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Large-scale Numerical Evaluation of Cabin-to-Exterior Propagation Characteristics for Sub-6GHz/5G Using Small Aircraft Model

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To estimate precise radio wave propagation characteristics for designing a newly developed wireless link system inside and outside aircraft, we investigate the applicability of large-scale FDTD analysis. Interference pass loss characteristics from the cabin to an external altimeter's vicinity are numerically predicted using a small aircraft model in the 5G sub-6 GHz frequency bands. Applicability of path loss models, namely alpha beta gamma (ABG) or floating intercept (FI) models with their parameters derived from simulation data, are discussed.

Key Words: Fifth-generation mobile communications system, Radar altimeter, Interference path loss, FDTD analysis

1. Introduction

The aircraft radio altimeter, which is operated between 4.2 GHz and 4.4 GHz, is used to measure the height of the aircraft from the ground. The measured height is used not only as visual confirmation for the pilot but as input for flight control avionics such as Flight Management Systems and Traffic Alert and Collision Avoidance System. Various wireless systems have been assigned the radio altimeter frequency band; in addition, the Wireless Avionics Intra-Commutation (WAIC) systems employ the same frequency band.[1)] Recently, newly developed mobile devices such as 5th generation cellular (5G) and Wi-Fi 6 smart radio are allowed onboard, and these wireless systems are assigned the adjacent frequency band of the aircraft radio altimeter. To ensure safe operations against radio wave interference, the coexistence conditions of each system are essential. Until now, the simple channel models were used for the stochastic interference evaluation because the on-site measurements are high cost and difficult work. On the other hand, radio wave behaviors are very complex due to many reflections in the cabin. Hence, interference to aircraft radio receivers was not evaluated in detail.

This paper discusses a method for estimating the radio altimeter interference path loss (IPL) characteristics,[2,3)] from in-flight to outboard radio altimeters in the 5G Sub-6 GHz frequency band using the small aircraft Beechcraft B300 (King Air 350) model.

2. IPL estimation based upon large-scale FDTD analysis

The authors study to apply the large-scale finite difference time domain (FDTD) technique to radio wave propagation characteristics in aircraft.[4-6)] FDTD simulations give us highly precise electromagnetic field

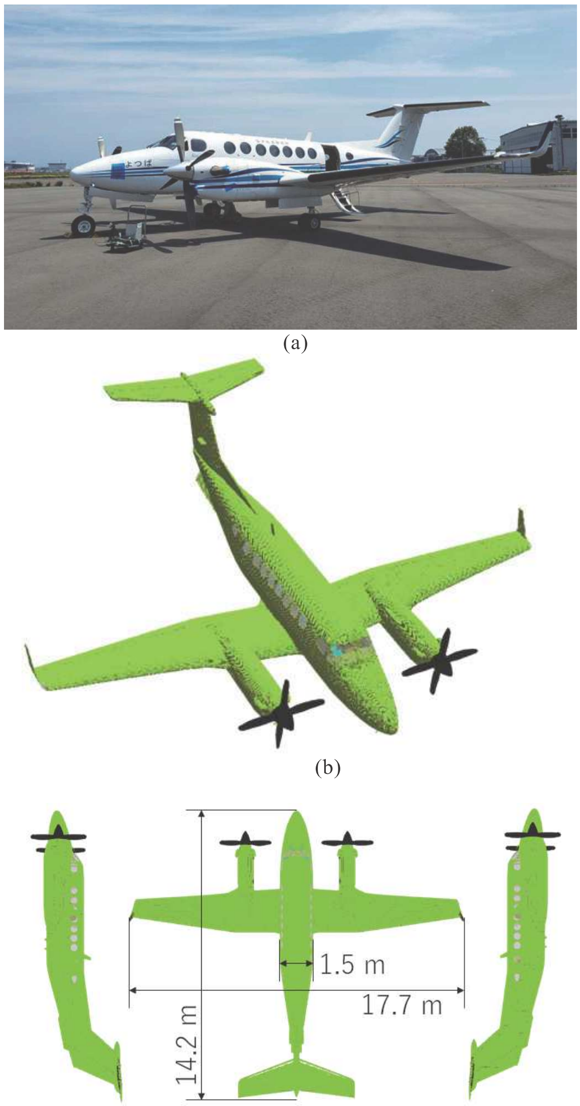

Fig. 1. small aircraft model: Beechcraft B300 aircraft(a), Numerical model overview (b), a top view and two cross-sectional views (c).

distributions of aircraft and their surroundings in detail with the conditions of the number and location of antennas and frequency bands. Figure 1 depicts the aircraft overview, cross-sectional, and top views with the dimensions. The fuselage consists of metal skins and window glasses. Hence the interference coupling paths are thought to be between the windows and a radio antenna mounted outside the aircraft. Here a half-wave dipole is used as an external transmit antenna to evaluate received power or IPL inside the airplane. The spatial resolution of 4.5 mm is specified to discretize the FDTD problem space, including an aircraft. Numerical simulations carried out on the high-performance computer system require main memory of 3.8 TB and a running time of 60 hours. Figure 2 shows the received power distribution on the horizontal observation plan of 0.6 m high above the floor at the frequencies of 3.7, 4.2, and 4.5 GHz, where the transmitted power is 1 W. The received power is seen to be slightly large in the rear of the fuselage, corresponding to the upper place of the external transmit antenna.

3. Results and Conclusion

The use of the FI and ABG models is proposed to derive the equations for calculating the IPL, and the model parameters are derived based on the analysis results obtained from a large-scale FDTD simulation. First, the IPL was obtained from the received power of a receiver antenna installed in the aircraft. In this case, the number of receiving antennas that can be installed in the aircraft is about several tens. We then applied a method for estimating the received power using the root-mean-square value of the field strength to derive the conversion coefficients. The model parameters presented above were analyzed and compared with the results obtained when receiving antennas were taken into account. The unique feature of this method is that it does not require the installation of receiving antennas, and the model parameters for all electric field components can be derived in a single numerical analysis. This is the first time that accurate parameter estimation for in-flight IPL statistical evaluation based on spatially comprehensive and large-scale electric field distribution data has been realized.

In the future, we will study the parameters of the FI and ABG models when the polarization direction and location of the transmitting antenna are changed. In addition, an analytical evaluation of the impulse response will be conducted to evaluate the main path of the interference wave.

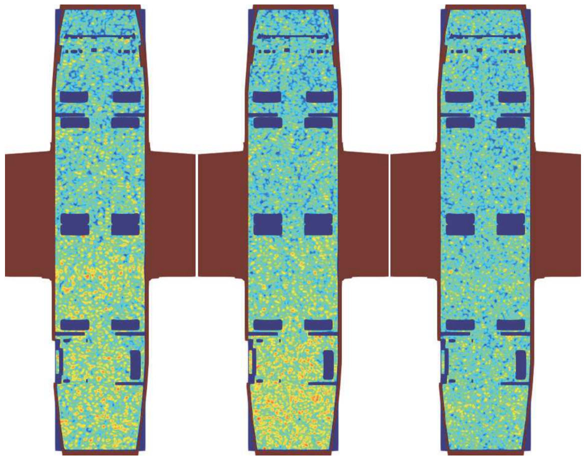

Fig. 2. Received powers in the cabin at 3.7 (a), 4.2(b) and 4.5 GHz(c).

Acknowledgments

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