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Abstract	
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Channel Modeling Suitable for MBWA

Vinko Erceg

January 2003

Outline

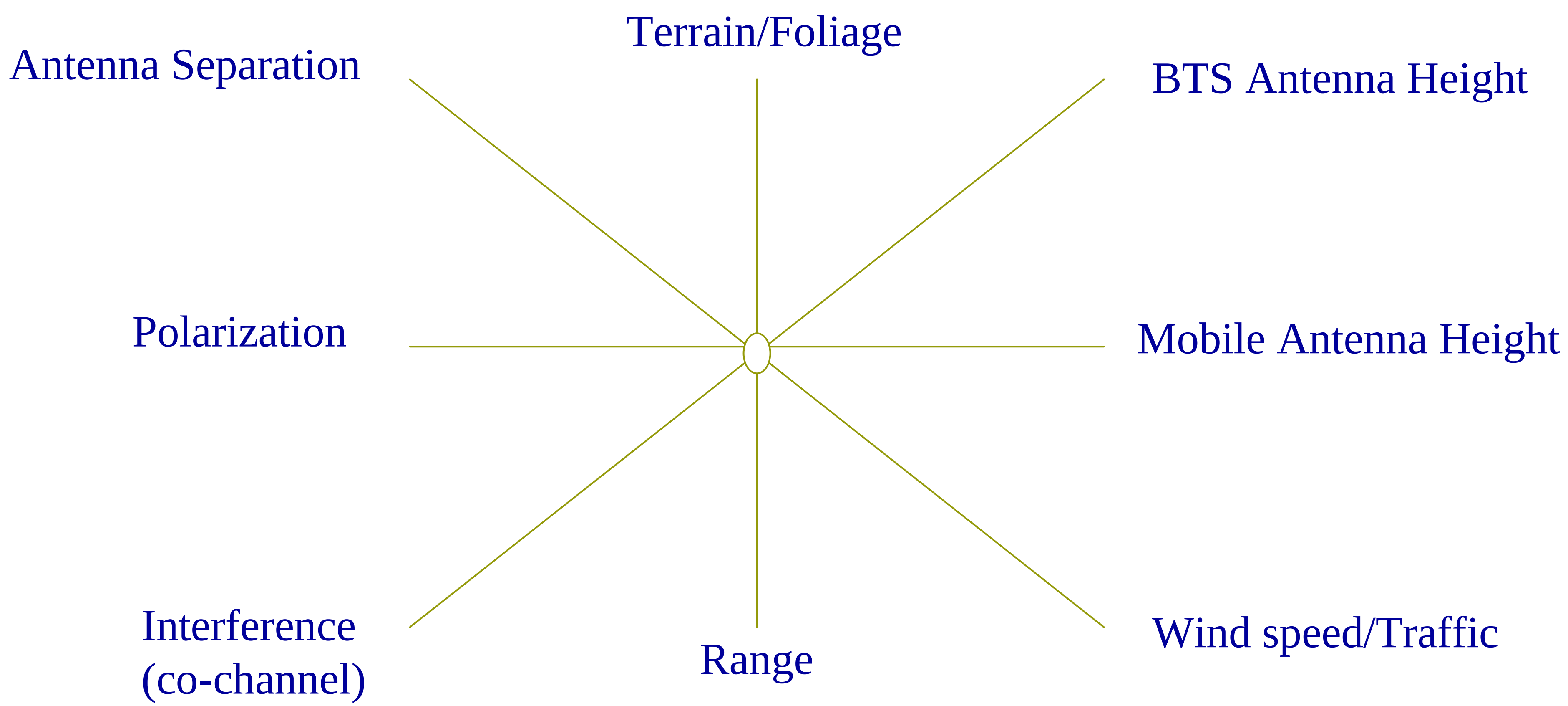
- Introduction
- Wireless Channel Models
  - Path Loss Model
  - RMS Delay Spread Model
  - K-Factor Model
  - Doppler Spectrum
  - Multiple Cluster Model
- Conclusion

