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-

Shunichi Futatsumori [1], Kazuyuki Morioka [1], Akiko Kohmura [1], Naruto Yonemoto [1], Takashi Hikage [2], Tetsuya Sekiguchi [2], Manabu Yamamoto [2], and Toshio Nojima [2]

[1] Surveillance and Communications Department, Electronic Navigation Research Institute
National Institute of Maritime, Port and Aviation Technology, Chofu, Tokyo 182-0025, Japan
futatsumori@mpat.go.jp, morioka@mpat.go.jp, kohmura@mpat.go.jp, yonemoto@mpat.go.jp

[2] Graduate School of Information Science and Technology
Hokkaido University, Sapporo, Hokkaido, Japan
hikage@wtemc.ist.hokudai.ac.jp, t-sekiguchi@wtemc.ist.hokudai.ac.jp, yamamoto@wtemc.ist.hokudai.ac.jp, nojima@wtemc.ist.hokudai.ac.jp

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 electro-magnetic 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].

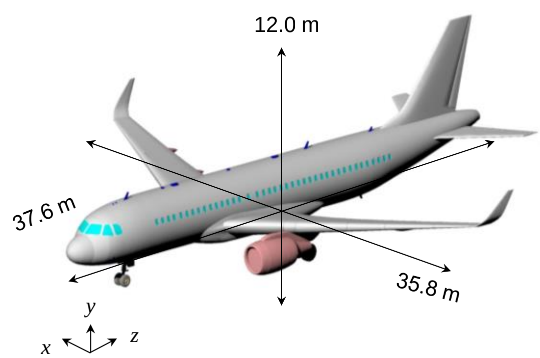

Fig. 1. Three-dimensional aircraft model based on Airbus A320-200.

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

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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.

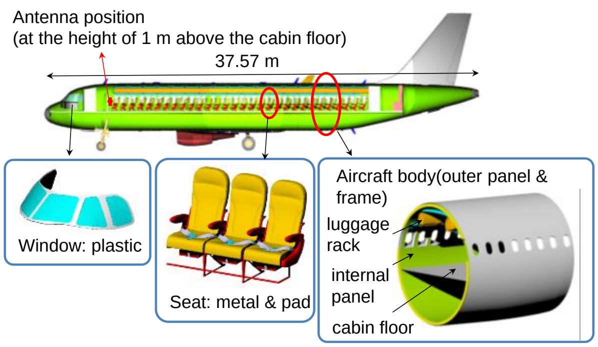

Fig. 2. Cabin configurations of the aircraft model.

Table 1: Parameters of FDTD analysis

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

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 ($\varepsilon_r = 2.25$, $\sigma = 8.34 \times 10^{-4}$ S/m) have limited electric conductivity [3]. This is because some materials used inside the aircraft cabin are non-flammable and have electro-magnetic 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.

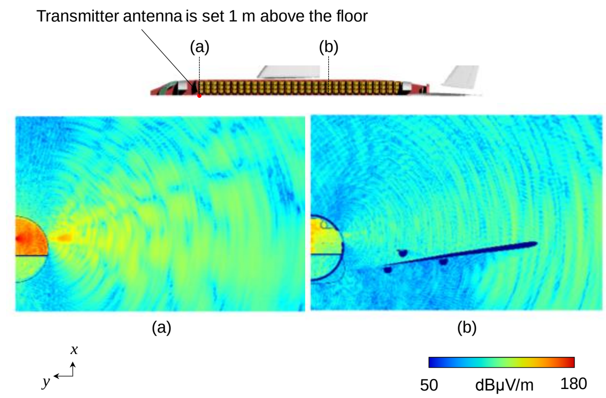

Fig. 3. Typical analyzed two-dimensional E-field strength distributions at the *xy*-plane. (a) E-field strength at the location of the antenna. (b) E-field strength at the middle of the aircraft body.

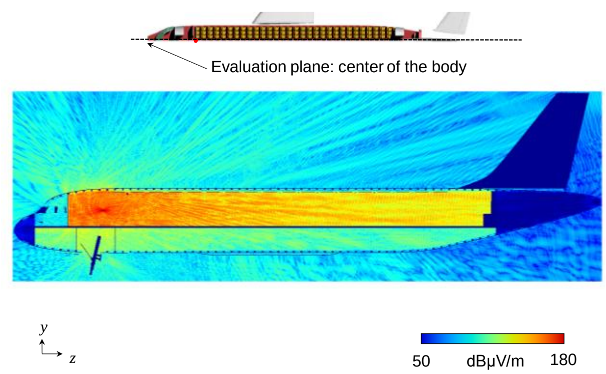

Fig. 4. Typical analyzed two-dimensional E-field strength distributions at the *yz*-plane.

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]:

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

Another example is as follows:

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

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.

