

Correlation Models for Shadow Fading Simulation

IEEE 802.16 Presentation Submission Template (Rev. 8.3)

Document Number:

IEEE S802.16m-07/060

Date Submitted:

2007-03-13

Source:

I-Kang Fu, Chi-Fang Li,
Ting-Chen Song, Wern-Ho Sheen

NCTU / ITRI

1001 Ta Hsueh Road, Hsinchu, Taiwan 300, ROC

E-mail: IKFu@itri.org.tw

richard929@itri.org.tw

tomtom@itri.org.tw

whsheen@itri.org.tw

Venue:

IEEE 802.16 Session #48, Orlando, USA

Base Document:

IEEE C802.16m-07/060

Purpose:

TGm Evaluation Methodology development

Notice:

This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release:

The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.

IEEE 802.16 Patent Policy:

The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <<http://iee802.org/16/ipr/patents/policy.html>>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <<mailto:chair@wirelessman.org>> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <<http://iee802.org/16/ipr/patents/notices>>.

Correlation Models for Shadow Fading Simulation

I-Kang Fu, Chie-Fang Li,
Ting-Chen Song, Wern-Ho Sheen

NCTU / ITRI

Outline

- Shadow Fading Model for System Level Simulation
- Auto-correlation Model for Shadow Fading
- Cross-correlation Model for Shadow Fading

Shadow Fading Model for System Level Simulation

- The shadow fading effect is usually modeled by a **log-normal** random variable in system level simulation
 - Its mean m is usually given as 0dB, and the standard deviation σ dB depends on the propagation environment (ex. 8dB for urban).
 - This random variable is normal distributed in dB
- When doing the system level simulation, a normal distributed random variable can be dropped from time to time to represent the shadow fading for each radio link.
 - The typical way is to drop the random variable independently for different time and for different radio link
 - i.e. the shadow fading effects for each radio link at each time instance are simulated in uncorrelated manner

Auto-correlation Model for Shadow Fading

- However, the shadow fading effect of the same radio link is highly correlated for the nearby locations.
- A simple and well accepted auto-correlation model was proposed by Gudmundson [1] for this effect:

the correlation of signal samples separated by k sampling instances:

$$R(k) = \sigma^2 a^{|k|}$$

$$a = e^{-vT/D}$$

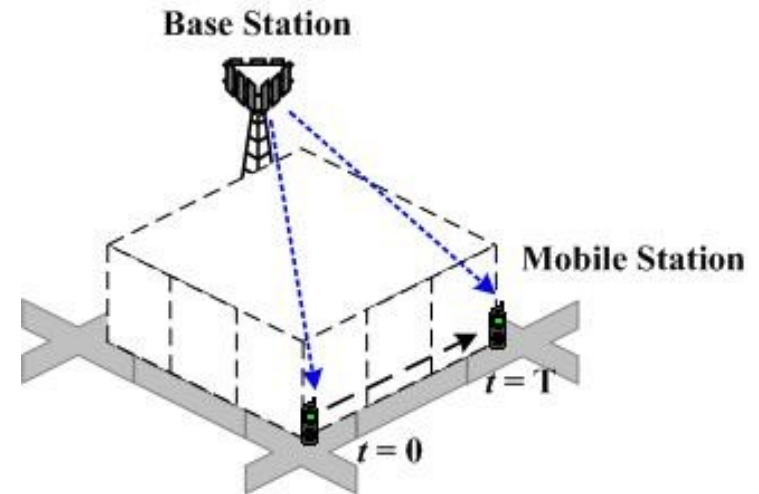
σ is the standard deviation of shadow fading model

a is the correlation coefficient

ε_D is the correlation between two locations separated by distance D

v is the mobile velocity

T is the sampling interval



Auto-correlation Model for Shadow Fading

- The aforementioned model was reference by [2] and modified as:

$$r(Vx) = e^{-\frac{|Vx|}{d_{cor}} \ln 2}$$

d_{cor} *de-correlation distance;*

its definition here is the distance separation at which the correlation coefficient reduces to $\frac{1}{2}$.

