POS1-20

Experimental Study and Modeling of Channel Parameters at Mobile Station in a Site-Specific Urban Macrocellular Environment

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1. Introduction

This paper gives a study of 3-D channel parameters, i.e. azimuth, elevation directions at MS (DMS), and delay. Both vertical and horizontal polarizations were transmitted and received in the measurement. By observing the azimuth power spectrum density (APSD), the analysis of the spatio-temporal channel parameters including full polarimetric behaviors was conducted. Power spectrum density (PSD) models are proposed for modeling measured azimuth, elevation DMSs and excess delay PSDs. The relationship between cross-polarization ratio (XPR) and best-fit parameters is discussed. As shown in [1], the extension of the models studied here to the MIMO channel model is possible by the assumption of kronecker model of the base station (BS) and MS.

2. Measurement Descriptions

The measurement was carried out in a residential area of Minami-Senzoku, Ota-ku, Tokyo by using the Medav RUSK Fujitsu channel sounder [2]. The measurement map is shown in Fig. 1. Most buildings along the measurement streets, which are about 5m in width, are two or three-story wooden houses with 6 to 8m in height. The measurement site was divided into segments of 10 m, which is the distance between adjacent circles in Fig. 1. The MS was moved manually in each segment, where consecutive snapshots of different scenarios were collected. The arrows in Fig. 1 show the moving direction of the MS. Important measurement parameters are summarized in Table 1.

Table 1: Measurement parameters.

Center frequency	4.5 GHz
Bandwidth	120 MHz
Excess delay window	3.2 μs
Transmitting power	40 dBm
BS antenna	2×4 uniform rectangular array of dual-polarized patch elements
MS antenna	2-ring circular array of 48 dual-polarized patch elements
BS and MS antenna height	30 and 1.65 m

A multidimensional gradient based maximum-likelihood estimator is used to estimate channel parameters. A multipath is modeled by its direction at BS (DBS), direction at MS (DMS), delay, and a matrix of polarimetric complex path weights, where the first and the second subscripts indicate the MS and BS, respectively. For any kth multipath, it is represented by

$$\begin{bmatrix} \gamma_{\mathrm{VV},k} & \gamma_{\mathrm{VH},k} \\ \gamma_{\mathrm{HV},k} & \gamma_{\mathrm{HH},k} \end{bmatrix} \delta(\phi^{\mathrm{BS}} - \phi_k^{\mathrm{BS}})\delta(\theta^{\mathrm{BS}} - \theta_k^{\mathrm{BS}})\delta(\phi^{\mathrm{MS}} - \phi_k^{\mathrm{MS}})\delta(\vartheta^{\mathrm{MS}} - \vartheta_k^{\mathrm{MS}})\delta(\tau - \tau_k), \quad (1)$$

ISBN: 978-4-88552-223-9 C3055©IEICE

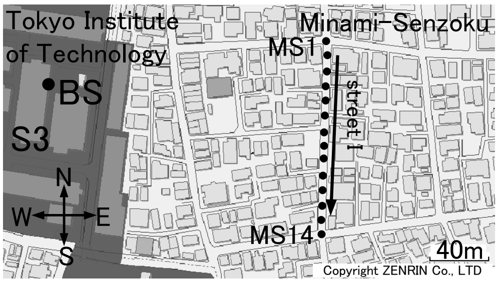

Figure 1: Measurement site map.

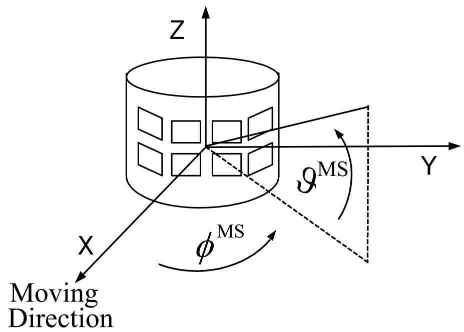

Figure 2: Coordinate system at the MS.

