MEASUREMENT OF MICROWAVE, MILLIMETER-WAVE BAND PROPAGATION CHARACTERISTICS IN ENVIRONMENTS ALONG RAILWAY TRACKS

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1. Introduction

Recently, the utilization of radio equipments along railways has been advanced rapidly in Japan. The importance of these radio communication systems rise in train control, information services and other communication systems. In almost Japanese train radio communication systems of conventional lines, 300MHz or 400MHz band are mainly utilized as a carrier frequency band presently. But the current frequency band width assigned to railway companies is narrow to satisfy future various requirements for railway works. Conventional systems are not suitable for dealing with increasing communication traffic volume. Therefore we have been proposed the large-capacity train radio communication system using upper microwave band radio. And we have been investigated theoretical propagation characteristics on the system[1][2].

In this paper, we mention results of the measurement on 20.0GHz and 51.1GHz propagation characteristics which is done with considering railway environments. Firstly, we classify railway environments by complication of structures along railway tracks to calculate received electrical field intensity theoretically. Next, we show examples of measured results on received levels in actual environments which are similar to representative classified environments. Through these examinations, we verify the validity of theoretical simulation techniques.

2. Classification of railway environments and theoretical calculation methods of reception field intensity

Table 1 Calculating methods for each area

	Calculated area	Nearby structures	Electrification	Calculating method
Between stations	Open ground ·straight line area	None	Non-electrified Region 1	2-path interference
			Electrified	Multi-path interference by ray tracing
	Side-wall· overhead area	Side-wall Overhead Tunnel	Non-electrified Region 2	Some-path interference by ray tracing
			Electrified	Multi-path interference by ray tracing
	Urban· mountain area	Cutting Building Crossing Gradient	Electrified· Non-electrified	
Station yard				

※ There are trolley wires, poles in electrified sections.

Normal railway environments are characterized by plane earth, side-walls, terrain cuttings, over bridges, masts, wires, tunnels, crossing trains, and so on. And radio base stations are generally located along rails. Therefore propagation paths in land mobile radio communications are multiplexed, due to the reflection, scattering and other phenomena. We first classify railway environments by complication of structures along railway tracks to calculate the reception field intensity theoretically. Railway environments can be divided into some regions under methods of 2-path interference and ray tracing[3] as table 1. Railway environments are first divided into "between stations" or "station yard". In "station yard", as there are some railway structures, we consider multiplexed interference by using ray tracing method. Meanwhile, in "between stations", environments are divided into three regions additionally and we apply the method based on 2-path interference or ray tracing.

Next, we present formulations simply in region 1 and region 2 which correspond to measured places. Figure 1 shows images of these regions. In region 1, received electrical field intensity E at the received antenna is calculated as equation (1) by considering 2-path interference.

$$E = E_0 \exp(-jkr_0)[D_0 + D_1 \cdot R \cdot \exp\{-jk(r_1 - r_0)\}] \qquad (1)$$

$$D_0 = D_T(\theta_0)D_R(\theta_0), \quad D_1 = D_T(\theta_1)D_R(\theta_1) \qquad (2)$$

$$k = 2\pi/\lambda \quad (\lambda: \text{wavelength}) \qquad (3)$$

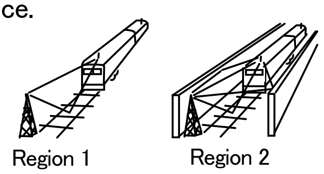


Fig. 1 Images of regions.

Here, r_0 and r_1 are the corresponding path length of a direct wave and a reflected one. θ_0 and θ_1 mean angles between the beam and the center axis of the antenna. D_T and D_R mean directivities of the transmitting and the receiving antenna. E_0 is the amplitude of the direct wave. R is the Fresnel reflection coefficient.

In region 2, received electrical field intensity E at the received antenna is calculated as equation (4) by using ray tracing method.

$$E = \sum_{i=1}^{M} \{E_0 \cdot D_i \cdot \exp(-jkr_i) \prod_{p=1}^{N} R_p\} \qquad (4)$$

Here, M is the number of rays. N is the reflection times. Di is the product of directivities on a wave i. Rp is the reflection coefficient in each reflection point p. For searching paths of rays, imaging method[4] is applied.

3. Measurement of microwave, millimeter-wave propagation characteristics

3.1 Configuration of the system for measurement

A system for measurement consists of a fixed equipment (it corresponds to a train) and a moving equipment (it corresponds to a base station). 20.0GHz and 51.1GHz band radio are used as carrier frequencies. The configuration of the system for measurement is shown as fig.2. And specifications of this system are given as table 2.

Table 2 Specifications of the system.

