1D4-2

Empirical Received Level Modelling of Mobile Propagation in Static Indoor Conditions

Yoshichika Ohta and Teruya Fujii
Laboratory, Softbank Telecom Corp.
2-38 Aomi, Koto-ku, Tokyo, 135-8070 Japan, yoshichika.ota@ tm.softbank.co.jp

1. Introduction

More people are using cellular phones indoors to communicate, in which case the mobile terminals are stationary while in use. In a parallel trend, indoor wireless access systems, such as WLANs, are becoming more popular and these terminals are also stationary. The communication characteristics created by indoor static use are quite different from those seen while the terminal moves. In static use, the terminal itself doesn't move but its radio environment is changed by moving objects around it, typically people. In order to evaluate the communication characteristics for static terminals used indoors, we have to clarify the propagation characteristics (channel characteristics). Up until now, few studies have addressed this subject [1]-[2].

This paper measures the channel characteristics of a static terminal used both in the indoor non line of sight (NLOS) and line of sight (LOS) conditions. We analyze the received level characteristics from the measured data and propose an empirical received level model for static indoor condition.

2. Measurements

We carried out measurements to obtain the received level characteristics in an indoor environment with both NLOS and LOS conditions. The measurements were carried out using a room in our laboratory. Fig.1 shows an overview of the room. The room is 23m by 15m with a ceiling height of 3m; two of the walls are windows. The room contained regular office objects such as desks, tables, and shelves. Table 1 shows the measurement parameters. The carrier frequency was 3.35GHz / CW. The Tx (base station) and Rx (mobile terminal) antennas always were fixed at 1.5m above the floor.

We measured the received level in two conditions. One condition (static condition) had no one moving around the Rx antenna. The other (dynamic condition) had people moving around the Rx antenna. In this condition, the people walked at a speed of about 1m/s in an annular region centered on the Rx antenna with radii of about 2 and 7m.

We set established the NLOS environment by inserting a radio wave absorbent panel between Rx and Tx antennas. In the static condition, we obtained the angle profile by rotating the directional antenna, half-power beam width of 3 degrees, and we found that the measurement environment was NLOS; multi-path waves with about the same power were uniformly distributed. Fig. 2 shows an example of the measured received level variation when 8 people walked around in the annular region. The parameter is the received levels at three slightly different positions of the terminal antenna in the static condition as shown in the upper right of the figure; the position of the terminal antenna was altered by several tens of cm [3]. The received levels in the static condition are also shown. This figure shows that when people walk around the terminal antenna, the received level dynamically fluctuates around the received level measured in the static condition; the magnitude of the variation greatly depends on the received level as determined by terminal position in the static condition. Fig. 3 shows an example of the measured received level variation with the number of moving people as a parameter when the level in the static condition is 'middle'.

In the LOS condition, the distance between Tx and Rx antennas was set to 4m and there was nothing between the Tx and Rx antennas as shown in Fig. 1. From an evaluation of the direct wave to multi-path power ratio (K-factor), the K-factor was about 12dB. Fig. 4 shows an example

ISBN: 978-4-88552-223-9 C3055©IEICE

of the measured received level variation when 7 people walked around in the annular region. The parameter is the received level (average received level measured in static condition). It is found that the received level changes dynamically and is degraded when the direct wave is cut off. Fig. 5 shows an example of the measured received level variation with the number of moving people as a parameter when the level in the static condition is 'middle'. Large degradations occur more frequently as the number of moving people increases.

3. Received level characteristics

3.1 NLOS condition

Fig. 6(a) and Fig. 6(b) show the cumulative probability of the received level with 3 and 8 moving people, respectively. The parameter is the received level, shown in the between Fig. 6(a) and Fig. 6(b). The horizontal axis is the relative received level normalized by average received power and the vertical axis is the cumulative probability. In these figures, we also plot a Nakagami-Rice distribution with K-factor as a parameter. From these figures, we find that the distribution of low (high) received level in static condition can be approximated as a Nakagami-Rice distribution with a small (large) K-factor. From this figure, we consider that the received level can be modelled as a Nakagami-Rice distribution with a K-factor that depends on the received level set by terminal position [4]. This is a noteworthy characteristic. In general, the K-factor is considered to be a function of not only the received level due to terminal position but also the number of people and the size of annular region etc. From these figures, the received level distributions are in good agreement with the following Nakagami-Rice distribution [4].

$$p(e, K(x)) = (K(x)+1)\exp[-(K(x)+1)e - K(x)]I_0(\sqrt{4(K(x)+1)K(x)e})\,. \qquad (1)$$

$K(x)$ represents the K-factor at position x, e is the received power, and $I_0(\ )$ is the first kind 0th-order modified Bessel function. It was found that the most suitable K-factors with 3 and 8 people are about 0dB, 8dB, and 12dB for low, middle, and high received power, respectively.

