On Distance Characteristics Parameters Evaluated by a Two-Ray Ground Reflection Model

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1. Introduction

Recently, in conjunction with the ubiquitous information and communication society, much effort has been focused on the development of efficient networks including both wired and wireless communications. In this study we consider field estimation for mobile terminals such as cellular phones and PHS moving around urban areas. In this case, MS (Mobile Station) must do hand-over from one BS (Base Station) to other to maintain quality of communications resulting in higher receiving powers. Failures of smooth hand-over lead to a poor quality of communications. One of these causes is a rapid disturbance of receiving powers due to reflections and diffractions by dense high rise buildings in urban areas [1], and the other is due to a poor access of MS to the appropriate BS.

In the real situations, the attenuations might be complicatedly related to building heights and density of buildings in the urban or suburban areas, and it is very difficult to evaluate their characteristics. Therefore, we have proposed a simple estimation method for electric field distributions in urban or suburban areas where there exist several accessible BSs and we have determined amplitude modification $\alpha[dB]$, propagation order β and modification distance $\gamma[m]$ using the proposed method by employing Hata's equations which were empirically obtained from many outdoor data. In that study we have used estimation method using incident wave [2].

In this paper we determine α and β using the proposed estimation method with incident and reflection waves by comparing with Hata's equations [3]. we neglect γ because it is very small compared with propagation distance. Then we simulate received powers when the MS moves around some cells, and we discuss the mechanism of hard and soft hand-overs for the MS in the cellular electromagnetic environments.

2. Field estimation

In this study, we assume cellular hexagons to cover all the communication areas. These cells construct honeycombs [4], and it is assumed that a BS exists at the center of each cell. In this paper, we propose an approximate method using the two-ray ground reflection model to estimate electric field intensity when MS moves around some cells randomly. The random walk of the MS is performed based on the Monte Carlo method [4]. The geometry of the cells and random walk are shown in Figure 1.

The present field estimation is based on a simple computational method using only an incident wave from the source at BS and a reflected wave from the ground plane. It is assumed that the antennas of BS and MS are both small dipole antennas. Figure 2 shows the unit vector $\boldsymbol{p}$ of source and the position vector $\boldsymbol{r}$ from source to observation point. The vector expressions of electromagnetic field are given as follows [5]:

$$\begin{aligned} \boldsymbol{E} &= \sqrt{45W}\sin\theta\frac{e^{-j\kappa r}}{r}\boldsymbol{\Theta}^v(\boldsymbol{r},\boldsymbol{p}) \\ \boldsymbol{H} &= Y_0\sqrt{45W}\sin\theta\frac{e^{-j\kappa r}}{r}\boldsymbol{\Theta}^h(\boldsymbol{r},\boldsymbol{p}) \end{aligned} \quad (1)$$

where the absolute gain of this antenna $G = 1.5$ has been used. The time dependence $e^{j\omega t}$ is assumed, and the wave number in the free space is given by $\kappa=2\pi/\lambda$. The small dipole antenna exhibits maximum

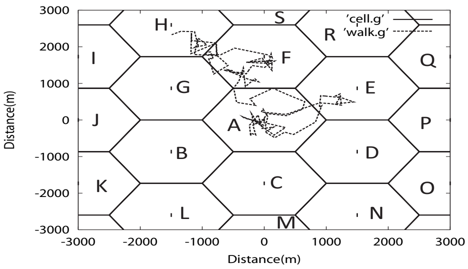


Figure 1: Cell geometry and Random walk at Mobile station

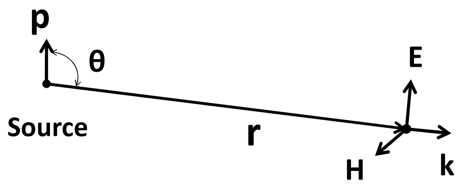


Figure 2: Polarization of Dipole Antenna $\boldsymbol{p}$ and Distance Vector $\boldsymbol{r}$ from Source to Observation Point with Electromagnetic Vectors $(\boldsymbol{E}, \boldsymbol{H})$.

radiation at $\theta = 90°$. However, we need a beam tilting angle ϕ for its directivity in order to reduce interferences of the waves from antennas in the adjacent cells. The unit vectors of electromagnetic polarization are given by

$$\begin{aligned} \boldsymbol{\Theta}^h(\boldsymbol{r}, \boldsymbol{p}) &= \frac{(\boldsymbol{r} \times \boldsymbol{p})}{|\boldsymbol{r} \times \boldsymbol{p}|} \\ \boldsymbol{\Theta}^v(\boldsymbol{r}, \boldsymbol{p}) &= \frac{[(\boldsymbol{r} \times \boldsymbol{p}) \times \boldsymbol{r}]}{|(\boldsymbol{r} \times \boldsymbol{p}) \times \boldsymbol{r}|}. \end{aligned} \tag{2}$$