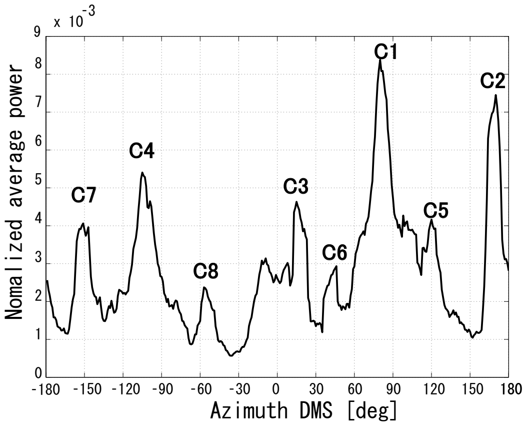

Figure 3: APSD of street I. 0° is the MS moving direction.

where $\gamma_{\alpha\beta,k}$ is a complex path weight. The quantities ϕ_k^{BS}, θ_k^{BS}, ϕ_k^{MS}, $\vartheta_k^{\mathrm{MS}}$, and τ_k denote the azimuth DBS, co-elevation DBS, azimuth DMS, elevation DMS, and delay, respectively. The definition of DMSs is shown in Fig. 2.

3. APSD

3.1 Class Identification

Figure 3 shows the APSD of streets I. The APSD is calculated from the total power of all polarization components. The APSDs are moving-averaged over 10 angular bins of 1 degree step to smooth the PSD for clear observation. The snapshots in one segment from an intersection are not used in the calculations to avoid the effect of changing the MS direction. The areas of azimuthal DMS having the distinct power are visually identified. A identified area is called “propagation class” or shortly “class” representing a dominant propagation mechanism in azimuth DMS. Eight classes are identified and assigned by C1 to C8. Spatio-temporal PSDs of the classes are modeled in the following subsection.

3.2 Modeling of Azimuth, Elevation DMSs and Excess Delay

By comparing with the truncated Laplacian PSD, it is found that the truncated Gaussian PSD gives a better fitting for azimuth DMS of most classes. The truncated Gaussian model for a $\{\beta\alpha\}$ polarization component of the cth class, $P^c_{\beta\alpha}(\phi^{\mathrm{MS}})$ is expressed as follows

$$P^c_{\beta\alpha}(\phi^{\mathrm{MS}}) \propto \exp\left[-\frac{\left(\phi^{\mathrm{MS}} - \phi^{c,\mathrm{MS}}_{0,\beta\alpha}\right)^2}{\sigma^{2,c}_{\phi^{\mathrm{MS}},\beta\alpha}}\right], \quad \phi^{c,\mathrm{MS}}_{1,\beta\alpha} \leqq \phi^{\mathrm{MS}} \leqq \phi^{c,\mathrm{MS}}_{2,\beta\alpha}, \tag{2}$$

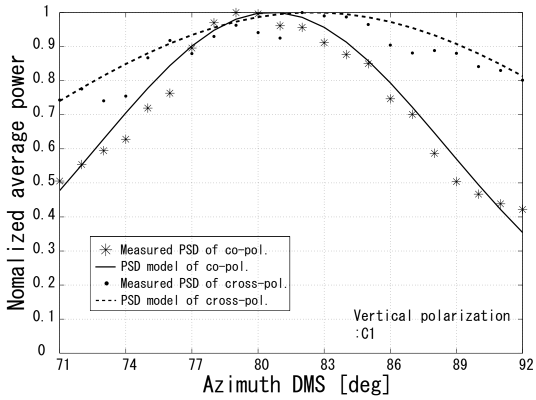

Figure 4: Azimuth DMS PSDs for C1 of street I.

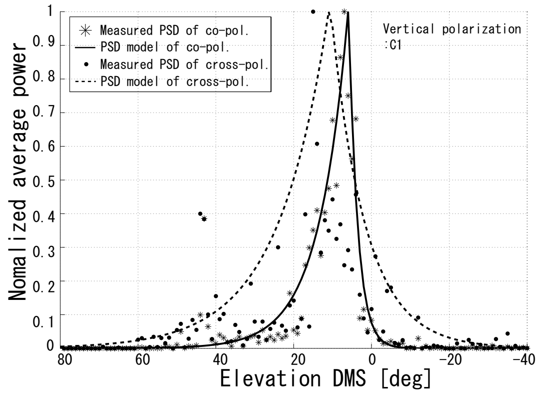

Figure 5: Elevation DMS PSDs for C1 of street I.

