Empirical Time-Spatial Propagation Model in Outdoor LOS Environments for Wideband Mobile Communication Systems

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1. Introduction

In 3rd generation mobile cellular systems such as W-CDMA and 4th generation mobile cellular systems, spatial processing techniques such as Multi-Input-Multi-Output (MIMO) techniques are being investigated. In order to accurately assess the performance of these spatial processing techniques for wideband mobile communication systems, a Time-Spatial Propagation (TSP) model that can simulate the characteristics of both the delay profile and the spatial arrival angular profile for travelling waves at the same time is required.

We proposed a TSP model in Non-line of sight (NLOS) environments for wideband mobile communication systems using UHF and SHF bands. Proposed model can predict the delay profile and the arrival angular profile in NLOS environments at the same time [1]-[4]. On the other hand, TSP model in line of sight (LOS) environments is necessary in order to evaluate these processing techniques in LOS environments.

This paper proposes a TSP model in LOS environments developed based on filed measurement data. This model can consider the propagation conditions such as BS antenna height, distance between BS and MS, and structure of surrounding buildings as well as the TSP model in NLOS environments.

2. Measurement

Fig.1 shows a LOS environment considered in order to create a predicted formula. In this LOS environment, the BS is located on the top of the building facing on the left or right side of the street and the MS is on the middle of the street and the BS can look at the MS directly as shown in Fig 1. The height of the BS is higher than the average height of buildings around the BS. Fig. 2 shows an example of measured street viewed from the BS.

To construct the TSP model in LOS environments, we carried out field measurements in this environment in Tokyo, Japan. We measured the delay profile and arrival angular profile. To measure the delay profile, we used a sliding correlator as a receiver in order to divide delay paths. The chip rate, which approximately corresponds to bandwidth, *B*, was 50Mchips per second. The carrier frequency, *f*, was 3.35GHz.

In measuring the delay profile, we used an omni directional antenna as the transmitting and receiving antennas. The transmitting antenna was placed on the tops of buildings and the receiving antenna was mounted on the rooftop of a van. We measured the delay profiles at the various points on the street.

In measuring the arrival angular profiles, we used a directional antenna with horizontal half angle of 3 degrees as the receiving antenna. On the other hand, we used an omni directional antenna as the transmitting antenna. The receiving antenna was placed on the tops of buildings and the transmitting antenna was mounted on the rooftop of a van. Then we measured the delay profiles at 3 degree intervals by rotating the directional antenna at the various points on the street.

3. Proposed TSP models in LOS environments

In creating the TSP model in LOS environments, the multiple regression analysis method was used. When performing multiple regression analysis, it is necessary to select major parameters. The BS antenna height h_b [m], distance *d* [km], average building height <*H*> [m], chip rate *B* [MHz], power reflection coefficient <*R*> and street width *W* [m] are the fundamental parameters that determine the delay and arrival angular profiles.

3.1 Delay profile

Here we describe only the final expression of the delay profile in LOS environments. When the excess delay time is set to τ [μs], the delay profile $PDP_{LOS}(\tau,d)$ normalized by the first arrival ray's power at distance *d* is given as follows.

$$PDP_{LOS}(\tau,d)=\left(1+\frac{300\tau\cdot 1000d}{W^2}\right)^{3.32\log<R>}+\gamma\cdot 10^{PDP_{NLOS}(\tau,d)/10} \tag{1}$$

where,

$$PDP_{NLOS}\left(\tau,d\right)=-\left\{19.1+9.68\ \log\left(h_b/<H>\right)\right\}B^{\{-0.36+0.12\log(h_b/<H>)\}}d^{\{-0.38+0.21\log(B)\}}\log(1+B\tau) \tag{2}$$

Here $PDP_{NLOS}\left(\tau,d\right)$ corresponds to the power delay profile formula in NLOS environments normalized by the first arrival ray's power at distance *d* [1],[2],[4]. γ is a constant value between -12dB and -16 dB and <*R*> is a constant value between 0.1 and 0.5. Especially, the value of <*R*> is 0.3 for the typical urban areas where the average building height <*H*> is higher than 20m.

