

Wideband Channel Modelling for Indoor Static Mobile Terminals

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1. Introduction

The number of customers who use cellular phones indoors is rapidly increasing. In this case, the mobile terminals are basically static. In static usage, the terminal itself doesn't move, but the environment around it changes due to the movement of people, for example. In order to accurately evaluate these communication characteristics, a new propagation model (channel model) is necessary [1]. In response to this request we proposed a physical channel model of narrowband propagation for static terminals [2]-[4].

A recent trend is the wide use of wideband wireless access systems such as WLAN and IMT-2000. In this paper, we propose a wideband physical channel model for static terminals used indoors. We compare analysis results of the proposed model with measured results and show that the proposed model well predicts the measured results.

2. Proposed model

First we express the basic concept of the proposed model [2]. It sets up two environments. One is the surrounding static environment; it contains no moving object. The radio waves arrive at the terminal without being blocked by moving objects. The other is the surrounding moving environment; it contains only moving objects and only radio waves scattered by the moving objects arrive at the terminal. The proposed model combines the two environments in a direct manner.

Fig. 1 shows the proposed model. A moving object is assumed to block the radio waves by perfectly absorbing their power. As the object moves, it blocks and absorbs other radio waves, so the received level at the terminal changes dynamically.

3. Analysis

3.1 Analysis model

Fig.2 shows the analysis model [2]. Here we analyze a two-dimensional model. The moving objects considered are only moving people; the i -th person is represented as a disk with diameter of Δw [m] separated from the terminal by r_i [m]. Each moving person walks in an arbitrary direction between 0 and 360 degrees at a constant speed of v [m/s]. Each moving person moves within an arbitrary area S_a around the terminal, centered on the terminal. The number of moving people is N_{person} and a moving person completely absorbs the power of paths that cross his width of Δw .

3.2 Propagation model

At first we discuss a temporal-spatial propagation model for indoor environments. Fig.3 shows an example of a ray tracing result in a rectangular room. In these figures, the black circle denotes Rx and the red circles denote Tx and its images due to wall reflection. The blue circles denote moving people and their images. Each line linking BS to Rx denotes a path. From these figures, we find that rays with the approximately same path length exist in large numbers and that these rays arrive from roughly all horizontal directions. So we assume that rays with the same path length arrive uniformly in a horizontal plane. Further, these rays suffer almost the same attenuation because their path length is the same and their reflection number is almost the same. Accordingly, we can assume that rays with same path length have the same power. As a result, the characteristics of rays with a certain path length are completely equivalent to those of our assumed narrowband indoor propagation model [2].

3.3 Moving object model

Fig. 3 shows actual people and their images due to wall reflections. To determine the number of people intersecting a ray we must consider both actual people and their images. Let the path length be l , the apparent number of people $I_{person}(l)$ is expressed as the number of actual people and their images within a circular with a radius of l , centered on the terminal as shown in Fig. 3. $I_{person}(l)$ can be calculated by using N_{person} and S_a as follows.

$$I_{person}(l) = \pi l^2 n_{person} = \frac{N_{person} \pi l^2}{XY} \quad (1)$$

where n_{person} denotes the number of people per unit area as follows.

$$n_{person} = N_{person} / S_a = N_{person} / XY \quad (2)$$

Here X and Y denote the width and length of a rectangular room, respectively.

3.4 Received level analysis

When we focus on the rays with path length l , the receiving model can be equivalently expressed as shown in Fig. 4. As shown in Fig. 4, $I_{person}(l)$ people walk in arbitrary directions at a constant speed of v in the area of a circle with radius l . The rays arrive uniformly from all horizontal directions.

Let the position of a terminal be $(x_0, 0)$ and the i th ray's level at the terminal with position of x_0 be $e_i(x_0, l)$. We assume that the number of rays is N_{path} and the rays' level absorbed by the k th moving person is $\eta_k(t, l)$. The received level at the terminal, $E(t, x_0, l)$, can be written as follows.

$$E(t, x_0, l) = \sum_{i=1}^{N_{path}} e_i(x_0, l) - \sum_{k=1}^{I_{person}(l)} \eta_k(t, l) = e(x_0, l) - \eta(t, l) \quad (3)$$

where the i th ray's level $e_i(x_0, l)$ is given by

$$e_i(x_0, l) = A(l) \exp \left[j \left(\frac{2\pi x_0}{\lambda} \cos \theta_i + \phi_i \right) \right] \quad (i=1, \dots, N_{path}) \quad (4)$$

where $A(l)$, θ_i and ϕ_i represent the amplitude, arriving angle, and phase of the i th path, respectively. λ [m] is the wavelength. On the other hand, $\eta_k(t, l)$ can be represented by using the lowest angle $\theta_k^L(t, l)$ and the highest angle $\theta_k^U(t, l)$ of paths absorbed by the k th moving person as follows.

$$\eta_k(t, l) = \sum_{i=\theta_k^L(t, l)}^{\theta_k^U(t, l)} e_i(x_0, l) \quad (5)$$

