

Propagation Loss Properties in Case Human Bodies Exist Between Transmitter and Receiver

#M. Yokota¹, K. Shiiya¹, Y. Ohta², T. Fujii²

¹Department of Electrical and Systems Engineering, University of Miyazaki
1-1 Gakuen Kibanadai Nishi, Miyazaki 889-2192, Japan
E-mail: m.yokota@m.ieice.org

²Wireless System Research Center, Softbank Mobile Corp.
2-38 Aomi, Koto-ku, Tokyo 135-8070, Japan

1. Introduction

In cellular mobile communications, the number of customers who use cellular phones indoors is rapidly increasing. Many examinations have been reported about the outdoor propagation loss characteristic, and the propagation model and the presuming method are standardized. On the other hand, the propagation loss characteristics such as an underground center and indoor has been examined. In this case, the increases of the propagation loss affected by the human bodies are one of the most important causes, since the human bodies interrupt propagation path between the transmitter and receiver. For example, the propagation presumption of an underground center examined by the multi-variable analysis has been proposed [1]. Although the presumed type based on an experiment has been proposed about the propagation loss characteristic, most examination of the physical model which can take into consideration the size of a passage and the number of passersby (passerby density) in detail is not carried out. We have so far studied the shadowing properties for one or two persons from the experimental and numerical points of view [2]–[4].

If the basic examination in this article can be extended to the cases for many persons, it is applicable to the analysis of the propagation loss characteristics by human bodies in the underground center. In this article, as the basic examination of the propagation loss characteristics in the closed space where two or three human bodies exist, the numerical analysis of the propagation loss characteristic when the distance between transmitter and receiver is comparatively short is tried. Human body is modeled by lossy dielectric cylinder and the propagation loss characteristics for the passerby density and distance are examined. In order to verify the numerical results, the experimental data is measured.

2. Formulation by MoM

Consider the scattering from human bodies as shown in Fig. 1. A human body is assumed to be the two dimensional model which is approximated by the lossy dielectric cylinder with the relative permittivity ϵ_r and the conductivity σ . It is assumed that the incident cylindrical wave E_i is polarized along the z -axis, which corresponds to an E -polarized wave. In this case, the scattered wave is expressed in the integral form as follows: [5]

$$E_z^s(\mathbf{r}) = k_0^2 \sum_{\ell=1}^M \int_{S_\ell} G(\mathbf{r}, \mathbf{r}') [\epsilon_r(\mathbf{r}') - 1] E_z(\mathbf{r}') dS'_\ell \quad (1)$$

where Green's function $G(\mathbf{r}, \mathbf{r}')$ is given by the Hankel function of the second kind of order 0. The integration

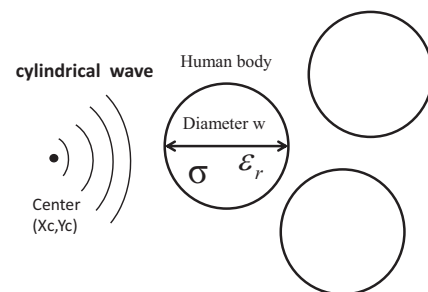


Figure 1: Modeling of the scattering by two-dimensional dielectric cylinders.

is performed over all scatterer. After adding the incident wave to the both side in Eq. (1) and applying the MoM, the following matrix equation can be obtained.

$$\sum_{n=1}^N C_{mn} E_n = E_m^i, \quad m = 1, \dots, N \quad (2)$$

where

$$C_{mn} = \delta_{mn} + \frac{jk^2}{4} \{\epsilon_r(n) - 1\} \int_{\text{cell } n} H_0^{(2)}(k\rho) dx' dy' \quad (3)$$

and E_n and $\epsilon_r(n)$ are the total electric wave and the relative permittivity at n th cell, respectively. Each cylinder is divided by N_ℓ cells and $N (= \sum_{\ell=1}^M N_\ell)$ is the total number of cells, ρ is the distance between the center of the m th cell and integration point, and E_m^i is the incident wave at (x_m, y_m) , which is the center of the cell m . The basis function of the MoM is the pulse function. The integration over each cell in C_{mn} can be obtained approximately by Richmond method. The scattered wave is calculated by using the total electric wave inside the cylinder.

3. Numerical Results

In this paper, the scattering of a cylindrical wave by lossy dielectric circular cylinders is calculated as shown in Fig. 2. The lossy cylinder is modeled as a person. The propagation properties for the passerby density and distance are examined. The center of the lossy cylinders are arranged between $-lx/2 + w/2 < X < lx/2 - w/2$ [m] and $-ly/2 + w/2 < Y < ly/2 - w/2$ [m]. As the parameters, the frequency $f = 3.35$ [GHz], relative permittivity $\epsilon_r = 50$, and conductivity $\sigma = 2$ [S/m] are assumed [6], respectively. The diameter of each cylinder is chosen by 0.35 [m], which is obtained by the proposed model in [3], [4]. The number of each cylinder is $N = 40 \times 40$.

