The Effect of Human Body Blockage to Path Loss Characteristics in Crowded Areas

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***Abstract* – To better design the coverage areas of wireless base stations, this paper reports the long-term fading, shadow fading, and fast fading characteristics of path loss at 4.7 and 26.4 GHz in a crowded area with pedestrians. We clarified that these fading characteristics of measured path loss broadly matches the Nakagami-Rice distribution. As the results of the analysis with two frequencies, we find that the K-factor becomes low with the increase in frequency.**

***Index Terms* — Propagation, Path loss, Human body shadowing, crowded area, K-factor.**

1. Introduction

Mobile data traffic will continue to increase [1], and the high data traffic loads will be big problem. To solve this problem, the high frequency bands (above 6 GHz) are expected to use in high data traffic areas [2], such as crowded areas, for example the public squares in front of large stations. In crowded areas, the propagation paths are expected to be blocked by human bodies. It is reported that the shadow fading triggered by human body is large in the high frequency bands [3]. However, the path loss characteristics created by a large number of human bodies is still unclear. To design the coverage areas of wireless base stations, it is important to clarify the path loss and its fading characteristics in the high frequency bands in crowded areas. In the case of cellular systems, the path loss characteristics have, up to now, been calculated by using several fading characteristics; the first is the long-term fading of path loss (median value of variation) and the others are shadow fading and the fast fading. In particular, fast fading has been represented by the K-factor of the Nakagami-Rice distribution in line-of-sight (LoS) situation. However, it is unclear whether the same characteristics are evident in the high frequency bands in crowded areas. Therefore, this paper reports an analysis of the path loss characteristics based on measurements at 4.7 and 26.4 GHz in a crowded area.

2. Measurement Method and Parameters

Fig. 1 and Fig. 2 show measurement environment. The photograph of Fig. 2 was taken at the Tx location. We measured the path loss around Shibuya station in Tokyo. The station is a typical crowded area as shown in Fig. 2. There are always many people in front of the station from daytime to midnight [2]. The main road width is about 15 m and the buildings around the station are more than 40 m high (10 stories). Therefore, the environment is a typical urban area.

Table I lists the measurement parameters. We mounted the transmitter (Tx) antenna on the measurement vehicle, and varied the antenna height. The receiver (Rx) antenna was set on a trolley. The height of the Tx antenna was either 4 or 10 m, and Rx antenna was 1.2 m. We measured the path loss while moving the trolley. In this measurement, the direct distance between Tx and Rx was up to 100 m. The red lines in Fig. 1 and Fig. 2 indicate Rx measurement route. In addition, we measured the path loss at the distance of 65 m for 5 minutes without moving. The orange circles in Fig. 1 and Fig. 2 indicate this Rx measurement point. There were no buildings between Tx and Rx antennas, so blockage was caused by human bodies. Measurement frequencies were 4.7 and 26.4 GHz. Tx and Rx antennas were omni-directional. We obtained 1-meter interval median values to analyze the long-term fading characteristics (path loss).

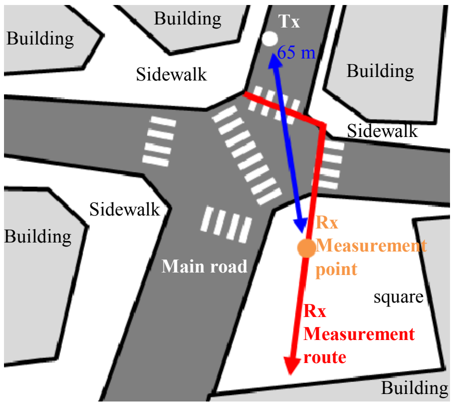

Fig. 1. Measurement environment.

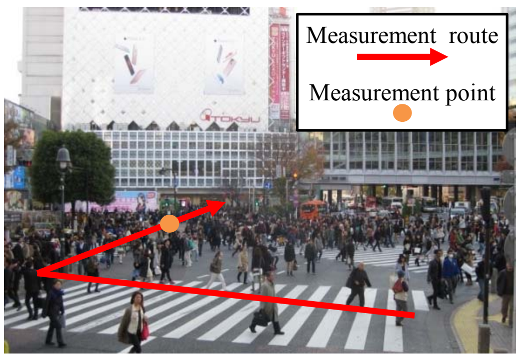

Fig. 2. Photograph from Tx location.

