New Prediction Method Using Visibility Factor for Path Loss Between Mobile Terminals in Residential Area in Microwave Band

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1. Introduction

The microwave band below 6 GHz is widely used by wireless communication systems such as wireless LANs [1] and WiMAX [2] systems because path loss is low compared to that for the millimeter-wave band, and the microwave band can provide a wider frequency bandwidth to wireless systems compared to that provided by the VHF band. In addition, the microwave band is used in radar systems and radio astronomy systems. Due to these factors, frequency resources in the microwave band are extremely tight [3]. Therefore, there is strong demand for frequency sharing techniques and systems that enable coexistence of several wireless systems using the same frequency in the same place and time.

Fundamentally, investigation of interference propagation characteristics is necessary and important to the study of frequency sharing wireless systems [4]. There are many scenarios to consider in the study of interference propagation, but we focus on the interference propagation between mobile terminals (MTs) in this paper, and study a path loss prediction method for the interference propagation between MTs with a low antenna height.

There have been proposed prediction methods for the path loss between a base station (BS) and MT with a low antenna height in a street microcell environment [5-6]. These methods use parameters related to the road (such as the road width and the road length) to calculate the path loss because the dominant path of the travelling waves in a street microcell environment is the path along the road. On the other hand, in a residential area, the transmitted wave travels not only along the road but also between houses and may pass through wooden houses. Therefore, a new parameter is necessary for the path loss prediction method in a residential area. In this paper, the measured results of path loss between MTs with a low antenna height in a residential area are presented. Based on the measured results, a new prediction method using a visibility factor [7] is proposed.

2. Path Loss Measurement in Residential Area

Measurement is carried out in a residential area in Tokyo. Figure 1 shows a map of the measurement area. In the measurement area, the average building height is 10 m. Table 1 summarizes the measurement parameters.

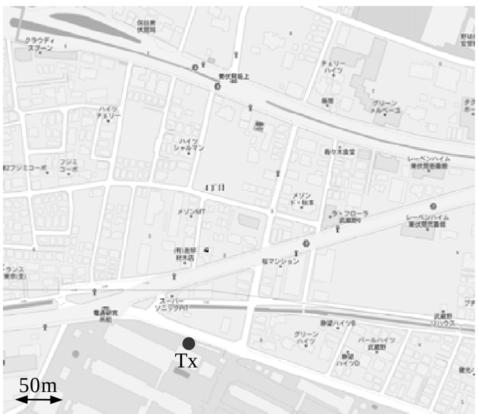

Figure 1: Measurement Environment

Table 1: Measurement Parameters

Measurement Frequencies	2.1975 GHz, 4.703 GHz, and 19.37 GHz
Height of antenna at Tx and Rx	2.5 m
Measurement antenna	Sleeve dipole antenna (Gain : 2 dBi)
Data acquisition cycle	1500 Hz
Measurement distance from transmitter	~300 m

The measurement frequencies are 2.1975 GHz, 4.703 GHz, and 19.37 GHz. A Tx is established beside the road. The radiation pattern for the Tx antenna is omni-directional in the horizontal plane. The height of the antenna is 2.5 m from the ground. The Rx antenna is an omni-directional antenna. The Rx antenna is fixed on the roof of a car, and the height is 2.5 m from the ground. The measurement car moves toward the Tx and the measurement distance from the Tx is within 300 meters. The receiving power is recorded by 1500 Hz sampling.

3. Measurement Results and Prediction Method Using Visibility Factor

3.1 Measurement Results

Figure 2 shows the measurement results of path loss at 2.1975 GHz. The circles in the figure represent the median value at 10 m intervals, and the solid line represents free space path loss. The figure shows that the path loss rapidly increases as the range decreases (around 40 meters), because both the transmitter and receiver antenna heights are low. For a low antenna height, the numbers of houses that shield or scatter the propagation waves increase in proportion to the distance between the transmitter (Tx) and receiver (Rx) antennas.