Δx *the distance between two observation locations*

ρ *the correlation coefficient*

- Simulation Methodology:
 - If L_1 is the log-normal component at position P_1 , L_2 is for P_2 which is Δx away from P_1 . Then L_2 is normally distributed in dB with mean $\rho(\Delta x)L_1$ and variance $(1-\rho(\Delta x)^2)\sigma^2$.
 - *derived in next page*

Auto-correlation Model for Shadow Fading

- Consider X and Y are Normal distributed random variables. Given $Y=y$ and correlation coefficient as ρ , then the distribution of $(X|Y=y)$ can be obtained as [3]:

m_1, m_2 and s_1^2, s_2^2 are the mean and variance of X and Y

$$\begin{aligned}
 f_X(x|y) &= \frac{f_{X,Y}(x,y)}{f_Y(y)} \\
 &= \frac{\exp\left\{-\frac{1}{2(1-r_{X,Y}^2)}\left[\frac{(x-m_1)}{s_1}\right]^2 - 2r_{X,Y}\left(\frac{x-m_1}{s_1}\right)\left(\frac{y-m_2}{s_2}\right) + \frac{(y-m_2)^2}{2s_2^2}\right\}}{\sqrt{2\pi s_1 s_2} \sqrt{1-r_{X,Y}^2}} \cdot \frac{\exp\left\{-\frac{(y-m_2)^2}{2s_2^2}\right\}}{\sqrt{2\pi s_2^2}} \\
 &= \frac{1}{\sqrt{2\pi s_1^2(1-r_{X,Y}^2)}} \exp\left\{-\frac{1}{2(1-r_{X,Y}^2)}\left[\frac{(x-m_1)}{s_1}\right]^2 - 2r_{X,Y}\left(\frac{x-m_1}{s_1}\right)\left(\frac{y-m_2}{s_2}\right) + \frac{(y-m_2)^2}{2s_2^2} - (1-r_{X,Y}^2)\left(\frac{y-m_2}{s_2}\right)^2\right\} \\
 &= \frac{1}{\sqrt{2\pi s_1^2(1-r_{X,Y}^2)}} \exp\left\{-\frac{1}{2(1-r_{X,Y}^2)}\left[\frac{(x-m_1)}{s_1} - r_{X,Y}\frac{y-m_2}{s_2}\right]^2\right\} \\
 &= \frac{1}{\sqrt{2\pi}\sqrt{s_1^2(1-r_{X,Y}^2)}} \exp\left\{-\frac{\left[\frac{(x-m_1)}{s_1} - r_{X,Y}\frac{y-m_2}{s_2}\right]^2}{2(1-r_{X,Y}^2)}\right\}
 \end{aligned}$$

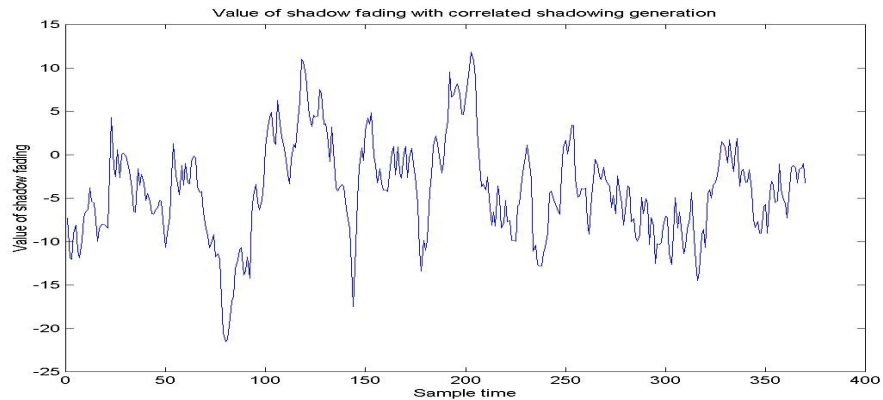
the mean of $f_X(x|y)$ is $m_1 + r_{X,Y} \frac{s_1}{s_2} (y - m_2)$, with variance $s_1^2(1 - r_{X,Y}^2)$.

Consider $m_1 = m_2 = 0$ and $s_1 = s_2 = s$, then the mean of $f_X(x|y)$ is $r_{X,Y}(y - m_2)$ and variance $s_1^2(1 - r_{X,Y}^2)$

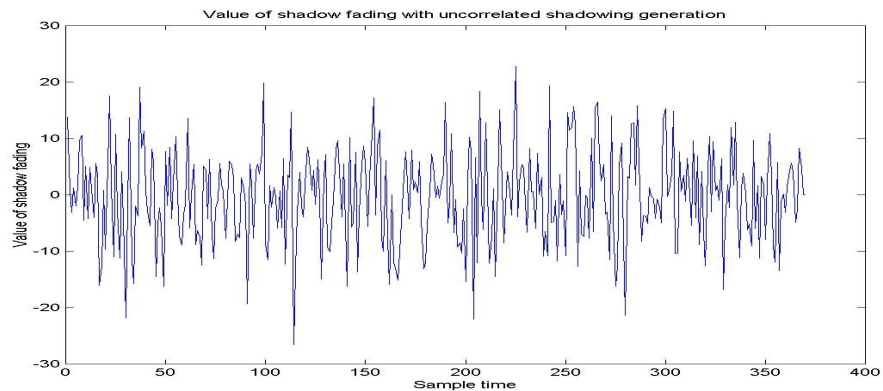
Auto-correlation Model for Shadow Fading

