MODELLING OF MULTIPATH DELAY PROFILE IN URBAN AREA

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1. INTRODUCTION

Mobile radio communication systems are in the process of being digitalized. Transmission performance of digital signals is degraded by multipath propagation caused by reflected and diffracted waves. Thus, any design system that is adapted will have to predict the average excess delay and the delay spread which affect the digital signal transmission performance.

The average excess delay and delay spread have been examined for various building configurations in urban and rural areas[1], and several delay profile models have also been proposed. To our knowledge, however, none of the models address the relation between the delay profile and urban propagation parameters. These models are thus not able to predict the delay characteristics required for systems design.

This paper proposes a multipath propagation model which can be used to predict the delay profile in urban areas using building configurations and distance between the base and the mobile stations. Finally, the accuracy of the model is verified through trial measurements.

2. MULTIPATH PROPAGATION MODEL

2.1 MODEL

The multipath propagation model proposed here is shown in Fig. 1. The model has two different propagation modes: the first delay wave, and the second delay wave group. The path of the first delay wave corresponds to P_0 and its time delay τ_0 is calculated from path length d_0. The path of the second delay wave group corresponds to P_i and its time delay τ_i is calculated from path length $d_{i1} + d_{i2}$.

In urban areas, a delay profile can be characterized by the first delay wave arriving at the mobile station and the second delay wave group, as shown in Fig. 2. The former wave arrives with the shortest time delay, and usually has a higher level than the second delay wave group. The propagation path of the latter wave group is from base station to specific building to mobile station.

2.2 PROPAGATION LOSS OF THE FIRST DELAY WAVE

The P_0 propagation path in urban areas is generally not line-of-sight because the mobile station antennas are much lower than the surrounding buildings. At a frequency of 1452.5[MHz], and antenna heights of 50[m] and 1.5[m] for the base and mobile stations, respectively, the propagation loss L_b is given by (d_0:[km])[2],

$$L_b = 127.37 + 33.77 \text{ Log } d_0 \quad [\text{dB}]. \qquad (1)$$

2.3 PROPAGATION LOSS OF THE SECOND DELAY WAVE GROUP

The specific reflective building is usually higher than the other buildings. The path between the base station and the specific building is a free space propagation path because it is line-of-sight. However, the path between the specific building and the mobile station is an urban propagation path.

Therefore, the loss L_i of path P_i is given by,

$$L_i = 20 \text{ Log } \{(d_{i1} + d_{i2}) / d_{i2}\} + L_b + L_r \quad [\text{dB}], \qquad (2)$$

where L_r is the reflection loss of buildings.

3. EXPERIMENT

3.1 EXPERIMENT METHOD

To evaluate the proposed model, measurements of time delay and received level were carried out in the Tokyo metropolitan area. Table 1 summarizes the experimental parameters. The delay profiles were measured by the correlating detection method. The receiving antenna was mounted on the roof of a vehicle. In order to gauge average levels of the first delay wave and second delay wave group, an average profile was calculated from about 100 delay profiles, as shown in Fig. 2.

3.2 PROPAGATION LOSS

Figure 3(a) shows the propagation loss of the first delay wave derived from Eq. (1) for urban areas. It can be seen that the measured values (asteriskes) agree well with the propagation loss curve.

Figure 3(b) shows the RMS value of the difference between the measured propagation loss and L_i derived from Eq. (2). The minimum RMS value was obtained at L_r =1.8[dB]. This value was thus adopted in the propagation loss simulation.

3.3 DELAY SPREAD

Based on the above examination results, propagation losses of path P_0, P_i are calculated using Eq's (1) and (2), and a value for L_r of 1.8[dB]. Time delaies τ_0, τ_i, of path P_0, P_i are also calculated for the distances d_0 and $d_{i1}+d_{i2}$, respectively. Therefore, it is possible to predict the delay spread[3]. The delay spread was estimated by simulation under the following conditions.

i) The specific buildings have a Gaussian distribution with respect to the radius of a circle, with the mobile station at center of the circle (The standard deviation is denoted as γ [m]). The buildings are also uniformly distributed in the circle.

ii) The level of the second delay wave group does not exceed that of the free space level of path distance $d_{i1}+ d_{i2}$ and the level of the first delay wave.

iii) Even if d_0 and d_{i2} are smaller than 1 km, Eq. (1) can be applied.

The solid lines in Fig. 4 show the simulation result, using standard deviation parameters of γ =100, 200 and 300[m]. The x's in Fig. 4 show the measured values.

In Ref's [4] and [5], the standard deviation γ of Gaussian distribution is about 150[m] in urban areas. As can be seen in the figure, most of the measured values fall roughly between the estimated value for γ=100[m] and 200[m]. The measured values almost agreed with the estimated values.

4. CONCLUSION

A propagation model has been proposed, which is characterized by a first delay wave and a second delay wave group. Although the model is extremely simple, it can be used to predict the delay profile in urban areas.