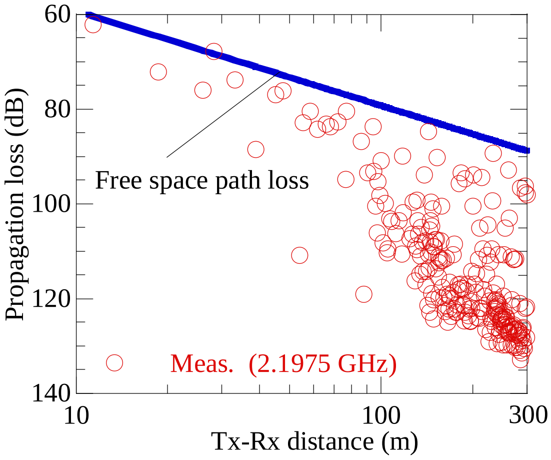

Figure 2: Measured Propagation Loss (2.1975 GHz)

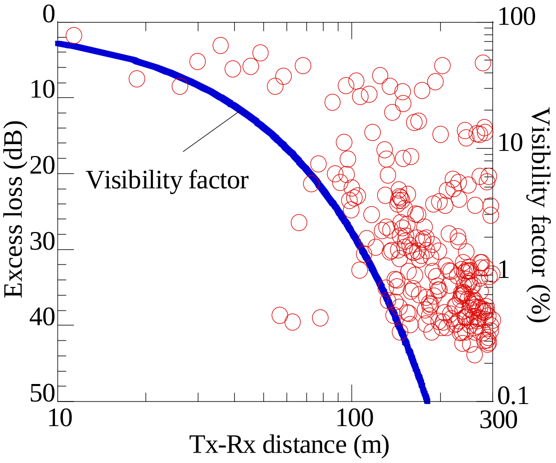

Figure 3: Relationship Between Excess Loss and Visibility Factor (2.1975 GHz)

3.2 Visibility Factor [7]

There is a parameter that can predict the visibility between two points called the “visibility factor”[7]. The feature of the parameter is that the visibility factor decreases in proportion to the distance between the Tx and Rx antennas (in proportion to the number of buildings that exist between the Tx and Rx). This parameter can be used to explain the path loss increase in proportion to the buildings existing between the Tx and Rx because the parameter can treat the number of buildings between the Tx and Rx directly. Therefore, the availability of the visibility factor [7] as a parameter that directly reflects the numbers of houses is studied for the evaluation of path loss.

The visibility factor can be calculated, for example, using the height of the antennas on the Tx and Rx sides, building density of the target area, the average building height, the distance between the Tx and Rx antennas. In addition, visibility factor *V(r)* is defined as

$$V(r) = \exp\left(-\frac{r}{R_v}\right) \tag{1}$$

where r is the distance from the Tx, and R_v is constant. The parameters for calculating R_v are defined as follows.

$$R_v = \frac{\gamma}{N_L w_p \{1 - \exp(-\gamma)\}} \exp\left(\frac{h_s - h_L}{h_{mL} - h_L}\right) \tag{2}$$

$$w_p = \frac{4w_0}{\pi}\left[1 - \frac{\alpha\{1-\exp(-\delta\gamma)\}}{\delta^2\{1-\exp(-\gamma)\}}\exp(-\beta h_s)\right] \quad (3)$$

$$\gamma = \frac{h_B - h_s}{h_{mL} - h_m} \quad (4)$$

$$\delta = 1 + \beta(h_{mL} - h_L) \quad (5)$$

Here, N_L is the building density, h_s is the Rx antenna height, h_B is the distribution boundary height, h_L is the minimum number of floors under the height of h_B, h_{mL} is the average building height less than h_B, h_m is the average building height greater than h_B, h_N is the Tx antenna height, and α, β, and w_0 are constants, respectively.

3.3 Path Loss Prediction Method Between MTs in Residential Area Using Visibility Factor

Parameters for calculating R_v are shown in Table 2. These parameters are referred to as building parameters in the measurement environment [8]. In Fig. 3, the circles represent excess loss from the free space path loss, and the solid line represents the visibility factor calculated using the parameters. Figure 3 shows that there is a strong association between the excess loss and the visibility factor with respect to the distance between the Tx and Rx antennas.

Table 2: Calculation Parameters

h_B	h_L	h_m	h_s	h_N	N_L	α	β	w_0
12	6	16	2.5	2.5	3171.7	0.55	0.18	15

Figure 4 shows the cumulative probability of the measured excess loss of all measured frequencies. In this figure, the circles, squares, and crosses represent the measurement results for 2.1975, 4.703, and 19.35 GHz, respectively. The figure shows that there is no obvious frequency dependency of the excess loss. Based on the results, the relationship between the excess loss and the visibility factor is approximated by using all measurement data.