Wireless Channel

- Propagation
  - Reflections, diffusion, absorption
- Antennas
  - Single-pol, dual-pol, directional, omni
- Mobility/stationarity

- Common Path Loss Channel models
  - Hata, COST-231, Walfish-Ikegami

Channel Has Many Dimensions



Suburban Path Loss Model

A model presented in [1] can be used. It is based on extensive experimental data collected by AT&T Wireless Services in 95 macrocell across US. It covers the following:

- 3 different terrain categories: hilly, moderate and flat terrain
- Low and high base station antenna heights : 10 - 80 m
- Extended to higher frequencies and receiver antenna heights

[1] V. Erceg et. al, "An empirically based path loss model for wireless channels in suburban environments," *IEEE J. Select Areas Commun.*, vol. 17, no. 7, July 1999, pp. 1205-1211.

Path Loss Model: Cont'

Slope and Fixed Intercept Model:

$$PL = A + 10\,\gamma\,\log10\,(d/d_o) + s;$$

Intercept: $A = 20\,\log_{10}\,(4\,\pi\,d_o\,/\,\lambda)$

Path Loss Exponent: $\gamma = (a - b\,h_b + c\,/\,h_b) + x\,\sigma$; h_b:10 - 80m

Shadow Fading Standard Deviation: $\sigma = \mu_\sigma + z\,\sigma_\sigma$

Frequency Correction Factor: $C_f = 6\,\log_{10}\,(f\,/\,1900)$

Height Correction Factor: $C_h = -\,10.7\,\log_{10}(h_r\,/2)$; h_r: 2 - 8m

RMS Delay Spread Model

A delay spread model was proposed in [3] based on a large body of published reports. The model was developed for rural, suburban, urban, and mountainous environments. The model is of the following form:

$$\mathbf{t_{rms} = T_1\, d^e\, y}$$

Where t_{rms} is the rms delay spread, d is the distance in km, T_1 is the median value of t_{rms} at $d = 1$ km, e is an exponent that lies between 0.5-1.0, and y is a lognormal variate. The model parameters and their values can be found in Table III of [3].

[3] L.J. Greenstein, V. Erceg, Y.S. Yeh, and M.V. Clark, "A new path-gain/delay-spread propagation model for digital Cellular Channels," *IEEE Trans. On Vehicular Technology*, vol. 46, no. 2, May 1997.

