Path Loss Models for Wireless Access Network Systems Using High Frequency Bands

Motoharu Sasaki, Minoru Inomata, Wataru Yamada, and Takeshi Onizawa

Abstract

To design coverage areas for wireless communication systems and evaluate the performance of the systems, it is necessary to develop a path loss model that can be used for the systems' frequency bands. The fifth-generation mobile communication system (5G) is expected to use high frequency bands above 6 GHz. Therefore, developing a path loss model for wireless access communication systems using high frequency bands has become a pressing issue. NTT Access Network Service Systems Laboratories has developed path loss models for the 20–40 GHz bands that are suitable for use scenarios of mobile phones and wireless local area networks. This article introduces the developed models.

Keywords: propagation, 5G, high frequency band

1. Introduction

In developing wireless communication systems, it is necessary to design their coverage areas and evaluate their performance such as the system throughput, the transmission capacity, and the system capacity. The system performance and the size of the area depend on the degree of propagation attenuation (path loss), as seen in **Fig. 1**. The propagation characteristics, including path loss, vary greatly depending on the frequency band. Therefore, it is necessary to develop a path loss model that can be used for the frequency band of the system.

Although it is assumed that the fifth-generation mobile communication system (5G) will use high frequency bands above 6 GHz, it is known that the propagation characteristics in high frequency bands differ from those for frequency bands below 6 GHz, which have long been used for conventional mobile communication systems. For example, the path loss increases as the frequency increases, and radio waves in high frequency bands do not reach shielded areas such as the areas behind buildings.

The frequency allocation of the high frequency bands for 5G will be discussed at the World Radiocommunication Conference in 2019. The propagation characteristics of the high frequency bands will be the basis of the discussion and should thus be studied in order to discuss appropriate allocation. Therefore, modeling the propagation characteristics of the high frequency bands has become a pressing issue.

At NTT Access Network Service Systems Laboratories, we are carrying out propagation modeling of a wide range of frequency bands in order to develop a variety of wireless communication systems. In this article, we introduce path loss models for the 20–40 GHz bands that can be useful for wireless communication systems in high frequency bands.

2. Path loss models

We clarified a propagation mechanism by measuring and simulating propagation, focusing on urban and residential environments. These environments are important use case scenarios of future wireless communication systems. They include mobile

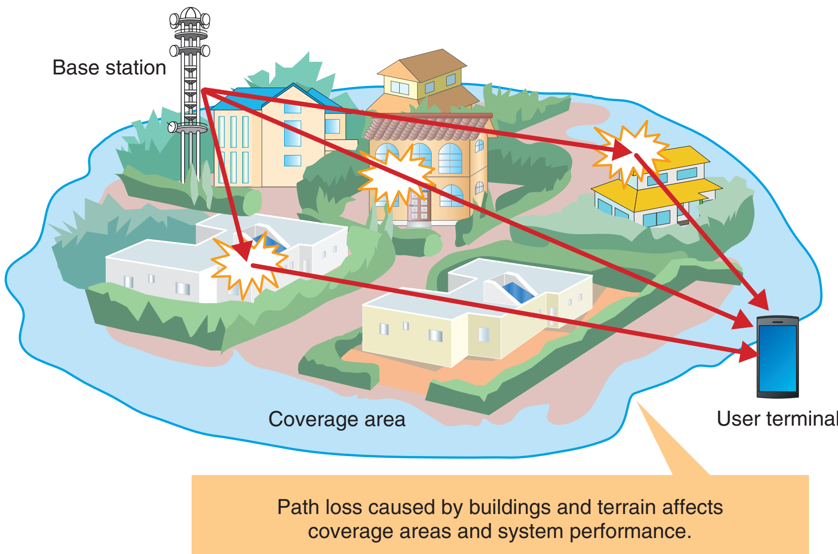


Fig. 1. Path loss model for designing wireless communication systems.

