# Channel Models for Broadband Wireless Access

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For information and discussion

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# Channel Models for Fixed Wireless Systems

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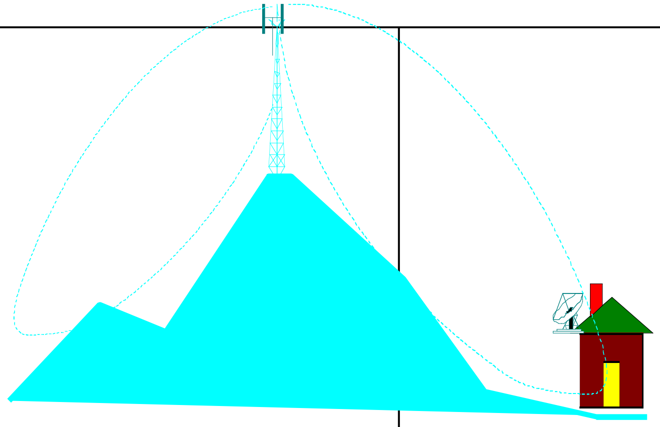
# Outline

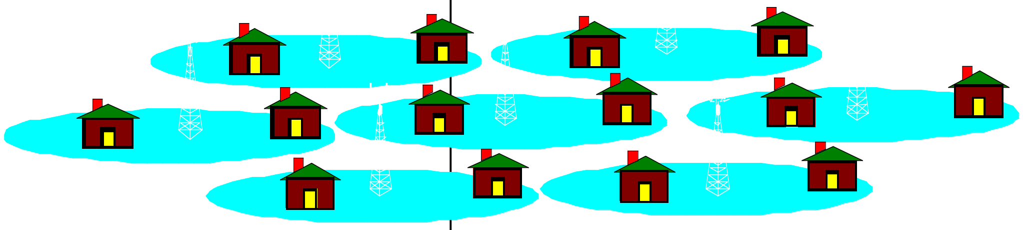
- Introduction
- Path Loss Model
- Antenna Gain Reduction
- RMS Delay Spread Model
- K-Factor Model
- Discussion and Conclusions