Fig. 3 shows the measured and predicted delay profiles at the point of *d*=0.13km and0.26km, respectively. In predictions, BS antenna height *hb*, average building <*H*>, average street width *W* and bandwidth were 45m, 20m, 25m and 50Mcps, respectively. On the other hand, γ and <*R*> were used the values of -16dB and 0.3, respectively. The predicted results are good agreement with the measured results, so the proposed model is sufficiently valid.

3.2 Arrival angular profile

We assume that the BS is located on the building facing on the left side of the street as shown in Fig. 1. Here we describe only the final expression of the arrival angular profile in LOS environments.

When the arrival angle is set to $\Delta\theta$ [degree], the arrival angular profile $AOD_{LOS}(\Delta\theta,d)$ at the BS normalized by the ray's power at the center of arrival angle is given as follows.

$$AOD_{LOS}(\Delta\theta,d)=\begin{cases}<R>^{1000d|\Delta\theta|\pi/180W}+\gamma\cdot 10^{\left(AOD_{NLOS}(\Delta\theta,d)\right)/10} & (\theta\geq 0)\\ \gamma\cdot 10^{\left(AOD_{NLOS}(\Delta\theta,d)\right)/10} & (\theta<0)\end{cases} \tag{3}$$

where

$$AOD_{NLOS}\left(\Delta\theta,d\right)=10\log\left(1+\frac{|\Delta\theta|}{-0.2d+2.1\left(\langle H\rangle/h_b\right)^{0.23}}\right)^{-\left(-0.015\langle H\rangle+0.63\right)d-0.16+0.76\log\left(h_b\right)} \tag{4}$$

Here $AOD_{NLOS}\left(\Delta\theta,d\right)$ corresponds to the angular profile formula in NLOS environments normalized by the ray's power at the center of arrival angle at distance *d* [2]- [4]. γ is set to the value from -12dB to -16 dB. Especially, the values of <*R*> is 0.3 for the typical urban areas where the average building height <*H*> is higher than 20m. However, it found that the arrival angular profile doesn't strongly depend on the bandwidth from measurement results, so this model doesn't have this parameter.

Fig. 4 shows the measured and predicted results at the point of *d*=0.2km and 0.36km, respectively. In predictions, BS antenna height *hb*, average building <*H*>, average street width *W* and bandwidth were 45m, 20m, 25m and 50Mcps, respectively. γ and <*R*> were used the values of -12dB and 0.3, respectively. The predicted results are good agreement with the measured results, so the proposed model is sufficiently valid.

3.3 Features of TSP Model

Previous propagation models such as the Okumura-Hata formula for example [5], generally employ different expressions according to the classification of the city structure such as urban, suburban, and rural. Therefore, first we must classify the city structure of each area in using this formula. However this procedure is very cumbersome and complicated.

In TSP model for LOS environments proposed in this paper and TSP model for NLOS environments proposed in previous papers [3], [4], however, all predicted formulas have the average building height <*H*> as a common parameter. So the proposed TSP model can easily handle various city structures by changing average building height <*H*>. Accordingly, the proposed TSP model doesn’t need the city structure to be classified and so eases complexity. This is a noteworthy feature of the proposed TSP model.

4. Conclusions

In this paper, we proposed the heuristically-derived Time-Spatial Propagation (TSP) model in LOS environments, which consists of delay profile model and arrival angular profile model at base station. As these models share key parameters such as the distance from base station, the antenna height of base station and city structure such as building height and street width, the proposed TSP model can easily generate highly accurate propagation models that well reflect the mutual relations inherent in each of the constituent models.