Model For τ_{rms}

$\tau_{rms} = T_1 \, r^{\varepsilon} \, y$,   where

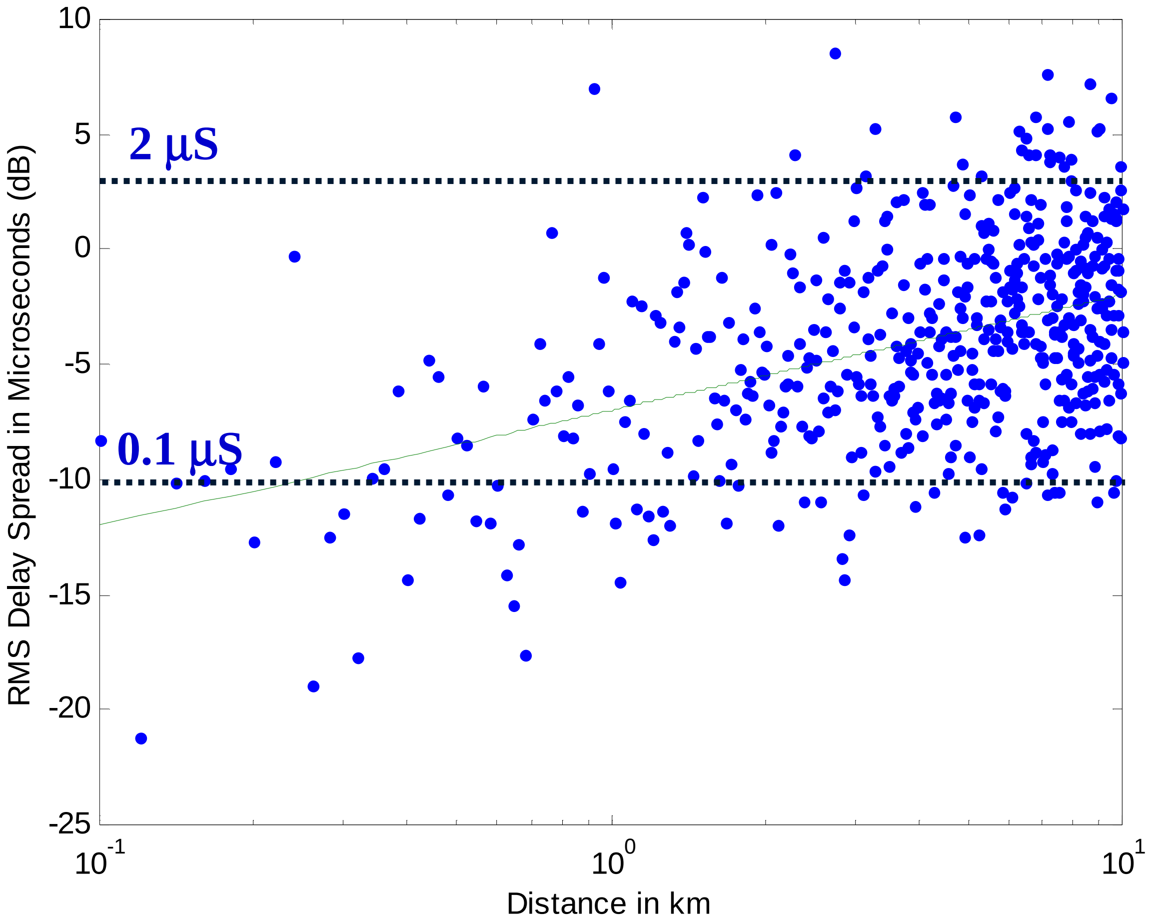
r = base-to-user distance

ε = 0.5 - 1.0

T_1 = median τ_{rms} at r = 1 km

ln y is a zero-mean unit –variance random variable with std. dev. σ between 2 and 6 dB.

RMS Delay Spread Cont': RMS Delay Spread vs. Distance (Suburban Environments) Simulation



Omni Receive Antenna

K-Factor Model

In [6,7], for fixed wireless systems, the K-factor distribution was found to be lognormal, with the median as a simple function of season, antenna height, antenna beamwidth, and distance.

$$K = F_s\, F_h\, F_b\, K_o\, d^{\gamma}\, u$$

[6] L.J. Greenstein, S. Ghassemzadeh, V.Erceg, and D.G. Michelson, "Ricean K-factors in narrowband fixed wireless channels: Theory, experiments, and statistical models," *WPMC'99 Conference Proceedings*, Amsterdam, September 1999.

[7] D.S. Baum, V. Erceg et.al., "Measurements and characterization of broadband MIMO fixed wireless channels at 2.5 GHz", *Proceedings of ICPWC'2000*, Hyderabad, 2000.

K-Factor Model: Cont'

F_s is the seasonal factor = 1 in summer and 2.5 in winter

F_h is the receiving antenna height factor = $(h/3)^{0.46}$; h in m

F_b is the antenna beamwidth factor = $(b/17)^{-0.62}$; b in deg.

