Time-Space Path Modeling with two different attenuation scattering disks for Wideband Mobile Propagation

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1.Introduction

In the 3rd generation mobile cellular system such as W-CDMA and the 4th generation of mobile cellular systems, examinations of spatial processing techniques such as Adaptive Array Antenna and Space diversity techniques have been investigated [1],[2]. In order to estimate accurately the performance of these spatial processing techniques in Wide-Band mobile communications, a time-space path model in which both characteristics of the delay profile and of the spatial arrival angle profile for traveling waves can be simulated at the same time is required.

In the privious works, the propagation model with a profile of the Gauss distribution is used as an angle propagation model and the model with a profile of the exponential distribution is used as the propagation delay time model [3]. These models are very simple and the analysis of the propagation characteristics using these propagation models is comparatively well in agreement with measurements. Then they have been widely used as the theoretical analytic and the numerical simulation model. On the other hand, Ray trace model and the scattering model are proposed as models which can explain measurement results. Especially, the scattering model which is simplified one of Ray trace model is used as the model which gives the arrival direction of the electric wave from the base station to the mobile station. However, it is known that the model can not always succeed to explain sufficiently the measured results of receptions at the base station.

In our privious works, we propsed a new time-space path model expanding the scattering model[4].We difine this model as " the privious proposed model".

In this paper, we propose a new time-space path model expanding the privious proposed model taking the arrengement of buildings in the city part into account. And we show that the analysis using the proposed model well agree with the field measurement results.

2. The model

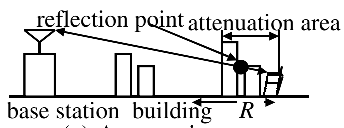
2.1 Clark's model and Modified Clark's model

In order to explain profiles of the received signal at the mobile station, Clark proposed the scattering model with the scattering ring around the mobile station. In this model, electric waves emmitted by the base station reach to the mobile station from all directions after scattered by the ring. This model can explain the instantaneous fading [3] . On the other hand, the reception model which uses Clark's model conversely has been proposed to explain the profile of the electric wave observed at the base station. This model is called Modified Clark's model. In this case, the electric wave transmitted at the mobile station is reflected on the scattering ring or on the scattering disk and reaches to the base station. However, it does not necessarily succeed to explain the measured profile of electric waves at the base station.

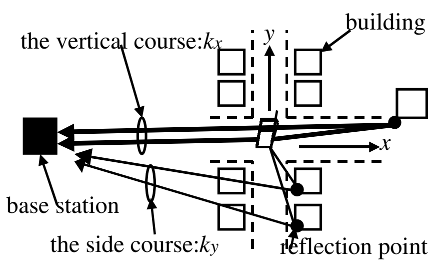
2.2 The privious proposed model

In our privious works, we proposed a new time-space path model expanding Modified Clark's model as follows[4].

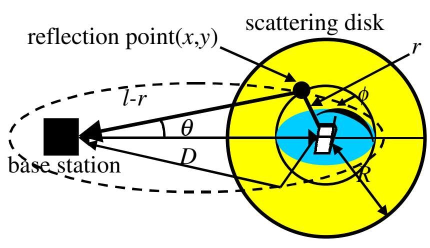
Usually the electric wave transmitted from a low antenna at the mobile station penetrates into buildings located around, and the power of the electric wave is attenuated. Here we define the area from the mobile station to reflection point as the "attenuation area of the electric wave". Fig.1(a) shows the attenuation area[5].In this model, the propagation loss in this area increase proportion-



(a) Attenuation area



(b) Different attenuation of courses



(c) The privious proposed model

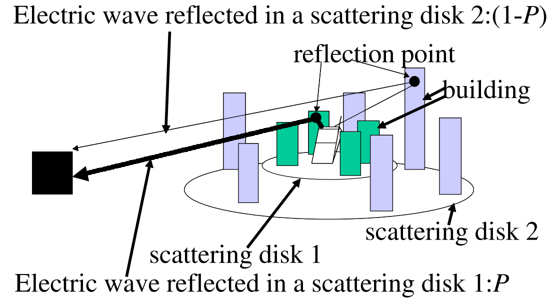
Fig.1 The privious proposed model

ally to propagation distance r, which has to be added to the free space propagation loss. The function of attenuation in this area is approximated by the exponential function