The first item $e(x_0, l)$ of the right side of Eqn. (3) represents the level due to the surrounding static environment and its value depends on position x_0 , but not time t . On the other hand, $\eta(t, l)$ of the right side of Eqn. (3) represents the level due to the surrounding moving environment, which does depend on time t . When the number of absorption paths in Eqn. (3) is relatively large, the complex amplitude of absorption paths $\eta(t, l)$ follows a complex Gaussian distribution due to the central limit theory. This is a noteworthy characteristic. From this characteristic, we find that Eqn. (3) can be presented as Nakagami-Rice fading with factor K ; K is defined as the ratio of direct path's power to the multipaths' power. In this case, the direct path's power and the multipaths' power correspond to the power of $e(x_0, l)$ and $\eta(t, l)$, respectively. The received power distribution of Nakagami-Rice fading is given by.

$$p(r_p, x_0, l) = (K + 1) \exp[-(K + 1)r_p - K] I_0(\sqrt{4(K + 1)Kr_p}) \quad (6)$$

where r_p is the received power and $I_0(x)$ is the first kind 0th-order modified Bessel function.

Next we calculate the K -factor $K(x_0, l)$ at the position of x_0 as follows.

$$K \equiv K(x_0, l) = |e(x_0, l)|^2 / \langle |\eta(t, l)|^2 \rangle = \left(\frac{|e(x_0, l)|^2}{P_m(l)} \right) \frac{\pi l}{I_{person}(l) \Delta w} \quad (7)$$

where $\langle |\eta(t,l)|^2 \rangle$ denotes the average power of the absorbed paths. The k th moving person at distance r_k absorbs the power of rays arriving at the terminal within the angle width of $\Delta w/r_k$.

Assuming that the total power of rays with path distance l is $P_m(l) (= \sum_{i=1}^{N_{path}} |e_i(x_0, l)|^2)$ and each ray has the same power of $P_m(l)/2\pi$ and that the moving people are distributed uniformly in the moving area $\langle |\eta(t,l)|^2 \rangle$ can be calculated as follows.

$$\langle |\eta(t,l)|^2 \rangle = \frac{N_{person}}{\pi l^2} \int_0^l \frac{P_m(l)\Delta w}{2\pi r} 2\pi r dr = \frac{I_{person}(l)P_m(l)\Delta w}{\pi l} \quad (8)$$

The second equation on the right side of Eqn. (7) can be obtained from Eqn. (8).

By the way, we can change the path length l [m] to delay time τ [μ s] by using the relation of $\tau = l/300$.

4. Results

In order to confirm the proposed model, we carried out measurements in a room of our laboratory. The room is 8m wide and 16m long with a ceiling height of 3m. This room holds common office equipment such as desks, tables. The carrier frequency is 3.4GHz and the chiprate is 100Mcps. The BS and MT antennas are omni directional in the horizontal plane. We made six people walk around the receiver's antenna at the constant speed of about 1m/s and measured the received level variation.

In the calculations, we set Δw , v and N_{person} to 0.3m, 1m/s, and 6, respectively. The room layout matched the room examined.

Fig. 5(a) shows an example of the measured delay profile. Fig. 5(b) shows the received level variation of rays at the delay time of 1, 2, and 3 in Fig.5(a). Fig. 5(c) shows the cumulative probability of calculated and measured received ray levels. We find that the measurement results closely track the Nakagami-Rice distribution and agree well with the calculated results.

Fig. 6 shows the calculated and measured K -factors of each ray in Fig. 5(a). In the calculation, the values of $|e(x_0, l)|^2 / P_m(l)$ are obtained from measurement data.

From Fig. 5(c) and Fig. 6, we find that the proposed model is in good agreement with the measured results.

5. Conclusion

We proposed a physical channel model of indoor wideband propagation for static terminals. We compared the analysis results of the proposed model to measured results and showed that the proposed model agreed well with the measured results. This confirms that the proposed model is sufficiently valid. The proposed model can evaluate various situations by changing the physical parameters, so it is very useful as a channel model for computer simulations.

Reference

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- [2] T. Fujii and Y. Ohta, "Dynamic Channel Modeling for Static Mobile Terminals in Indoor NLOS Environments," Proceeding of IEEE 2007VTC Fall, 2007.
- [3] Y. Ohta and T. Fujii, "Dynamic Channel Model for Static Mobile Terminals in Indoor LOS and NLOS Environments," Proceeding of IEEE 2008 VTC Spring, 2008.
- [4] T. Fujii and Y. Ohta, "Channel Modeling for Mobile Terminals in Static Indoor Conditions," ISAP2007, 2007.

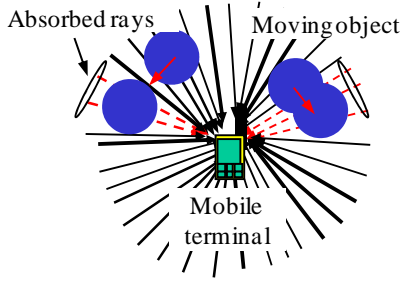


Fig. 1 Modeling of surrounding moving environment.