Frequency	20.0 GHz	51.1 GHz
Transmission power	15.0 dBm	12.0 dBm
Antenna gain	12.5 dBi	19.2 dBi
Polarization	vertical	

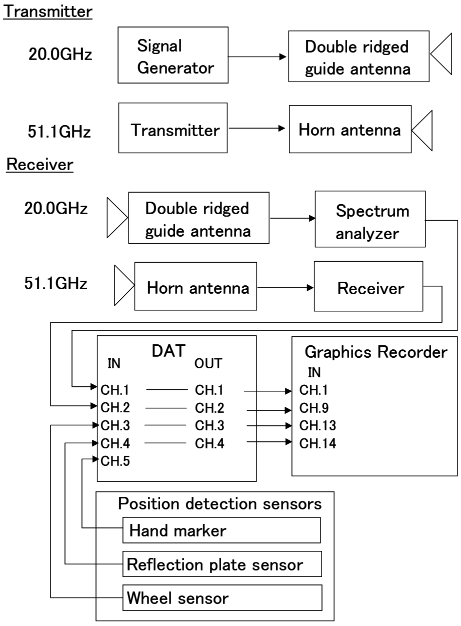
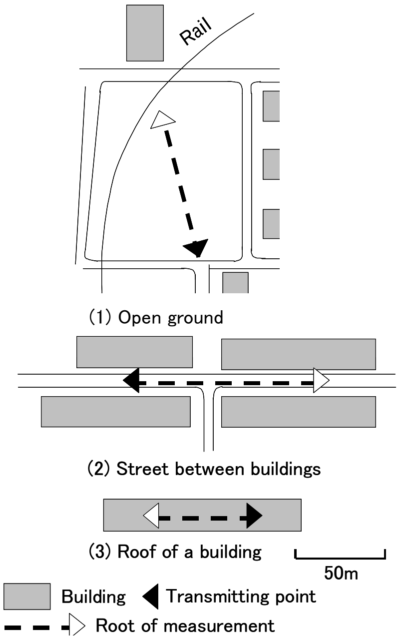


Fig.2 Configuration of the system for measurement.



(1) Open ground

(2) Street between buildings

(3) Roof of a building

Fig.3 Location of places for measurement.

3.2 Location of places for measurement

Figure 3 shows the location of measurement places. An open ground and a roof of a building correspond to region 1 in table 1. A street between buildings correspond to region 2. However, actual places are different from classified regions as fig.4 and fig.5. Therefore, in calculating received levels, we apply equation (1) in a open ground, and apply equation (4) in a street between buildings and a roof of a building.

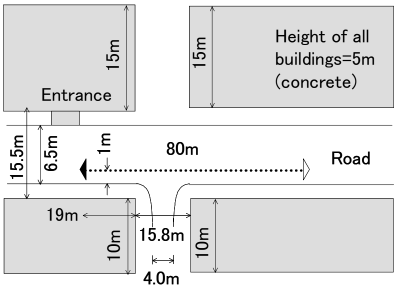


Fig.4 Street between buildings.

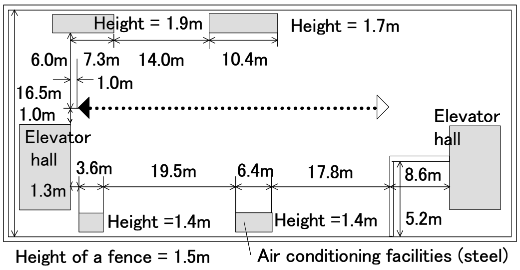


Fig.5 Roof of a building.

3.3 Influences by the complexity of railway environments

Propagation characteristics are influenced by the complexity of railway environments. Therefore we examine those influences in open ground and street between buildings. Then, computational values are compared with measurement to verify the validity of theoretical simulation techniques. Figure 6, 7 show propagation characteristics by complexity of environments. Here, Hb means height of mobile antenna. Ht means height of fixed antenna. Fading of levels in a street between buildings is more intense than that of levels in an open ground. Figure 8, 9 show comparison results between measurements and computational values on 20.0GHz. Computational values agree with measurements well.

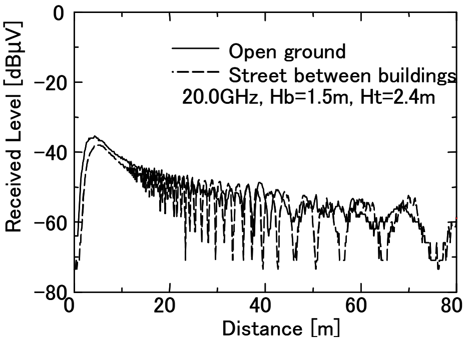


Fig.6 Propagation characteristics (1).

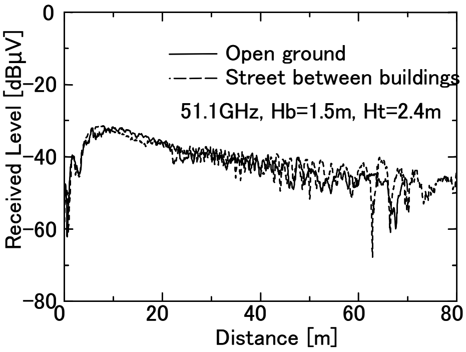


Fig.7 Propagation characteristics (2).