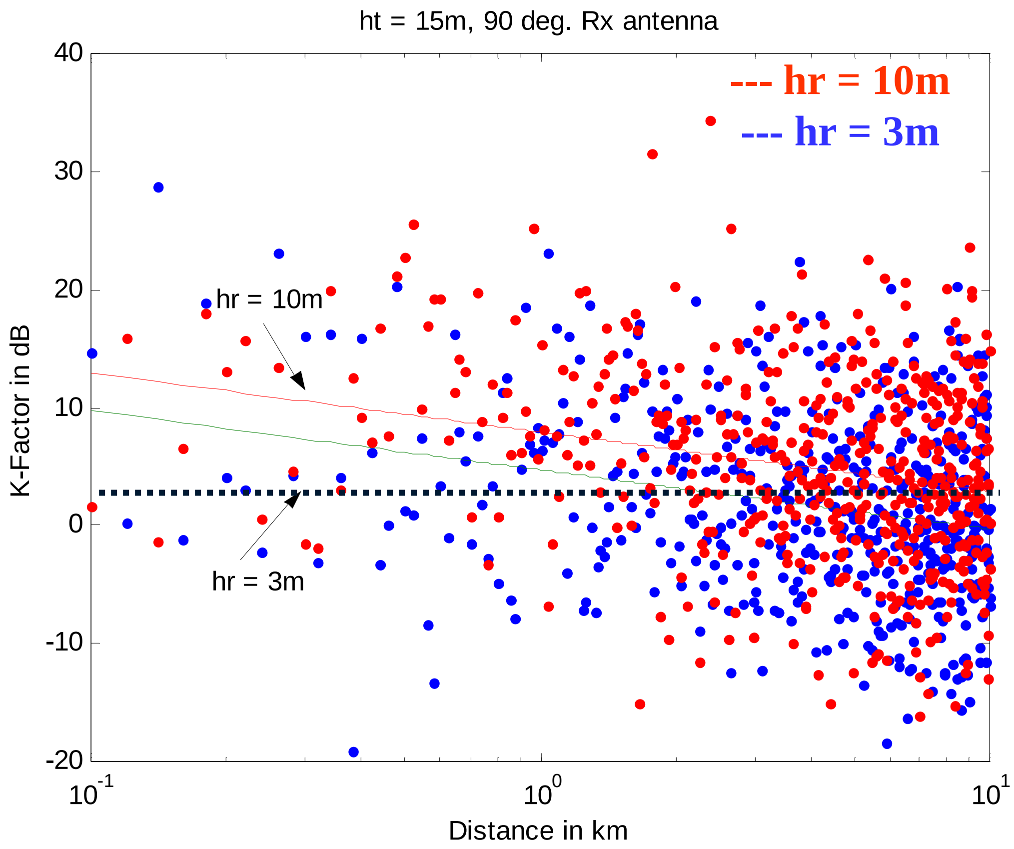
d is the distance in km

γ is the exponent = - 0.5

K_o is the 1 km intercept = 10 dB

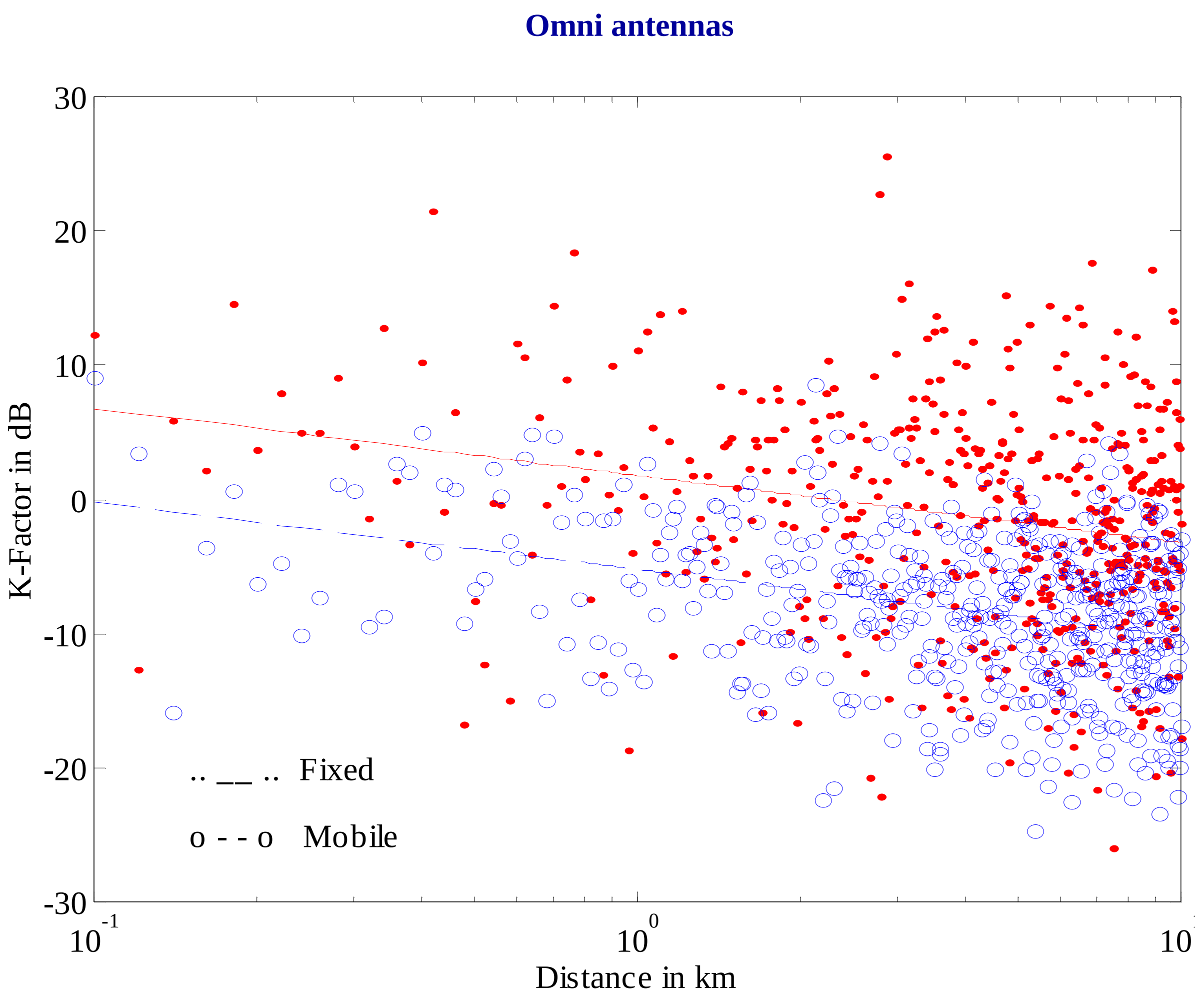
u is the zero-mean lognormal variate with a 8.0 dB standard deviation over the cell area.

K-Factor vs. Distance for Suburban Environments (Simulation, Fixed Scenario)

