Analysis of Effective Coverage Area in 60GHz-Band Millimeter Wave Wireless LAN for High Speed Railway Passenger Car and Indoor Room

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Abstract- **Based on the transmission power and polarization, we conducted a basic research on how effectively the signal transmission coverage area can be expected even in the same 60 GHz band. We use the ray-tracing method to simulate two types of environment. One is high speed railway passenger car and other is indoor room.**

I. INTRODUCTION

In recent years, the radio waves have been used for various applications in various environments. Above all, the radio waves in the millimeter wave band (30 - 300 GHz) are useful for effective use of frequency resources [1], [2].

In this paper, the radio wave propagation analysis simulator by ray-tracing [3] method is used to visualize the radio wave propagation [4] under the assumption of the ultra-high speed wireless LAN of millimeter wave 60 GHz band used in IEEE 802.11ad. The simulated results indicate the effective coverage area to communicate speed almost 1 Gbps [5]. The ultra-high speed communication coverage area is visualized [6].

II. RAY TRACING ANALYSIS

As analysis conditions, transmission power was classified into two types of 10mW and 250mW. The Tx power 250mW become usable by the revision of the Radio Law Enforcement Regulations. Furthermore, the polarization of the transmitting and receiving antenna is two types. The linear polarization and the circularly polarization are selected our research.

III. SIMULATED MODEL

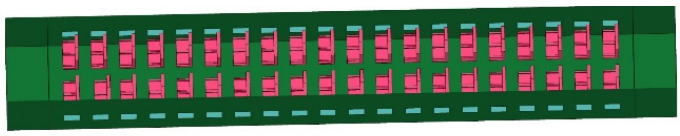
We have analyzed the location and required number of base stations serving as access points for millimeter wave 60 GHz band wireless devices whose use will be expanded from this.

Although the millimeter wave 60 GHz band capable of ultra-high speed and large-capacity communication are promising. We need to be evaluate using an analysis space close to the actual communicable coverage area. Therefore, we model and simulate the Takushoku University Faculty of Engineering Tsunemitsu Laboratory. The dimension of the laboratory room is 2.73m in height to the ceiling from floor, 7m in width (wall to wall), and 11.3m in width (door to window). And the dimension of the E5 Shinkansen E526-100 (car No. 2), The dimension of the E5 Shinkansen is 2.65m in height to the ceiling from floor, 3.35m in width (wall to wall), 21.41m in the length (door to door), and 1.545m in the length (the entrance).

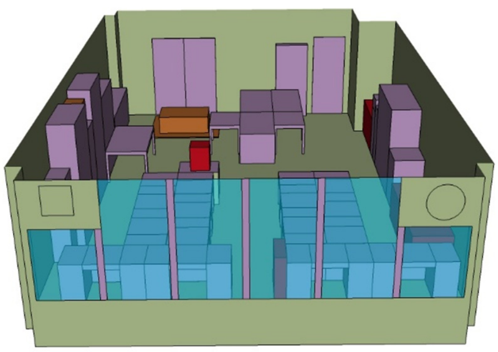
(a) High speed railway passenger car

(b) Indoor room

Figure 1. The situation of simulation models.



(a) The high speed railway passenger car. (E5-series Shinkansen E523)



(b) The indoor room. (Our Laboratory)

Figure 2. The analysis models

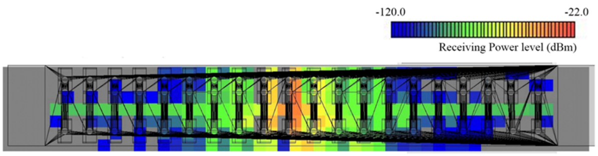
TABLE I Material for modeling

Material	concrete	glass	iron	copper	wood (5GHz)
Relative permittivity	6.76	5	1	1	1.99
Volume resistivity	43.5	1.0×10^{12}	9.71×10^{-8}	1.74×10^{-8}	37.88
Relative permeability	1	1	5000	0.999991	1
thickness (mm)	100	20	10	10	10

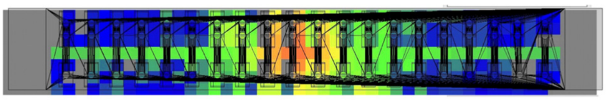
IV. ANALYSIS RESULT

Figures 1 shows the actual environment for modeling. First we are modeling high-speed railway passenger car as shown in Fig.1 (a). Second we are modeling indoor room (our laboratory). If you compare 10 mW with 250 mW transmission power, you can see that the reception level is about 10dBm lower overall.