The expression of reflected ray is written as follows:

$$\boldsymbol{E_0} = \sqrt{45W} \sin\theta_0 \frac{e^{-j\kappa r_0}}{r_0} \boldsymbol{e_0} \tag{3}$$

where $r_0 = r_1 + r_2$, and the following relation is given by

$$\begin{aligned} \boldsymbol{e_0} &= R^v(\theta_i)[\boldsymbol{\Theta}^v(\boldsymbol{r_1}, \boldsymbol{p}) \cdot \boldsymbol{\Theta}^v(\boldsymbol{r_1}, \boldsymbol{n})]\boldsymbol{\Theta}^v(\boldsymbol{r_2}, \boldsymbol{n})] \\ &+ R^h(\theta_i)[\boldsymbol{\Theta}^h(\boldsymbol{r_1}, \boldsymbol{p}) \cdot \boldsymbol{\Theta}^h(\boldsymbol{r_1}, \boldsymbol{n})]\boldsymbol{\Theta}^h(\boldsymbol{r_2}, \boldsymbol{n})] \end{aligned} \tag{4}$$

where $\boldsymbol{r_1}$ is a distance vector from source to reflection point, and $\boldsymbol{r_2}$ is a distance vector from reflection point to observation point. And $\boldsymbol{n}$ is a normal vector. Received power is subject to a rapid disturbance due to reflections and diffractions by dense high rise buildings in urban areas. Therefore, we propose the following total received electoric field distribution [5].

$$\begin{aligned} \boldsymbol{E_t} &\simeq \sqrt{45W} \sin\theta \frac{e^{-j\kappa r}}{r^\beta} \boldsymbol{e_t} \\ \boldsymbol{e_t} &= \boldsymbol{\Theta}^v(\boldsymbol{r}, \boldsymbol{p}) + \frac{\sin\theta_0}{\sin\theta} \cdot \frac{r^\beta e^{-j\kappa(r_0 - r)}}{r_0^\beta} \boldsymbol{e_0} \end{aligned} \tag{5}$$

where β is a propagation order. Eq.(1) shows $|E| \propto r^{-1}$, that is, $\beta = 1.0$ in the free space. In the urban areas, however, we have $\beta \neq 1.0$ and attenuation is enhanced as β is increased. We apply the amplitude modification $\alpha[dB]$ to Eq.(5), and rewritting the its relation in dB leads to the following equation:

$$|\boldsymbol{E_t}| \simeq A + \alpha - 20\beta \log_{10}(r) \ \ [\mathtt{dBV/m}]. \tag{6}$$

3. Decision of Parameters

In the real situations, the attenuations might be complicatedly related to building heights and density of buildings in the urban or suburban areas, and it is very difficult to evaluate their characteristics. In this section, we determine the amplitude modification $\alpha[dB]$ and the propagation order β by employing Hata's equations which were empirically obtained from many outdoor data [3].

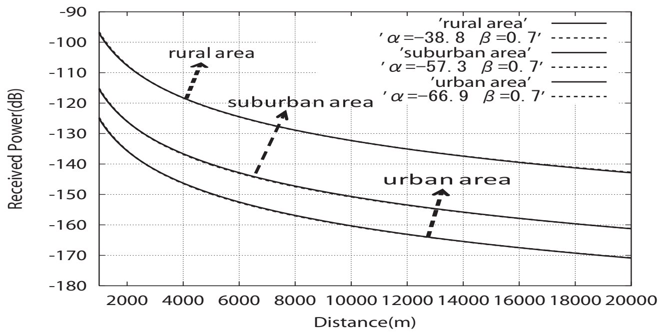
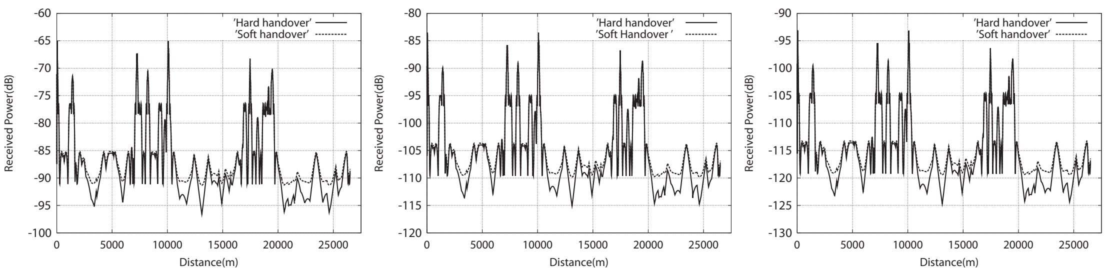


Figure 3: Hata's equation and two-ray ground reflection model using α and β.

