Channel Models for Fixed Wireless Systems

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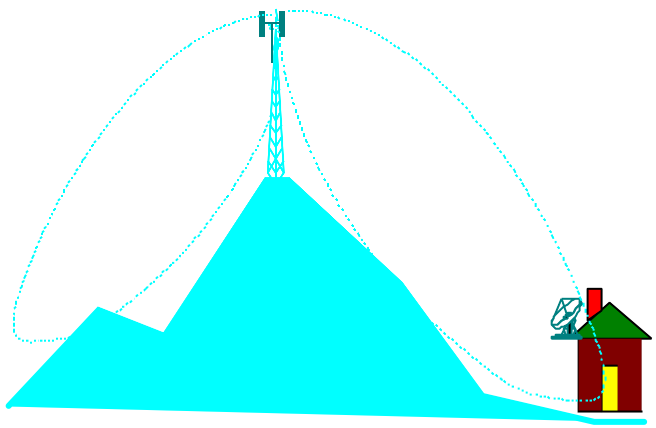
Outline

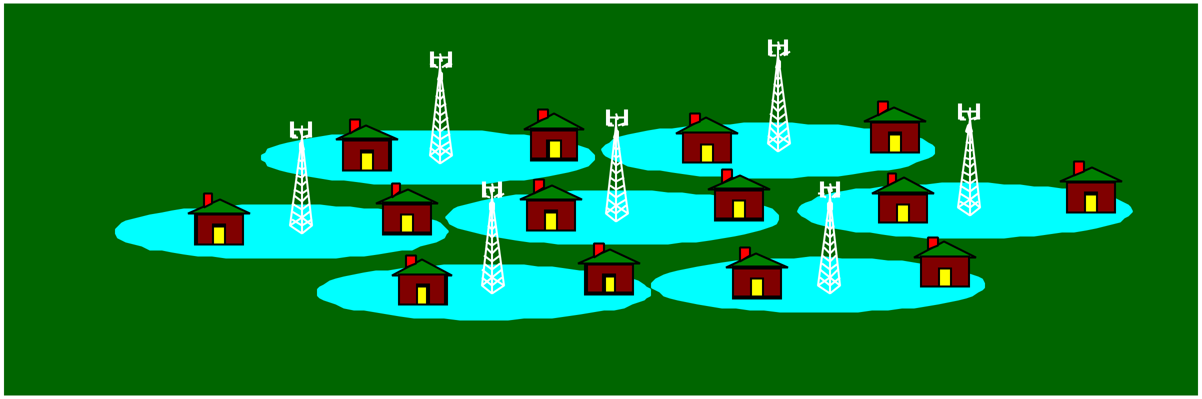
- Introduction
- Path Loss Model
- Antenna Gain Reduction
- RMS Delay Spread Model
- K-Factor Model
- Discussion and Conclusions