# “Super Cell” System Scenario



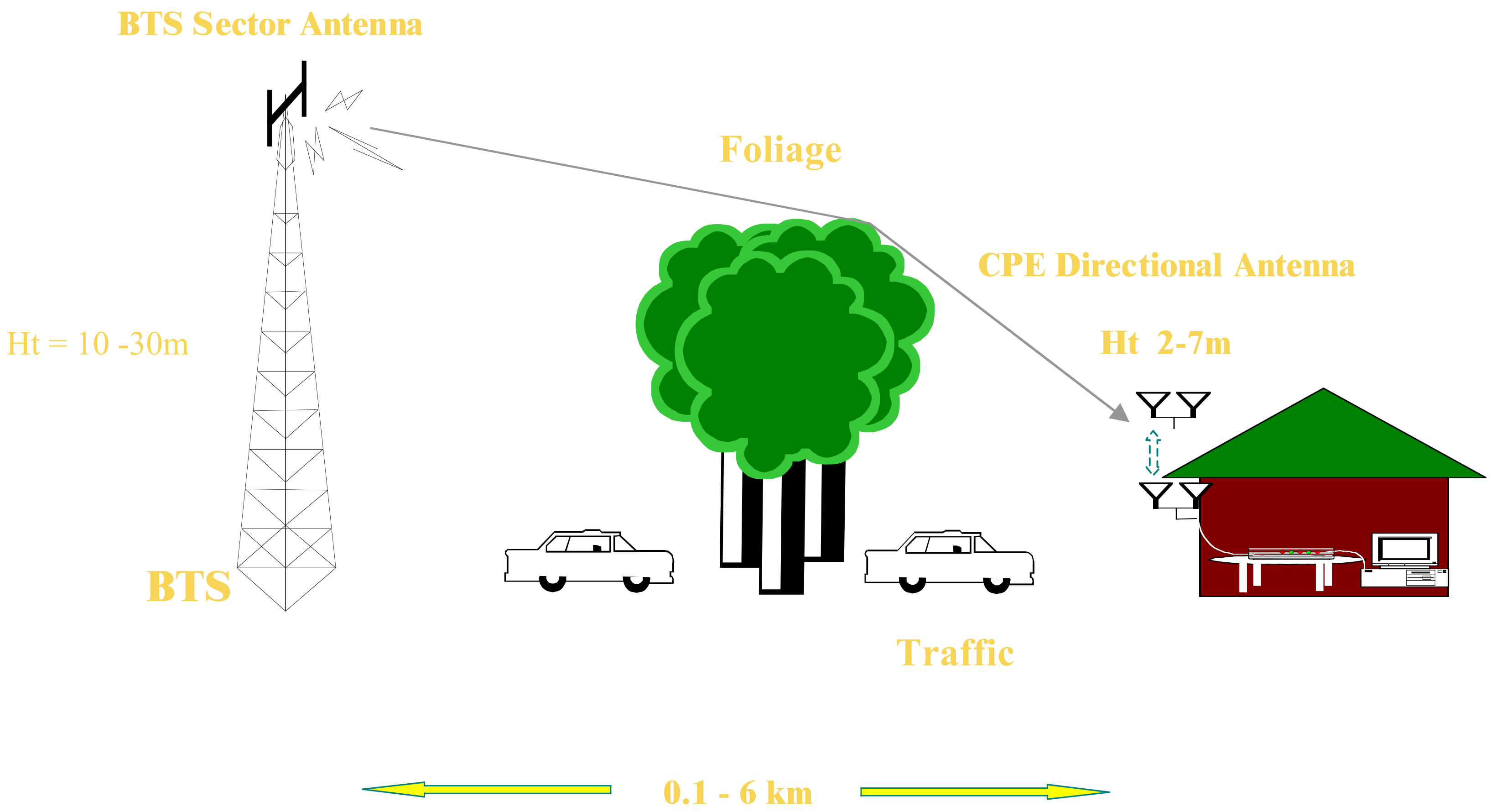
- LOS
- High BTS > 300 m
- Rooftop CPE Antenna
- Single Cell / PSA

# ystem Scenario



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

# Propagation Scenario



BTS Sector Antenna

Foliage

CPE Directional Antenna

Ht = 10 -30m

Ht 2-7m

BTS

Traffic

0.1 - 6 km

# 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 Intercept Model:

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

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

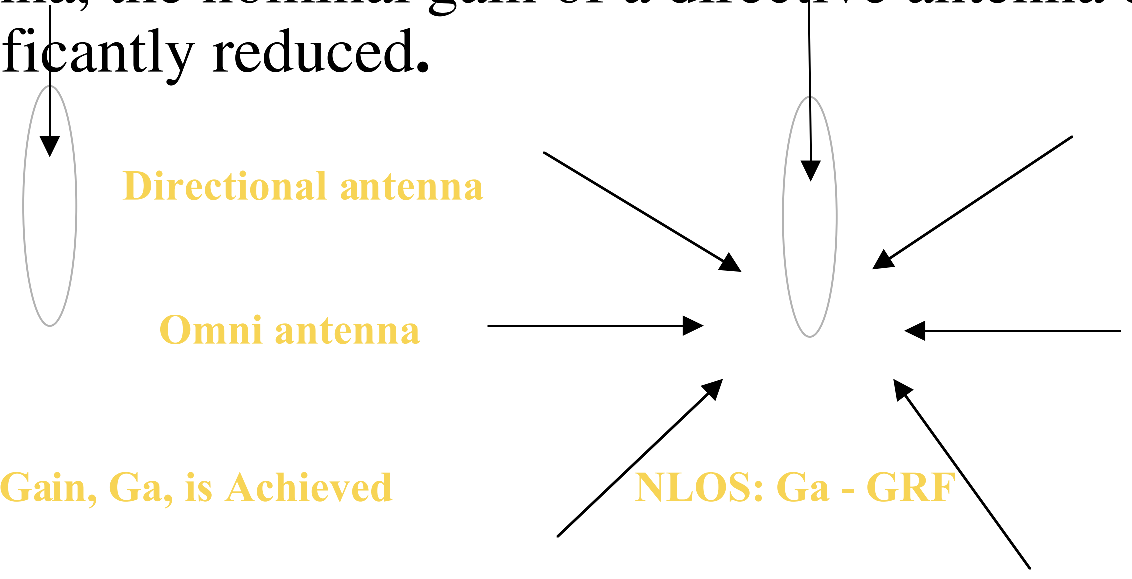
Path Loss Exponent: $\gamma = (a - b\,h_b + c\,/\,h_b) + x\,\sigma\,;$