Acknowledgments

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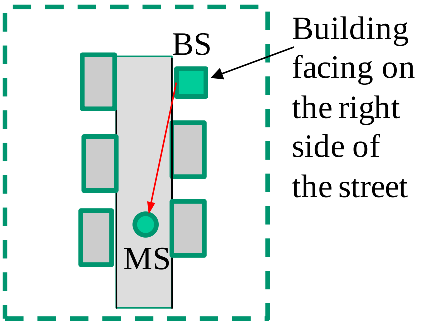
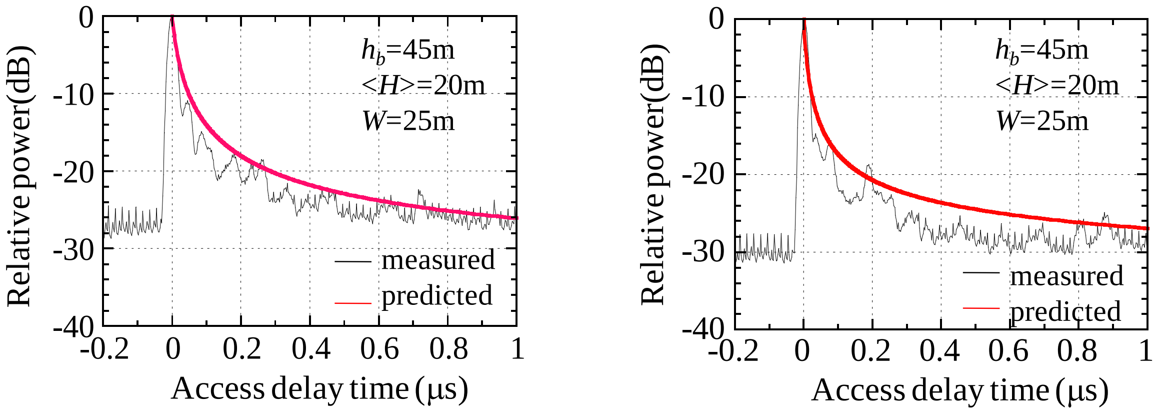


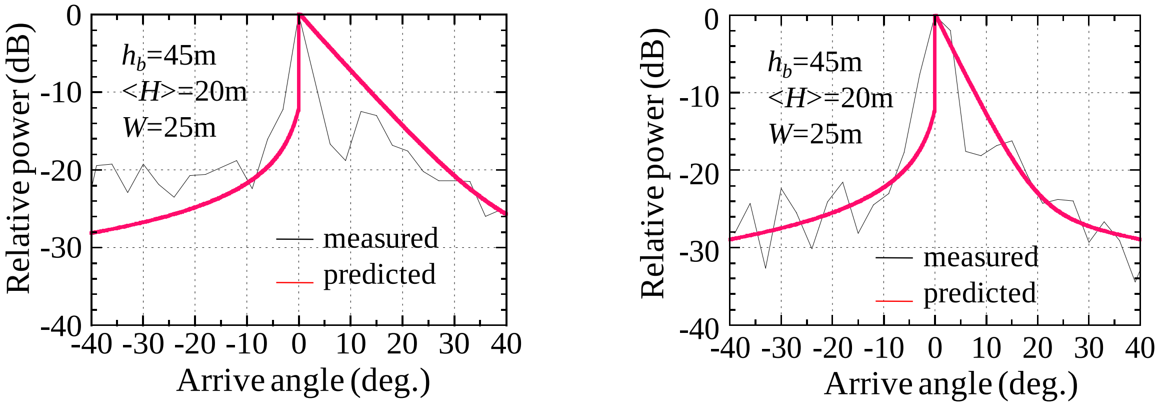
Fig. 1 LOS environment considered

Fig. 2 Measurement street viewed from the BS.



(a) *d*=0.13km (b) *d*=0.26km

Fig. 3 Measured and predicted power delay profiles



(a) *d*=0.2km (b) *d*=0.36km

Fig. 4 Measured and predicted power arrival anglular profiles