where $\phi^{\mathrm{c,MS}}_{0,\beta\alpha}$ and $\sigma^{c}_{\phi^{\mathrm{MS}},\beta\alpha}$ are a mean azimuth DMS and spread parameter, respectively. $\phi^{\mathrm{c,MS}}_{1,\beta\alpha}$ and $\phi^{\mathrm{c,MS}}_{2,\beta\alpha}$ denote the azimuth DMS range of a $\{\beta\alpha\}$ polarization component of the cth class. Figures 4 shows the PSD of C1 of street I (NS). C1 is identified in the range of 71° to 92° in the azimuth DMS. A general double exponential PSD model [3] has been proposed for elevation DMS. The PSD model is realistic since it takes into an account the asymmetrical structure in elevation caused by the building rooftop and the ground. The model is applicable for our results. For a $\{\beta\alpha\}$ polarization component of the cth class, the general double exponential PSD, $P^{c}_{\beta\alpha}(\vartheta^{\mathrm{MS}})$, is expressed as follows

$$P^{c}_{\beta\alpha}(\vartheta^{\mathrm{MS}}) \propto \begin{cases} \exp\left[-\frac{\sqrt{2}|\vartheta^{\mathrm{MS}}-\vartheta^{c,\mathrm{MS}}_{0,\beta\alpha}|}{\sigma^{-,c}_{\vartheta^{\mathrm{MS}},\beta\alpha}}\right], & -\frac{\pi}{2} \leqq \vartheta^{\mathrm{MS}} \leqq \vartheta^{c,\mathrm{MS}}_{0,\beta\alpha} \\ \exp\left[-\frac{\sqrt{2}|\vartheta^{\mathrm{MS}}-\vartheta^{c,\mathrm{MS}}_{0,\beta\alpha}|}{\sigma^{+,c}_{\vartheta^{\mathrm{MS}},\beta\alpha}}\right], & \vartheta^{c,\mathrm{MS}}_{0,\beta\alpha} \leqq \vartheta^{\mathrm{MS}} \leqq \frac{\pi}{2} \end{cases} \tag{3}$$

where $\vartheta^{\mathrm{c,MS}}_{0,\beta\alpha}$ is a peak elevation DMS of $\{\beta\alpha\}$ polarization component of the cth class. $\sigma^{-,c}_{\vartheta^{\mathrm{MS}},\beta\alpha}$ and $\sigma^{+,c}_{\vartheta^{\mathrm{MS}},\beta\alpha}$ are elevation DMS spread parameters in negative and positive elevation DMSs. Figures 5 exemplifies the PSDs of C1 of street I. For the excess delay PSD of a class, we also propose to use the general double exponential PSD as its PSD model as follows $P^{c}_{\beta\alpha}(\acute{\tau})$, expressed as

$$P^{c}_{\beta\alpha}(\acute{\tau}) \propto \begin{cases} \exp\left[-\frac{|\acute{\tau}-\acute{\tau}^{c}_{0,\beta\alpha}|}{\sigma^{-,c}_{\acute{\tau},\beta\alpha}}\right], 0 \leqq \acute{\tau} \leqq \acute{\tau}^{c}_{0,\beta\alpha} \\ \exp\left[-\frac{|\acute{\tau}-\acute{\tau}^{c}_{0,\beta\alpha}|}{\sigma^{+,c}_{\acute{\tau},\beta\alpha}}\right], \acute{\tau} \geqq \acute{\tau}^{c}_{0,\beta\alpha} \end{cases} \tag{4}$$

where $\acute{\tau} = \tau - \tau^{s}_{0}$, τ^{s}_{0} denotes a delay of fist arrival multipath at the sth snapshot. $\acute{\tau}^{c}_{0,\beta\alpha}$, $\sigma^{-,c}_{\acute{\tau},\beta\alpha}$, and $\sigma^{+,c}_{\acute{\tau},\beta\alpha}$ are a peak excess delay, excess delay spread parameters in negative and positive excess delay, respectively. The PSD model, which includes the conventional single-sided exponential PSD as a special case, seems to be suitable, especially for classes in the street direction as shown in Fig. 6.