$h_b$: 10 - 80m

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

# 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.



Directional antenna

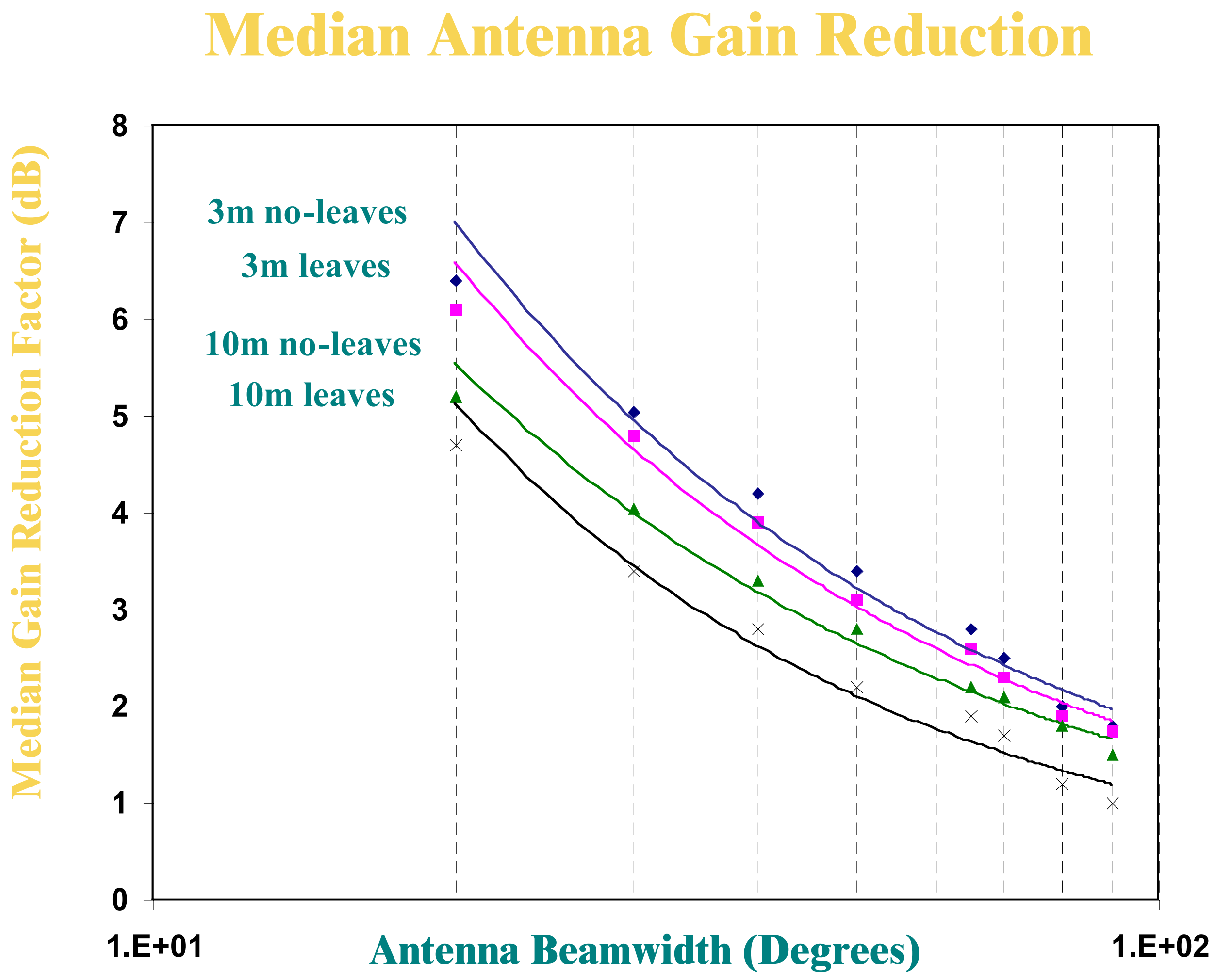
Omni antenna

Pure LOS: Full Gain, Ga, is Achieved

NLOS: Ga - GRF

[2] L.J. Greenstein and V. Erceg, "Gain reductions due to scatter on wireless paths with directional antennas," *IEEE Communications Letters*