TABLE I
Measurement parameters

Frequency	4.7, 26.4 (GHz)
Tx antenna height	4, 10 (m)
Rx antenna height	1.2 (m)
Tx / Rx antenna half power beam width	H-plane : Omni-directional V-plane : 60 degrees
Sampling rate	1.5 (kHz)

3. Measurement and Analysis Results

First, we analyzed the long-term fading characteristics. Fig. 3 plots the median values derived from the measured path losses. In this figure, logarithmic regression results are also shown. The regression results were yielded by the following equations.

$$L=26.6*\log_{10}(d) + 41.2 \ (f=4.7 \text{ GHz}, h_{Tx} = 4 \text{ m}) \quad (1)$$
$$L=23.3*\log_{10}(d) + 45.9 \ (f=4.7 \text{ GHz}, h_{Tx} = 10 \text{ m}) \quad (2)$$
$$L=26.2*\log_{10}(d) + 59.9 \ (f=26.4 \text{ GHz}, h_{Tx} = 4 \text{ m}) \quad (3)$$
$$L=20.2*\log_{10}(d) + 67.7 \ (f=26.4 \text{ GHz}, h_{Tx} = 10 \text{ m}) \quad (4)$$

where L is path loss, d is direct distance between Tx and Rx antennas, f is frequency (GHz), and h_{Tx} is Tx antenna height. When Tx antenna height was 4 m, path loss exponents of both frequencies were large compared to the case of the Tx antenna height of 10 m. This is because the view between Tx and Rx were shielded by human bodies more frequent, when the Tx antenna height was low.

Next, we analyzed the shadow fading (short-term fading) characteristics. Table II shows the shadow fading values, which are the standard deviation obtained by subtracting the calculation results of (1)-(4) from the median values of path loss. The shadow fading in the four situations are almost the same although the value at 26.4 GHz is slightly bigger than that at 4.7 GHz regardless of antenna height. This may show that the shadow fading by human bodies is larger in the high frequency bands.

Finally, we show the analysis results of the fast fading characteristics. Fig. 4 shows the cumulative distribution function (CDF) of the measured path loss. Here, we used the data measured at the Tx-Rx distance of 65 m for 5 minutes. Dotted and dashed lines show the CDF of measurement results at 4.7 and 26.4 GHz, respectively. In this figure, ideal CDFs of Nakagami-Rice distributions with K-factors of 0, 5.5, 9 dB are also plotted for reference. The measurement results and ideal CDFs agree well. Therefore, it is expected that the path loss variation of high frequency bands in crowded environments can be also represented by a Nakagami-Rice distribution. The K-factor values of the measurement results are summarized in Table III. We found that the K-factor is higher at 4.7 GHz than at 26.4 GHz. This is because that the Fresnel zone is large at low frequency which weakens the shielding offered by the human body. Conversely, at high frequency, the Fresnel zone was smaller and blockage often occurred. In addition, when the Tx antenna is low, the K-factor becomes low at each frequency. This is because the paths are frequently shielded by human bodies when the Tx antenna height is low.

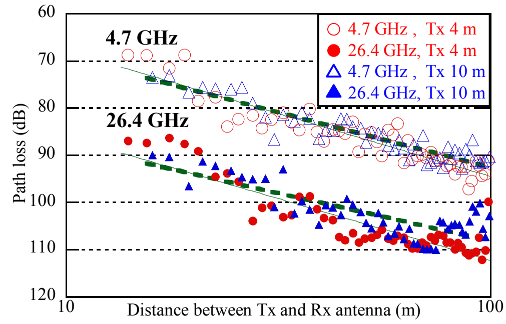

Fig. 3. Long-term fading of path loss.

TABLE II
Standard deviation of shadow fading

	Antenna height	
Frequency	4 (m)	10 (m)
4.7 (GHz)	3.20 (dB)	3.12 (dB)
26.4 (GHz)	3.41 (dB)	3.43 (dB)

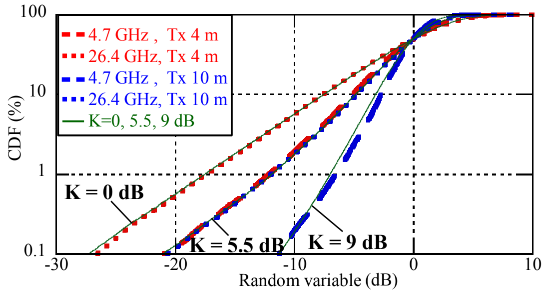

Fig. 4. CDF of measured path loss.

TABLE III
K-factor

	Antenna height	
Frequency	4 (m)	10 (m)
4.7 (GHz)	5.5 (dB)	9 (dB)
26.4 (GHz)	0 (dB)	5.5 (dB)

4. Conclusion

This paper reported the long-term fading, shadow fading, and fast fading characteristics of path loss in a crowded area with pedestrians. By using the empirical formulas, shadow fading values, and K-factor values, we can estimate the path loss characteristics in high frequency bands in crowded areas. Finally, we clarified how path loss characteristics are affected by Tx antenna height and frequency.

References

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