Figure 3 shows a comparison of our proposed method with Hata's equation. In this figure six curves are shown: three curves are numerical results computed by Eq.(6), other three curves are numerical results obtained by Hata's equation in rural, suburban and urban areas. We select parameters as cell radius 20[km], source height 30[m], receive height 1.5[m], input power 1[kW], dielectric constant ϵ_r=5.0, conductivity σ=0.0023[S/m] and frequency f=800[MHz]. It is shown that two curves obtained by proposed method and Hata's equation are in good agreement within an error of 0.084[%] in rural area. It is also demonstrated that two curves obtained by proposed method and Hata's equation in suburban area are in good agreement within an error of 0.092[%], and two curves obtained by proposed method and Hata's equation in urban area are in good agreement within an error of 0.072[%]. In Figure 3, we have selected α and β such as $\alpha = -38.8[dB]$ and $\beta = 0.7$ in rural area, $\alpha = -57.3[dB]$ and $\beta = 0.7$ in suburban area, $\alpha = -66.9[dB]$ and $\beta = 0.7$ in urban area. As a result, values of β are all the same, and it is found that amplitude modification α is very important.

4. Numerical examples

Using α and β defined in the previous section, we numerically compute received power for handover simulation where the MS moves randomly along cells shown in Figure 1. The same frequency is used for each cell, since we have assumed the W-CDMA system in this numerical simulation. We select parameters as cell radius 1[km], frequency 800[MHz], source height 30[m], receive height 1.5[m], beam tilting angle $\phi 3.43^\circ$, input power 1[kW], dielectric constant ϵ_r=5.0, conductivity σ=0.0023[S/m]. The times for random walk are 100, and distance deviation of one step is 200[m].



(a) rural area (b) suburban area (c) urban area

Figure 4: Handover simulation.

Figure 4 shows the received power of MS for handover simulation, and hard handover simulation and soft handover simulation are shown in each figure. However, the values in y-axis are different in these figures: (a) shows an example of received power where all the cell are rural area. (b) shows an example of received power where all the cell are suburban area. (c) shows an example of received power where all the cell are urban area. It is shown in these figures that the received power of soft handover keeps higher than that of hard handover.

We consider reduction rate of times for soft handover in comparison with hard handover. Table 1 shows the reduction rate of handover times computed in Figure 4. In the Table 1, we use a margin which means a margin of received power given by BSs, that is, MS carries out handover when present received power from one BS is lower over 1.0[dB] than other BS in case of margin=1.0[dB]. It is shown in the Table 1 that the reduction rate is 18.5[%] when the margin is 1.0[dB], the reduction rate is 31.9[%] when the margin is 2.0[dB], and the reduction rate is 39.8[%] when the margin is 3.0[dB]. It is demonstrated that the reduction rate is large when the margin becomes large.

Table 1： Reduction rate

Margin [dB]	Reduction Rate [%]
1.0 dB	18.5 %
2.0 dB	31.9 %
3.0 dB	39.8 %

5. Conclusion

In this paper, we have determined α and β using the proposed estimation method with incident and reflection waves by comparing with Hata's equations, and we have calculated numerically the received power for handover simulation when the MS moves randomly along cells whose propagation environments are assumed to be rural, suburban and urban areas. In the numerical simulations, it has been shown that the received power of soft handover is higher than that of hard handover. It has been demonstrated that the reduction rate is large when the margin becomes large.

We have to investigate handover simulation of MS when the MS walks randomly around inhomogeneous cells. This study deserves as our future work.

Acknowledgments

The work was supported in part by a Grand-in Aid for Scientific Research (C) (21560421) from Japan Society for the Promotion of Science.

References

[1] K. Uchida, H. Fujii. M, Nakagawa. X.F. Li, and H. Maeda, , "FVTD analysis of electromagnetic wave propagation along rough surface," IEICE Trans. Commun. (Japanese Edition), vol.J90-B, no.1, pp.48-55, Jan. 2007.

[2] T. Tamaki, K. Uchida, J. Honda, "Decision of Parameters for Distance Characteristics and Simulation of Handover," Communication and Information Netwarking, vol.34, no.3, BCT2010-12 pp.45-48, Jan. 2010.

[3] M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Radio Services", *IEEE Trans. Veh. Technol.*, vol. VT-29, no.3, pp.317-325, Aug. 1980.

[4] Y. Nagayasu, T. Tamaki, J. Honda and K. Uchida:"Field Estimation in Relation to Hand-Over in Cellular Electromagnetic Environments", Proceedings of KJJC-AP/EMC/EMT 2009, pp.323-326, May 2009.

[5] K. Uchida, T. Tamaki, and J. Honda, "On Received Power Electric Field of Mobile Station Walking Randomly in a Cellular Electromagnetic Environment," IEEJ Technical Report, EMT-09-138, EMT-09-138, pp.21-24, Nov. 2009.