When compared with the measured data using the 60 GHz band ultra-high-speed wireless transmission device (technologically acquired), the effective range can be derived as compared with the received power that can maintain 1 Gbps communication.

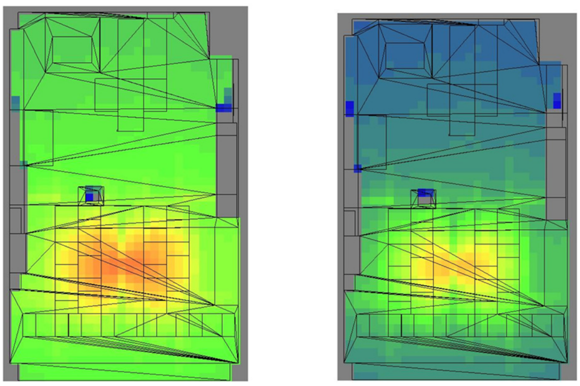


(a) Using linear polarization



(b) Using circularly polarization

Figure 3. The simulated results of only one 60GHz Wi-Fi AP setting to the center of the high speed railway passenger car ceiling. Tx power is 250mW.



(a) Tx power is 250mW. (b) Tx power is 10mW.

Figure 4. The simulated results of only one 60GHz Wi-Fi AP setting to indoor room (our laboratory) ceiling using linear polarization.
(a) Tx power is 250mW. (b) Tx power is 10mW.

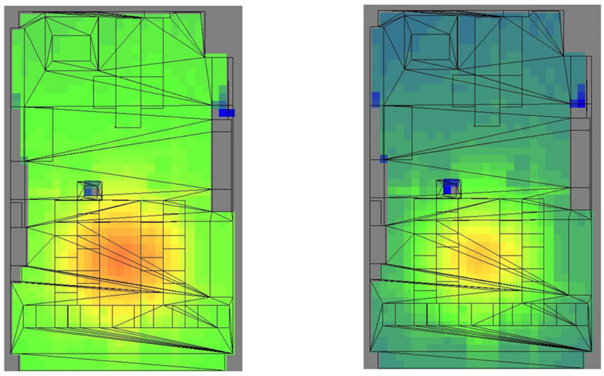


Figure 5. The simulated results of only one 60GHz Wi-Fi AP setting to indoor room (our laboratory) ceiling using circularly polarization.

V. COMPARISON OF ANALYSIS AND EXPERIMENT

As a result of the analysis by RapLab, it is possible to simulate that the effective range of the area which the receiving power from access point is above -65dBm. In this case, the length of the access point to receiving point are about 1.8 m at 10 mW Tx power and about 2.5 m at 250 mW Tx power.

We measured the receiving power level using IEEE 802.11ad Wireless Access Units in various environment. Almost the data throughput 1 Gbps was able to obtain at the receiving power level above -65dBm.

By the comparison of analysis and experiment results, the range of throughput 1Gbps is the receiving power level above -65dBm. We marked the area with color orange as shown in Fig.5.

In the case of circularly polarized waves and circularly polarized waves, it can be confirmed that the portion that cannot be received due to the influence of the polarization plane is reduced and the shape is like a circle as shown in Fig.4 and Fig.5.

Table 2 The condition of the experiment

Frequency (GHz)	57~66 (GHz)
Tx power	10mW
The height of Tx point	2.4m
The height of Rx point	1.3m

This wireless access unit IEEE 802.11ad is shown in Fig.6. This unit can transmit and receive wireless communication almost maximum 1Gbps throughput by point to point. This wireless access unit has the USB3.0 interface for Windows PC or Linux PC.

The measurement environment is shown in Fig.7. The Tx point is set the ceiling of the room. The Rx point is set to the receiving height for the condition of the human using wireless terminal. Figure 8 is simulated results of the distance between Tx point and Rx point versus the receiving power level (dBm).

Figure 9 and Fig.10 are measurement results of the distance between Tx point and Rx point versus the received signal strength indicator (dBm) and Throughput (Mbps). The difference is only the beamforming function off or on.

Figure 6. The picture of IEEE 802.11ad Wireless Access Unit

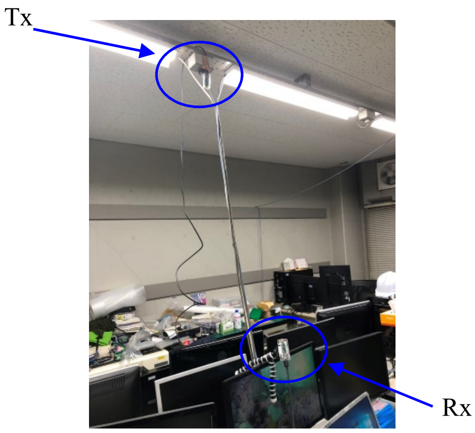


Figure 7. The picture of the measured environment of room.