“Super Cell” System Scenario



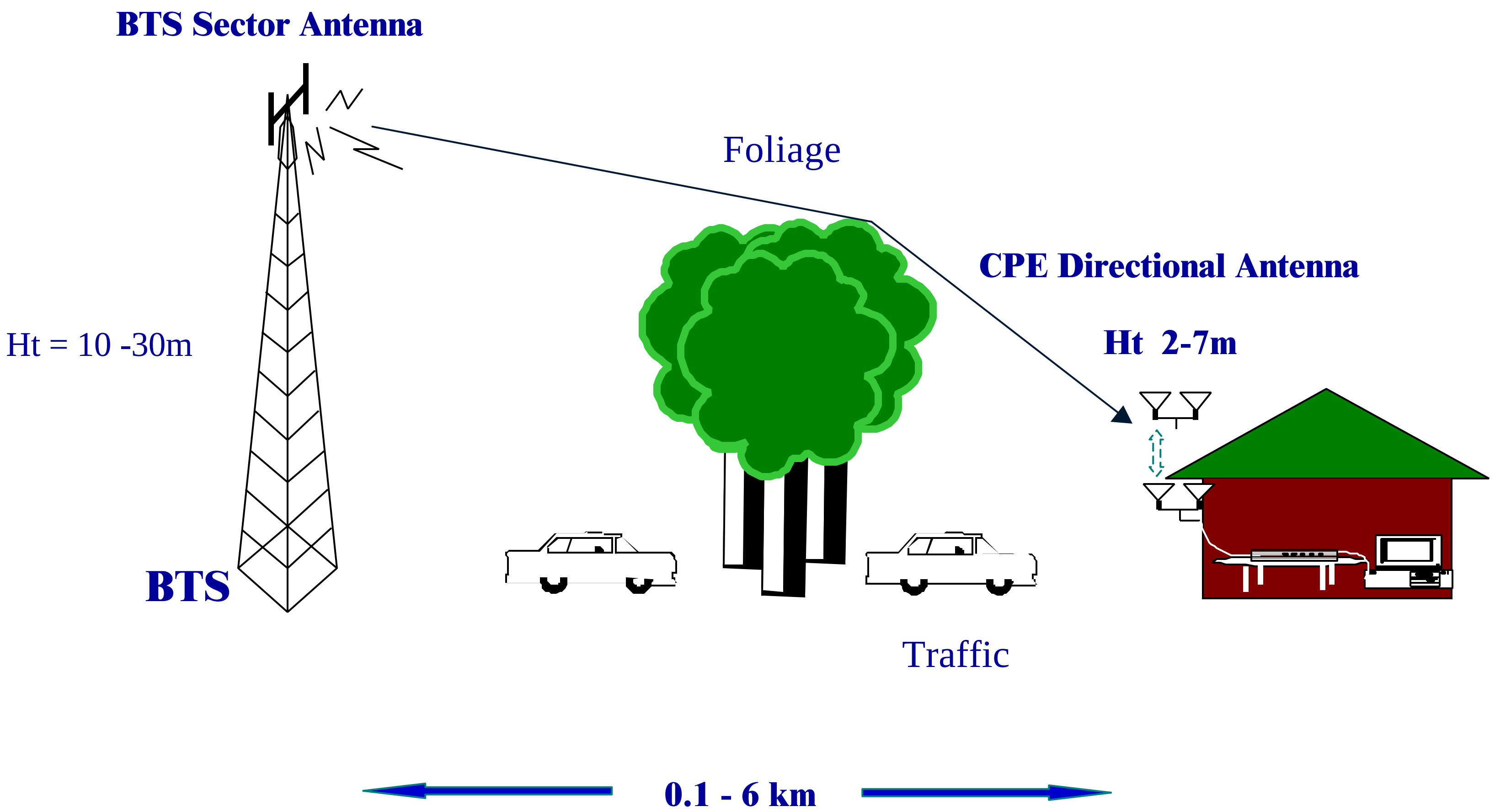
- LOS
- High BTS > 300 m
- Rooftop CPE Antenna
- Single Cell / PSA

Multicell System Scenario



- Low BTS antennas
- Non-LOS propagation/fading
- More path loss (less range)
- Co-channel Interference

Propagation Scenario



Suburban Path Loss Model

We propose a model presented in [1]. 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 meters

- 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: Con't

Slope and Fixed Intercept Model:

$$PL = A + 10\ g\ \log 10\ (d/d_o) + s;$$

Intercept: $A = 20 \log_{10} (4\ p\ d_o\ /\ l)$

Path Loss Exponent: $g = (a – b\ h_b + c\ /\ h_b) + x\ s\ ;$ h_b:10 - 80m

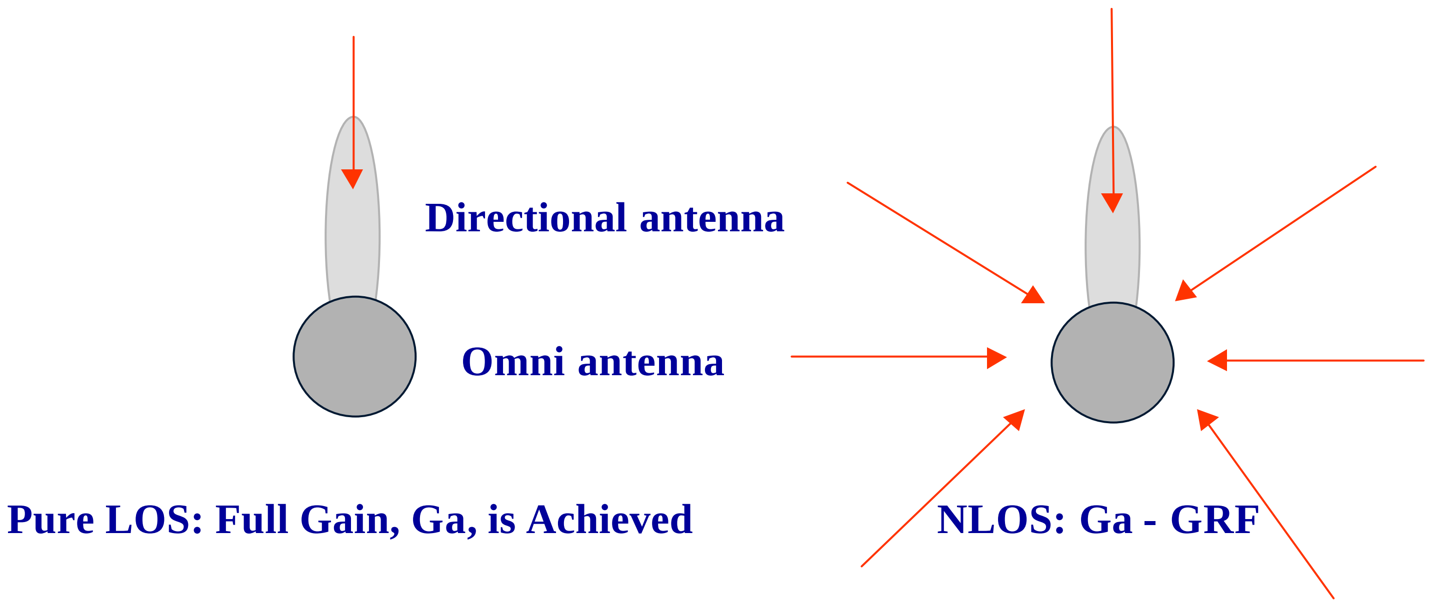
Shadow Fading Standard Deviation: $s = m_s + z\ s_s$