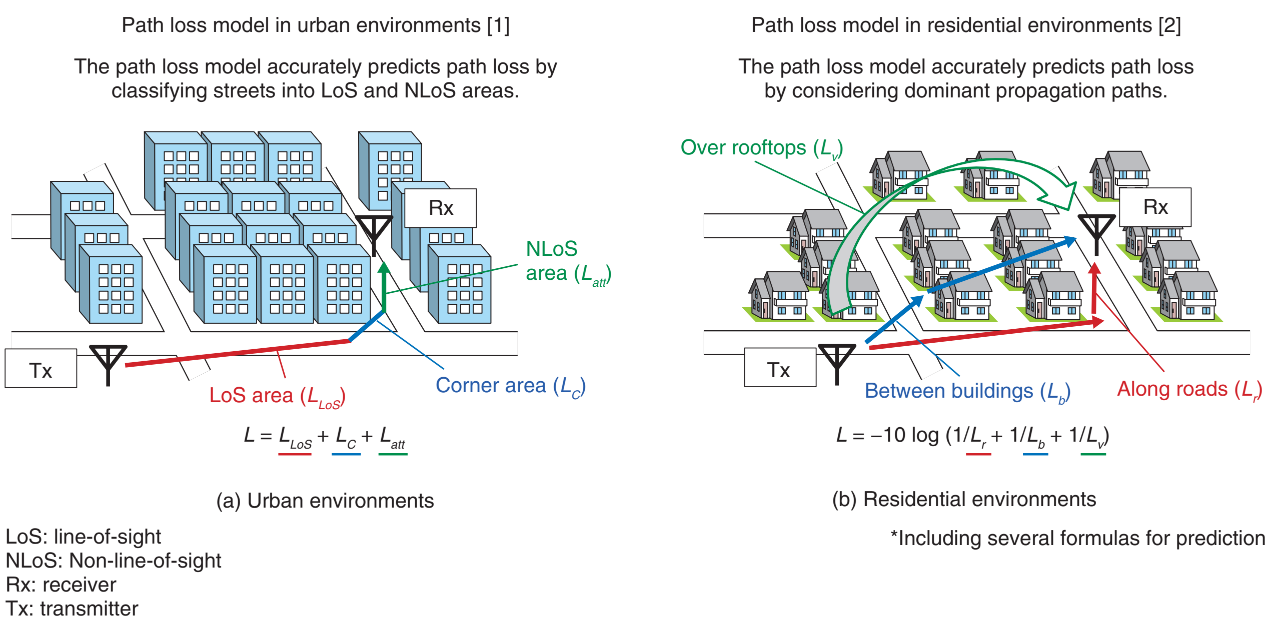
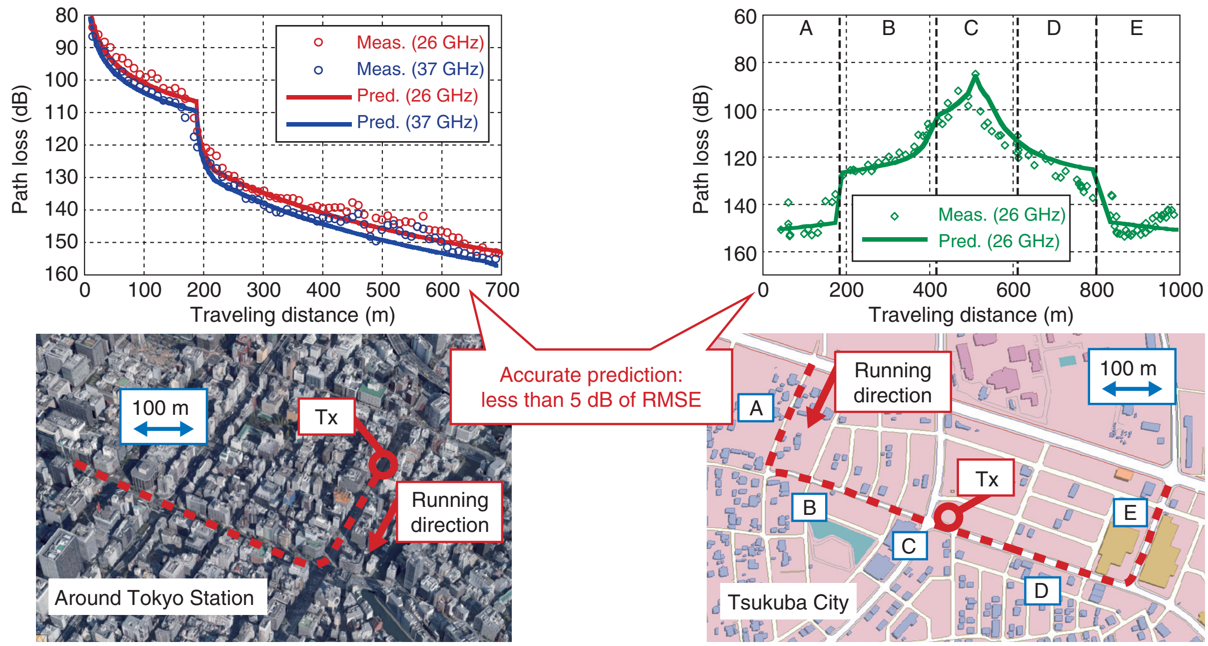


