Numerical Examination of EM Wave Shadowing by Human Bodies Between Transmitter and Receiver

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1. Introduction

Various wireless communication services such as cellular phone and WLAN etc. in indoor environment are provided. In this case, mobile terminals frequently remain stationary. So, the communication characteristics are considerably different from those in outdoor mobile use. Now recently, the number of customers who use cellular phones indoors is rapidly increasing. Many recent studies have tackled static terminals, but all base their modeling approaches on empirical formula [1], [2]. In this case, mobile terminals used in a stationary condition receive a level variation different from that in a moving condition. Then, it was proposed that a physical channel model for a static terminal used in indoors [3]. As shown in Fig. 1, the proposed model can be considered physical parameters such as the number of moving people, their size and moving speed in order to evaluate various situations preciously [4], [5]. An experimental verification has been performed [6]. The model is two dimensional, and assumes that a moving person is represented as a disk with diameter of W [m] and its moving person perfectly absorbs the power of the paths across this width of W for simplicity. In the channel model for indoor static mobile terminals, W which corresponds to human body size is one of the most important parameters.

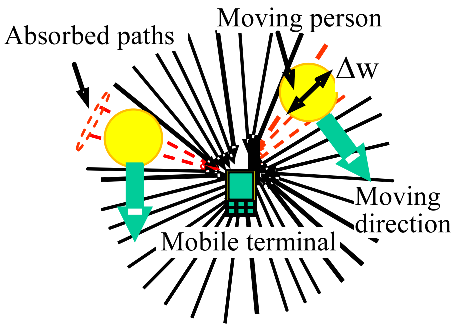


Figure 1: Proposed physical channel model for indoor static mobile terminals.

So far, each human body was modeled when human body can be assumed to exist independently even if many bodies approach. However, this assumption is not exact for many human bodies, since the absorption of electromagnetic wave is not independent due to mutual interference. So, the scope of the conventional modeling that bodies assume to exist independently is clarified in this paper. Also, another modeling is proposed when the bodies approach and can not treat independently. The scattering problem is examined by using Method of Moment (MoM) as the numerical technique. As numerical results, the received power for two circular cylinders, which are the simplest model for modeling many human bodies, is examined from the viewpoints of changing the position of the cylinders. Also, the superposition of the scattered field by each cylinder is compared with that of the original situation.

2. Numerical Analysis

Consider the scattering from human bodies as shown in Fig. 2. 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 plane 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: [7]

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

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

$$\sum_{n=1}^{N} C_{mn} E_n = E_m^i, \quad m = 1, \cdots, N \tag{2}$$

where

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

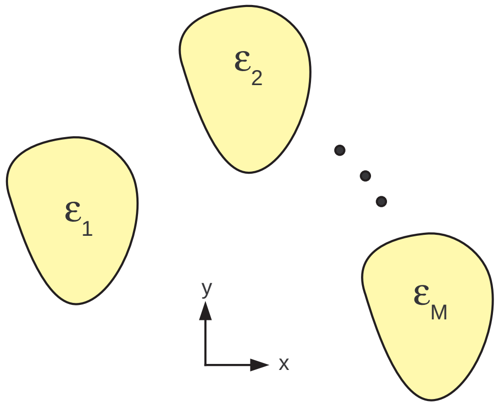
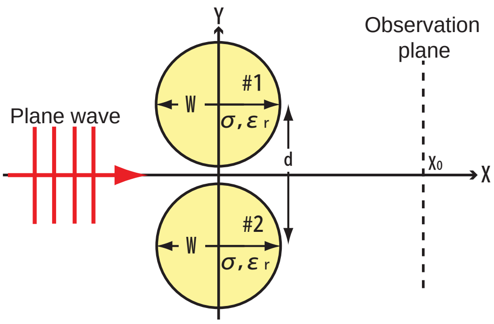


Figure 2: Geometry of scattering by dielectric cylinders.