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

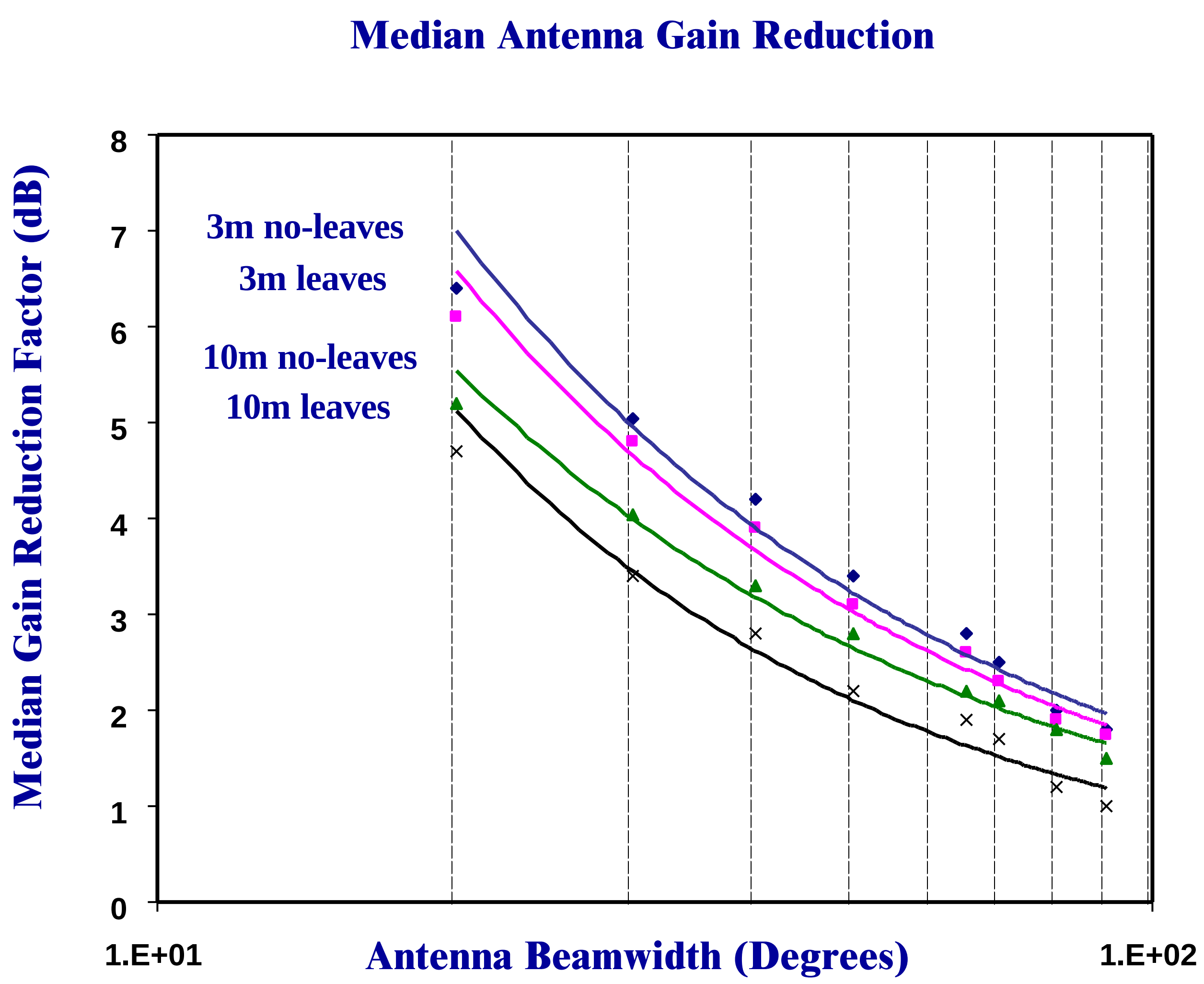
Antenna Gain Reduction Factor (GRF)

In local scattering, when compared to an omnidirectional antenna, the nominal gain of a directive antenna can be significantly reduced.



[2] L.J. Greenstein and V. Erceg, “Gain reductions due to scatter on wireless paths with directional antennas,“ *IEEE Communications Letters*, Vol. 3, No. 6, June 1999 (also in *VTC’99 Conference Proceedings*, Amsterdam, September 1999).

Antenna Gain Reduction Factor: Con't



Antenna Gain Reduction: Con’t

In [3], approximately 10 dB gain reduction factor can be observed from figures for a flat suburban environment for a 10^{o} receive antenna (hr = 5.2m).

The base station antenna height was 43 m and the receive antenna heights were 5.2, 10.4, and 16.5 m. This result closely matches results reported in [2].

[3] J.W. Porter and J.A. Thweatt, “Microwave propagation characteristics in the MMDS frequency band,” *ICC’2000 Conference Proceedings*, pp. 1578-1582.