In what follows, the case of $lx = 2$ [m], $ly = 2$ [m], 4 [m], and 6 [m] are treated. The center of each cylinder is allocated randomly, then the trial number is chosen as 150. The relative power is used and defined as the received power which is normalized by the incident power without cylinder at the same position.

Also, passerby density (η) is defined as the number per unit cross section.

Figures 3 (a) and (b) are the relative power for $\eta = 1/2$ [persons/m²] and $\eta = 3/4$ [persons/m²], respectively. The position of the source is $Y_c = 0.5$ [m]. The meaning of each line of color shows inset of figures.

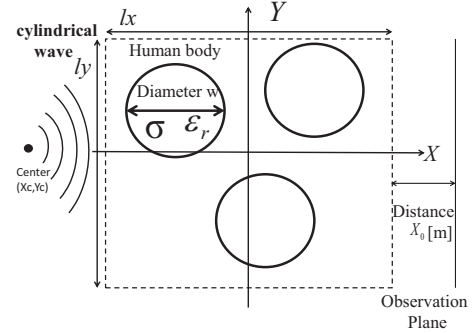
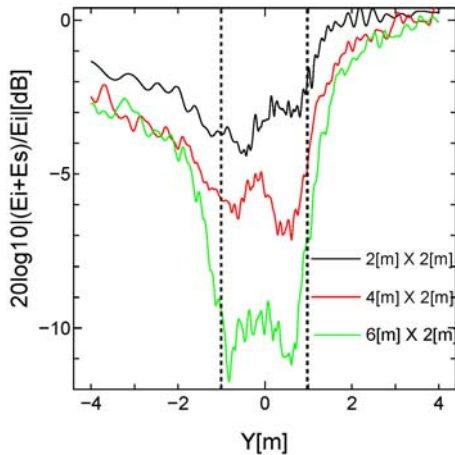
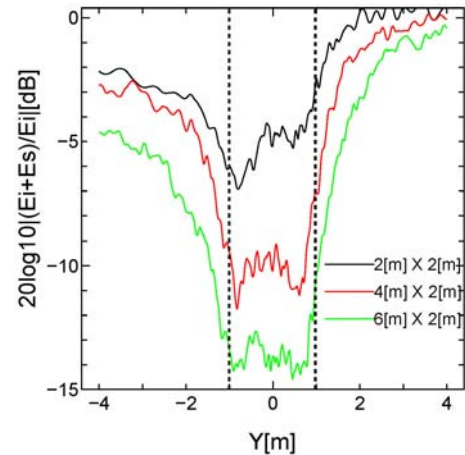


Figure 2: Geometry of the calculation of propagation loss for three persons.



(a) $\eta = 1/2$ [persons/m²]



(b) $\eta = 3/4$ [persons/m²]

Figure 3: Relative power by three lossy cylinders for $Y_c = 0.5$ [m].

From these figures, it is found that the relative power decreases as the distance becomes long and the number of persons increases. Also, the distribution of the relative power is asymmetric due to the shifted position of the source Y_c .

Figures 4 (a) and (b) are the propagation loss for the distance between the transmitter and receiver as two cases of the source position. The propagation loss is calculated by taking the average of the relative power where persons exist ($-1 \text{ [m]} \leq y \leq 1 \text{ [m]}$). From these results, it is found that the propagation loss for the distance between the transmitter and receiver is approximately 1.5 [dB/m] for $\eta = 1/2$ [persons/m²] and 2.5 [dB/m] for $\eta = 3/4$ [persons/m²], respectively.

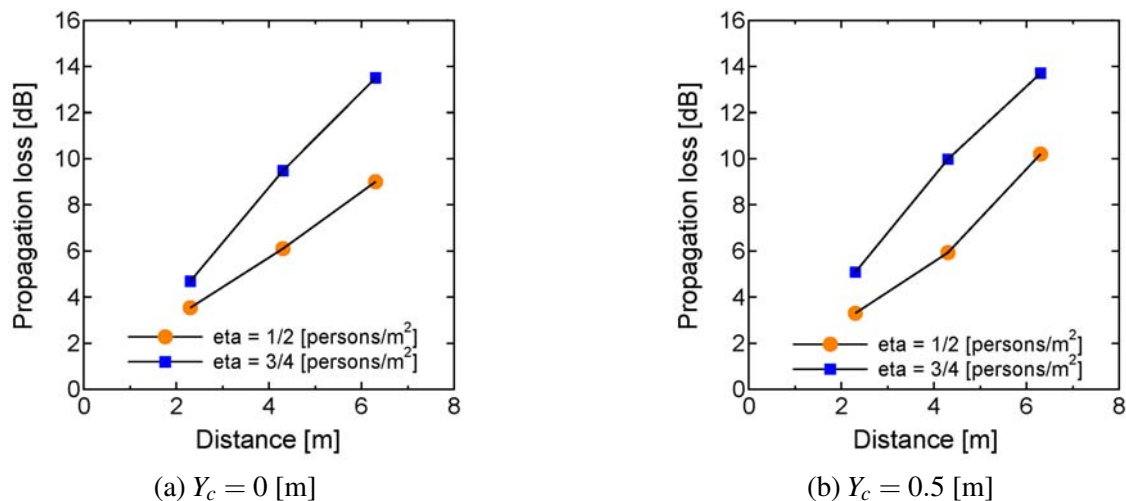


Figure 4: Propagation loss for the distance between the transmitter and receiver.