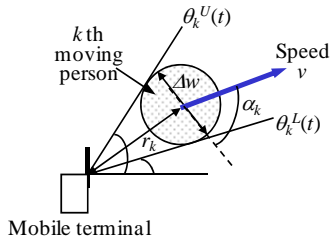
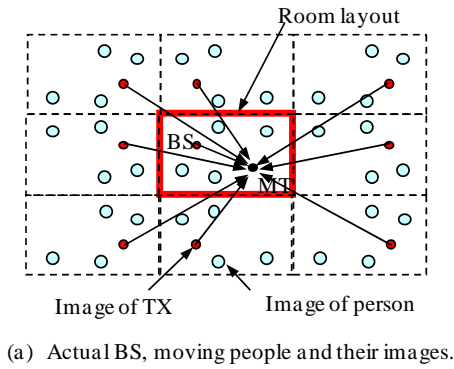
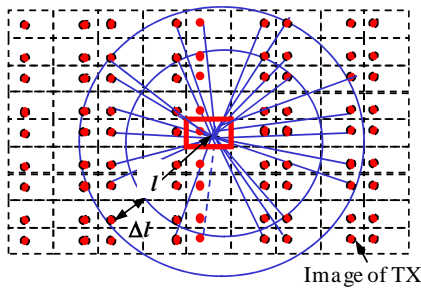


Fig.2 Analysis model



(a) Actual BS, moving people and their images.



(b) Rays with path length of between l and $l + \Delta l$

Fig. 3 Ray tracing

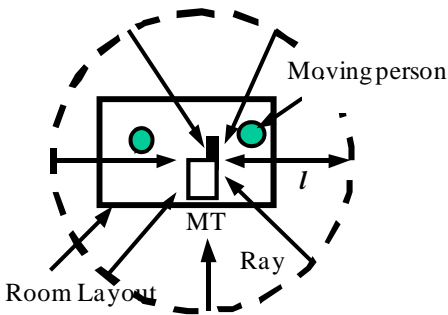
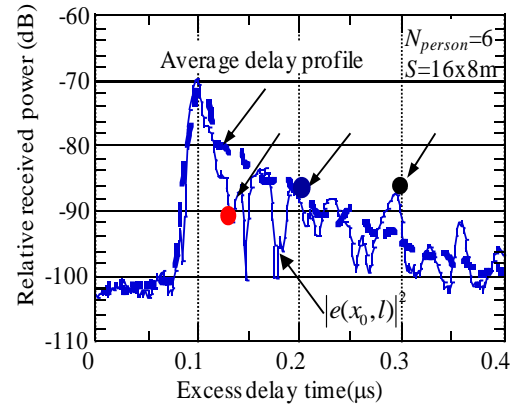
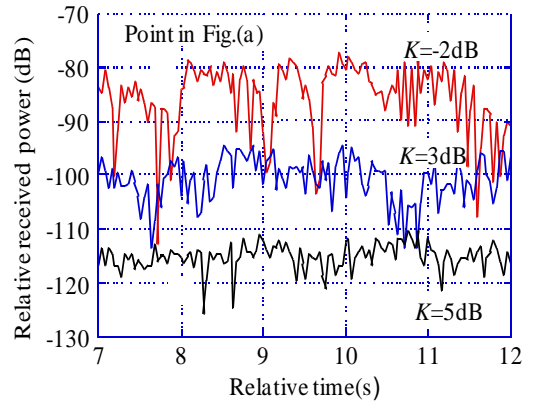


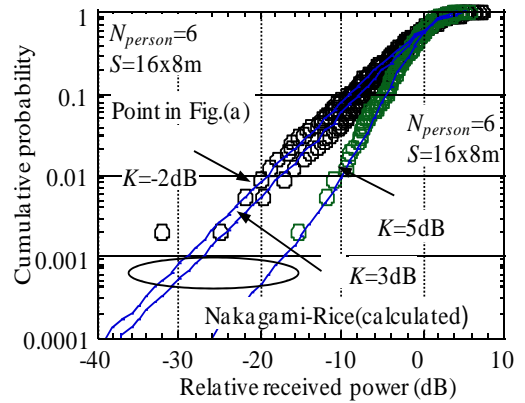
Fig. 4 Received model



(a) Instantaneous and average delay profiles



(b) Time variation of rays with different delay time



(c) CDF of rays of rays with different delay time

Fig.5 Measurement and analytical Results

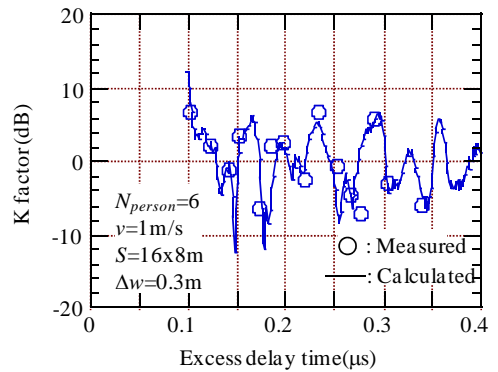


Fig. 6 Measured and calculated K-factor for delay paths