Channel Models for Fixed Wireless Systems

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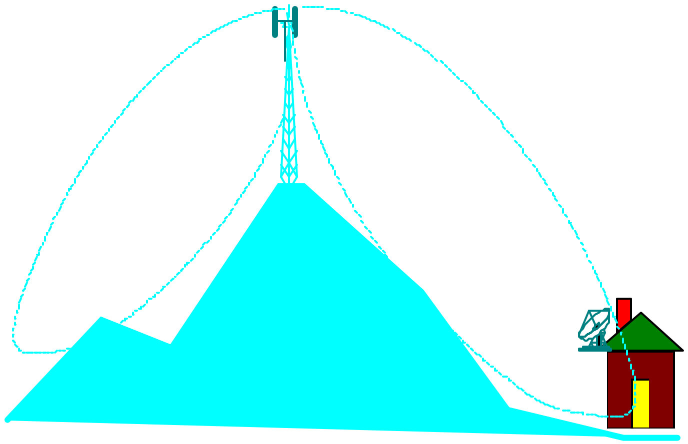
February 2002

iospan wireless

Outline

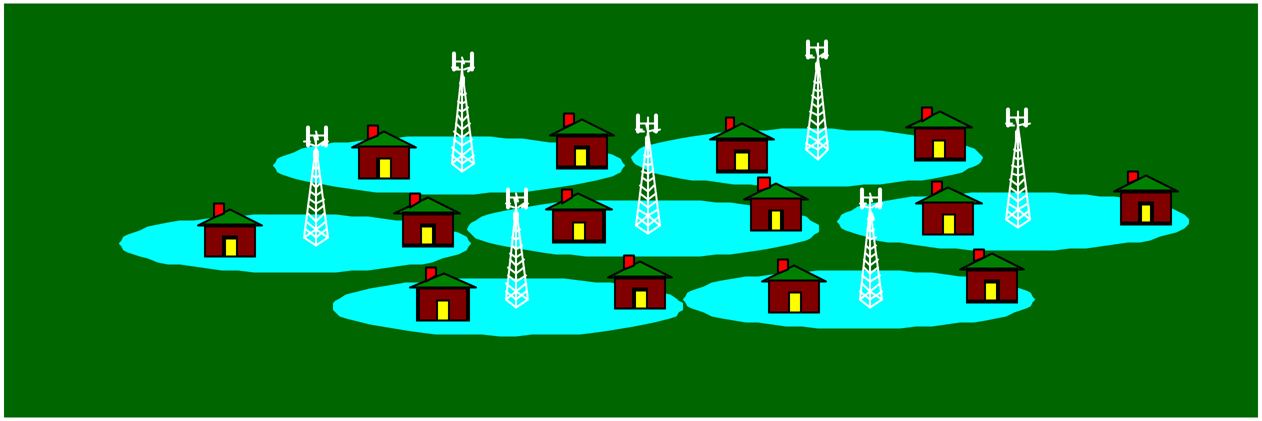
- Introduction
- Fixed Wireless Channel Models
  - Path Loss Model
  - Antenna Gain Reduction
  - RMS Delay Spread Model
  - K-Factor Model
  - Doppler Spectrum
- Diversity Combining Advantage
- Modified SUI Channel Models
- Conclusion