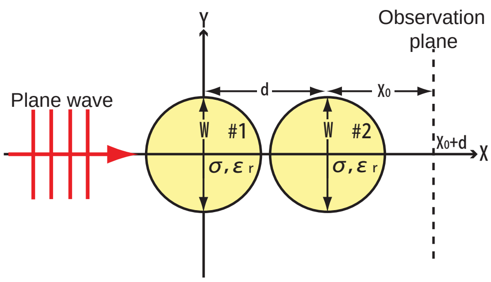
and E_n and $\varepsilon_r(n)$ are the total electric wave and the relative permittivity at nth cell, respectively. Each cylinder is divided by N_ℓ cells and $N(= \sum_{\ell=1}^{M} N_\ell)$ is the total number of cells, ρ is the distance between the center of the mth cell and integration point, and E_m^i 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 Richimond 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 plane wave by two lossy dielectric circular cylinders is calculated using the MoM. The lossy cylinder is modeled as a person. The effect of the position of cylinders is examined and the validity of the superposition of the scattered fields by each cylinder is clarified.



(a) Arrangement on y axis.



(b) Arrangement on x axis.

Figure 3: Geometry of the scattering by two lossy dielectric cylinders.

Figures 3 (a) and (b) show the geometry of the scattering by two lossy dielectric cylinders that are arranged on y and x axis, respectively. As the parameters, the frequency $f = 3.35$[GHz], relative permittivity $\varepsilon_r = 50$, and conductivity $\sigma = 2$[S/m] [8] are assumed, respectively. The diameter of each cylinder is chosen by 0.35[m], which is obtained by the proposed model in [4], [5].

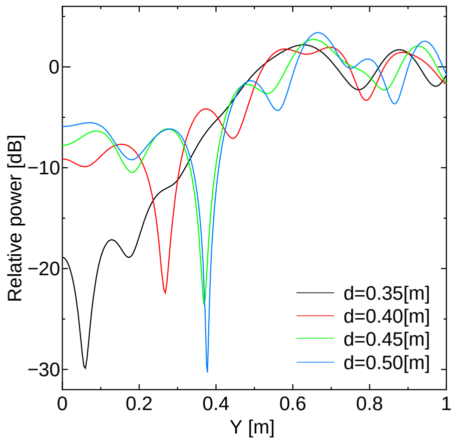


Figure 4: Relative power by two lossy dielectric cylinders arranged on y axis. ($X_0 = 1$m)

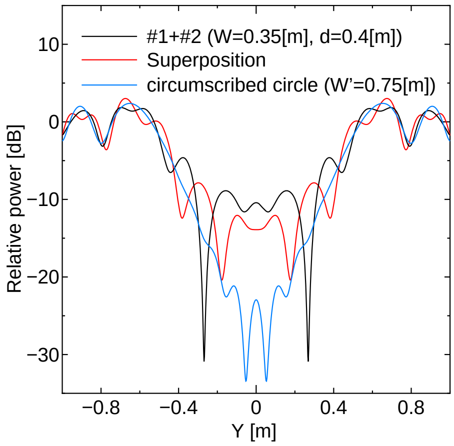


Figure 5: Comparison of the relative power by the superposition by one cylinder with $W =$ 0.35m arranged on y axis.

The relative power by two cylinders that are arranged on the y axis for various distance d of each cylinder is shown in Fig.4. The relative power is defined as the received power which is normalized by the incident power without cylinder at the same position. It is found that the incident wave is shadowed by the two cylinders and absorbed in the region of the cylinder back. Also, on the outer region of the cylinder, the scattered field interferes with the incident field. Figure 5 shows the comparison the results of the superposition of the scattered field by each cylinder and the original situation. Also, the scattered field by the cylinder that is circumscribed two cylinders is shown. Although the result near the x axis is different each other because the incident fields go through, the agreement with the results of the outer region of the cylinder is seen.

For the case of $W = 0.35$m, two cylinders are touched each other. In this case, the equivalent circular cylinder with the double radius 0.70m is one of the models as shown in Fig. 6. Figure 7 shows the relative power for the equivalent cylinder. The black line indicates the relative power by this equivalent circular cylinder. The red line shows the relative power of the two cylinders. These results are good agreement each other. From this point, it is found that the relative power by the two cylinders is almost the same as that of the equivalent cylinder due to touching.

