# Large-Scale FDTD Analysis of 4.4 GHz-band Propagation Characteristics in Aircraft Cabin

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***Abstract*** **– Electromagnetic field (EMF) distributions generated by a 4.4 GHz-band wireless transmitter used in Wireless Avionics Intra Communications (WAIC) technology inside an aircraft cabin are analyzed and fundamental propagation characteristics are discussed from the analysis results. This paper uses FDTD method and a large-scale parallel computing technique to achieve calculation of whole aircraft (Airbus A320-200 model) including wings.**

***Index Terms*** **—Wireless Avionics Intra Communications, Aircraft, Propagation characteristics, Large-scale FDTD analysis.**

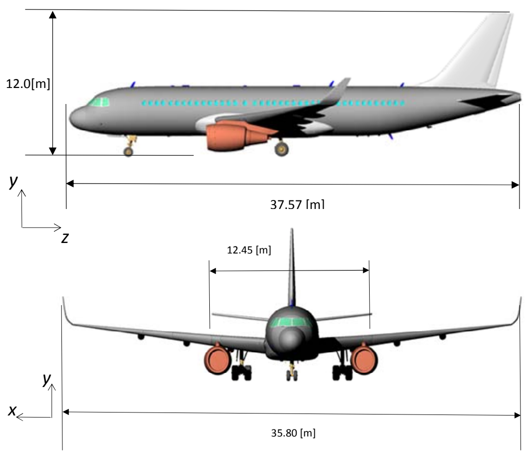
## 1. Introduction

WAIC (Wireless Avionics Intra Communications) is a new wireless communication system that interconnects avionics system in the aircraft [1]. This system is researched and developed by AVSI (Aerospace Vehicle Systems Institute), ICAO (International Civil Aviation Organization), and ITU (International Telecommunication Union) to substitute cable redundancy in the avionics system. The WAIC might substitute 30% of total cables in the aircraft. The frequency band 4200–4400 MHz is the most recommended band for the WAIC system [2]. In order to advance the wireless link design, accurate and reliable estimation method for propagation characteristics in aircraft is needed. However, comprehensive measurements cost too much, and it is difficult to carry them out precisely. Therefore, we propose to apply large-scale numerical simulations to examine the EMF created by wireless terminals inside aircrafts [3-5].

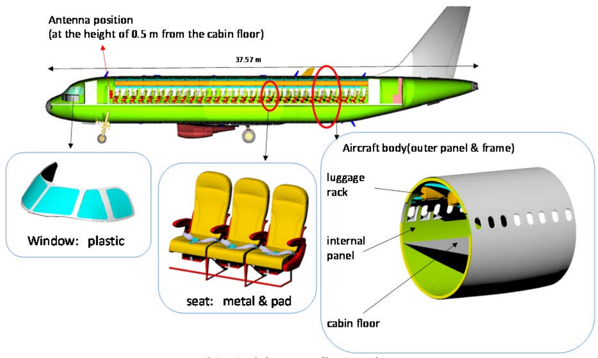
In this paper, electromagnetic field (EMF) distributions created by a 4.4 GHz-band wireless transmitter used in WAIC inside an aircraft cabin are analyzed and fundamental propagation characteristics are discussed. Large-scale parallel FDTD analysis technique [6, 7] is used to estimate the propagation characteristics in the cabin of Airbus A320-200 aircraft model including wings.

## 2. Numerical model of aircraft and FDTD parameters

The commercial aircraft model is for the Airbus A320-200 aircraft. Fig. 1 overviews the numerical aircraft model and the cabin configuration. The dimensions of the aircraft used in the analysis are as accurate as possible. The dimensions of the aircraft model are: length of 37.57 m, width of 35.8m and height of 12.0 m. Metallic parts of the cabin model are made of perfect electric conductor (P.E.C.). FDTD analysis is applied in order to derive three dimensional spatial field distributions throughout the cabin, which contains many materials. The FDTD problem space is quantized by Yee cells. The cell size must be small enough to obtain accurate results. In order to achieve calculation of whole the A320-200 model including wings, symmetry boundary condition is applied at center of the problem space (yz-plane). Tables 1 and 2 summarize the simulation parameters and the parameters of the materials, respectively. 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.




(a) Numerical aircraft modeled based on Airbus A320-200




(b) Cabin configuration

Fig. 1. Aircraft model.

## 3. Estimation results of 4.4 GHz-band propagation characteristics

A 4.4 GHz-band wireless transmitter simulator, a vertical polarized half-wavelength dipole antenna (Tx-antenna) located 0.5 m above the floor, is assumed to be placed at the front of the cabin as shown in Fig. 2. Field distribution inside the cabin is very complicated due to the multi-reflection environment. Here, we estimate fundamental characteristics of electric field distributions created by a 4.4 GHz-band transmitter inside the cabin. Vertical (Ey) polarized electric field distributions are estimated in this paper. The Fig. 3 shows 1-dimensional electric field distributions toward longitudinal direction (z-axis) of the aircraft from the Tx-antenna position inside the cabin. The height of the field estimation plane for these results is 0.5m, 1.0 m and 1.5 m from the cabin floor. These exemplary results show that the averaged value of propagation loss on each height of estimation plane at 4.4 GHz-band inside the aircraft cabin might be approximately 10 dB smaller compared to free-space propagation case.