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Shunichi Futatsumori received the B.E. and M.E. and Ph.D. degrees in Electronics and Information Engineering from Hokkaido University, Sapporo, Japan, in 2004, 2006 and 2009, respectively. From 2008 to 2009, he was a Research Fellow of the Japan Society for the Promotion of Science. In 2009, he joined the Electronic Navigation Research Institute (ENRI), Japan, where he has been engaged in the research of millimeter-wave radar systems and electromagnetic compatibility issues. He is currently a Chief Researcher of ENRI. Futatsumori received the Young Researcher's Award of IEICE and APMC prize, both in 2009. Futatsumori is a Member of the IEEE and IEICE.

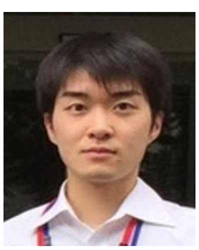
Kazuyuki Morioka received the B.Ec. from Hokkaido University, Japan in 2005 and M.E. and Ph.D. degree in Information Engineering from Shinshu University in 2010 and 2014 respectively. From 2005 to 2011, he was with Artiza Networks, Inc. From 2011 to 2012, he was a Technical Engineer at National Institute of Information and Communication Technology (NICT), Japan. He is currently a Senior Researcher at the Electronic Navigation Research Institute (ENRI), Japan. His research interest is wireless communication systems. Morioka is a Member of the IEEE, IEEJ and IEICE.

Akiko Kohmura received the B.E. and M.E. and Ph.D. degrees in Electronic Engineering from the University of Electro-Communications, Tokyo, Japan. Since 2007, she joined the Electronic Navigation Research Institute (ENRI), Japan. She is currently a Chief Researcher of ENRI. She was a Visiting Researcher of Laboratory of Electronic, Antennas and Telecommunication in France from 2011 to 2012. Her research interest are millimeter-wave radar systems and electromagnetic compatibility. Kohmura is a Member of IEEE, IEICE.

Naruto Yonemoto received the B.S. and M.S. and Ph.D. degrees from Saga University, Japan, in 1995, 1997 and 2000, respectively. He joined the Electronic Navigation Research Institute (ENRI), Japan in 2000. His carrier includes a Visiting Researcher of Laboratory of Electronic Antennas, and Telecommunications, in France from 2005 to 2006. He is also a Visiting Associate Professor of Tokyo University of Marine Science and Technology University, Japan from 2010. He is currently a Principal Researcher of ENRI. His research interest includes millimeter-wave radar systems and electromagnetic compatibility. Yonemoto is a Member of IEEE, IEICE, EuMA.

Takashi Hikage received the B.E., M.E., and Ph.D. degrees from Hokkaido University, Sapporo, Japan, in 1997, 1999, and 2002, respectively, all in Electronics and Information Engineering. From 1999 to 2003, he was with the Graduate School of Engineering, Hokkaido University. He is currently an Assistant Professor of the Graduate School of Information Science and Technology, Hokkaido University. His main research interests include experimental and numerical estimation on electromagnetic field exposure assessment, propagation for wireless communication systems, and biomedical applications, as well as implantable medical device EMI thereof.

Hikage is Member of the Institute of Electronics, Information, and Communication Engineers of Japan (IEICE), the Bioelectromagnetics Society (BEMS), and IEEE.



Tetsuya Sekiguchi received the B.S. degree in Engineering from National Institute of Technology, Asahikawa College, Hokkaido, Japan, in 2017. He currently belongs to the Ph.D. course at the Graduate School of Information Science and Technology, Hokkaido University, Japan. His research interest includes the development of an accurate and reliable method for estimating the propagation characteristics inside and outside aircraft cabins to advance the radio link design techniques for WAIC systems.

Manabu Yamamoto received his B.E., M.E., and Ph.D. degrees in Electronics and Information Engineering from Hokkaido University in 1993, 1995, and 1998. From 1998 to 2003, he was with the Graduate School of Engineering, and is now an Associate Professor at the Graduate School of Information Science and Technology. His research interests are analysis and design of millimeter-wave antennas and ultra-wideband antennas.

Toshio Nojima received the B.E. degree in Electrical Engineering from Saitama University, Saitama, Japan, in 1972 and the M.E. and Ph.D. degrees in Electronic Engineering from Hokkaido University, Sapporo, Japan, in 1974 and 1988, respectively. From 1974 to 1992, he was with Nippon Telegraph and Telephone (NTT) Communications Laboratories. From 1992 to 2001, he was with the Research Laboratory, NTT DoCoMo, Yokosuka, Japan. From 2002 to 2015, he was a Professor with the Graduate School of Information Science and Technology, Hokkaido University, where he conducted research on radio safety and EMC issues related to mobile radio systems as well as microwave circuit technologies. Currently, he is a professor emeritus of Hokkaido University.

Nojima is a Fellow of the Institute of Electronics, Information and Communication Engineers of Japan.