“Super Cell” System Scenario



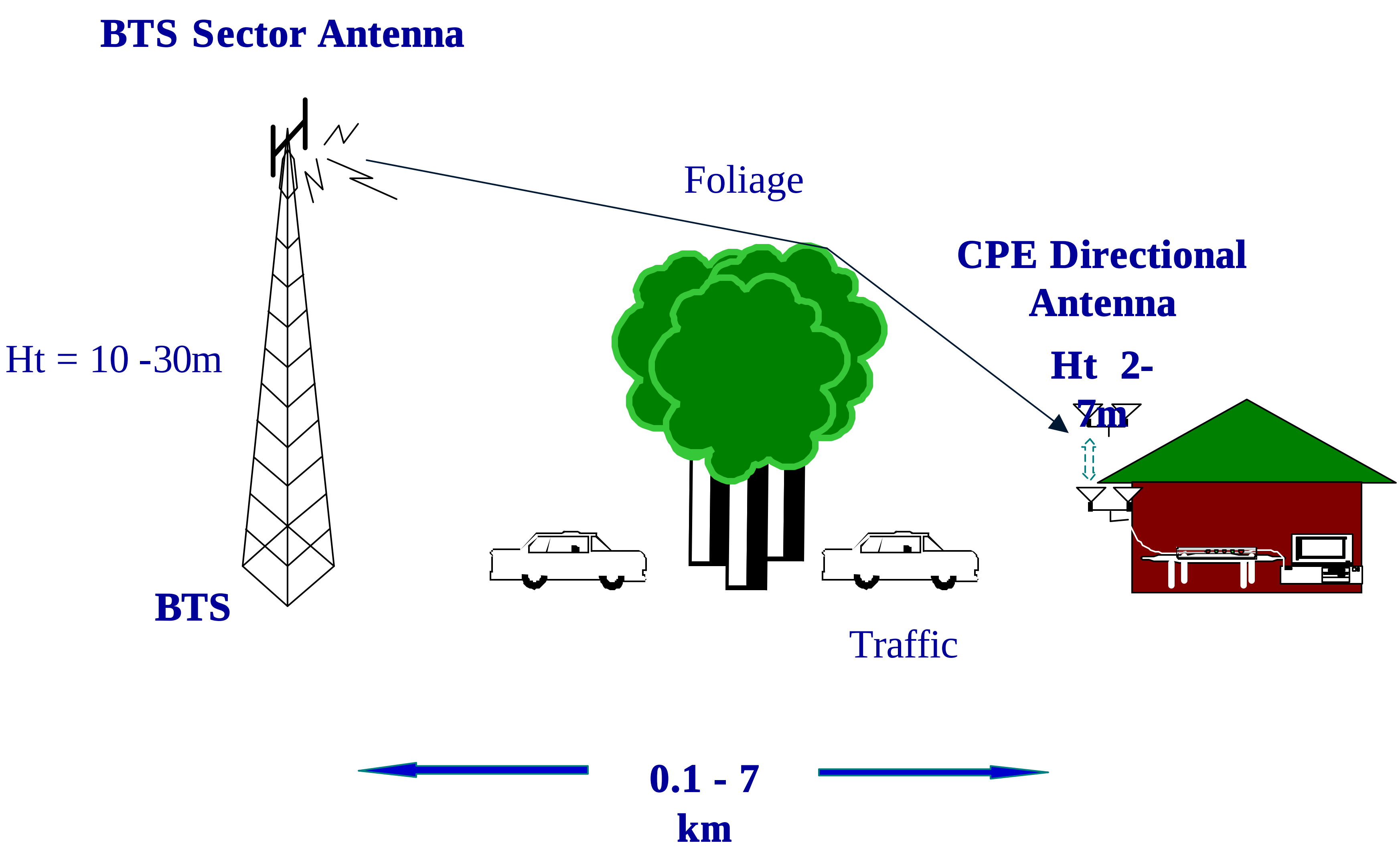
- LOS
- High BTS > 300 m
- Rooftop CPE Antenna
- Single Cell / PSA

