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Investigation of Ray Tracing Accuracy in Street Cell Environment in High-SHF Band

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Abstract – **Recently, mobile networks employing high-speed high-capacity communications have been investigated extensively to satisfy the demand for the faster and larger data communication. As one of the approaches, High-SHF (6 – 30 GHz) and EHF (mainly 30 – 60 GHz) bands are the candidates to utilize the relatively wide frequency band widths. As one approach, High-SHF (6 – 30 GHz) and EHF (mainly 30 – 60 GHz) bands are candidates to utilize the relatively wide frequency bandwidths. Accordingly, the characteristics of radio propagation loss in the frequency bands must be characterized. We investigate the characteristics of radio propagation loss in a street cell environment in the High-SHF bands using Ray Tracing (RT) based on measurement results. We observe that RT calculation tends to exhibit estimation error as the frequency increases.**

Index Terms — **Radio propagation, Channel model, Channel measurement, Diffraction, Propagation loss. 5G.**

I. INTRODUCTION

Recently, mobile networks employing high-speed high-capacity communications have been investigated extensively to satisfy the need for the higher and larger data communication beyond 2020 as the 5th generation (5G) mobile communication system. As one of the approaches to satisfy the needs, High-SHF (6 – 30 GHz) and EHF (mainly 30 – 60 GHz) bands are the candidates to utilize the relatively wide frequency band widths [1,2] for higher data rate. The METIS 2020 project has been investigating channel models for frequencies higher than 6 GHz to achieve a sufficiently wide spectrum to fulfill the 5G requirements [3]. Accordingly, the characteristics of radio propagation loss in these frequency bands must be characterized. In this report, the propagation loss characteristics in a street cell environment are investigated using Ray Tracing (RT) based on measurement results.

II. MEASUREMENT CONFIGURATION

Measurement is conducted in Hatchobori, Tokyo. Ten-story (approximately 40 m high) buildings surround this area along the streets. A transmitter (Tx) antenna is installed on a car roof with an elastic pole to adjust the height while a receiver (Rx) antenna is fixed on the roof of another car. The received instantaneous power level is measured while driving the car with the Rx antenna along the course shown in Fig. 1. Different values of frequencies and Tx heights are used as given in Table I.

The measured data are post-processed in the following manner. (1) Reference data points are established every meter. (2) The data at the reference point and other data recorded within 5 m before/after the reference point are considered as a data set for the reference point. (3) The median of the data set is determined as the measurement results at the reference point.

III. RAY TRACING (RT)

RT calculation considers the model shown in Fig. 1 as the street canyon model [4]. The rays calculated are shown in Fig. 2 depending on the type of route. Multiple reflections of ten times are accounted for in each route. The material surrounding the routes is assumed to be concrete with the dielectric constant of 7 and conductivity of 0.0023 S/m [5]. Although different material parameters have been reported for the frequency range between 3 to 30 GHz in [6], we confirm that the difference in these values does not significantly impact our simulation results. Calculation is performed every 0.1 m, then the results are post-processed in the same manner as described in Section II for the measurement results.

IV. COMPARISON

In this section, RT and measurement results of the path loss are compared for different frequencies and Tx heights. Distance *d* is defined as the distance between the Tx and Rx antennas along the street. In order to evaluate the dependencies of the difference between the RT and measurement results, the difference is quantified using the RMS (Root-Mean-Square) values for each route. Different frequencies and Tx heights are evaluated here.

Fig. 3 shows the path loss for the RT and measurement results for 2.2, 4.7, and 26.4 GHz. Fig. 4 shows the path loss for the RT and measurement results for the Tx heights of 6 and 1.5 m at 26.4 GHz. Table II gives the RMS values of the difference. We observe that the RMS values tend to increase as the frequency increases while they are almost independent of the variation in the Tx height.

V. CONCLUSION

The accuracy of the RT calculation is investigated for the High-SHF bands based on comparison with measurement results in terms of the path loss. The results show that the difference becomes large as the frequency increases and is independent of the transmitter height.

The estimation error of the RT calculation in the High-SHF bands needs to be clarified and fixed for accurate calculation. The effect of the roughness of the material, e.g., concrete, may be a contributing factor to the error. Reflecting the roughness effect in the simulation will be considered in the near future.