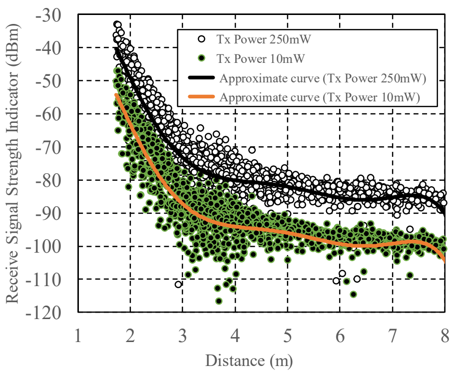
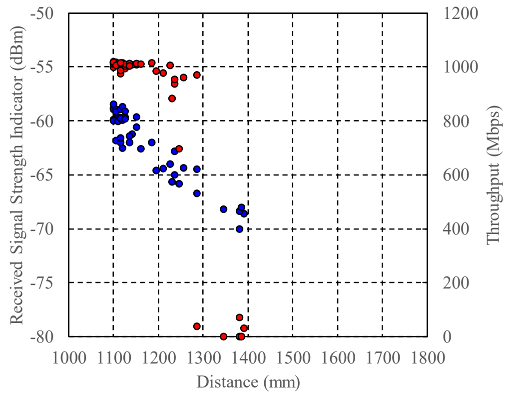


Figure 8. The simulation results of the distance between Tx point and Rx point versus the receiving power level (dBm).

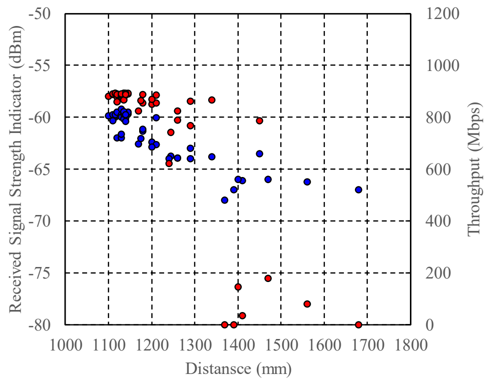
VI. CONCLUSION

Based on the transmission power and polarization, we conducted a basic research on how effectively the signal transmission range can be expected even in the same 60 GHz band. Changes in propagation characteristics occur in various environments.

In the future, not only indoors and cars but also outdoor models will be created and analyzed.



(a) The beamforming function is off.



(b) The beamforming function is on.

Figure 9. The measured results of the distance between Tx point and Rx point versus the received signal strength indicator (dBm) and Throughput (Mbps).

REFERENCES

[1] A. KANAZAWA, H. OGAWA, K. SAKAMOTO, S. TAGO, F. OHKUBO, M. IDA, A. AKEYAMA, N. KURIBAYASHI, and T. HIROSE, "Measurement of Complex Permittivity of Construction Materials at 62 GHz and 70 GHz," IEICE Trans. Commun. Vol.J87-B, No.3, pp.462-466, Mar. 2004.

[2] R. NAKAMURA, and A. KAJIWARA, "Intra-vehicle Wideband Radio Propagation Characteristics at 60GHz Band," IEICE Trans. Commun. Vol.J95-B, No.2, pp.302-308, Feb. 2012.

[3] T. IMAI, "Prediction of Propagation Characteristics in Tunnels using Ray-tracing Method," IEICE Trans. Commun. Vol.J85-B, No.2, pp.216-226, Feb. 2002.

[4] T. IMAI, "Mobile Radio Propagation Simulation Based on Ray-Tracing Method," IEICE Trans. Commun. Vol.J92-B, No.9, pp.1333-1347, Sep. 2009.

[5] T. ISHIMINE and K.SATO, "Shadowing of Millimeter Waves due to the Human Body," IEICE Trans. Commun. Vol.J83-B, No.4, pp. 615-621, Apr. 2000.

[6] Y.KUNISAWA, A.YAMAGUCHI, F.LU, K.TAKEUCHI, and H.SHINBO, "An Experimental Study of MmWave Access Points Allocation Patterns inside the Passenger Car of a High Speed Train," IEICE Technical Report. SR2018-123, pp.17-22, Mar. 2019.