra-Communication Systems by Using Large-Scale FDTD Method -Investigation on Airbus A320 Class Passenger Aircraft-

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Abstract —Radio altimeters and wireless avionics intra-communication (WAIC) systems are both operated at the frequency band 4,200 MHz – 4,400 MHz. Hence, a detailed analysis is required for spectrum sharing in the same band. Firstly, a large-scale finite-difference time-domain analysis is performed to obtain the detailed characteristics of the electromagnetic field (EMF) around the three-dimensional Airbus A320 aircraft model, which assumes that a WAIC device is located inside the cabin. Then, the 4-GHz EMF propagation characteristics are evaluated based on the analyzed results. Finally, the methodology of the interference analysis is discussed based on the obtained EMF characteristics.

Index Terms — Aircraft, interference, large-scale finite-difference time-domain method, radio altimeter, wireless avionics intra-communication.

I. INTRODUCTION

Wireless avionics intra-communication (WAIC) systems are employed for wireless communications among sensors in an aircraft for monitoring and telemetry applications [1]. The usage scenario and the standardization of the WAIC systems have been widely studied in recent years. On the other hand, the electromagnetic compatibility (EMC) between the WAIC systems and the existing avionics systems requires to be investigated for further implementation. For WAIC systems, the frequency band 4,200 – 4,400 MHz is allocated. Radio altimeters are operated in the same frequency band as the WAIC systems. To investigate the EMC issues of the WAIC systems, the electromagnetic field (EMF) estimation method has been developed based on the large-scale finite-difference time-domain (FDTD) analysis [2], [3].

In this paper, the feasibility of the 4-GHz band radio altimeter interference investigation, which is due to WAIC systems, based on the large-scale FDTD method is discussed. The 4-GHz EMF propagation characteristics around the three-dimensional (3D) model of an Airbus A320 passenger aircraft are obtained by the FDTD analysis. In addition, the desensitization criteria of the radio altimeter are discussed and the EMF distributions are analyzed.

II. LARGE-SCALE FDTD ANALYSIS AT 4 GHZ

The detailed distributions of the EMF that radiates from the WAIC device is estimated by using the FDTD analysis. The FDTD method is employed for the analysis because it is suitable to simulate complicated 3D models.
with various material constants. Figure 1 and Fig. 2 show the overview of the 3D model based on Airbus A320-200 developed for analysis purposes and the cabin configurations, respectively. This model is developed based on a commercially available 3D aircraft model [3]. In addition, an in-house FDTD program is used for the analysis. As shown in the figures, the outlines and the internal structure of the model are designed to have the dimensions of the actual aircraft.

Table 1: Parameters of FDTD analysis

<table>
<thead>
<tr>
<th>Problem Space (mm^3)</th>
<th>18,125 × 12,245 × 37,625</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell size (mm)</td>
<td>5</td>
</tr>
<tr>
<td>Number of cells</td>
<td>3,625 × 2,449 × 7,525</td>
</tr>
<tr>
<td>Frequency (GHz)</td>
<td>4.4</td>
</tr>
<tr>
<td>A. B. C.</td>
<td>CPML (10 layers)</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>40</td>
</tr>
<tr>
<td>Required memory</td>
<td>6,400 GB</td>
</tr>
<tr>
<td>Antenna</td>
<td>1/2 dipole (0.1 W input power)</td>
</tr>
</tbody>
</table>

The aircraft structures such as the body, cabin partition, lavatory, galley, and ceiling luggage rack consist of a perfect electric conductor. On the other hand, some structures such as the seat ($\varepsilon_r = 2.0, \sigma = 3.02 \times 10^{-3}$ S/m), the cabin floor and the inside panel wall ($\varepsilon_r = 3.5, \sigma = 1.51$ S/m), and the windows ($\varepsilon_r = 2.25, \sigma = 8.34\times10^{-4}$ S/m) have limited electric conductivity [3]. This is because some materials used inside the aircraft cabin are non-flammable and have electromagnetic lossy characteristics.

No passengers are modeled in the aircraft cabin to obtain the fundamental characteristics of the EMF propagation around the aircraft. The transmitting antenna is located at 1 m above the cabin floor as shown in Fig. 2. As this analysis is a feasibility investigation, parameters such as the antenna type, height, and input power will be varied in the future.

**III. ELECTROMAGNETIC FIELD CHARACTERISTICS**

Table 1 shows the parameters used in the FDTD analysis. Uniform 5-mm cubic cells are used for the analysis. In addition, to reduce the size of the memory required for the analysis, a perfect magnetic conductor is modeled at the center of the aircraft. The numbers of cells including the 10-layer convolutional perfectly matched layer (CPML) absorbing boundary condition (ABC.) were 3,625 × 2,449 × 7,525. Assuming that the WAIC system operates at the 4-GHz band, the transmitting frequency is set as 4.4 GHz. A HITACHI SR16000 M-1 supercomputer is employed for the analysis. The number of analysis nodes and required memory are 40 nodes and 6,400 GB, respectively. Figure 3 and Fig. 4 show the typical analyzed two-dimensional electric-field (E-field) strength distributions at the xy-plane and yz-plane, respectively. As shown in the figure,
detailed EMF distributions are obtained both inside and outside the aircraft.

The desensitization criteria of the radio altimeter are defined as follows [4]:

$$N = -114dBm + 10\log(B_{R,IF}) + N_F.$$  \(1\)

Another example is as follows:

$$I_{T,IF} \geq N - 6dB,$$  \(2\)

where \(B_{R,IF}\) is the IF bandwidth of the radio altimeter in MHz and \(N_F\) is the noise figure at the receiver input in dB, respectively. In addition, \(I_{T,IF}\) is the interference power threshold at which the radio altimeter performance starts to degrade. Radio altimeter characteristics such as \(B_{R,IF}\) and \(N_F\) are described in the [4]. The interference power can be directly calculated from the parameters of the radio altimeter antenna.

VI. CONCLUSION

The feasibility of radio altimeter interference investigation using the FDTD method were discussed. The detailed EMF propagation characteristics around the A320 class passenger aircraft at 4 GHz were obtained for analyzing the interference due to the WAIC systems. In addition, the desensitization criteria of the radio altimeter were defined for the future interference assessments based on the large-scale FDTD analysis. The sensitivity degradation of the radio altimeter by the WAIC devices will be analyzed and investigated in the future.

REFERENCES


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