RMS Delay Spread Model

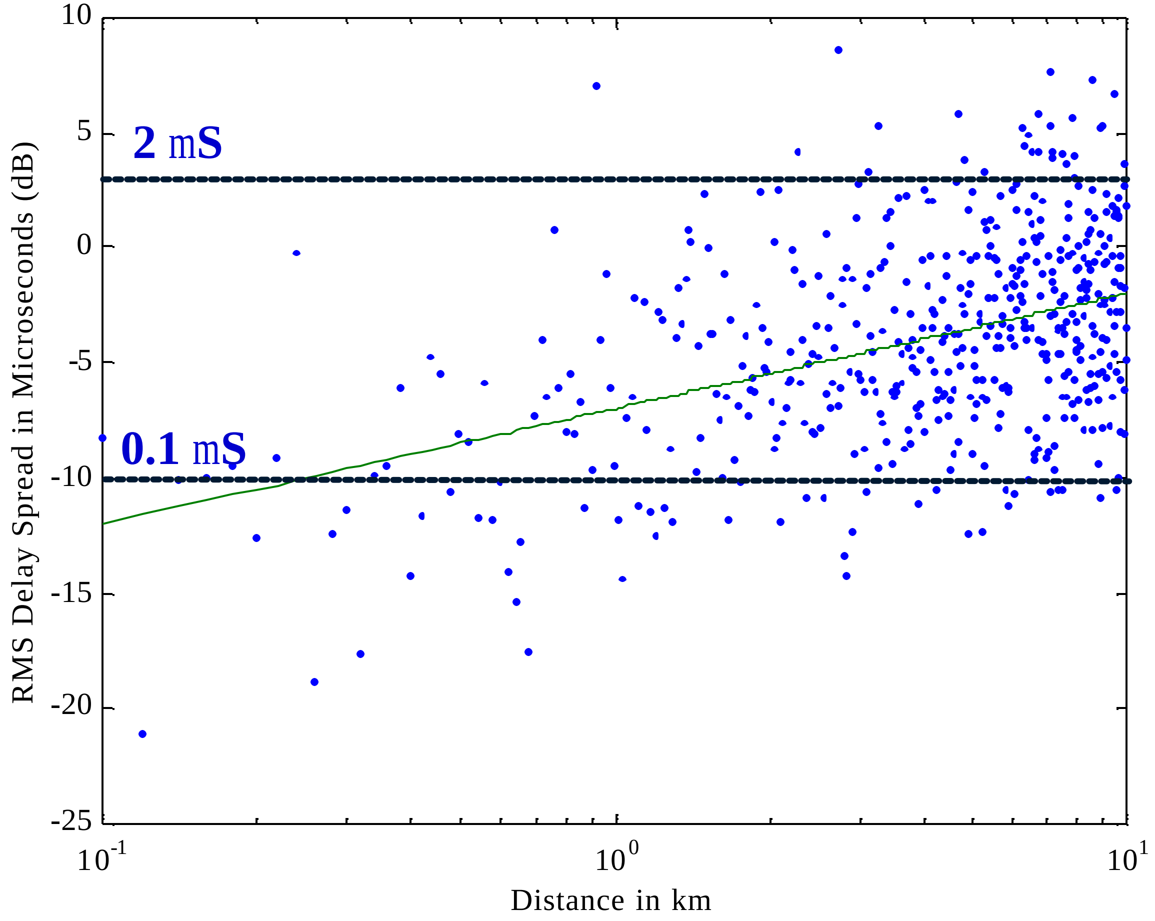
A delay spread model was proposed in [3] based on a large body of published reports. The model was developed for rural, suburban, urban, and mountainous environments. The model is of the following form:

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

Where τ_{rms} is the rms delay spread, d is the distance in km, T_1 is the median value of τ_{rms} at d = 1 km, ε 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.

RMS Delay Spread Con't: RMS Delay Spread vs. Distance (Suburban Environments) Simulation



Omni Receive Antenna

RMS Delay Spread: Con't

Antenna Directivity Effect:

- **In [3] It was shown that a 10^o directional antenna reduces the RMS delay spread 2.6 times in suburban environments.**
- **In [4], it was shown that a 32^o directional antenna reduces the RMS delay spread 2.3 times.**

[3] J.W. Porter and J.A. Thweatt, "Microwave propagation characteristics in the MMDS frequency band," *ICC'2000 Conference Proceedings*, pp. 1578-1582.