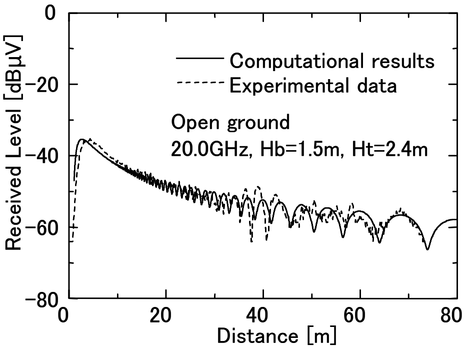


Fig.8 Propagation characteristics (3).

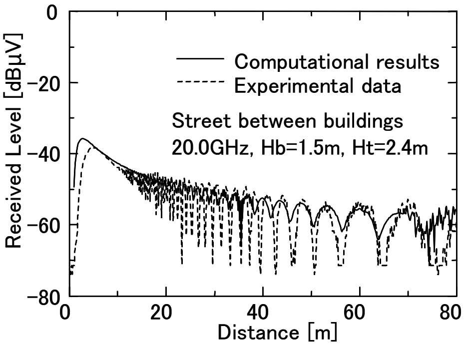


Fig.9 Propagation characteristics (4).

3.4 Influences by the antenna height

On the radio communications between trains and ground facilities, the mounted position of train antenna is under restrictions considerably. Meanwhile, the mounted position of base station antenna is relatively unrestrained. Therefore we examine influences by the antenna height of base station antenna. Figure 10, 11 show propagation characteristics in a roof of a building. On peak levels, influences of height of antenna are not observed. On fading intervals, the interval of low antenna is more wide than that of high antenna. Next, Figure 12, 13 show comparison results between measurements and computational values on 20.0GHz. These results are qualitatively appropriate.

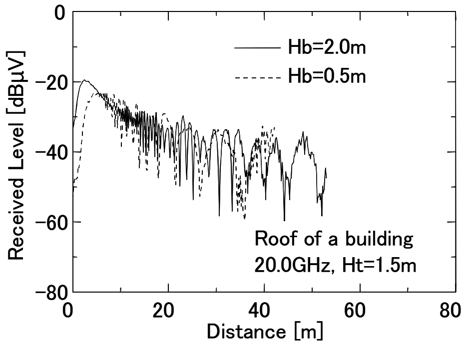


Fig.10 Propagation characteristics (5).

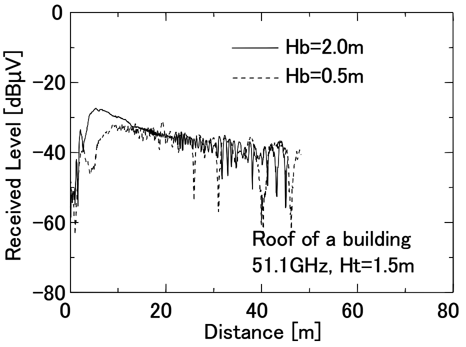


Fig.11 Propagation characteristics (6).

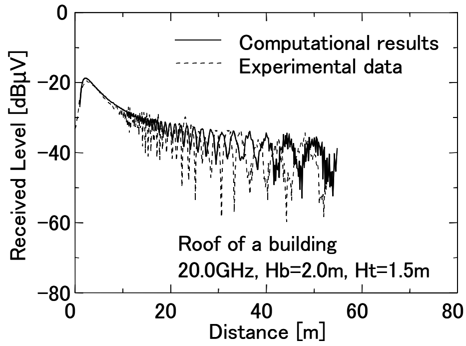


Fig.12 Propagation characteristics (7).

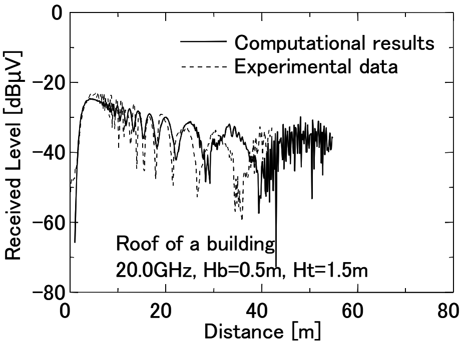


Fig.13 Propagation characteristics (8).

4. Conclusion

We have been investigated theoretical propagation characteristics on the large-capacity train radio communication system using microwave and millimeter-wave band radio. This paper first describes classification of railway environments and simulation techniques to calculate propagation characteristics of reception field intensity along railway tracks simply. Next, we show examples of measured results on received levels on 20.0GHz and 51.1GHz band in actual environments which are similar to representative classified environments. In region 1 and 2, propagation characteristics obtained by measurements and simulations returned results indicating that classification of railway environments and theoretical calculation methods are appropriate.

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