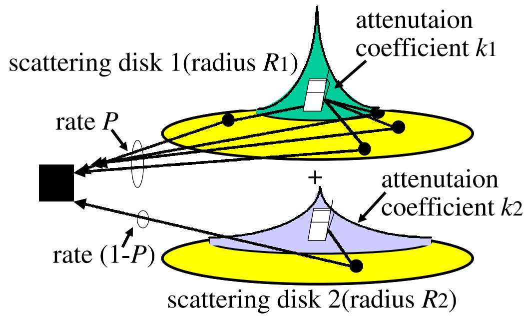
$$f(r) \propto \exp\left[-\frac{r}{k}\right] \tag{1}$$

where k is the attenuation coefficient.

Furthermore, we have to take the direction of road into the consideration. As is shown in Fig.1(b), the propagation characteristics depends on the direction of the road where the mobile station is situated on. In the following, "the vertical course" is defined to be parallel and "the side course" is defined to be perpendicular to the direction of the base station [6]. In "the vertical course" , the propagation loss is relatively small because the prospect spreads to the direction of the base station. On the other hand, in "the side course", the propagation loss is relatively large because the direction of the base station is blocked off. Taking this fact into consideration, it is reasonable to use different attenuation coefficients in the direction of "the vertical course" and in the direction of "the side course". In this model, "the vertical course" and "the side course" are given by x axis and y axis, respectively. And we denote the attenuation coefficients of the x and y axis by k_y and k_y, respectively. Fig.1(c) shows the privious proposed model.



(a) Reflection rate by the arragement of buildings



(b) The model with two scattering model

Fig.2 The proposed model

2.3 The proposed model with two scattering disks

In general the mobile station is surrounded by various types of buildings in the city area as shown in Fig.2(a). In this case, almost all electric waves are reflected by the buildings located near the mobile station and arrive at the base station. On the other hand a few electric waves pass through an area of the building group near the mobile station and be reflected by remote high-rise buildings, then arrive at the base station.

So, we propose a new time-space path model (expanding the privious proposed model) with two kinds of scattering disks. One of these scattering disk(disk 1) covers the area of the building group located near the mobile staion, and the other(disk2) contains high- rise buildings remote from the mobile station. In this model, the rate of reflection in disk 1 is assumed to be P(The rate of reflection in the disk 2 becomes then to (1-P)).

The attenuation coefficient while passing the attenuation area in the disk 1 is denoted by k_1 and in the disk 2 is denoted by k_2. Generally the amount of attenuation in the disk 1 is lager than that in the disk 2. The propose model with two scattering disks is shown in Fig.2(b).

The attenuation functions f_1(in the scattering disk 1) and f_2(in the scattering disk 2) are approximately given by exponential function

$$f_1(x, y; k_{1x}, k_{1y}) = \alpha_1 \bullet \exp\left(-\sqrt{\left(\frac{x}{k_{1x}}\right)^2 + \left(\frac{y}{k_{1y}}\right)^2}\right) \tag{2}$$

$$f_2(x, y; k_{2x}, k_{2y}) = \alpha_2 \bullet \exp\left(-\sqrt{\left(\frac{x}{k_{2x}}\right)^2 + \left(\frac{y}{k_{2y}}\right)^2}\right) \tag{3}$$

where α_1 and α_2 are normalization factors and x and y are local coordinates with the position of the mobile station to be (0,0).The whole amount of attenuation $f(x,y)$ is then expressed in terms of P as

$$f(x, y) = p \bullet f_1(x, y; k_{1x}, k_{1y}) + (1-p) \bullet f_2(x, y; k_{2x}, k_{2y}) \; . \tag{4}$$

3. Evaluation Items

In this paper , we evaluate the arrival angle distribution and the delay time distribution using quantities such as the arrival angle θ, the angle spread σ_θ, the propagation distance l, the propagation distance spread σ_l, the spatial correlation ρ_s, and the frequency correlation ρ_f.

We define the arrival angle probability distribution $p_\theta(\theta)$ as the electric power from the angle θ normalized by all the received electric power. In terms of $p_\theta(\theta)$ the arrival angle spread σ_θ is given by

$$\sigma_\theta = \sqrt{\int_0^{2\pi} (\theta - \theta_0)^2 p_\theta(\theta) d\theta} \qquad (5)$$

where θ_0 represents the average value of arrival angle profile, and is given by $\theta_0 = \int_0^{2\pi} \theta p_\theta(\theta) d\theta$.