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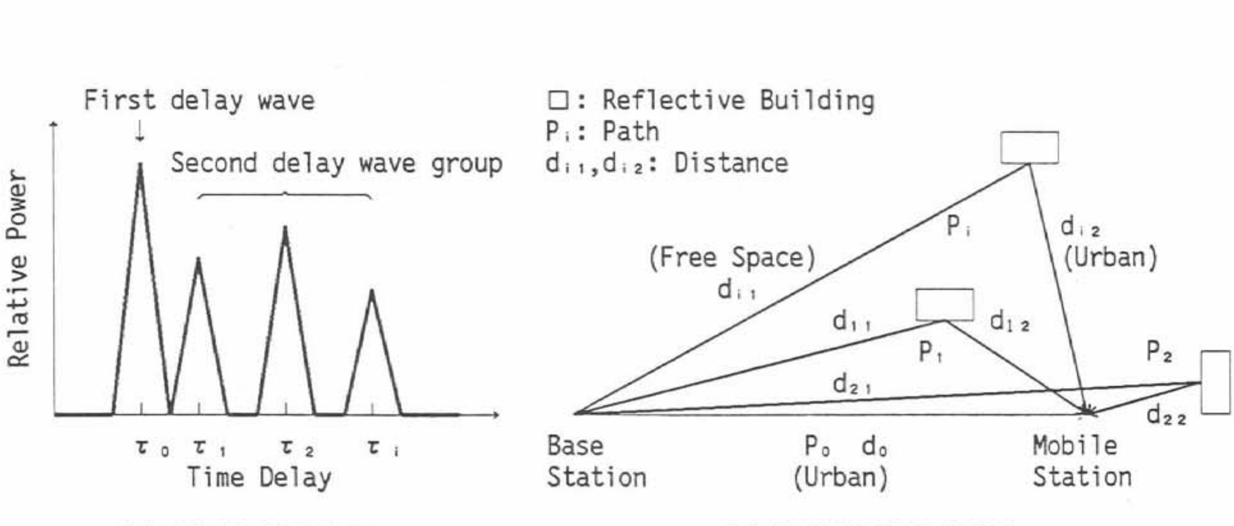


(a) DELAY PROFILE (b) PROPAGATION MODEL

Fig.1 DELAY PROFILE AND PROPAGATION MODEL

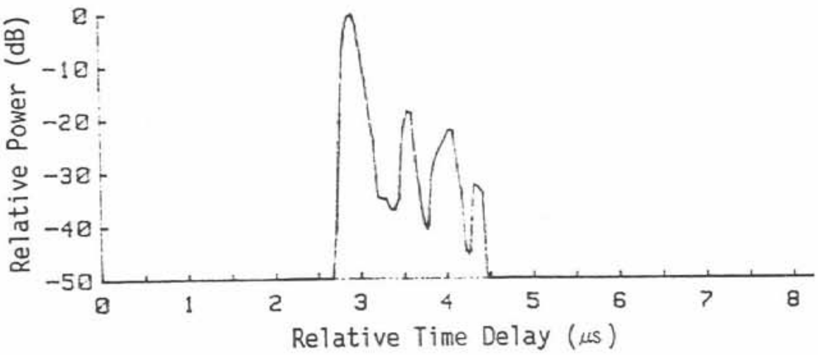
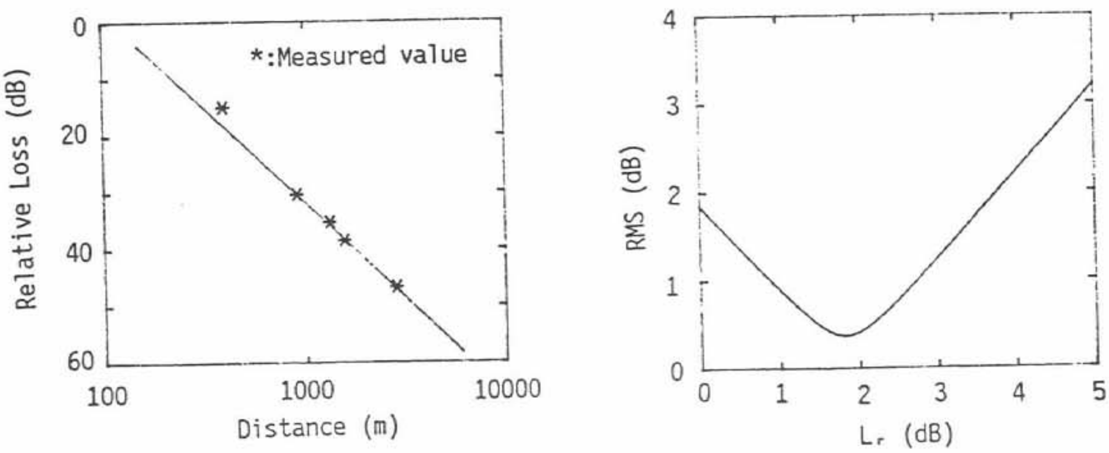


Fig.2 AVERAGE DELAY PROFILE

Table 1 EXPERIMENTAL PARAMETERS

Frequency	1452.5MHz
Modulation	BPSK Modulated by 511-bit Pseudorandom Binary Sequence
Bit Rate	5 Mbps
Average Power	10 W
Base Station Antenna	Dipole Antenna (h_1:50m)
Mobile Station Antenna	Sleeve Antenna (h_2:1.5m)

($h_{1,2}$:Antenna Height)



(a) FIRST DELAY WAVE (b) SECOND DELAY WAVE GROUP

Fig.3 PROPAGATION LOSS

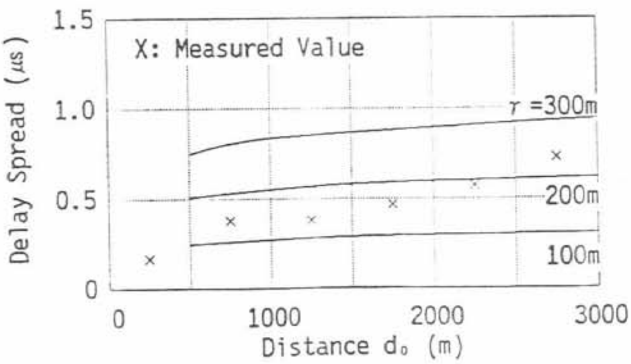


Fig.4 DELAY SPREAD DEPENDENCE ON DISTANCE