3.2 LOS condition

Fig. 7 shows the cumulative probability of the received level with 3 moving people. The horizontal axis is the relative received level normalized by average received power and the vertical axis is the cumulative probability. We also plot a Nakagami-Rice distribution with K-factor as a parameter. At low and high levels of the received signals, the distribution can be approximated as a Nakagami-Rice distribution with a small K_1 and a large K_2 respectively. From this result, these phenomena correspond to the conditions in which the direct-wave is cut off and not by people. Therefore, the distribution can be expressed as the following distribution created by combining two Nakagami-Rice distributions,

$$p_{LOS}(e, K_1(x), K_2(x)) = a\, p(e, K_1(x)) + (1-a)\, p(e, K_1(x)) \qquad (2)$$

where a is the ratio cut-off of the direct wave. Fig. 8(a) shows the cumulative probabilities both measured and calculated by Eq.(2) with the most suitable parameters: a, $K_1(x)$, $K_2(x)$. From this figure, the proposed received level model, Eq. (2), is in good agreement with the measured values. Fig. 8(b) shows the cumulative probability of the received level measured and calculated by Eq. (2) with the number of moving people as a parameter at middle received level. As the number of moving people increases, the K factors of each distribution decrease. This is because the frequently cut off of direct wave increases, and the ratio of received direct wave decreases.

4. Conclusion

In this paper, we measured the channel characteristics for stationary terminals used in indoor NLOS and LOS conditions, and proposed an effective received level model. In NLOS condition, the distribution of received level can be modelled as a Nakagami-Rice distribution whose K factor depends on the received level established by terminal position. On the other hand, in

LOS condition, the distribution of received level can be modelled as a combination of two Nakagami-Rice distributions with different K factors.

Acknowledgments

Strategic Information and Communications R&D Promotion Program (SCOPE) of the Ministry of Internal Affairs and Communications of Japan supported a portion of this research.

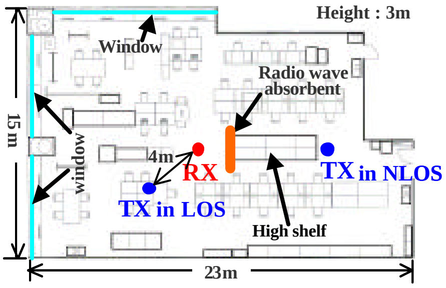


Fig. 1 Measurement environment

Table 1 Measurement parameters

Condition	NLOS	LOS
Carrier Frequency	3.35GHz	
Tx Power	1mW	
Tx Antenna	Dipole Antenna (2.5dBi)	Directional antenna (14.3dBi) Half-power beam width : 90°
Tx Antenna Height	1.5m	
Rx Antenna	Dipole Antenna (2.5dBi)	
Rx Antenna Height	1.5m	

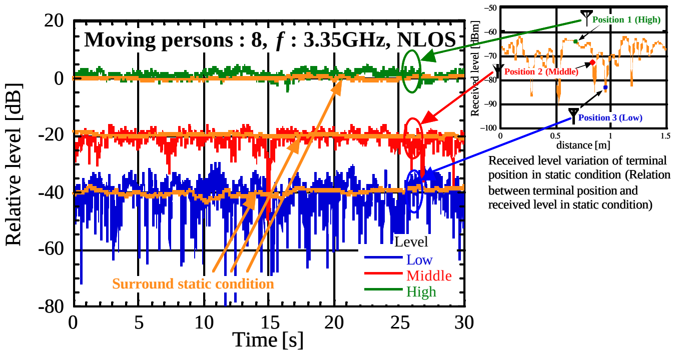


Fig. 2 Received level variation: parameter is received level in static condition in NLOS

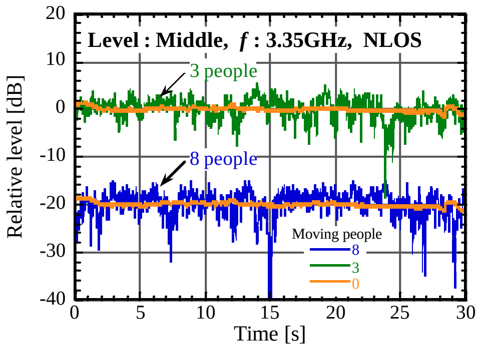


Fig. 3 Received level variation: parameter is number of moving people in NLOS

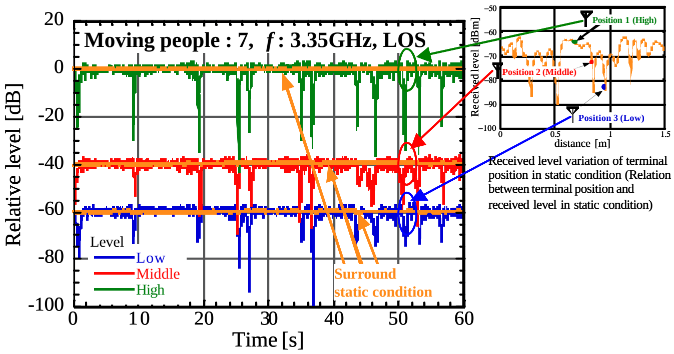


Fig. 4 Received level variation: parameter is received level in static condition in LOS