# 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° receive antenna.

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.**

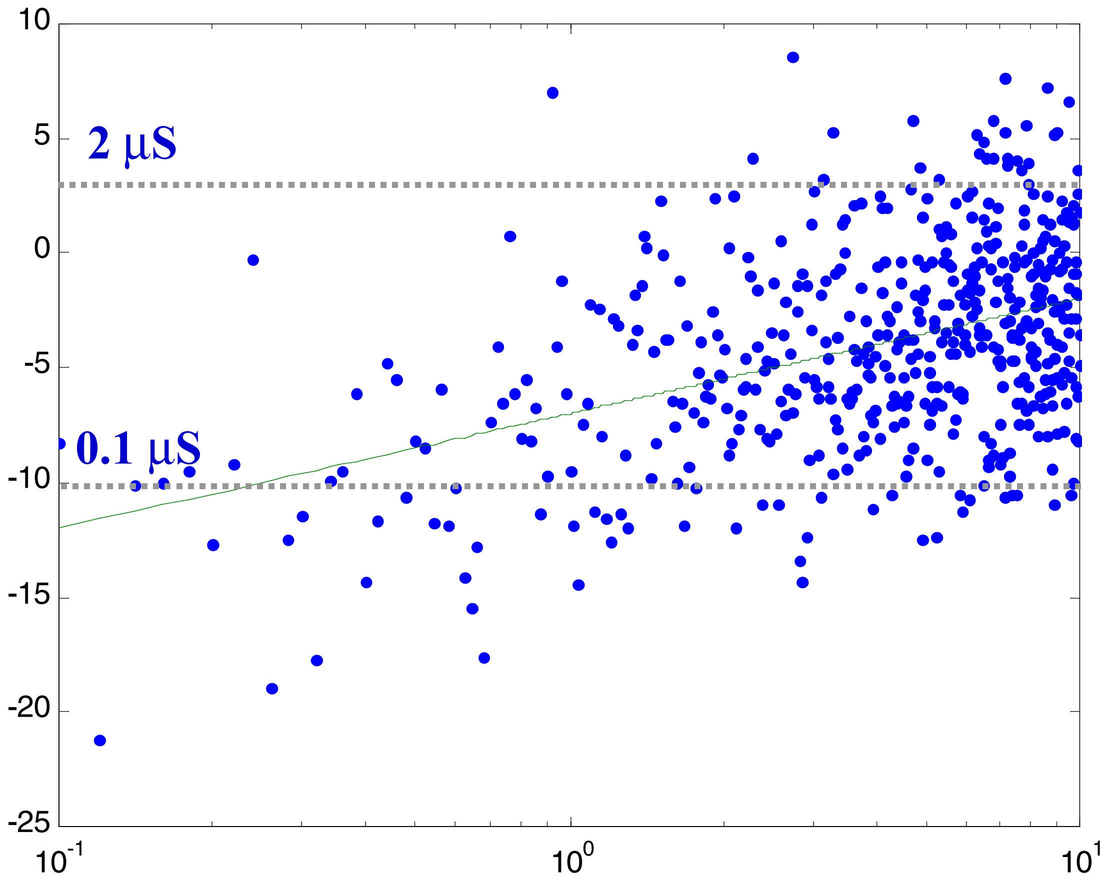
# RMS Delay Spread Model

**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:**

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

**Where $\tau_{rms}$ is the rms delay spread, d is the distance in km, $T_1$ is the median value of $\tau_{rms}$ at $d = 1$ km, $\varepsilon$ 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]**