In order to verify the numerical results, we experimented. Figure 5(a) shows the overview of the experiment under consideration. The area where person can move is 2 [m] wide and 2 [m] long. The transmitting and receiving antenna is collinear antenna. We use Advantest R3765CH as the transmitter and receiver. The location of transmitting and receiving antenna is 0.15 [m] behind the area. The person is allocated the center of the area and the position of the transmitter is (-1, 0) [m]. The frequency of the measurement is 3.35 [GHz]. Figure 5(b) is the relative power for one person. The dot mark and the solid line show the measurement and the numerical result, respectively. The measurement data is good agreement with the numerical results.

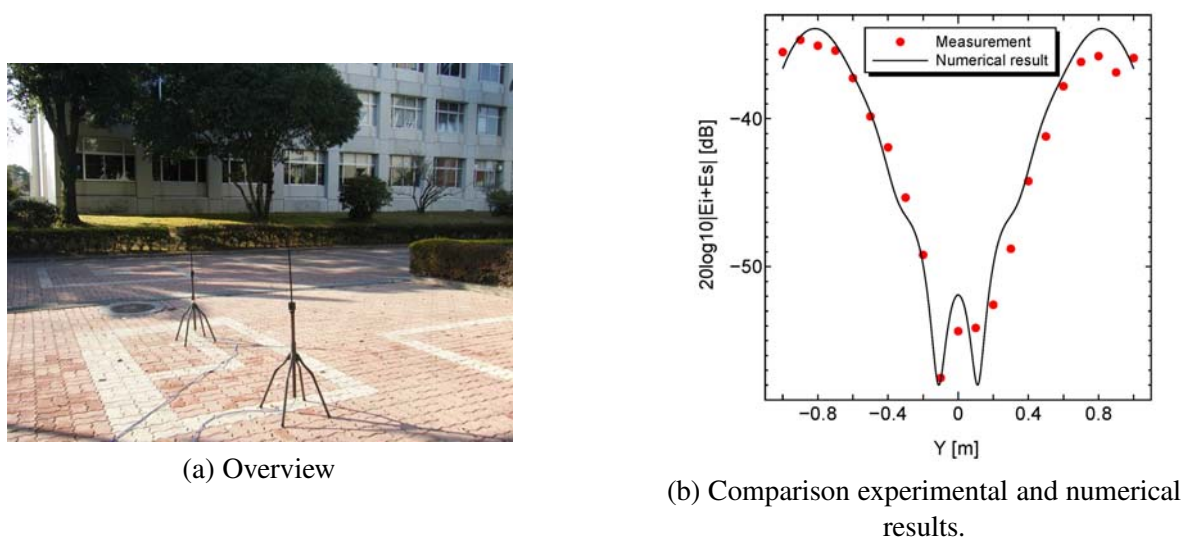


Figure 5: Experimental overview (a) and measurement result (b).

4. Conclusions

The scattering by lossy dielectric cylinder has been examined by MoM in order to presume the indoor propagation loss characteristics by human bodies between transmitter and receiver. As the numerical examination, the propagation loss for 2 to 6 human bodies in free space has been calculated, and it is found that the propagation loss for the distance between the transmitter and receiver is approximately 1.5 [dB/m] for the passerby density $\eta = 1/2$ [persons/m²] and 2.5 [dB/m] for $\eta = 3/4$ [persons/m²], respectively. As the experimental measure, it is good agreement with the numerical result. We will examine the propagation loss characteristics for many cylinders, and those for the case with walls from the statistical points of view as the future works.

Acknowledgements

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. The authors also thank to Ms. Chiharu Tomonaga for the support of calculation and experiment.

References

- [1] K. Itokawa, *et. al.*, "Propagation Characteristics in an Underground Shopping Area for 5 GHz-band Wireless Access Systems", IEEJ Trans. on Electronics, Information and Systems, Vol.124, No.1, pp.41–48, 2004.
- [2] T. Fujii and Y. Ohta, "Dynamic Channel Modeling for Static Mobile Terminals in Indoor NLOS Environments", Proc. of IEEE 2007VTC fall, 2007.
- [3] T. Fujii and Y. Ohta, "Proposal of Fading Model in Indoor Environment (1) -In case of Fixed Terminal and NLOS-", IEICE Tech. Report, AP2005-55, Jul., 2007.
- [4] Y. Ohta and T. Fujii, "An Empirical Study on Radio Wave Shadowing by Human Body", IEICE Tech. Report, AP2008-159, Jan., 2009.
- [5] A. Ishimaru, *Electromagnetic Wave Propagation, Radiation, and Scattering*, Prentice Hall, 1991.
- [6] C. C. Johnson and A. W. Guy, "Nonionizing electromagnetic wave effects in biological materials and systems", Proc. IEEE, vol.60, pp.692-718, 1972.