## 4. Summary

EMF distributions excited in the commercial aircraft cabin due to a 4.4 GHz band wireless transmitter were estimated. To the best of the authors' knowledge, this is the first report estimating fundamental propagation characteristics of a radio transmitter of WAIC system inside the Airbus A320-200 aircraft model using full 3D-FDTD analysis. We intend to conduct other estimations that consider energy absorption effects of the passengers' bodies, more antenna sources, and new radio terminals in the near future.

TABLE I
FDTD simulation parameters.

| | |
|---|---|
| *Problem Space( x, y, z)* | 3580 × 2352× 7514 (cells) |
| *Cell Size* | Δ = 5 mm |
| *Frequency* | 4.4 GHz |
| *Tx-Antenna* | λ/2 dipole (Vertical Polarization) Input 0.1 W |
| *Absorbing B.C.* | C.P.M.L ( 10 layers ) |
| *Total required Memory* | 6.44 TB |

TABLE II
Electric constants of each material.

| Media | $\varepsilon_r$ | σ [S/m] |
|---|---|---|
| *Aircraft body* | - | ∞ (PEC) |
| *Cabin partition* | - | ∞ (PEC) |
| *Cabin floor* | 3.5 | 1.51 |
| *Inside panel* | 3.5 | 1.51 |
| *Window* | 2.25 | $8.34\times10^{-4}$ |
| *Seat (metal & Pad)* | - | ∞ (PEC) |
| | 2.0 | $3.02\times10^{-3}$ |

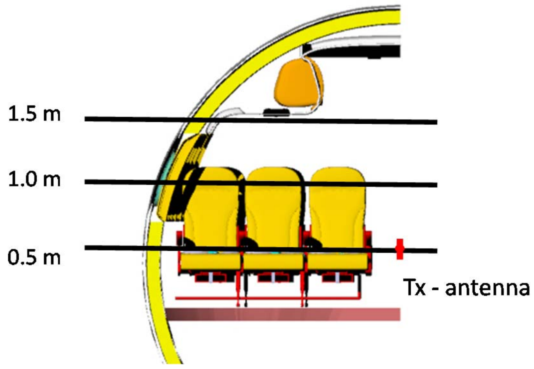



Fig. 2. Tx-antenna position and estimation planes for field distribution in the cabin.

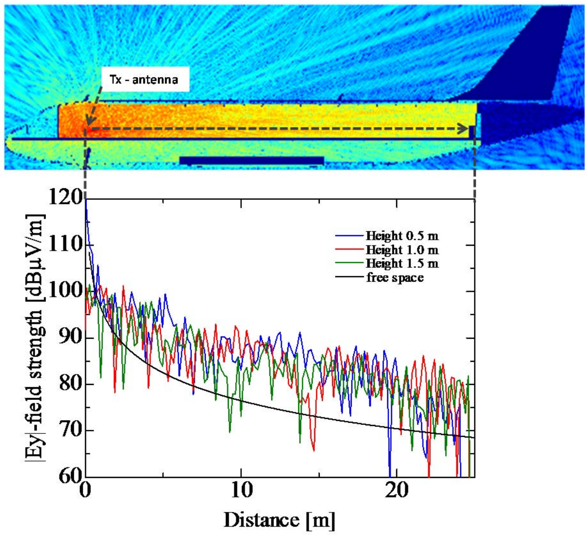



Fig. 3. Simulation results of Electric field distributions inside the cabin.

## References

[1] ITU Radiocommunication Study Groups, "Working Document Towards a Preliminary Draft New Report ITU- R M: Characteristics of WAIC systems and bandwidth requirements to support their safe operation," ITU- R, Geneva, Switzerland, Dec. 2013.

[2] U. Schwark, "Update on Compatibility Studies between WAIC Systems and Radio Altimeters in the Frequency Band 4200–4400 MHz," ICAO Aeronautical Communications Panel (ACP), Lima, Peru, Sep. 2013.

[3] M. Kinoshita, T. Hikage, T. Nojima, S. Futatsumori, A. Kohmura, N. Yonemoto: "Numerical Estimation of RF Propagation Characteristics of Cellular Radio in an Aircraft Cabin," Proceedings of the Asia-Pacific Microwave Conference 2011, pp.82-85, Dec. 2011.

[4] T. Hikage, M. Shirafune, T. Nojima, S. Futatsumori, A. Kohmura, and N. Yonemoto: "Numerical Estimation of RF Propagation Characteristics of Wireless Terminal in a Commercial Aircraft Cabin," Proc. of 2013 IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, 305.9, Jul. 2013.

[5] T. Hikage, M. Shirafune, T. Nojima, S. Futatsumori, A. Kohmura, and N. Yonemoto: "Numerical Estimations of Propagation Characteristics and Interference Path Loss Due to Personal Electric Device in a Commercial Aircraft Cabin," IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition, pp.243-244, Aug. 2014.

[6] Taflove, Computational Electromagnetics, Artech House, Boston, 1995

[7] C. Guiffaut and K.Mahdjoubi, "A Parallel FDTD Algorithm Using the MPI Library," IEEE Antenna and Propagation Mag., vol. 43, no. 2, pp. 94-103, 2001