We define the propagation delay probability distribution $p_l(l)$ as the received electric power normalized by all the received electric power. The delay spread σ_l is given, in terms of $p_l(l)$, by

$$\sigma_l = \sqrt{\int_0^{\infty} (l - l_0)^2 p_l(l) dl} \qquad (6)$$

where l_0 represents the average value of delay profile, and is given by $l_0 = \int_0^{\infty} l p_l(l) dl$. The spatial correlation ρ_s can be given by

$$\rho_s \simeq \left| \int_0^{2\pi} \exp\left(j\frac{2\pi d_H}{\lambda} \cos\theta \right) p_\theta(\theta) d\theta \right|^2 \qquad (7)$$

where d_H represents the distance between two antennas, and the frequency correlation ρ_f can be given by

$$\rho_f \simeq \left| \int_0^{\infty} \exp\left(j\frac{2\pi \Delta f l}{c} \right) p_l(l) dl \right|^2 \qquad (8)$$

where Δf represents the difference of frequency and c is the speed of light.

4. Numerical simulation

In our numerical simmulation, reflection points are generated at random in the scattering disk 1 with a rate of P and in the scattering disk 2 with a rate of $(1-P)$. The local position (x,y) of the reflection point can be given by

$$(x, y) = (r\cos\phi, r\sin\phi) \qquad (9)$$

where r is a distance between the mobile station and reflection point and ϕ is the angle between the line from the mobile station to the reflection point and the line from the base station to the mobile station as shown in Fig.1(c).

The attenuation of the electric power is expressed by (2),(3). And then, we can compute the received electric power, the propagation distance and the arrival angle. In the numerical simulation the arrival angle is divided into 0.1 degree intervals and the propagation distance is divided into 1m intervals.

5. Results and Discussions

Here, we take a distane D=2km, the radius of the scattering disk 1 R_1=1km, and the radius of the scattering disk 2 R_2 =1km, for example.

In the measurement in the urban area, it is known that σ_θ has the value of $1° \sim 3°$ approximately and that σ_l has the value of 0.2km~0.3km approximately [7]. It can be shown that these results are obtained in this model with k_{1x}=0.01km, k_{1y}=0.01km, k_{2x}=0.17km, k_{2y}=0.04km. Then, in the follwing analysis we adapt these values for the attenuation coefficients k_{1x},k_{1y},k_{2x} and k_{2y}.

In Fig.3 the P-dependence of σ_θ and σ_l are given, from which we can see that the measured results of σ_θ $(=1° \sim 3°)$ and σ_l (=0.2km~0.3km) are satisfied with P<0.98.

Fig.4 show the probability density function $p_\theta(\theta)$ of arrival angle θ for various values of P. From Fig.4 we find that $p_\theta(\theta)$ can be approximately expressed in the exponential distribution.

Fig.5 show the probability density function $p_l(l)$ of the propagation distance with the parameter P. From Fig.5, the point of 2.2km is a point of inflection point, and this graph can be approximately expressed in