Fig. 2. Path loss models developed for urban and residential environments.

communication systems and wireless local area network systems. We obtained dominant paths from invisible propagation phenomena. The results enabled us to develop path loss models for high frequency bands that had been unclear except for the bands below 6 GHz. These models are depicted in **Fig. 2**.

For urban environments, we developed a model by deriving dominant path loss characteristics for three areas in which waves sent from a transmitter (Tx) to a receiver (Rx) are either visible or invisible: a line-of-sight (LoS) area, a non-line-of-sight (NLoS) area, and a corner (i.e., an intersection) area that is a transition area between LoS and NLoS areas [1]. The



(a) Urban environment

(b) Residential environment

RMSE: root mean square error

Fig. 3. Results of predicting and measuring path loss in urban and residential areas.

respective path losses in these areas are indicated as L_{LoS}, L_{att}, and L_C, as seen in Fig. 2(a). The radio waves transmitted from the Tx propagate to the Rx through these areas, with the three path losses added. We modeled the total path loss by using the frequency, the distance along a road between the Tx and the Rx, and the distance along a road between the Tx and the corner as parameters.

For residential environments, we developed a model by deriving three dominant paths: a path along a road, a path between buildings, and a path above a rooftop. The respective losses for these paths are indicated as L_r, L_b, and L_v, as seen in Fig. 2(b) [2]. We modeled these path losses using parameters including the distance along a road between the Tx and the Rx, building density, and building height. In our study, the equation for the residential environment model differs from that for the urban environment model because the received power at the Rx in a residential environment depends on which of the three paths has the least path loss.

In this way, we were able to develop models from the dominant paths that can easily predict actual path loss with high accuracy using simple parameters. These models have the potential to play a major role on the world stage in studies on the propagation characteristics of high frequency bands.

3. Prediction results obtained with developed path loss models

The results of predicting path loss using the models are plotted in **Fig. 3**. We verified the models' validity by comparing the prediction results and the measurement results obtained using 26 GHz and 37 GHz frequencies in an urban and residential environments.

In the urban environment, as shown in Fig. 3(a), the Rx moves along the road about 180 m and then turns the corner. The path loss increases sharply at the corner because the Rx moves from a LoS area to a NLoS area.

In the residential environment on the other hand, as shown in Fig. 3(b), the path loss shows significant variation when the Rx moves from area A to area E. This is caused by situational variations such as the number of corners between the Tx and the Rx and the degree of building shielding.

In both environments, the developed models accurately predicted the actual path losses. The root mean square error (RMSE) values are less than 5 dB. These results indicate that the models provide sufficient prediction accuracy for designing future wireless communication systems.

4. Future overview

This article presented path loss models that can accurately predict actual path losses using simple parameters. The derived models are suitable for designing coverage areas and evaluating the performance of various future wireless communication systems using high frequency bands. The models are expected to be utilized for the 5G system, which has been the focus of much research and development in the wireless communication field worldwide.

To contribute to the construction of various wireless communication systems, we intend to actively engage in the modeling of propagation phenomena for a wider range of frequencies and environments.

References

[1] M. Inomata, W. Yamada, M. Sasaki, M. Mizoguchi, K. Kitao, and T. Imai, “Path Loss Model for the 2 to 37 GHz Band in Street Microcell Environments,” IEICE Commun. Express, Vol. 4, No. 5, pp. 149–154, 2015.

[2] M. Sasaki, W. Yamada, N. Kita, and T. Sugiyama, “Path Loss Model with Low Antenna Height for Microwave Bands in Residential Areas,” IEICE Trans. Commun., Vol. E96-B, No. 7, pp. 1930–1944, 2013.

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