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The Concept of Intrinsic Delay Spread

David G. Michelson and Aidan Hughes
The University of British Columbia, Vancouver, BC, Canada V6T 1Z4, email: davem@ece.ubc.ca

Scattering by objects and structures in the vicinity of the propagation path gives rise to time-delayed replicas of the transmitted signal at the receiver. The excess delay refers to the difference between the propagation delay associated with the direct path or line-of-sight component and that associated with a given multipath component. The delay profile is the expected power per unit of time received with a certain excess delay. Obtained by averaging a large set of impulse responses over time or location, it typically follows an exponential shape when expressed in linear units [1].

Several different metrics are used to characterize delay spread including the maximum delay spread, average delay spread (first central moment) and rms (root-mean-square) delay spread (second central moment). The latter is the most commonly used measure. The threshold for the weakest multipath component affects the value of the rms delay spread. That is, as the threshold increases, the rms delay spread decreases. In previous work, it has been common to report multipath delay spread for various thresholds but little effort has been devoted to determining if a pattern exists. Here, we show that such a pattern does indeed exist and can be applied to both non-line-of-sight (Rayleigh) and line-of-sight (Rician) scenarios.

Consider a delay profile of the form $P(\tau) = P_0\, e^{-(\tau-\tau_0)/\tau_1}$ where τ is the delay, τ_1 is the delay constant and τ_0 represents the propagation delay associated with the direct path. We make the following observations that are not widely recognized:

1. The parameter τ_1 is identical to the rms delay spread given by the second central moment of the delay profile.
2. If the minimum signal threshold is set to zero, the calculated rms delay spread achieves its maximum value. We refer to this as the *intrinsic delay spread* of the channel. A simple closed form expression gives the actual delay spread given the value of the intrinsic delay spread and the ratio of the peak response to the minimum signal threshold, i.e., the dynamic range of the response.
3. In the case of a Rician channel in which a line-of-sight component is superimposed on the exponential delay profile, we use results presented in [2] as the basis for an exposition of how the actual delay spread is related to the intrinsic delay spread, Ricean K-factor, and the minimum signal threshold or dynamic range.

These results provide a particularly useful framework to which time-domain channel measurements collected in built-up areas can be compared and assessed.

References

[1] S. R. Saunders and A. Aragón Zavala, *Antennas and Propagation for Wireless Communication Systems*, 2nd ed., Wiley, 2007.

[2] V. Erceg, D. G. Michelson, S. S. Ghassemzadeh, L. J. Greenstein, A J., Rustako, P. B. Guerlain, M. K. Dennison, R. S. Roman, D. J. Barnickel, S. C. Wang, R. R. Miller, "A Model for the Multipath Delay Profile of Fixed Wireless Channels," *IEEE J. Sel. Areas Communic.*, vol. 17, no. 3, pp. 399-410, 1999.