Multicell System Scenario

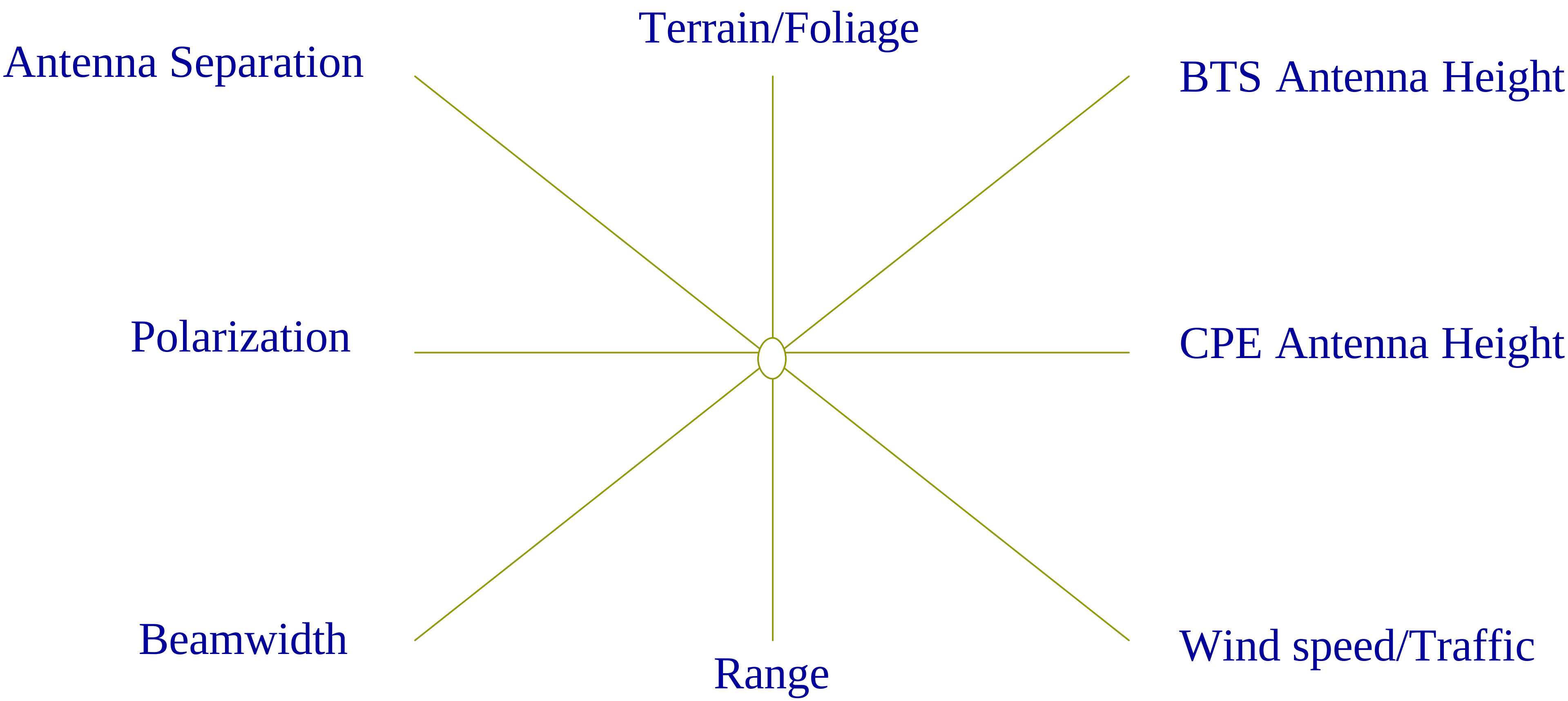


- ☞Low BTS antennas
- ☞Non-LOS propagation/fading
- ☞More path loss (less range)
- ☞Co-channel Interference

Propagation Scenario



Channel Has Many Dimensions



Fixed Wireless Channel Models

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 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:

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

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

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

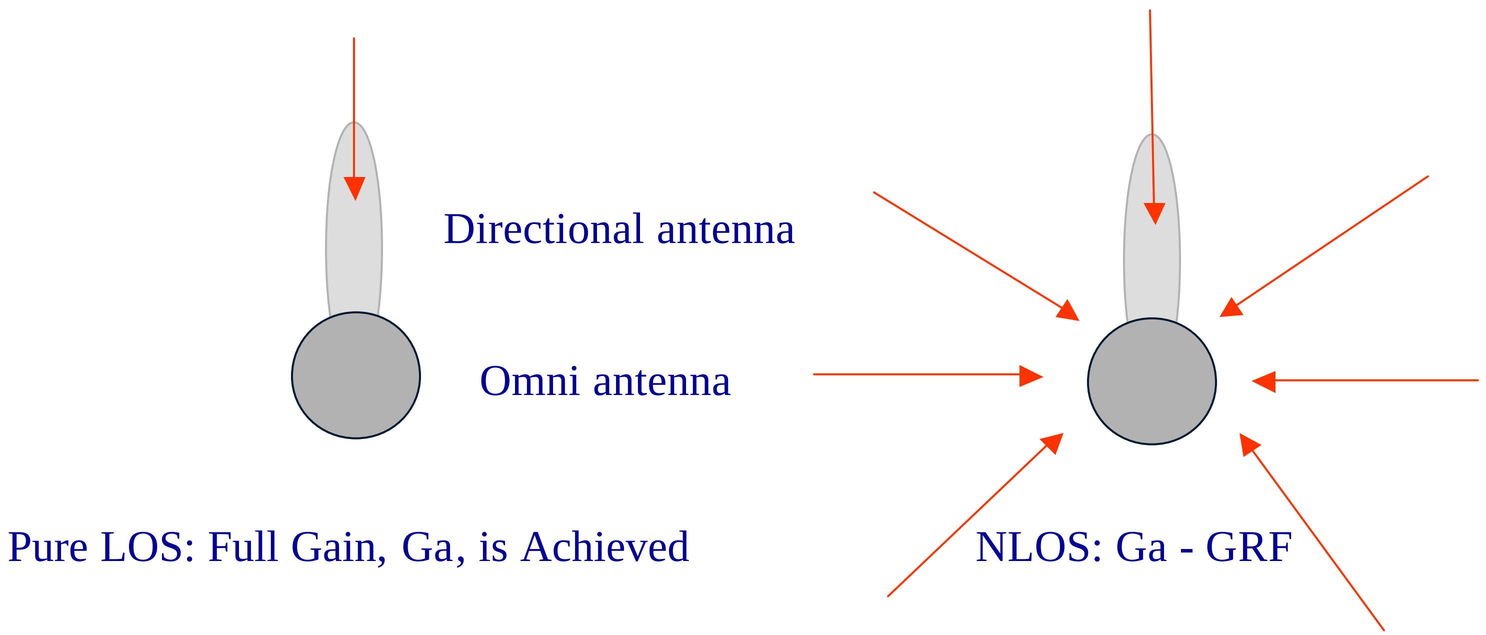
Shadow Fading Standard Deviation: $\sigma = \mu_\sigma + z\,\sigma_\sigma$