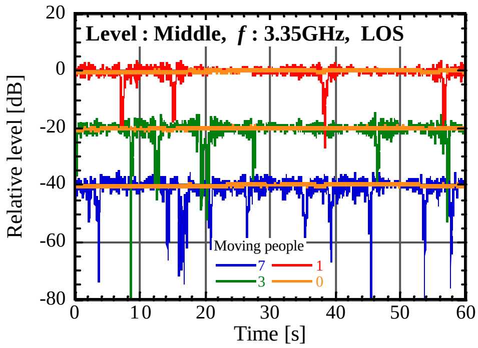
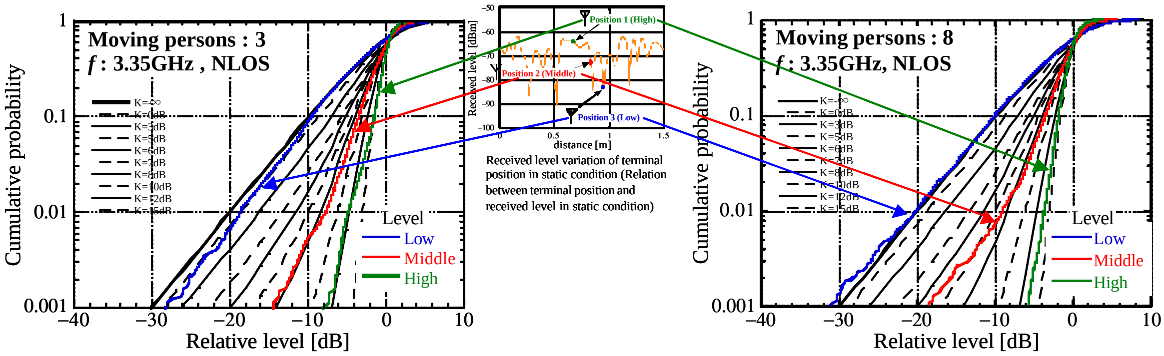


Fig. 5 Received level variation: parameter is number of moving people in LOS



(a) Moving people : 3 (b) Moving people : 8

Fig. 6 Cumulative probability of received level in NLOS

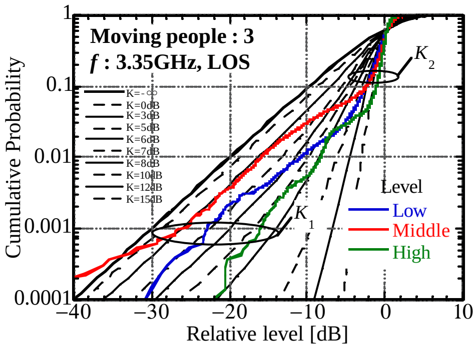
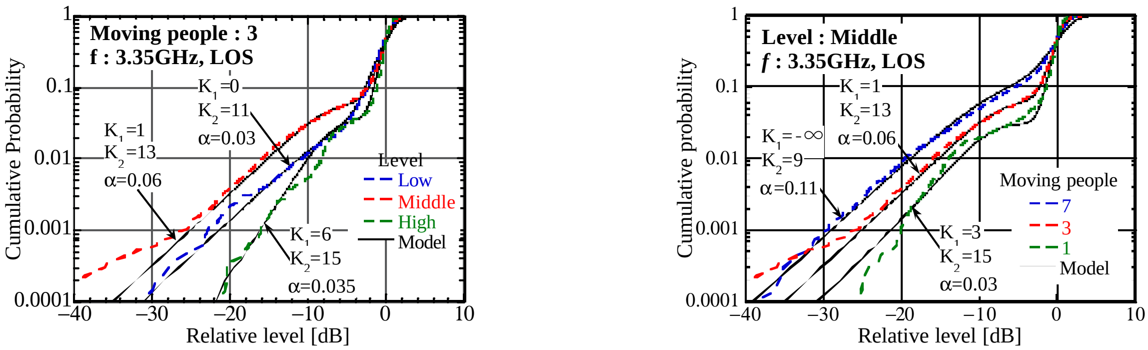


Fig. 7 Example of cumulative probability of received level in LOS



(a) Received level dependency in static condition (b) Number of moving people dependency

Fig. 8 Cumulative probability of received level in LOS

References

[1] V.Erceg, et al., "TGn Channel Models," doc. :IEEE 802.11-03/940r4, May 2004.

[2] Rec. ITU-R P.1238-4: "Propagation data and prediction methods for the planning of indoor radio communication systems and radio local area networks in the frequency range 900 MHz to 100 GHz," 2005 P series, ITU, Geneva, May 2005.

[3] Y. Ohta, T. Fujii, "Fading Characteristics in Indoor Environment," IEICE Technical Report, Japan, vol.106, no. 140, AP2006-54, pp. 91-96, July 2006 (Japanese).

[4] T. Fujii， Y. Ohta， "Proposal of Fading Model in Indoor Environment (1)， " IEICE Technical Report, Japan, vol.106, no. 140, AP2006-55, pp. 97-102, July 2006 (Japanese).