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Propagation Characteristic Estimations of 2 GHz Inter-Car Wireless Links in High-Speed Train Cars in a Railway Tunnel

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Abstract **- The aim of this study is to develop an accurate and reliable method to estimate field distributions in train cars so as to advance radio link design of wireless LANs operating inside the cars. This paper describes effects of reflected waves due to tunnel wall and/or train passing on opposite track on propagation characteristics inside the high-speed train cars in a typical railway tunnel. Field distributions created by a 2.4 GHz-band wireless transmitter inside cars are analyzed and exemplary propagation characteristics are determined statistically from large-scale numerical analysis results.**

Index Terms **—propagation characteristics, 2GHz-band WLAN, high-speed train cars, railway tunnel**

I. Introduction

The proliferation of wireless devices inmany different areas of the daily life of humans has highlighted the importance of communication systems. Smart phone usage has extended to a wide range of environment such as places surrounded by conductive surfaces, e.g., elevators, airplanes, and trains. Actually, several railway companies have recently begun in-car wireless LAN services [1].

The aim of this study is to develop an accurate and reliable method of estimating the estimating electromagnetic field (EMF) distributions in high-speed train cars so as to advance radio link design of wireless terminals operating inside the cars. Given the rapidly increasing variety of mobile communication devices, comprehensive measurements cost too much [2, 3], 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 train cars [4].

Our research has the effect of passengers and connecting doors on propagation characteristics inside train cars [5, 6]. Previous measurement results reported that propagation path via scatters outer train-car body such as polls or tunnels effected propagation characteristics [3]. This paper uses the parallel FDTD analysis technique to estimate propagation characteristics inside the high-speed train cars which are running through a double-track railway tunnel. EMF distributions created by a 2.4 GHz wireless LAN access point inside cars are simulated. In order to estimate the effect by the tunnel statistically, we derive histograms of the electric field distributions throughout the whole interior of the cars.

II. Estimation Method and Model

Fig. 1 shows the two adjacent High-Speed 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 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.

Geometries of FDTD analysis model in this paper are shown in Fig.2. In order to estimate the effect of reflected waves due to scatters, the FDTD model is changed as following three conditions, 1) train cars are in free-space, and 2) train cars are in the tunnel. Here, we use two FDTD models, one has no train car on opposite track, and the other has opposite train cars. The distance between these train cars is 1.2m. The tunnel is made of dry concrete, the relative permittivity is 5.5 and the conductivity is 0.022.

Table I summarized the details of the FDTD analysis configurations. In this model, we set the spatial resolution to 5 mm. To conduct the FDTD calculation of the train model, we used 48 computational nodes of a super computer. The total required memory size for the entire train model is about 4.4 TB. The material parameters of train cars are as same as [6].

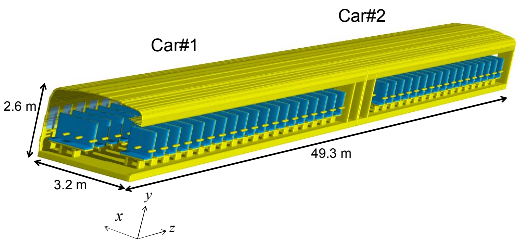

Fig. 1. FDTD model of high-speed train (consists of two-adjacent cars)

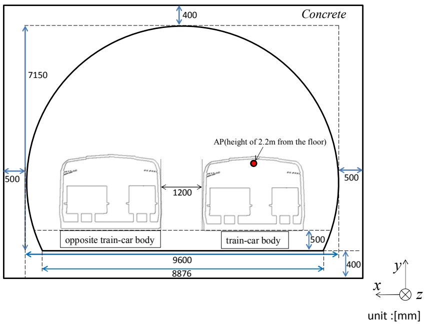

Fig. 2. Geometry of FDTD analysis model in a double-track railway tunnel

TABLE I
FDTD SIMULATION PARAMETERS

Problem space	1058 × 795 × 4920 cm³
Cell size	Δ = 5 mm
Frequency	2.45 GHz
Antenna	λ/2 dipole (Vertical Polarization)
Absorbing Boundary Conditions	C.P.M.L. (15 layers)
Iteration	4800 periods
Number of nodes	48
Required Memory	4.40 TB (75.8 GB per node)

III. RESULTS

Fig. 3 shows 2-dimensional electric field distributions obtained by the FDTD analyses for three cases. A vertically polarized wave at 2.4 GHz is radiated from a half-wavelength dipole, located at the centre of car #1. Vertical (Ey) polarized electric field distributions on the horizontal plane at the height of 0.68 m from the floor are shown in the figures. These figures show that reflected waves due to tunnel surface or opposite train-car body are clearly observed at the outside of the car. Next, we apply histogram analysis to take into account the effects of these scatters quantitatively. Based on the field distributions, we examined the histograms of each train car. Fig. 4 shows histograms for the three conditions from EMF distributions shown in Fig.3. Additionally, the modes of the each histogram are plotted by markers. These are evaluated from 2-dimensional electric field distributions of the whole observation plane, 0.68 m above the floor. From the figures, we found that the averaged attenuation of inter-car wireless link that held the 2.4 GHz band transmitter in this exemplary case might decrease about 2 dB due to reflected waves from car-body on opposite track in railway tunnel.

IV. CONCLUSION

EMF distributions established in high-speed train cars due to a 2.4 GHz wireless access point were estimated. Based on field distribution analyses, the effects of the scatters outer train-car body were conducted. The effect of reflection wave due to tunnel cannot be neglected. Numerical estimation method can evaluate degradation of quality and service availability of wireless access 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.

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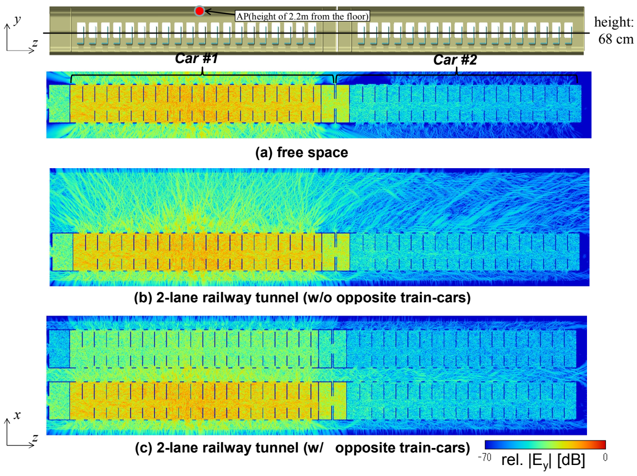

Fig. 3. Electric field distribution on the horizontal plane at the height of 0.68 m above the floor.

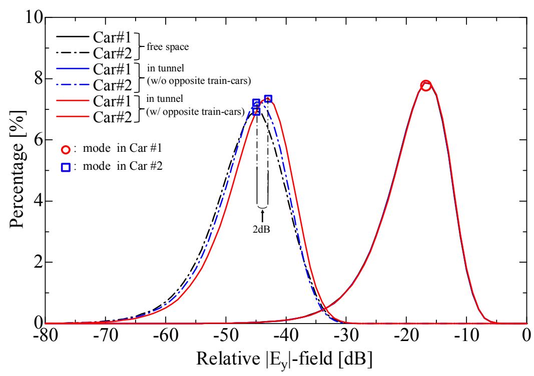

Fig. 4. Electric field histograms