Estimation of RF Leakage to Oncoming Train Cars From Wireless Access Point Operating in Bullet Train Passing Through a Tunnel

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Abstract - **The aim of this study is to develop an accurate and reliable method of estimating field distributions in train cars so as to advance radio link design of wireless LANs operated inside the cars. This paper describes effects of absorption and shielding caused by a large number of passengers on propagation characteristics of RF leakage from wireless access point operating in a bullet train. Field distributions created by a 2.4 GHz-band wireless transmitter inside cars, when oncoming train cars are passing through a double track railway tunnel, are analyzed and propagation characteristics are determined from the analysis results**

Index Terms **—propagation characteristics, wireless LAN, bullet train, large-scale FDTD simulation, railway tunnel**

I. Introduction

Mobile communication device usage has extended to a wide range of environment such as places surrounded by conductive surfaces, e.g., airplanes, and trains. In such environments, RF propagation characteristics become very complicated due to multi-reflection wave. Given the rapidly increasing variety of wireless devices, comprehensive measurements cost too much, and it is difficult to carry them out precisely [1, 2]. It is required to develop an accurate and reliable method of estimating electromagnetic field (EMF) distributions so as to advance radio link design of wireless access service operated inside the environments. Therefore, we propose to apply large-scale numerical simulations to examine the EMF created by wireless terminals inside train cars [3]. Previously, we reported RF propagation characteristics inside commuter trains and bullet trains [4- 6]. In this paper, we evaluate the effect of many passengers existing onto bullet train on propagation characteristics of RF leakage from a 2.4GHz-band wireless access point to oncoming cars which are passing through 2-lane railway tunnel. EMF distributions created by a 2.4 GHz wireless local area network (LAN) access point inside cars are simulated. In order to estimate the effect statistically, we derive cumulative distributions of the electric field distributions having higher spatial resolution of 5 mm throughout the whole interior of the cars using large-scale finite-difference time-domain (FDTD) simulation.

II. Estimation model

Figure 1 shows the two adjacent bullet train cars model used in this paper. The dimensions of the train used in the analysis model are as accurate as possible. The dimensions of the two adjacent cars are: length of 49.3 m, width of 3.2 m and height of 2.6 m.

Schematic of FDTD analysis model in this paper is shown in Fig.2. Homogeneous numerical humans [7] with seated posture are used as passengers. This model is based upon accumulated MRI images of adult of average build (height and weight), and the electric parameters are taken from a 2/3 muscle-equivalent value [8]. In order to estimate the effects of absorption and shielding caused by the large number of passengers' bodies, the occupancy rate is set to 0% or 100% (0%: without passengers, 100%, that is, full capacity: 372 passengers). The FDTD parameters are summarized in TABLE I. In this paper, a vertically polarized wave at 2.45 GHz is radiated from a half-wavelength dipole, located at the centre of car #1 on track A. As absorbing boundary conditions, 15-layers convolutional perfectly matched layer (C.P.M.L.) is applied. These simulations were executed by our own code FDTD program.

III. Results

Figure 3 shows 2-dimensional electric field distributions obtained by the FDTD analyses for three cases. Vertical (Ey) polarized electric field distributions on the horizontal plane at the height of 0.68 m from the floor, in one example, are shown in the figures. These figures clearly indicate that the effect of absorption and shielding due to passengers are observed in bullet train cars, especially on track B. Next, we apply statistical analysis to take into account the effects of these scatters quantitatively. Based on the EMF distributions having 5 mm spatial resolution, we examined the cumulative distributions of each train car. Fig. 4 shows obtained results for the three conditions based on 2-dimensional electric field distributions of the whole observation plane. In the figure, solid line and dotted line show occupancy rate 0 % and 100 %, respectively. From the results, we found that effect of absorption and shielding due to passengers can be estimate quantitatively. As an example, in car #1 on track B, we can confirm that the value of cumulative probability 90% with passengers is approximately 16 dB lower than that without passengers.

IV. CONCLUSION

EMF distributions established in bullet train cars by a 2.4 GHz wireless LAN access point were estimated using large-scale FDTD simulations. Based on field distribution analyses, the effects of the passengers in bullet train cars passing through in 2-lane railway tunnel were estimated. The RF absorption and shielding caused by a large number of passengers indicated the obvious decrease of radio-wave leakage to oncoming cars. Numerical estimation method can evaluate degradation of quality and service availability of wireless access due to the attenuation quantitatively and contribute to advance radio link design of wireless LANs operated inside train cars. We intend to conduct other estimations that consider different types of transmitting antenna of access point. Furthermore, authors investigate propagation characteristics of passengers' mobile terminals in the near future.

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TABLE I. FDTD PARAMETERS

Cell size (cubic)	5 [mm]
Problem space	2116×1590×9840 [cells]
Absorbing boundary conditions	C.P.M.L. (15 layers)
Iteration	4800 [periods]
Required Memory	4.40 [TB]
Number of nodes	48
Computation time	72 [hours]

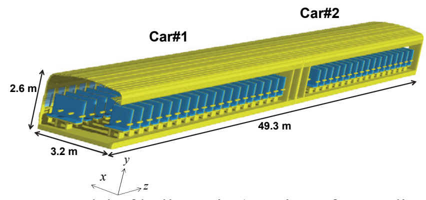

Fig. 1. FDTD model of bullet train (consists of two-adjacent cars)

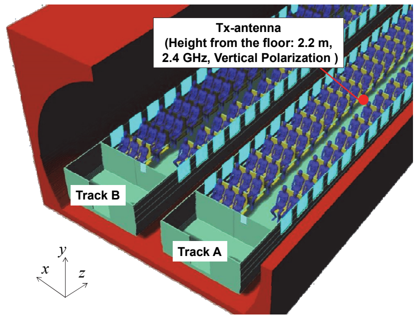

Fig. 2. Schematic of FDTD analysis model

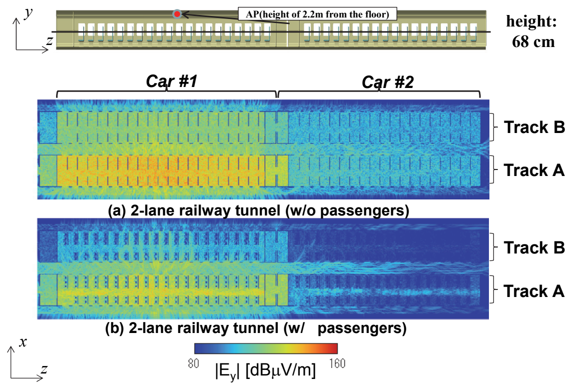

Fig. 3. Electric field distribution on the horizontal plane at the height of 0.68 m above the floor.

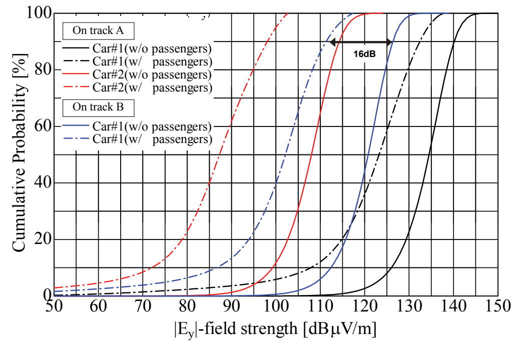

Fig. 4. Cumulative distributions