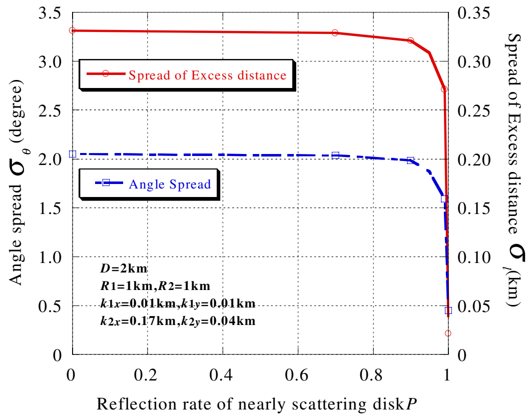


Fig.3 Spreads

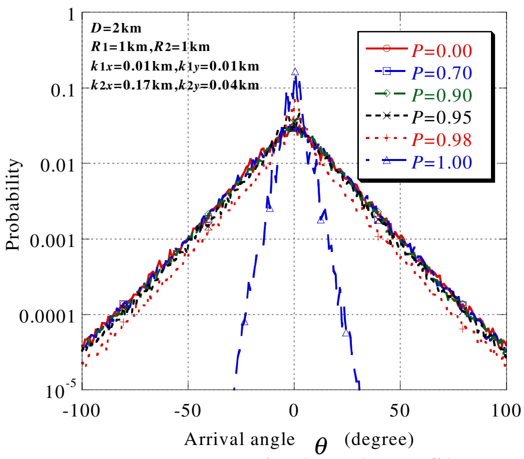


Fig.4 Arrival angle profile

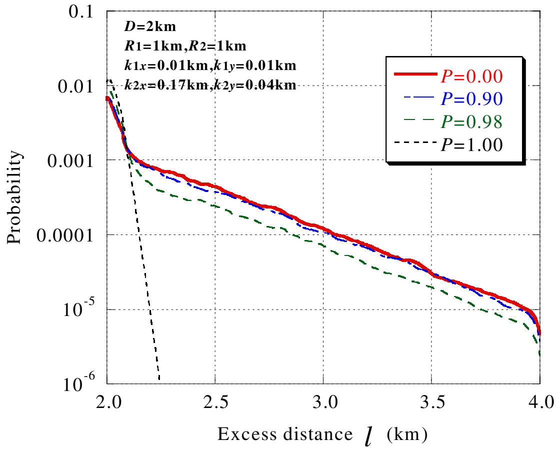


Fig.5 Delay profile

terms with two kinds of exponential distributions.

The spatial correlation ρ_s and the frequency correlation ρ_f with the parameter P are shown in Fig.6 and Fig.7, respectively. The measured values of ρ_s shown in Fig.6 were obtained in Tokyo using the frequency of the 900MHz band[7]. The antenna height of the base station is 135m. The measured result can be explained with choosing the suitable values of P(example for P=0.98). Also, the measured values of ρ_f observed in Tokyo using the frequency of the 800MHz band are shown in Fig.7[7],[8], which shows that these values are given in the range of 0.90<P<0.98. From these results, we can prove that the proposed model can explain both the arrival angle distribution and the delay distance distribution.

6.Conclusions

In this paper, we proposed the new time-space path model with two scattering disks. The disk 1 is assumed to scatter electric waves by buildings located near the mobile station and disk 2 is assumed to scatter electric waves by buildings in the remote area. This assumption can be verified by Fig 5 which show that the disk 1 works effectively, in the efficiency of attenuation in the near area to the mobile station, and the disk 2 works in the remote area. Then, we can conclude that the proposed model explain well the field measurement results of the arrival angle distribution and the delay time distribution in the urban area at the same time.

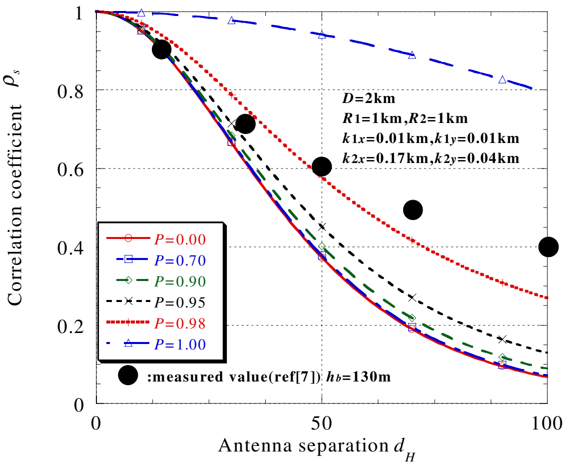


Fig.6 Spatial correlation

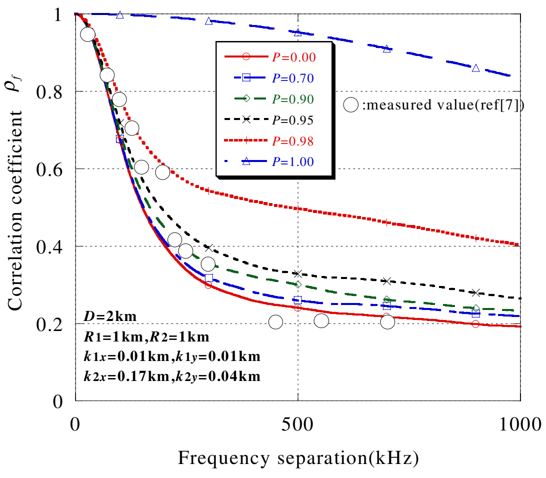


Fig.7 Frequency correlation

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