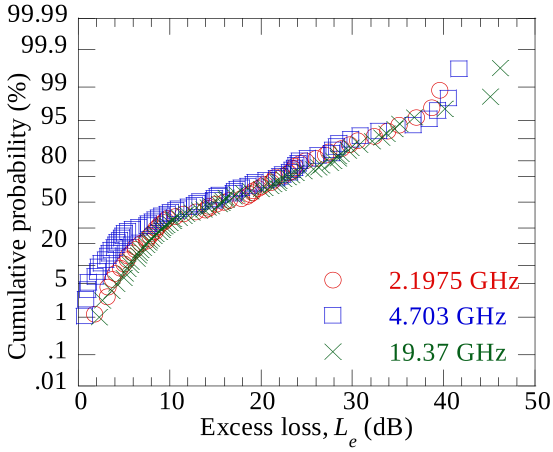

Figure 4: Cumulative Probability of Measured Excess Loss

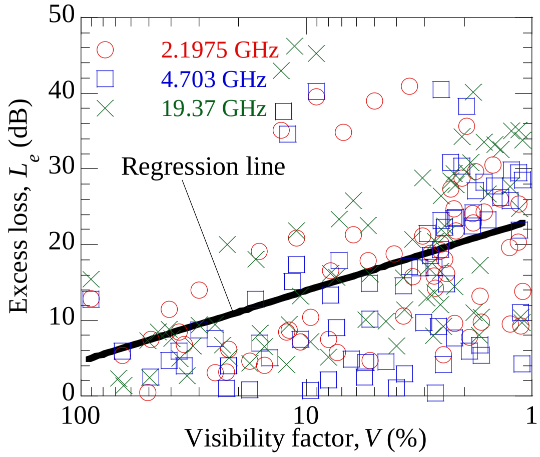

Figure 5: Relationship Between Excess Loss and Visibility Factor

Figure 5 shows the relation of excess loss to the visibility factor, and the regression line is also shown in the figure. In the figure, the circles, squares, and crosses are the measurement result for 2.1975, 4.703, and 19.35 GHz, respectively. The approximated line is formulated as follows.

$$L_e = -9.33\log 10\{V(r)\} + 23.25 \quad (6)$$

where L_e is the excess loss and *V(r)* is the visibility factor. Therefore, from (6), path loss *L* can be predicted using (7).

$$L = 20 \cdot \log\left(\frac{4\pi r}{\lambda}\right) - 9.33\log 10\{V(r)\} + 23.25 \qquad (7)$$

where λ is the wavelength.

Calculation examples using (7) and the measurement results are shown in Fig. 6. In this figure the circles, squares, and crosses are the measurement results for 2.1975, 4.703, and 19.35 GHz, respectively. The solid, dashed, and dotted lines represent the estimated results for 2.1975, 4.703, and 19.35 GHz using (7), respectively. From this figure, we can see that the prediction results of the path loss using the visibility factor agree with the measurement results. After 40 meters in particular, the difference between the estimated results and measurement results becomes small.

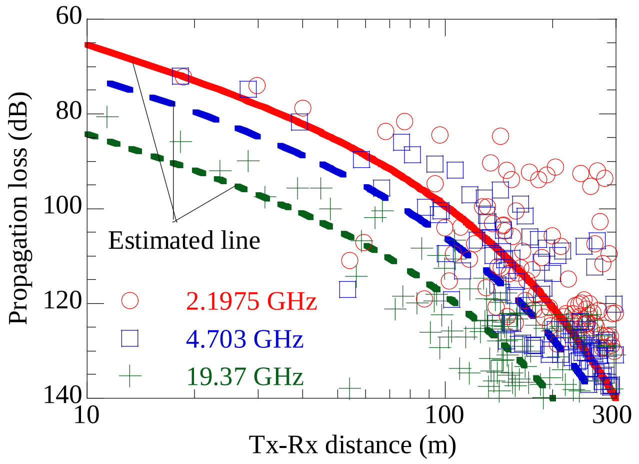

Figure 6: Estimation and Measurement Results

4. Conclusion

In this paper, the measured results of the path loss between MTs with a low antenna height in a residential area were presented. Based on the measurement results, it was shown that the relationship between the path loss and the visibility factor has a high correlation. A prediction method using the visibility factor was proposed. In addition, there was no clear frequency dependency of the excess loss from the free space path loss observed in this study.

References

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