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

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

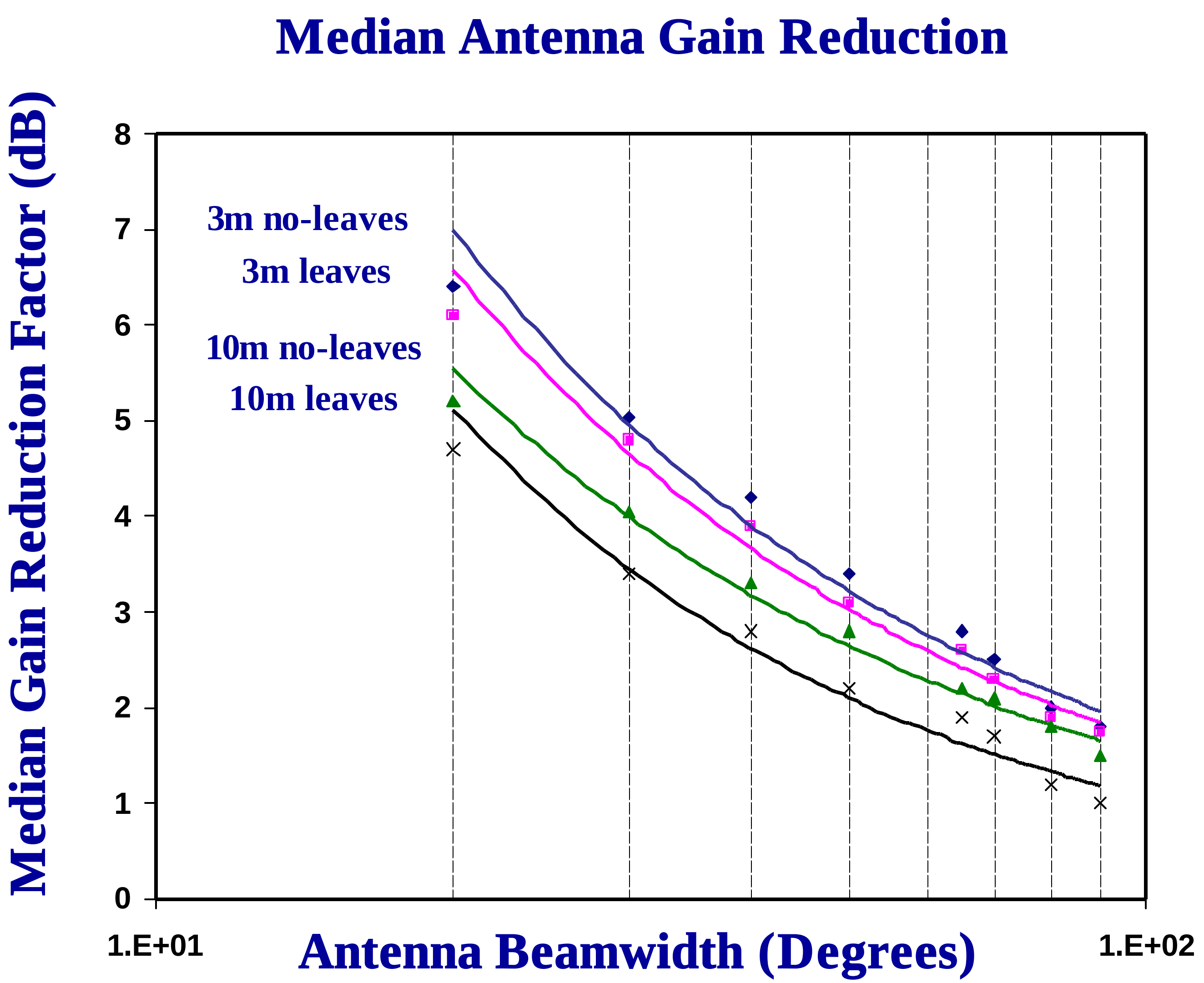
Antenna Gain Reduction Factor (GRF)

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: Cont’



Antenna Gain Reduction: Cont’