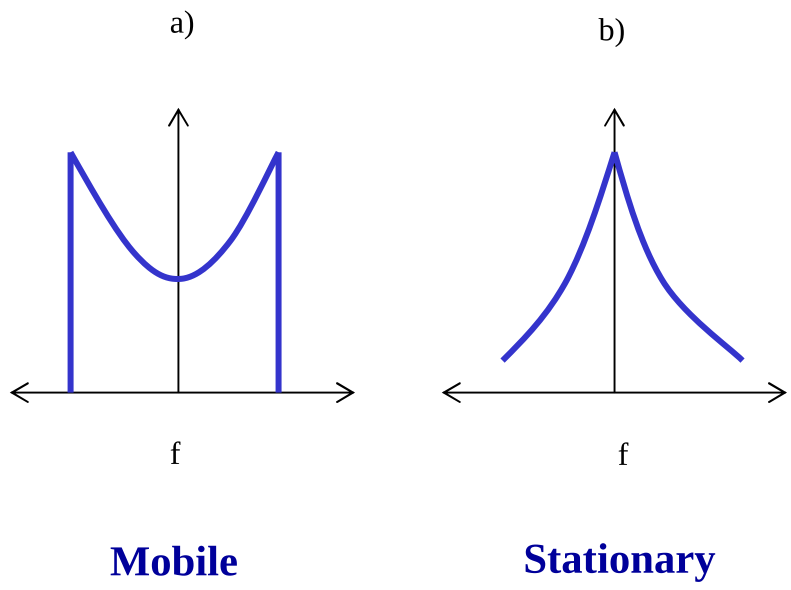


High probability that K < 0 dB

K-factor vs. Distance for Mobile Channels

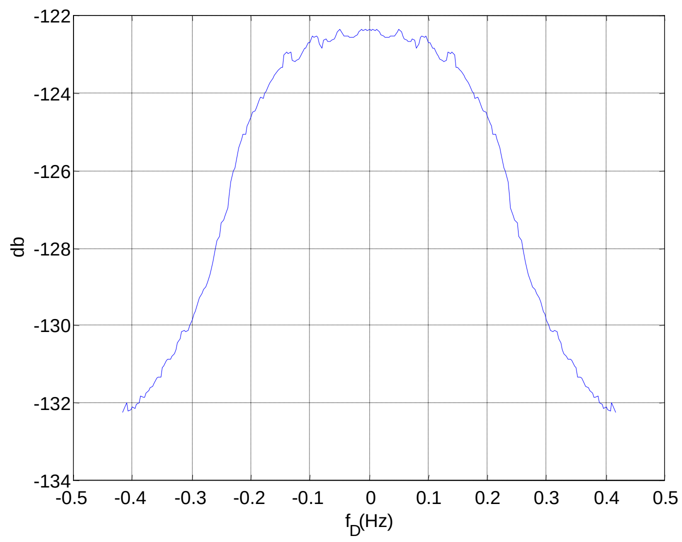


Doppler Spectrum for Mobile and Stationary users

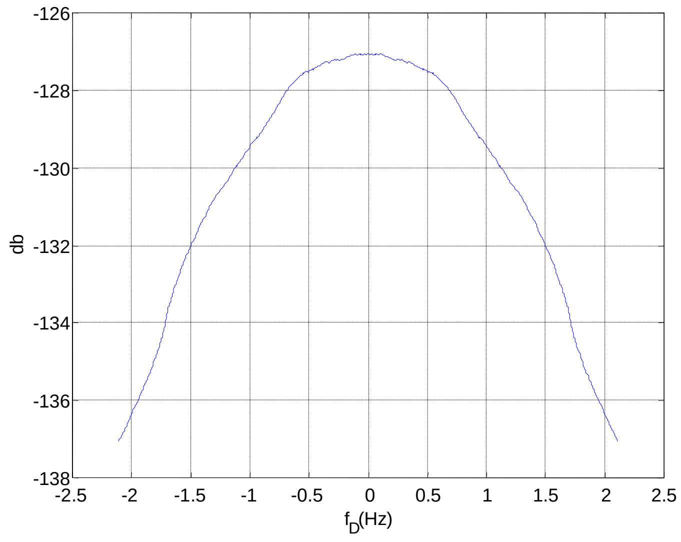


Doppler Power Spectrum for Stationary Users

Low Wind

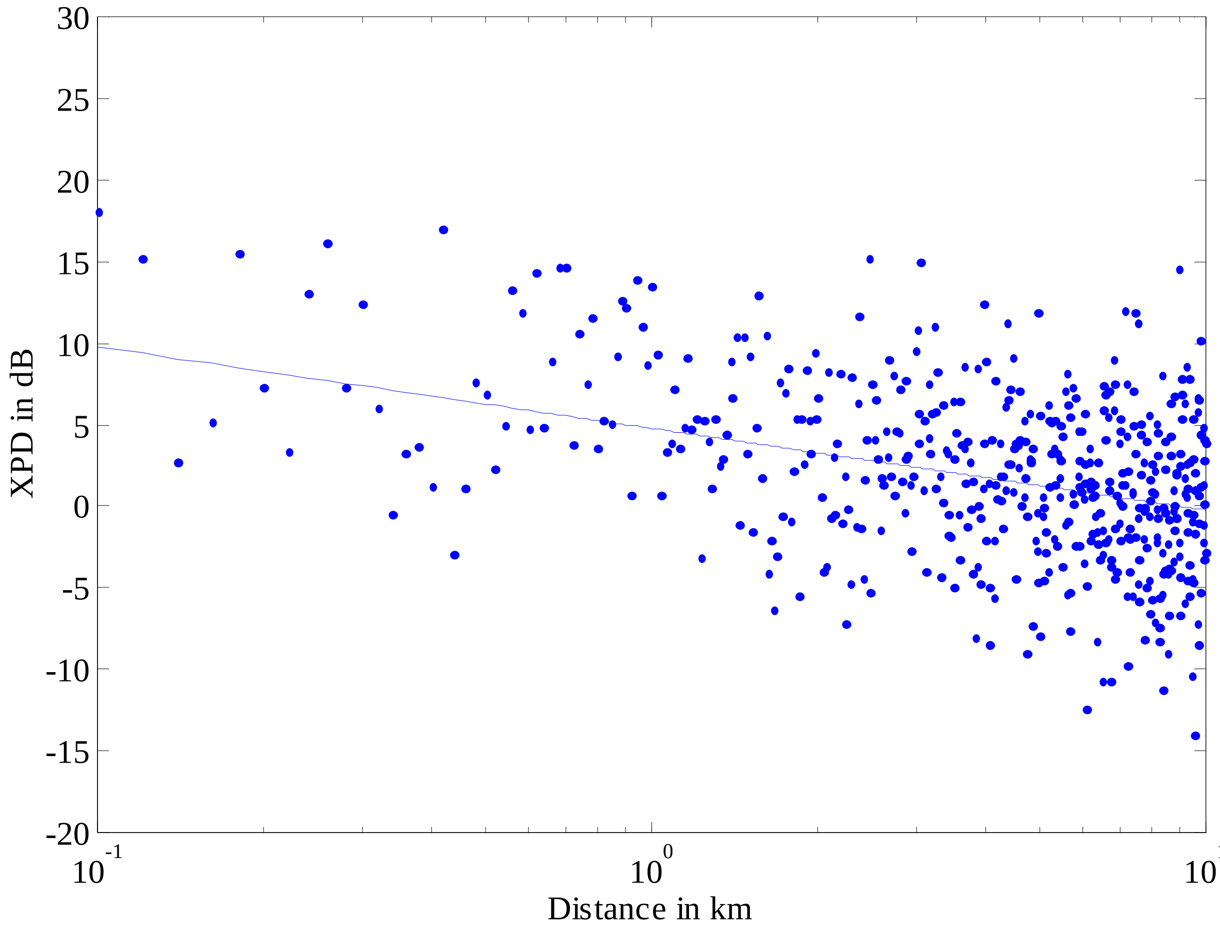


High Wind

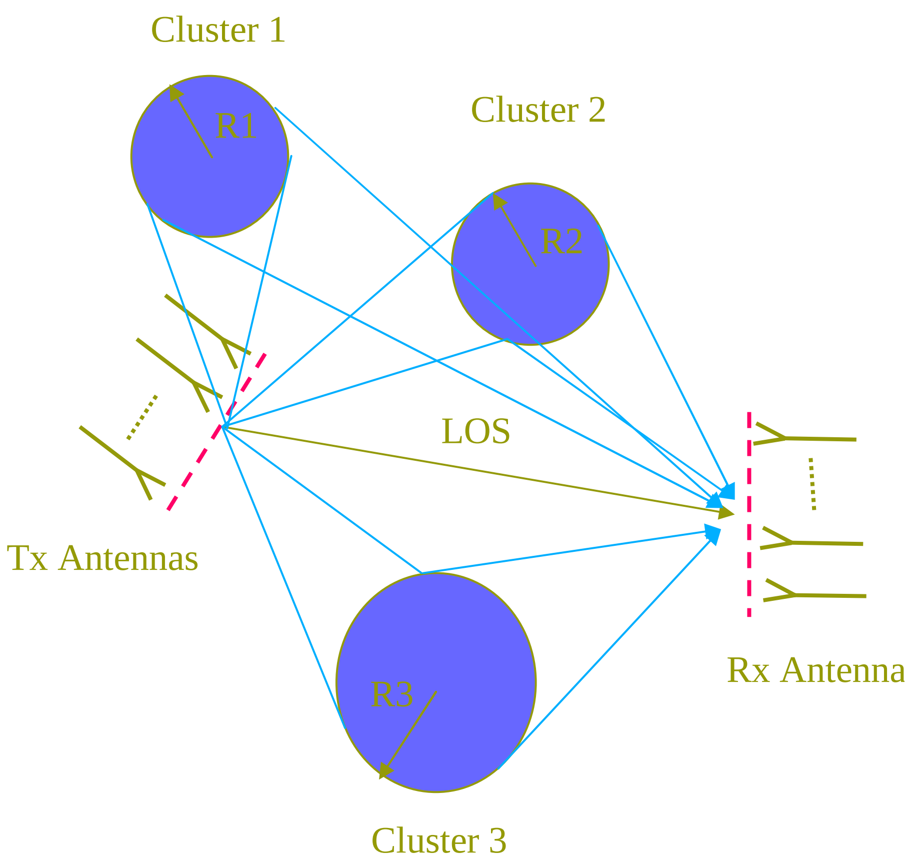


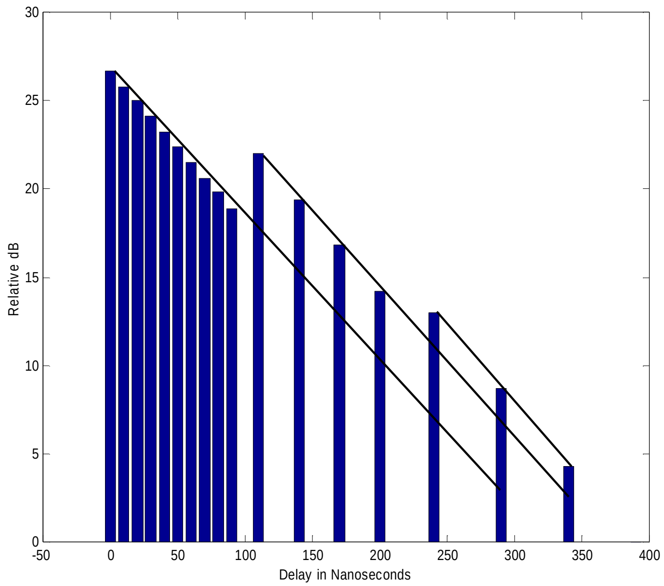
Rounded Spectrum with f_D~ 0.1Hz- 2Hz
(at 2.4 GHz)

Cross-Pol. Discrimination (XPD) vs. Distance



Cluster Modeling Approach





Indoor and Outdoor Channel Parameters

	Indoor Picocell	Outdoor Macrocell
Path loss exponent	2 – 3.5	3.5 – 5
RMS delay spread	20 – 250 ns	0.2 – 5 μs
Cluster Angular Spread	20^o – 40^o	< 10^o BTS 10^o – 40^o MS

Cluster Model: Cont'

- For multiple antennas, antenna correlation can be determined using:
  - Power Azimuth Spectrum (PAS) cluster shape (Laplacian, Gaussian, or uniform)
  - Cluster Azimuth Spread (AS), i.e. root second central moment of PAS
  - Receive and transmit antenna geometry and spacing (uniform linear array (ULA), circular, rectangular, etc., array)
  - Mean Angle of Arrival (AoA) of each cluster

Discussion and Conclusions

For multi-cell MBWA deployments:

- ☞ K = 0 (Rayleigh fading) should be assumed for robust system design
- ☞ Excess delay spread values vary from 0 - 20 μs
- ☞ Doppler: hundreds of Hz, depending on mobile speed and carrier frequency
- ☞ Diversity combining can be used to dramatically improve system coverage/reliability