# 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.

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

**[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 et.al., "Measurements and characterization of broadband MIMO fixed wireless channels at 2.5 GHz", to appear in** ***Proceedings of***

# 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**

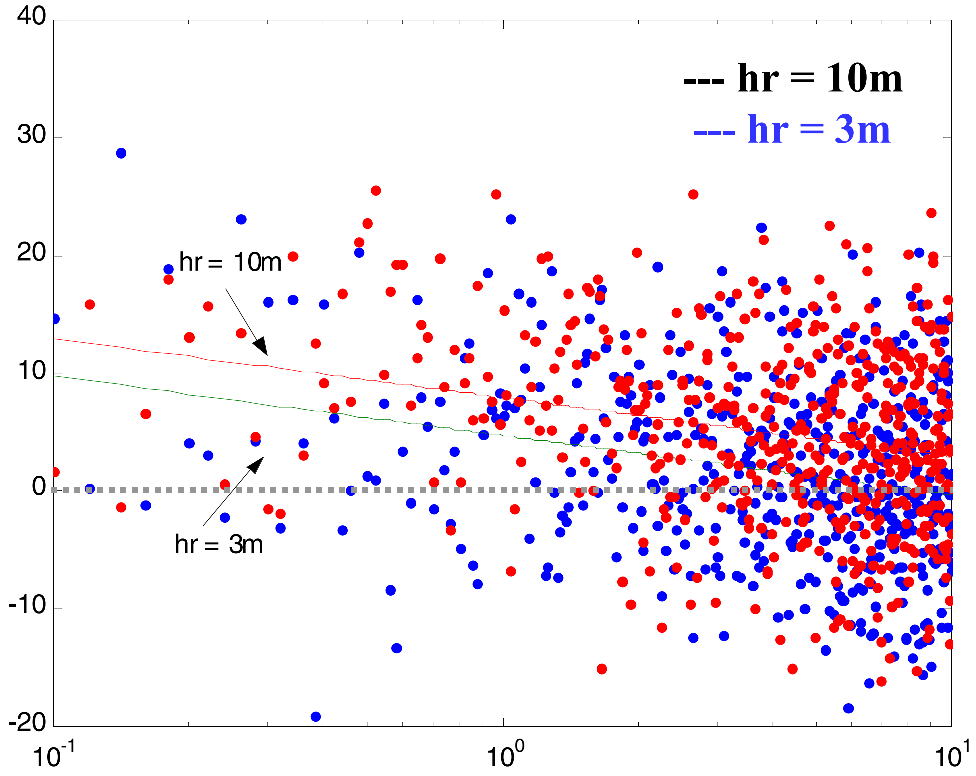
**$F_b$ is the antenna beamwidth factor = $(b/17)^{-0.62}$ ; b in degrees**

**d is the distance in km**

**$\gamma$ is the exponent = - 0.5**

**K is the 1 km intercept = 10 dB**

# K-Factor vs. Distance (Suburban Environments)
# Simulation



30-40% prob. that K < 0 dB

K=0 is necessary assumption for reliable deployments

# Discussion and Conclusions

For multi-cell BWA deployments:

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

2) Delay spread values vary from 0 - 20 µs ($\tau_{rms}$ in the 0 - 5 µs range)

- Single Carrier Systems must be designed for at least 5µs $\tau_{rms}$
- OFDM Systems must be robust in flat fading conditions

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

4) More suitable path loss models need to be used