A Large Scale FDTD Analysis of Propagation Characteristics for Wireless Link Design of 4.4 GHz-band WAIC Installed on Passenger Aircraft

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***Abstract*—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 wireless link design for Wireless Avionics Intra-Communication (WAIC) system. This paper estimates propagation characteristics from inside cabin to exterior mounted antenna of WAIC system installed on a passenger aircraft (Airbus 320-200 model). EMF distributions excited by a 4.4 GHz wireless transmitter inside cabin are analyzed and fundamental characteristics for the WAIC system are derived from the analysis results.**

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

I. Introduction

Demand for reduced cabling and wiring system cost in aircraft continues to grow. Wireless Avionics Intra Communications (WAIC) is a new wireless communication system that interconnects avionics systems in the aircraft. This system is being researched and developed by AVSI, ICAO, and ITU to minimize the cables used by avionics systems [1, 2]. This system has been proposed to use frequency band from 4.2 GHz to 4.4 GHz. In order to realize highly reliable wireless communication, radio link design that can be considering the propagation characteristics both inside and outside aircraft cabin is required. However, to perform comprehensive measurement using actual passenger aircraft under real circumstances is difficult. To achieve accurate and reliable estimation on propagation characteristics for large passenger aircraft cabin, the authors have proposed applying the finite-difference time-domain (FDTD) method [3, 4] and a parallel computing technique using a supercomputer [5-9]. Electromagnetic waves radiated from antenna installed inside the cabin are reflected by surrounding metal wall surface of the aircraft, and leak to outside cabin from many windows. Moreover, due to reflection from the exterior objects of the aircraft, such as wings, engines and so on, the field distribution becomes more complex. Therefore, highly accurate evaluation of electromagnetic fields (received power) at the installation position of the antenna device is important to carry out link design of the WAIC system between the inside and outside cabin. Previously, the authors reported on the attenuation characteristics of electromagnetic field intensity and the polarization dependency of WAIC system [10, 11]. In this paper, propagation characteristics, path loss from transmitting antenna installed inside the aircraft cabin to exterior receiving antenna installed near the tip of main wing, are estimated to evaluate height dependency of the antenna installing position.

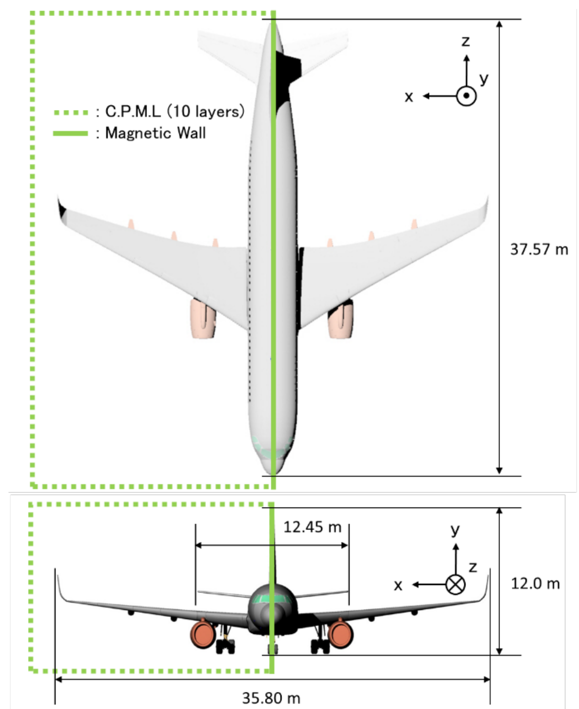

Fig. 1. Aircraft cabin model

TABLE I. Table Type Styles

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

II. Numerical Model of Narrow Body Passenger Aircraft and Simulation Parameters

Figure 1 shows the outline of a numerical model constructed based on the structure and dimensional data of Airbus 320-200 model that is a narrow body passenger aircraft. Table 1 summarizes the FDTD analysis parameters. In the Fig 1, the green solid line shows the magnetic wall and symmetries of the simulation model are exploited to reduce the memory and run time required for their analysis with FDTD method. 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 the analysis are set 6000 periods considering convergence. We assume a transmit antenna as a 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. Resultantly, the memory required to execute the analysis is about 6.4 TB. The calculations were performed by large-scale parallel computing based upon 64 nodes of a supercomputer.

III. Results and Discussion

We evaluate the propagation characteristics of WAIC frequency band electromagnetic waves that radiate from transmit antennas installed inside the aircraft cabin. As shown in Fig. 2, the transmit antenna is located at height of 1.0 m above the floor of aircraft cabin, and evaluation points 1, 2 and 3 are located at a distance of 15 m from the transmit antenna. These points are outside the aircraft cabin (+ x axis direction) and the height of each points correspond to be at 0.5 m, 1.0 m, 1.5 m from the cabin floor. Figure 3 shows an example of two-dimensional field distribution (xy plane) obtained by the FDTD analysis. Black dotted lines indicate the location of the aircraft cabin that is outside the evaluation plane. Height pattern is clearly appears due to wave reflection from mainly 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]. Here, values of electric field intensity in area of 70 mm × 70 mm for each point are evaluated. The results show that variation of the field strength depending upon the height of antenna installing position could not be negligible.

IV. Conclusions

In this paper, fundamental propagation characteristic of 4.4 GHz band WAIC system was estimated. The authors derived propagation loss from inside cabin to exterior mounted antenna based upon numerically obtained two-dimensional field distributions. From the results, the radio link design considering the dispersion of the field intensity with regard to the installation position of the external WAIC system is highly required to achieve reliable wireless communication. We intend to conduct other estimations such as considering the energy absorption effects of the passengers' bodies and other characteristics in the future.

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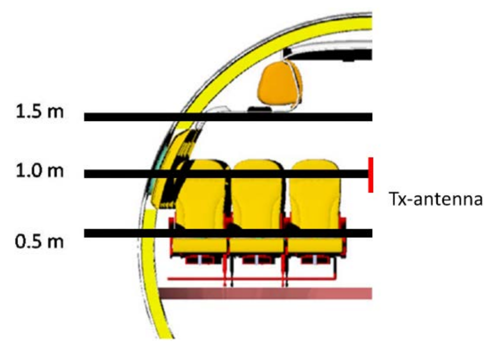

Fig. 2. Transmit antenna and height of evaluation points

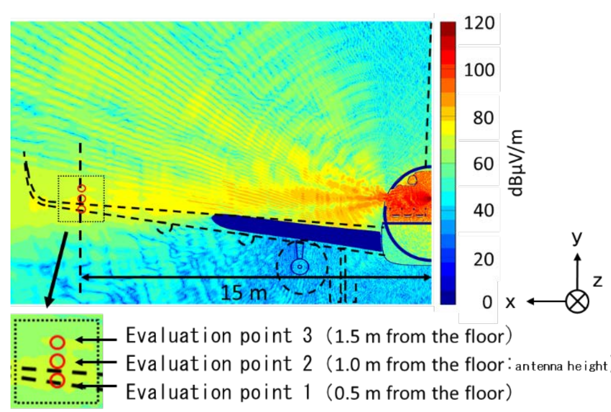

Fig. 3. Two-dimensional electric field distributions at transmit antenna installation position