4. Cross-Polarization Ratios (XPRs) and Class Parameters

The total power ratios between the polarization components, when vertical or horizontal polarization signal is sent from BS, are denoted by $\mathrm{XPR}^{c}_{\mathrm{V}}$ and $\mathrm{XPR}^{c}_{\mathrm{H}}$, respectively. They are obtained as the normalized power weighted ratio in dB follows

$$\mathrm{XPR}^{c}_{\alpha} = \frac{\sum_{s=1}^{S} \tilde{P}^{s,c}_{\alpha} \cdot \mathrm{XPR}^{s,c}_{\alpha}}{\sum_{s=1}^{S} \tilde{P}^{s,c}_{\alpha}}, \tag{5}$$

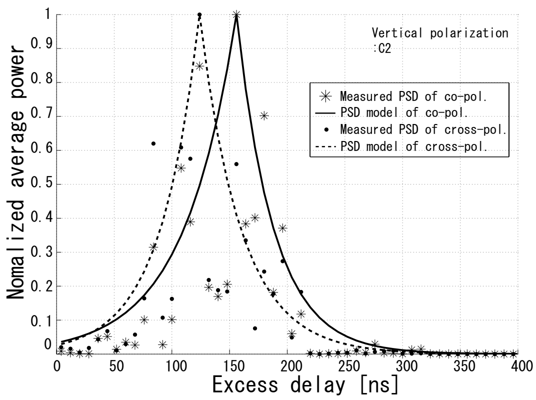

Figure 6: Elevation DMS PSDs for C1 of street I.

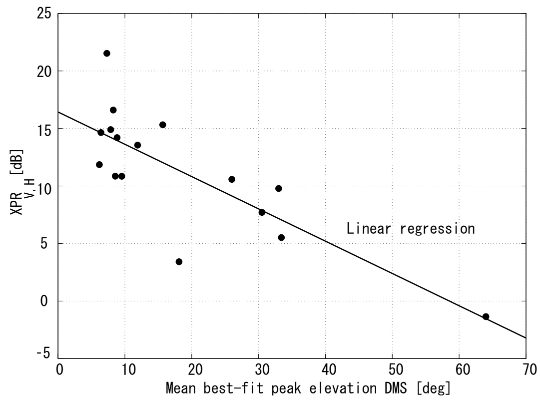

Figure 7: $\mathrm{XPR}_{\alpha,l}$ and mean of best-fit elevation DMS.

where $\mathrm{XPR}_{\alpha}^{s,c}$ is the cross-polarization ratio of the cth class at the sth snapshot in dB, S is the number of snapshots, and $\tilde{P}_{\alpha}^{s,c}$ is the normalized total power. They are expressed as follows

$$\mathrm{XPR}_{\mathrm{V}}^{s,c} = 10\log_{10}\left(\frac{\sum_{k_c^s=1}^{K_c^s}\left|\gamma_{\mathrm{VV},k_c^s}\right|^2}{\sum_{k_c^s=1}^{K_c^s}\left|\gamma_{\mathrm{HV},k_c^s}\right|^2}\right)[\mathrm{dB}] \quad \text{and} \quad \mathrm{XPR}_{\mathrm{H}}^{s,c} = 10\log_{10}\left(\frac{\sum_{k_c^s=1}^{K_c^s}\left|\gamma_{\mathrm{HH},k_c^s}\right|^2}{\sum_{k_c^s=1}^{K_c^s}\left|\gamma_{\mathrm{VH},k_c^s}\right|^2}\right)[\mathrm{dB}] \quad (6)$$

$$\tilde{P}_{\alpha}^{s,c} = \frac{\sum_{k_c^s=1}^{K_c^s}\sum_{\beta=\{\mathrm{V,H}\}}|\gamma_{\beta\alpha,k_c^s}|^2}{\sum_{k_s=1}^{K_s}\sum_{\beta=\{\mathrm{V,H}\}}|\gamma_{\beta\alpha,k_s}|^2} \quad (7)$$

K_c^s is the number of multipaths in the cth class at the sth snapshot and K^s is the total number of multipaths at the sth snapshot. A high correlation of −0.79 could be found between XPRs and the best-fit elevation DMS as shown in Fig. 7. With the correlation of 0.25, XPRs seem to be independent of the best-fit excess delay.

5. Conclusion

We discussed the channel characteristics at the MS based on identified dominants azimuth DMSs each called 'class'. The PSD models for azimuth, elevation DMSs and excess delay for a class were presented together with their relationship to class XPRs.

Acknowledgments

This research is supported by the National Institute of Information and Communications Technology of Japan.

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