Height and Angle Characteristics of Point Source Transmitting Power of Wireless Avionics Intra-Communication Systems Based on FDTD Analysis

Shunichi Futatsumori
Surveillance and Communications Department, Electronic Navigation Research Institute
National Institute of Maritime, Port and Aviation Technology
Chofu, Japan
futatsumori@mpat.go.jp

Kazuyuki Morioka
Surveillance and Communications Department, Electronic Navigation Research Institute
National Institute of Maritime, Port and Aviation Technology
Chofu, Japan
morioka@mpat.go.jp

Takashi Hikage
Graduate School of Information Science and Technology
Hokkaido University
Sapporo, Japan
hikage@wtemc.ist.hokudai.ac.jp

Tetsuya Sekiguchi
Graduate School of Information Science and Technology
Hokkaido University
Sapporo, Japan
t-sekiguchi@wtemc.ist.hokudai.ac.jp

Manabu Yamamoto
Graduate School of Information Science and Technology
Hokkaido University
Sapporo, Japan
yamamoto@wtemc.ist.hokudai.ac.jp

Toshio Nojima
Graduate School of Information Science and Technology
Hokkaido University
Sapporo, Japan
nojima@wtemc.ist.hokudai.ac.jp

***Abstract*—The equivalent isotopically radiated power (EIRP) of a wireless avionics intra-communication (WAIC) system is limited to 6 dBm/MHz at the geometrical center of the aircraft, to avoid interference with aircraft radio altimeters, which are operated at the same frequency band between 4,200–4,400 MHz. In this paper, the height and angle characteristics of the point source EIRP of a WAIC system are analyzed based on the large scale FDTD analysis. Firstly, the strength of the electric field (E-field) around the three-dimensional model of Airbus A320-200 is analyzed. Then, the point source EIRP is calculated based on the analyzed E-field strength. Finally, the height and angle characteristics are analyzed to estimate the electromagnetic field characteristics of the aircraft.**

***Keywords*—aircraft, large-scale finite-difference time-domain method, point source transmitting power, radio altimeter interference, wireless avionics intra-communication.**

I. INTRODUCTION

A wireless avionics intra-communication (WAIC) system offers wireless connections between the various components in an aircraft. These systems are allocated the frequency band of 4,200–4,400 MHz [1]. However, conventional aircraft radio altimeters are already operated over the frequency band. Therefore, the condition of frequency coexistence between WAIC systems and radio altimeters are discussed at standardization organizations. The minimum aviation system performance standard (MASPS) of WAIC systems limit the equivalent isotopically radiated power (EIRP) of the WAIC transmitter to less than 6 dBm/MHz at the geometrical center of the aircraft [2]. We have been developing a method for a detailed estimation of the electromagnetic field (EMF) distribution, based on the large-scale finite-difference time-domain (FDTD) analysis method [3].

In this paper, the height and angle characteristics of the point source EIRP estimations based on FDTD analysis are discussed. Firstly, the electric field (E-field) strength around the Airbus A320-200 aircraft, in which the WAIC transmitting antenna is installed inside the cabin, are analyzed. Then, the point source EIRP is calculated based on the analyzed E-field strength. This procedure is the same as the measurement procedures for the WAIC MASPS [2]. Finally, the evaluation height and angle characteristics of the point source EIRP are discussed to determine the EMF characteristics.

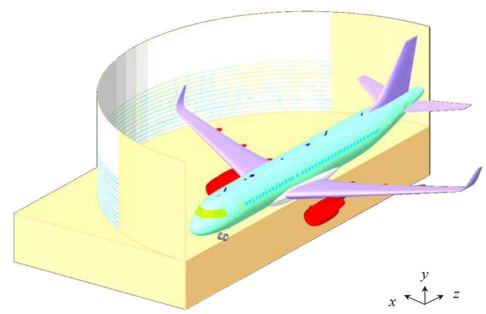


Fig. 1. Overview of the electric field strength evaluations on the circle around the aircraft based on the three-dimensional Airbus A320-200 model.