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

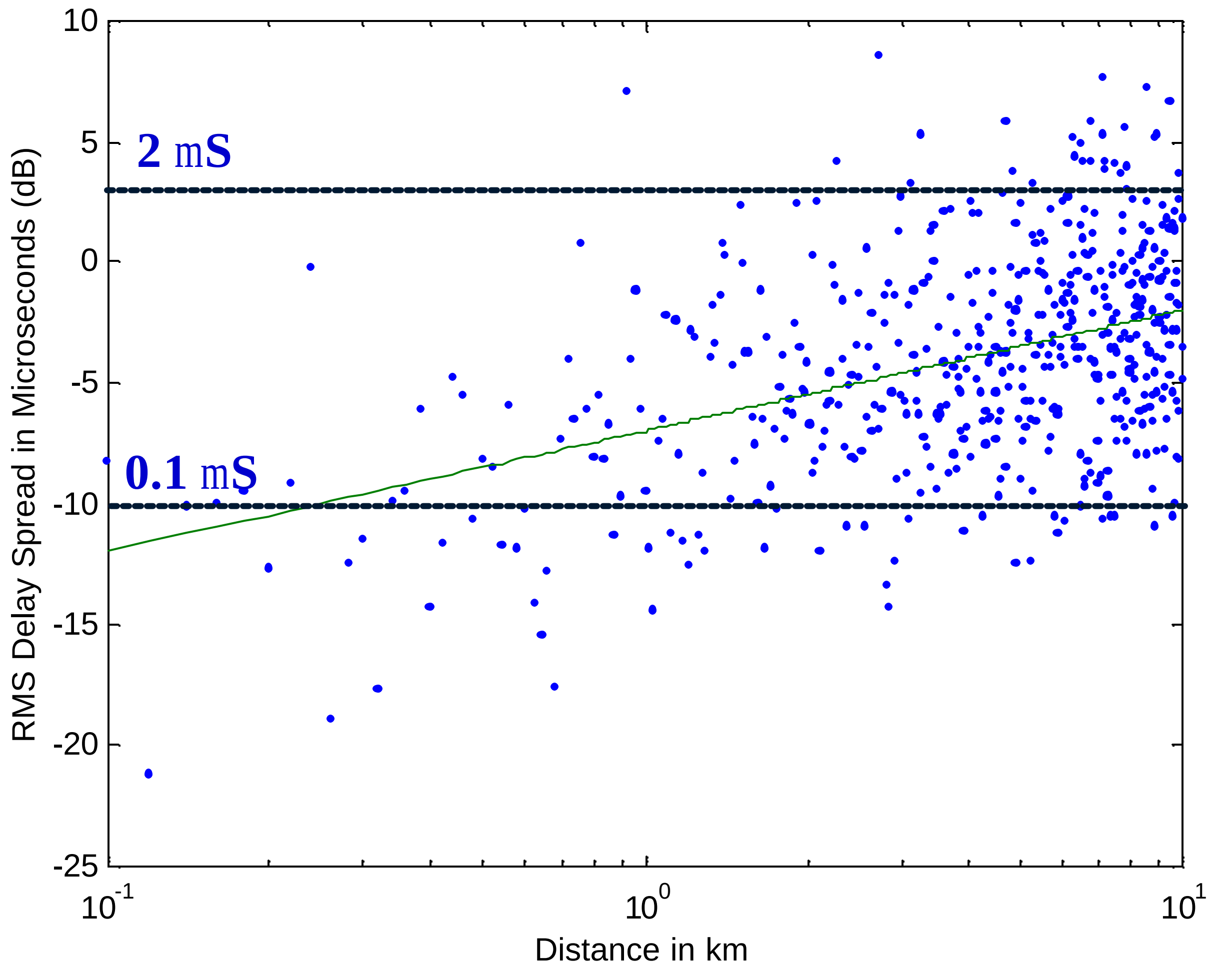
A delay spread model was proposed in [3] based on a large body of published reports. The model was developed for rural, suburban, urban, and mountainous environments. The model is of the following form:

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

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



Omni Receive Antenna

RMS Delay Spread: Cont'

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”, *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.