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TABLE I
MEASUREMENT SPECIFICATIONS

Frequency [GHz]	2.1, 4.7, 26.4
Tx antenna height [m]	1.5, 6, 10
Rx antenna height [m]	2.5
Directivity	Omni directional (horizontal plane)

TABLE II
RMS FOR DIFFERENT FREQUENCIES AND TX HEIGHTS

	Frequency				
	2.2 GHz	4.7 GHz	26.4 GHz		
	Tx height				
	10 m			6 m	1.5 m
LOS	8.3	6.2	9.6	11.6	10.7
NLOS	5.8	7.0	8.7	9.0	7.9
All	6.3	6.8	8.9	9.5	8.8

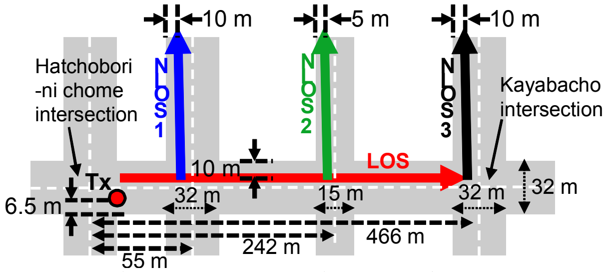
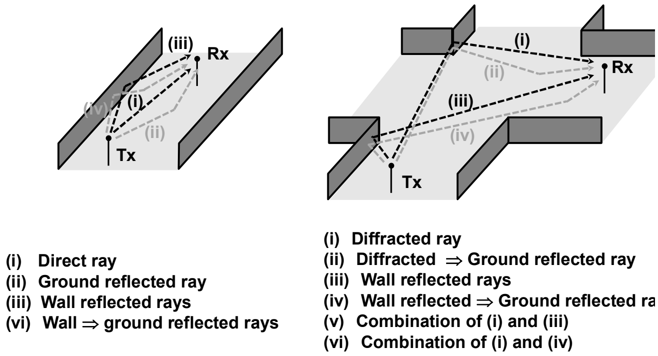
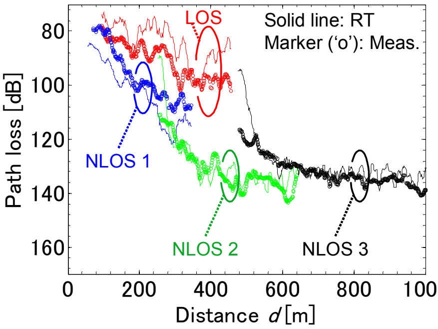


Fig. 1. Measurement environment and routes.

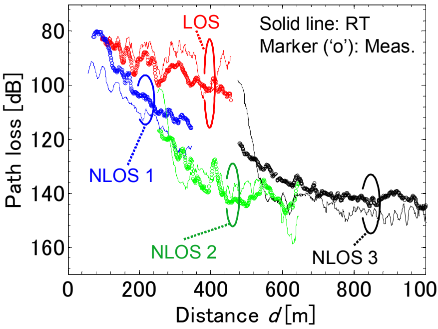


(a) Line-of-Sight (LOS) (b) Non Line-of-Sightte (NLOS)

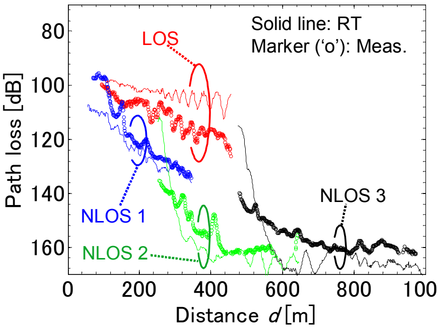
Fig. 2. Rays calculated in RT simulation.



(a) 2.2 GHz

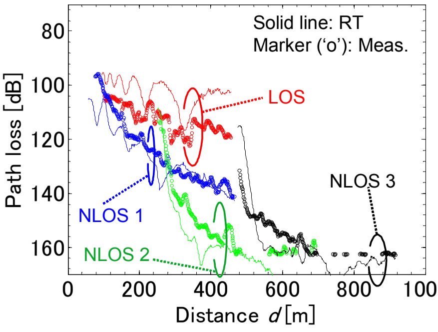


(b) 4.7 GHz

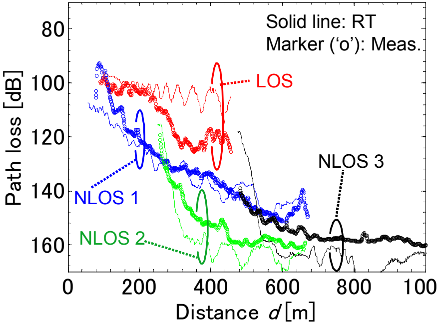


(c) 26.4 GHz

Fig. 3. Path loss due to RT and measurement for different frequencies.



(a) Tx height of 6 m



(b) Tx height of 1.5 m

Fig. 4. Path loss due to RT and measurement at different Tx heights.