II. E-FIELD ESTIMATION BASED ON FDTD ANALYSIS

The strength of the E-field, which is converted to the point source EIRP, is obtained by using the large-scale FDTD analysis [3]. Fig. 1 shows the overview of the E-field strength evaluations at a radius of 20 m for a three-dimensional model of Airbus A320-200. The center of the circle is also the geometrical center of the aircraft. The strength of the E-field at the surface of the cylinder is evaluated. Fig. 2 shows the analysis model and the location of the transmitting antenna. The vertically polarized dipole antenna is located at the center of the aircraft and at 1.0 m from the floor. The frequency and transmitting power are 4,400 MHz and 20 dBm, respectively. The aircraft model possesses internal structures and electric constants such as the conductivity and the loss tangent [3]. The dry ground with a thickness of 10 cm (relative dielectric constant = 15 and conductivity = 0.001 S/m) is modeled.

The perfect magnetic walls are located at the center of the aircraft to reduce the required analysis memory. The total cell size of the analysis and the required memory are 66,800 M cells and 6,400 GB, respectively [3]. Fig. 3 shows the typical analyzed three axis combined E-field strength distributions along (a) the *xz*-plane at the antenna height (4.7 m from the ground), and along (b) the radius of 20 m.

Submitted On: September 8, 2020
Accepted On: September 9, 2020
https://doi.org/10.47037/2020.ACES.J.351106

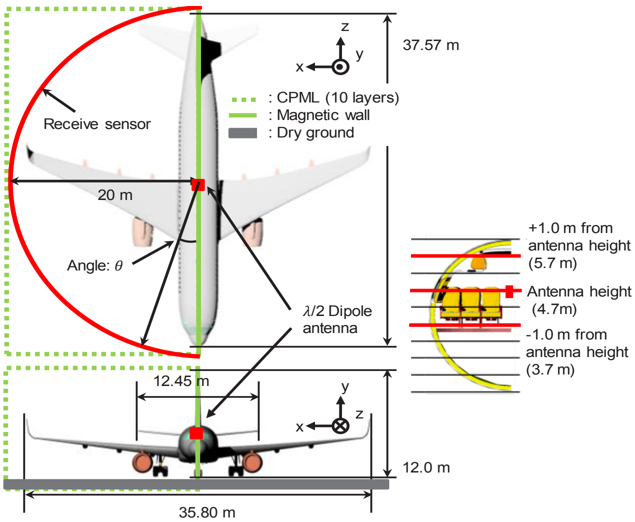
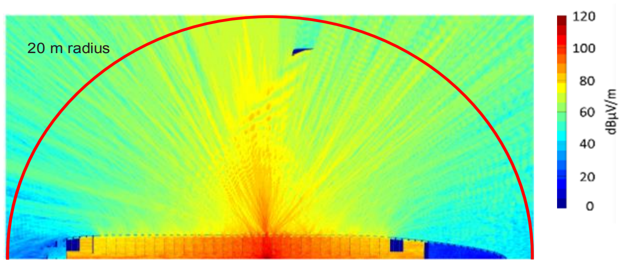
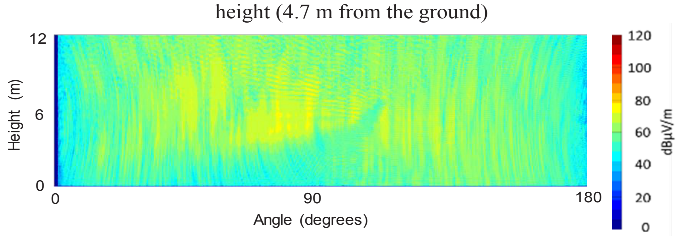


Fig. 2. Three-dimensional aircraft model based on Airbus A320-200 and the evaluation height.



(a) E-field strength distributions along the *xz*-plane at the transmitting antenna height (4.7 m from the ground)



(b) E-field strength distributions along radius of 20 m

Fig. 3. Analyzed three axis combined E-field strength distributions along: (a) the *xz*-plane at the antenna height and along; (b) a radius of 20 m.