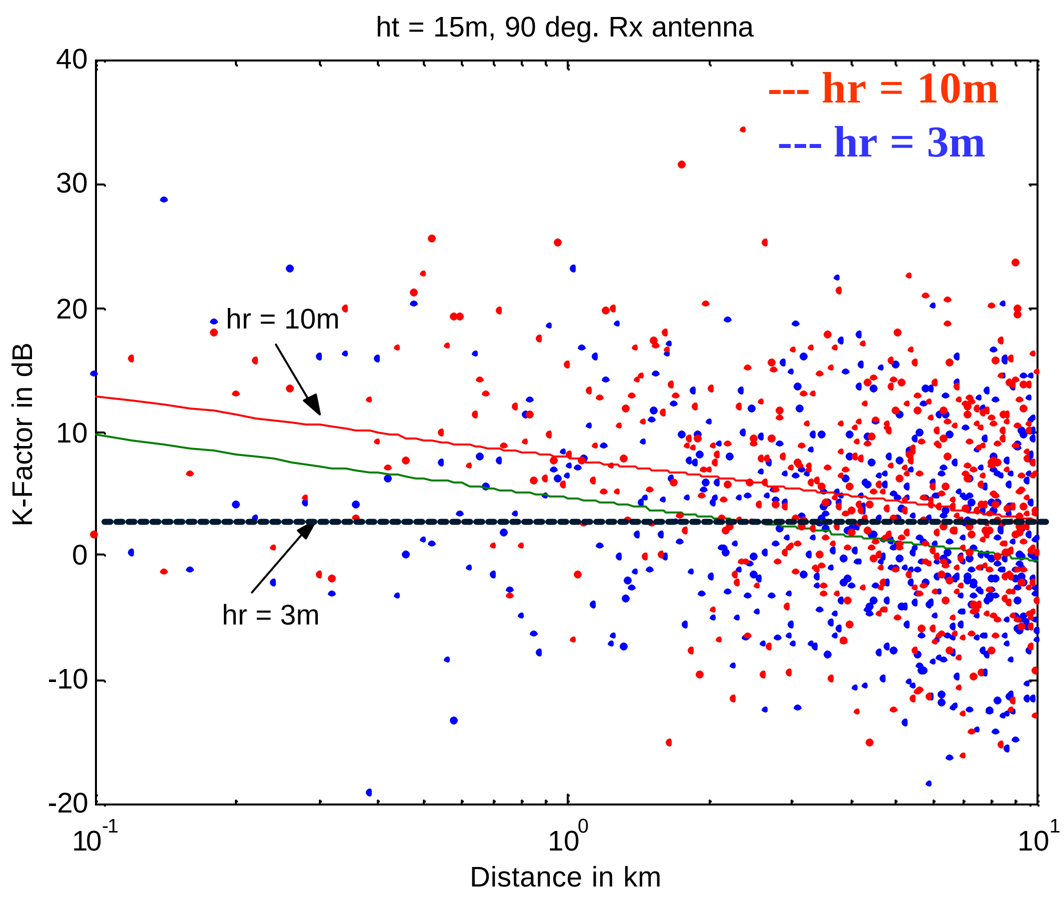
d is the distance in km

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.

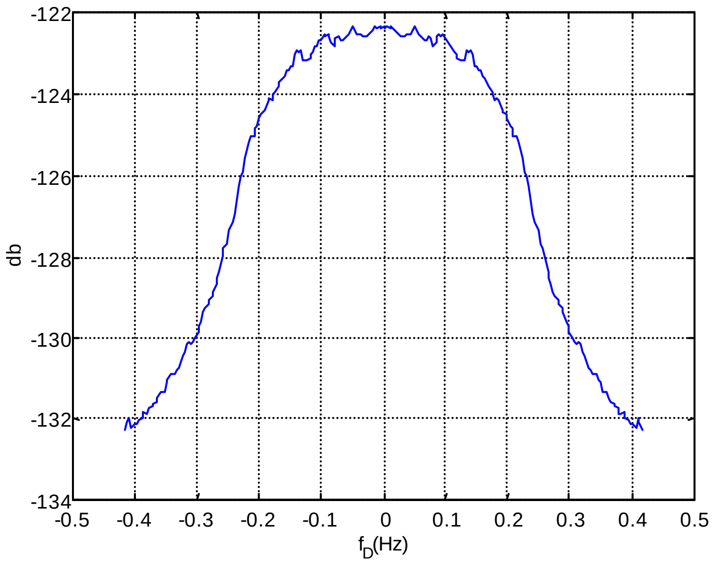
K-Factor vs. Distance (Suburban Environments) Simulation



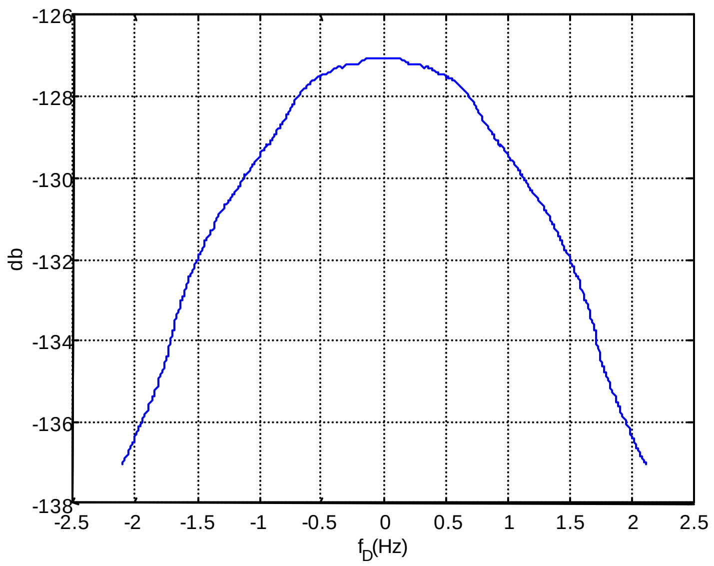
High probability that K < 0 dB

Doppler Power Spectrum

Low Wind



High Wind



Rounded Spectrum with f_D~ 0.1Hz- 2Hz

Diversity Combining Advantage

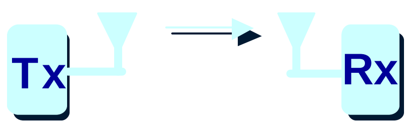
Antenna Correlation

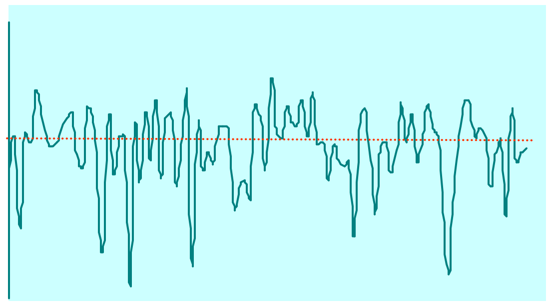
For SIMO, MISO, MIMO channels, correlation between multiple channels depends on