- Example:
 - Shadow fading effect simulated with and without auto-correlation model

*Correlated shadow fading
(with auto-correlation[2])*



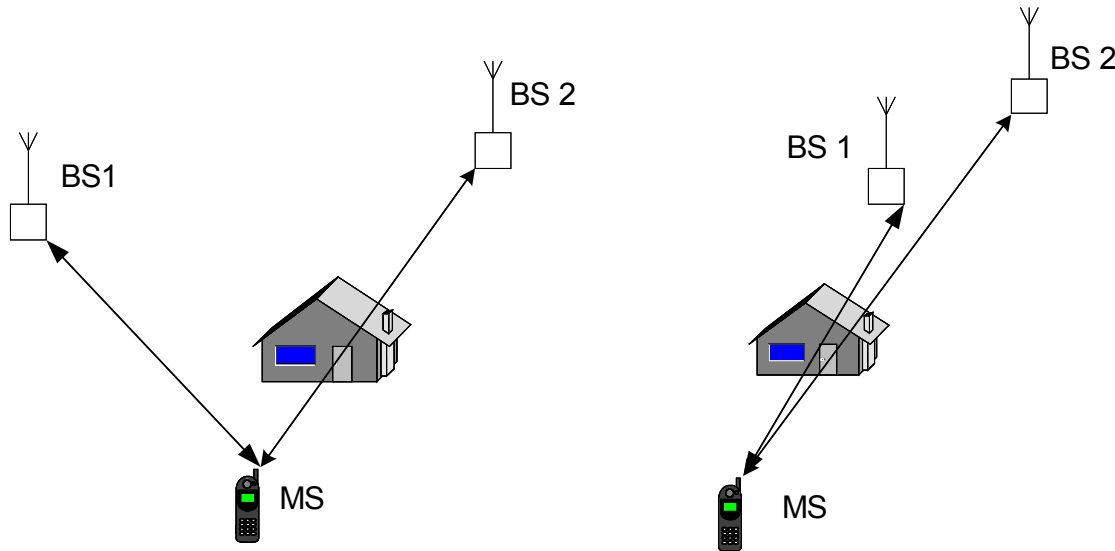
Uncorrelated shadow fading



Cross-correlation Model for Shadow Fading

- As for the shadow fading effect among different radio link, the cross-correlation indicates the similarity of the propagation environment.
- For example, the shadow fading effects for the two radio links are less correlated in the left figure then in right one.

Longer common propagation path induce higher correlation



Cross-correlation Model for Shadow Fading

- Cross-Correlation Model for Shadow Fading[4] :

θ : *Angle-of-Arrival Difference (AAD)*

ρ : *correlation coefficient*

$$r(q) = \begin{cases} 0.8 - \frac{|q|}{150} & \text{if } |q| \leq 60^\circ \\ 0.4 & \text{if } |q| > 60^\circ \end{cases}$$

Cross-correlation Model for Shadow Fading

- Simulation Methodology:
 - Generate the uncorrelated random variables $X=[x_1, x_2, \dots, x_N]$
 - each x_n is Normal distributed with zero mean and std σ_n in dB
 - Obtain the correlation coefficient matrix C

$$G = \begin{bmatrix} \sigma_1^2 & r_{12} & \dots & r_{1N} \\ r_{21} & 1 & \dots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N1} & r_{N2} & \dots & 1 \end{bmatrix}$$

and

$$G = CC^T$$

C can be obtained by Cholesky decomposition
(note: it takes high computation power)

- Then cross-correlated shadow fading effect $Y=[y_1, y_2, \dots, y_N]$ can be obtained by

$$Y=CX$$

References

- [1] Gudmundson, M., “Correlation Model for Shadow Fading in Mobile Radio Systems,” *Electronics Letters*, pp.2145-2146, vol. 27, No 23, November 1991.
- [2] ETSI TR 101.112 v3.2.0, “Selection procedures for the choice of radio transmission technologies of the UMTS”, April 1998.
- [3] I-Kang Fu, “A Dynamic Simulation Platform for Heterogeneous Multiple Access Systems,” Master Thesis, Department of Electrical Engineering, National Chung Cheng University, Taiwan, R.O.C., July 2002.
- [4] Thomas Klingenbrunn, Preben Mogensen “Modelling Cross-Correlated Shadowing in Network Simulations”, *IEEE VTC*, 1999, pp.1407-1411.