[4] V. Erceg et.al, "A model for the multipath delay profile of fixed wireless channels," *IEEE J. Select Areas Commun.*, vol. 17, no.3, March 1999, pp. 399-410.

K-Factor Model

In [6,7] 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", to appear in *Proceedings of ICPWC'2000*, Hyderabad, 2000.

K-Factor Model: Con't

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 meters

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

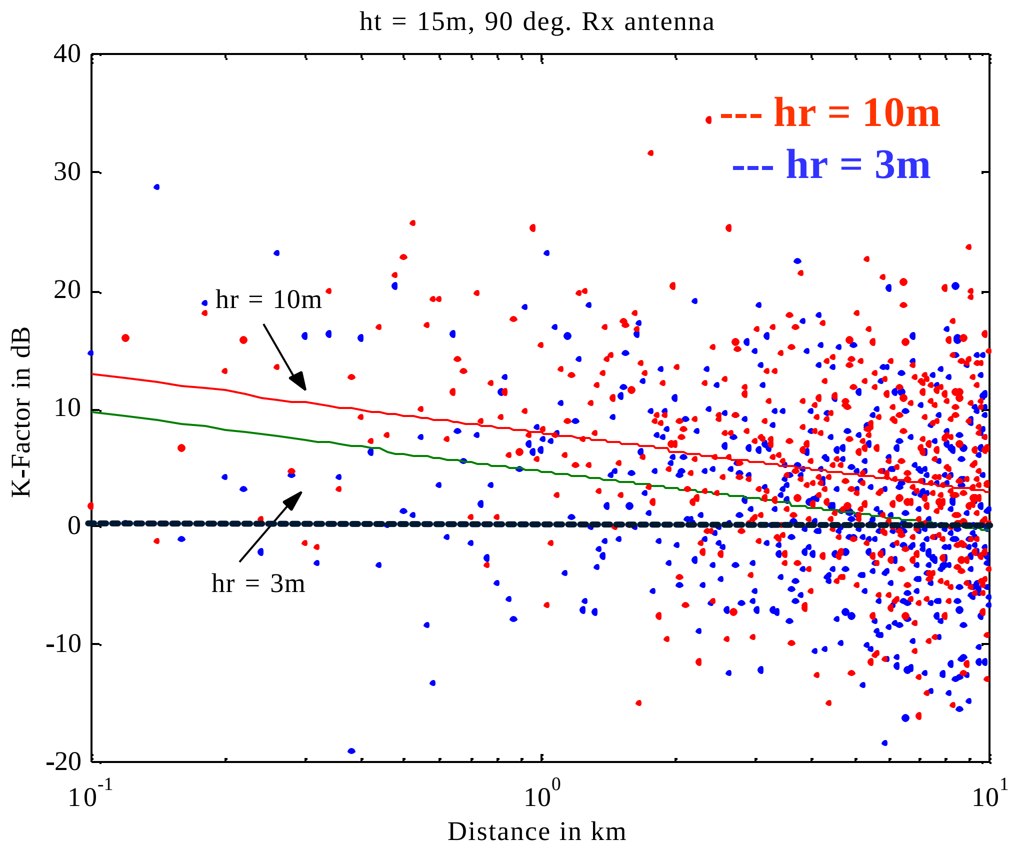
d is the distance in km

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 (Suburban Environments) Simulation



30-40% prob. that K < 0 dB

K=0 is necessary assumption for reliable NLOS deployments

Discussion and Conclusions

For multi-cell BWA deployments:

1) K = 0 (Rayleigh fading) must be assumed for robust system design

2) Excess delay spread values vary from 0 - 20 ms

3) Antenna Gain Reduction Factors (GRF) must be accounted for in link budgets

4) More suitable path loss models need to be used