A Note on Discrete-Time Triply-Selective MIMO Rayleigh Fading Channel Models

Jan Mietzner, *Associate Member, IEEE,* Chengshan Xiao, *Senior Member, IEEE,* Peter A. Hoeher, *Senior Member, IEEE,* and Khaled Ben Letaief, *Fellow, IEEE*

***Abstract*— We discuss recent results on discrete-time models for triply-selective multiple-input multiple-output (MIMO) Rayleigh fading channels. Our key finding is that a previously proposed model [2], which allows for efficient computer simulations, is sufficiently accurate for a wide range of practical scenarios.**

***Index Terms*— Channel modeling, dispersive channels, MIMO systems, Rayleigh channels, time-varying channels.**

IN digital mobile communication systems, baseband signal processing is typically carried out in the discrete-time domain. Correspondingly, an end-to-end discrete-time channel model comprising the continuous-time physical channel model, the (analog) transmit and receive filters, as well as the sampling process at the receiver is of great interest. In [1], a statistical discrete-time model for single-input single-output (SISO) wide-sense stationary (WSS) Rayleigh fading channels with uncorrelated scattering (US) and selectivity in time and frequency was proposed. This model was later extended in [2] to MIMO WSSUS Rayleigh fading channels with selectivity in time, frequency, and space. It was concluded in [2] that the correlations between channel coefficients of the discrete-time MIMO channel model can be written as the product of temporal correlation, inter-tap correlation, and spatial correlations. This property enables computationally efficient computer simulations on MIMO triply selective channel fading.

For a general case, the correlation structure in time, frequency, and space was recently derived in [3]. In this context, it was reported in [3] that the aforementioned correlation property in [2] was "erroneous" and "may lead to significant modeling errors." We would like to clarify that these comments appear rather inappropriate. Based on the discrete-time model in [2], modeling errors can only occur if Assumption 2 of [2] is not met. However, there is no flaw in the presented derivations.

We further clarify that Assumption 2 of [2] implies the following three assumptions:

Manuscript received January 14, 2008; accepted January 26, 2008. The associate editor coordinating the review of this letter and approving it for publication is V. K. Bhargava.

J. Mietzner is with the Department of Electrical & Computer Engineering, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada (e-mail: janm@ece.ubc.ca).

C. Xiao is with the Department of Electrical & Computer Engineering, Missouri University of Science & Technology, Rolla, MO 65409, USA (e-mail: xiaoc@mst.edu).

P. A. Hoeher is with the Information and Coding Theory Lab, Faculty of Engineering, University of Kiel, Germany (e-mail: ph@tf.uni-kiel.de).

K. Ben Letaief is with the Department of Electronic & Computer Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong (e-mail: eekhaled@ee.ust.hk).

Digital Object Identifier 10.1109/TWC.2008.080058.

(α) the power delay profile of the physical channel model is identical for all transmit and receive antenna indices,

(β) the normalized temporal autocorrelation function is identical for all resolvable physical multipaths,

(γ) the spatial correlations are identical for all resolvable physical multipaths

(see [2] for further details). Assumption (α) is reasonable for MIMO systems with a maximum antenna spacing that is small compared to the distance between transmitter and receiver. Assumption (β) is commonly employed in the literature for SISO channels and was therefore adopted in [2] for the MIMO case.

Based on numerical results for quasi-static channel conditions, it was found in [3] that Assumption (γ) is a good approximation as long as the spatial correlations are more or less balanced over the individual resolvable multipaths, which will be the case for a wide range of practical scenarios (focus in [3] was on $M = 1, 2$ transmit and $N = 2$ receive antennas). In a parallel and independent[1] work [4], complementary results for SISO WSSUS Rayleigh fading channels with selectivity in time and frequency were established. It was shown that Assumption (β) is also a good approximation as long as the maximum Doppler frequency is small compared to the system bandwidth, which is the case for most, if not all, practical systems.

Combining the findings of [2]–[4], we conclude that the discrete-time triply-selective MIMO Rayleigh fading channel model [2] with separate temporal, inter-tap, and spatial correlations, which permits computationally efficient computer simulations, is sufficiently accurate for a wide range of practical scenarios, where a limited number of antennas with moderate antenna spacing is employed. In the general case, however, the more complex space-time-frequency correlation structure derived in [3] should be taken into account, when the computational efficiency is not a concern.

REFERENCES

[1] P. Hoeher, "A statistical discrete-time model for the WSSUS multipath channel," *IEEE Trans. Veh. Technol.*, vol. 41, no. 4, pp. 461–468, Nov. 1992.

[2] C. Xiao, J. Wu, S.-Y. Leong, Y. R. Zheng, and K. B. Letaief, "A discrete-time model for triply selective MIMO Rayleigh fading channels," *IEEE Trans. Wireless Commun.*, vol. 3, no. 5, pp. 1678–1688, Sept. 2004.

[3] J. Mietzner and P. A. Hoeher, "A rigorous analysis of the statistical properties of the discrete-time triply-selective MIMO Rayleigh fading channel model," *IEEE Trans. Wireless Commun.*, vol. 6, no. 12, pp. 4199–4203, Dec. 2007.

[4] C. Sgraja and C. Xiao, "On discrete-time modeling of time-varying WSSUS fading channels," in *Proc. IEEE Int. Conf. Commun. (ICC'06)*, Istanbul, Turkey, June 2006, pp. 5486–5490.

[1]We note that [3] was submitted to *IEEE Trans. Wireless Commun.* in August 2005.