III. Point Source EIRP Evaluation

The point source EIRP is evaluated based on the analysis results. The point source EIRP P_T is calculated using the following equation:

$$P_T = \frac{P_R}{G_T G_R} \times \frac{(4\pi r)^2}{\lambda^2}, \quad (1)$$

where G_T and G_R are the transmitting and receiving antenna gains, respectively. In addition, P_R is the received power at each point on the measurement circle. The terms r and λ denote the radius of the measurement circle and the wavelength, respectively. Assuming point source radiation, G_T and G_R are equal to 0 dBi, and r and λ are equal to 20 m (i.e., the evaluation radius) and 0.068 m (4,400 MHz), respectively. Fig. 4 shows the analyzed point source EIRP angle characteristics along the circle around the aircraft, with respect to different evaluation planes. The estimated point source EIRP at 3.7 m (antenna height -1.0 m), 4.7 m (antenna height), and 5.7 m (antenna height +1.0 m) are shown. The point source EIRP between 0° and 60°, 120° and 180°, which corresponds to the noise and tail directions of the aircraft, exhibit identical trends for all evaluation heights. On the contrary, different EIRP height patterns are observed between 60° and 120°. This is mainly due to the reflection from the main wing, which includes the winglets. Table I lists the maximum point source EIRP at different evaluation heights and angles. The maximum EIRP value of -4.3 dBm is observed at a height of 5.7 m and between 90° and 120°. On comparing the 20 dBm transmitting power, it is confirmed that a minimum of approximately 24 dB additional pass loss is obtained at this antenna location.

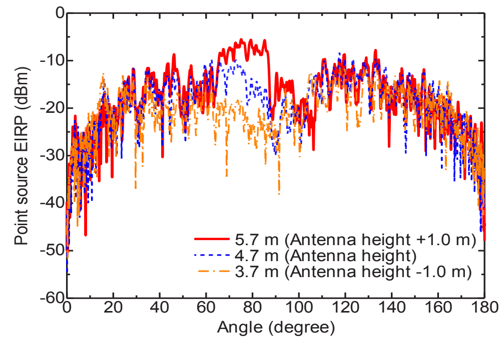


Fig. 4. Analyzed point source equivalent isotopically radiated power (EIRP) angle characteristics on the circle around the aircraft for different evaluation planes.

TABLE I. The Maximum Point Source EIRP at Different Evaluation Height and Angle

Evaluation Height/Angle	0°–30°	30°–60°	60°–90°	90°–120°	120°–150°	150°–180°
0.7 m	-19.1	-21.1	-23.2	-16.6	-12.9	-15.1
1.7 m	-14.6	-17.1	-20.7	-11.9	-12.7	-13.9
2.7 m	-12.5	-13.5	-15.8	-11.4	-11.2	-13.1
3.7 m	-11.6	-10.6	-9.8	-8.30	-9.6	-12.1
4.7 m	-11.6	-8.7	-5.5	-8.7	-7.8	-11.8
5.7 m	-12.7	-6.9	-4.6	-4.3	-11.4	-14.6

Unit: dBm

IV. Conclusions

The height and angle characteristics of the point source EIRP of a WAIC system was evaluated based on the large-scale FDTD analysis. The point source EIRP evaluation was performed on a developed three-dimensional model of Airbus A320-200. Then, the E-field strength around the aircraft was calculated along a radius of 20 m. Finally, the height and angle characteristics of the maximum point source EIRPs were calculated. These results can be used to estimate the transmitting power tolerance of WAIC systems.

References

[1] International Telecommunication Union, Resolution 424 of World Radiocommunication Conference 2015, "Use of wireless avionics intra-communications in the frequency band 4200-4400 MHz," Nov. 2015.

[2] Radio Technical Commission for Aeronautics, "DO-378 - Minimum Aviation System Performance Standard (MASPS) for Coexistence of Wireless Avionics Intra-Communication Systems within 4200-4400 MHz," July 2019.

[3] S. Futatsumori, et. al, "Analysis of Radar Altimeter Interference due to Wireless Avionics Intra-communication Systems by Using Large-scale FDTD Method—Investigation on Airbus A320 Class Passenger Aircraft," Proceedings of the 34th International Review of Progress in Applied Computational Electromagnetics, pp. 1-2, Mar. 2018.