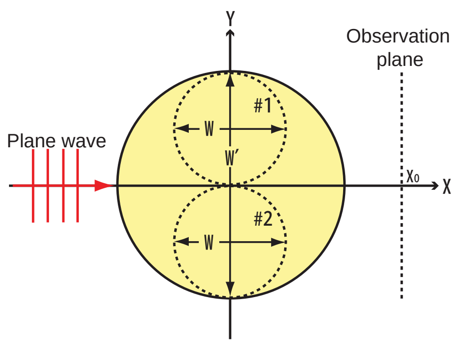


Figure 6: Modeling of a equivalent cylinder]

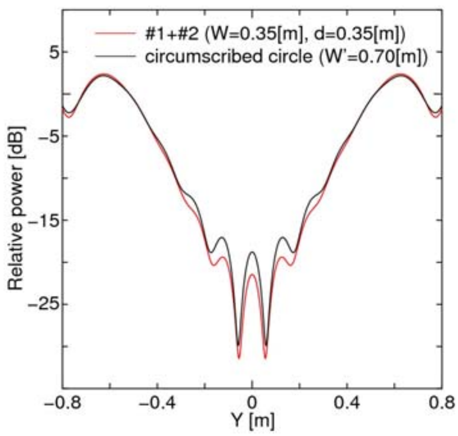


Figure 7: Comparison of the relative power for the equivalent cylinder. ($X_0 = 1.0$m)

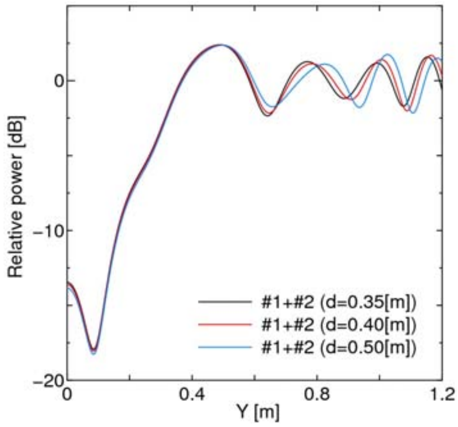


Figure 8: Relative power by two cylinders arranged on x axis for various distance d. ($X_0 =$ 1.0m)

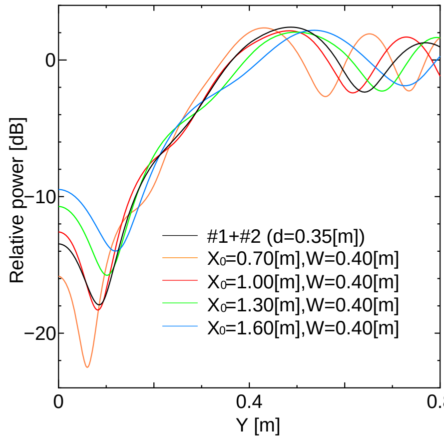


Figure 9: Relative power for the superposition by one cylinder with $W = 0.4$m arranged on x axis for various observation position.

The relative power by two cylinders arranged on x axis is shown in Fig. 8 for various distance d. The relative power behind the cylinder is the same for three cases of the distance. This is due to the attenuation of the electromagnetic power at the first cylinder. Figure 9 indicates the relative power for one cylinder with $W = 0.4$m arranged on x axis for various observation position. When the observation position is near the cylinder, the relative power is approximated by the results of one cylinder.

4. Conclusions

The scattering by lossy dielectric cylinder has been examined by MoM in order to investigate the shadowing by human bodies between transmitter and receiver. In this paper, the relative power for two cases of the cylinders arrangements has been indicated. It has been shown that the superposition of the scattered field by each independent cylinder is useful under certain situation. We will examine the shadowing property for many cylinders from the statistical points of view as the future works.

Acknowledgments

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