- Spacing between antennas
- Height of the antennas
- Beamwidth
- Polarization
- Distance from the BTS
- Environment

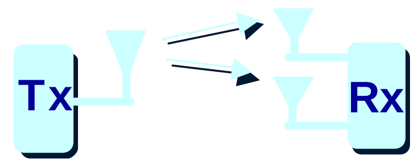
Diversity Gain

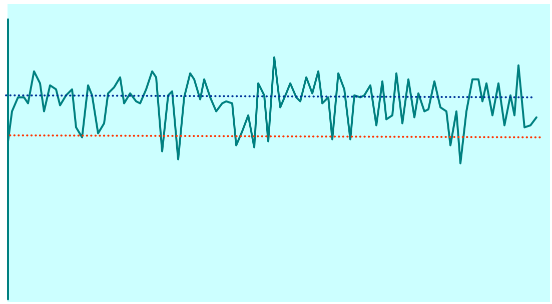
1×1



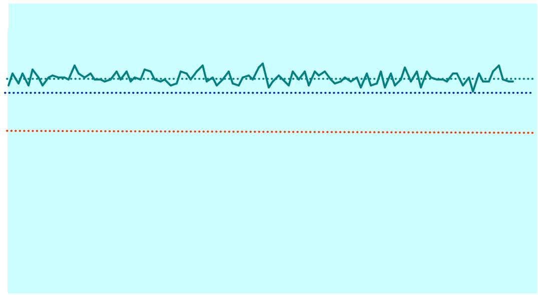


1×2



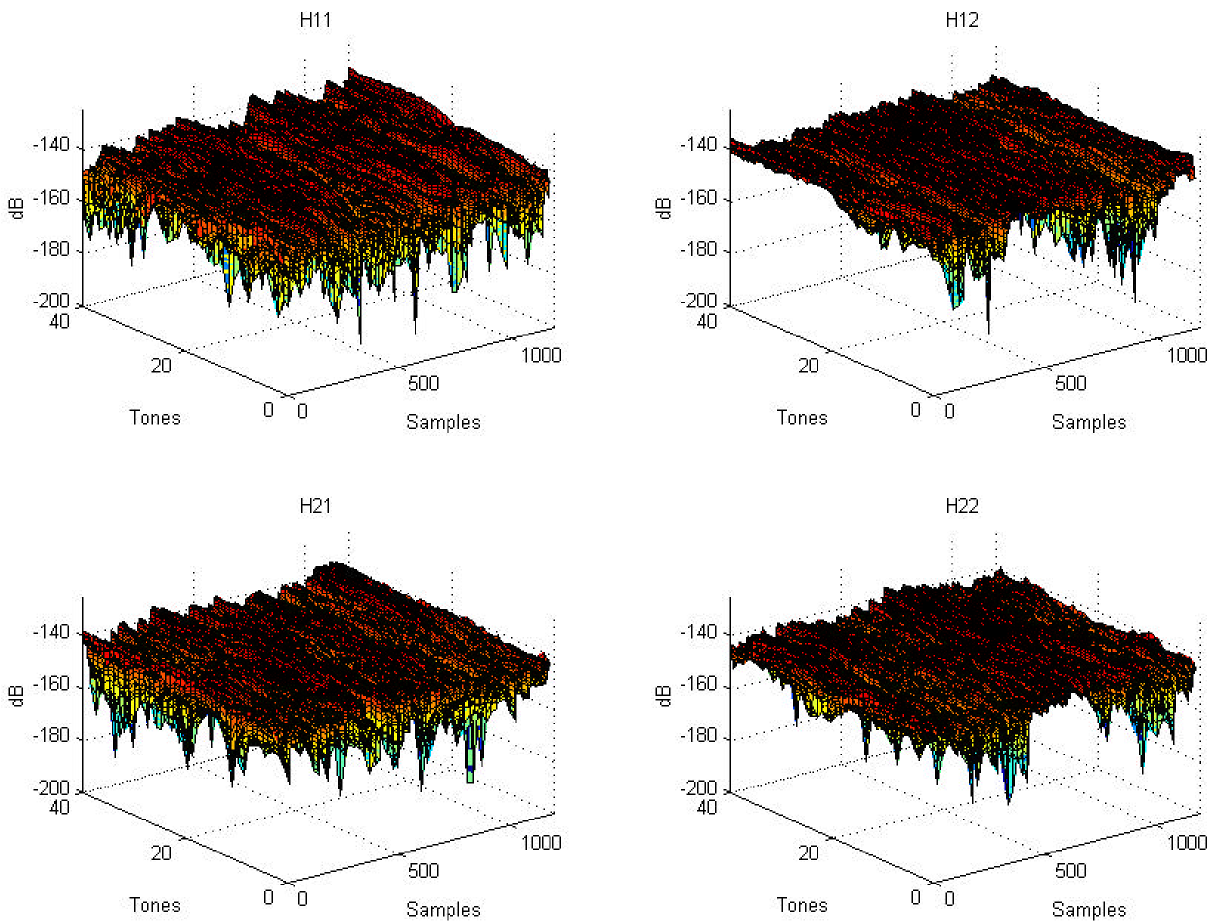


N×M

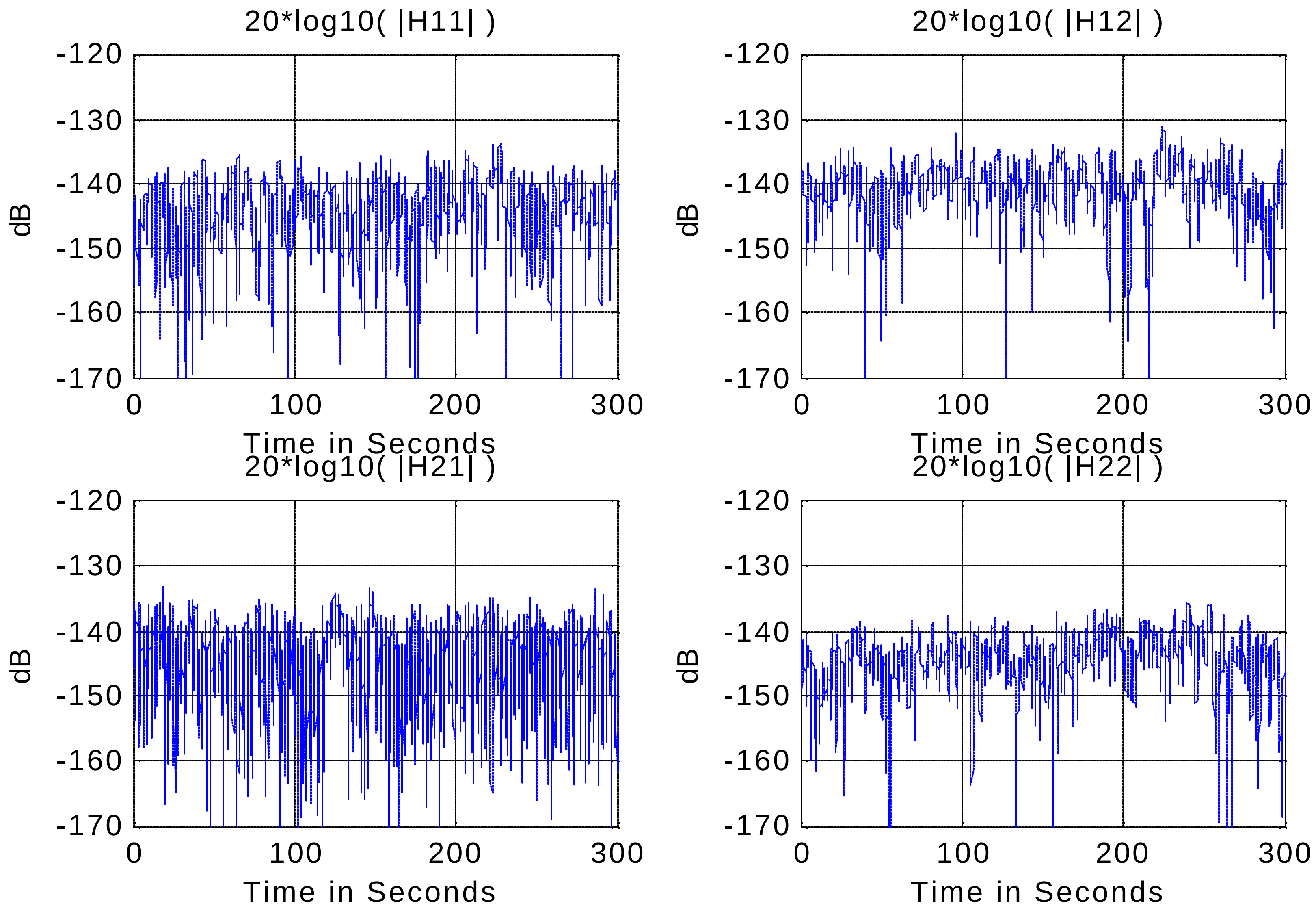


2 x 2 Channel Matrix (Frequency vs. Time) - Measured

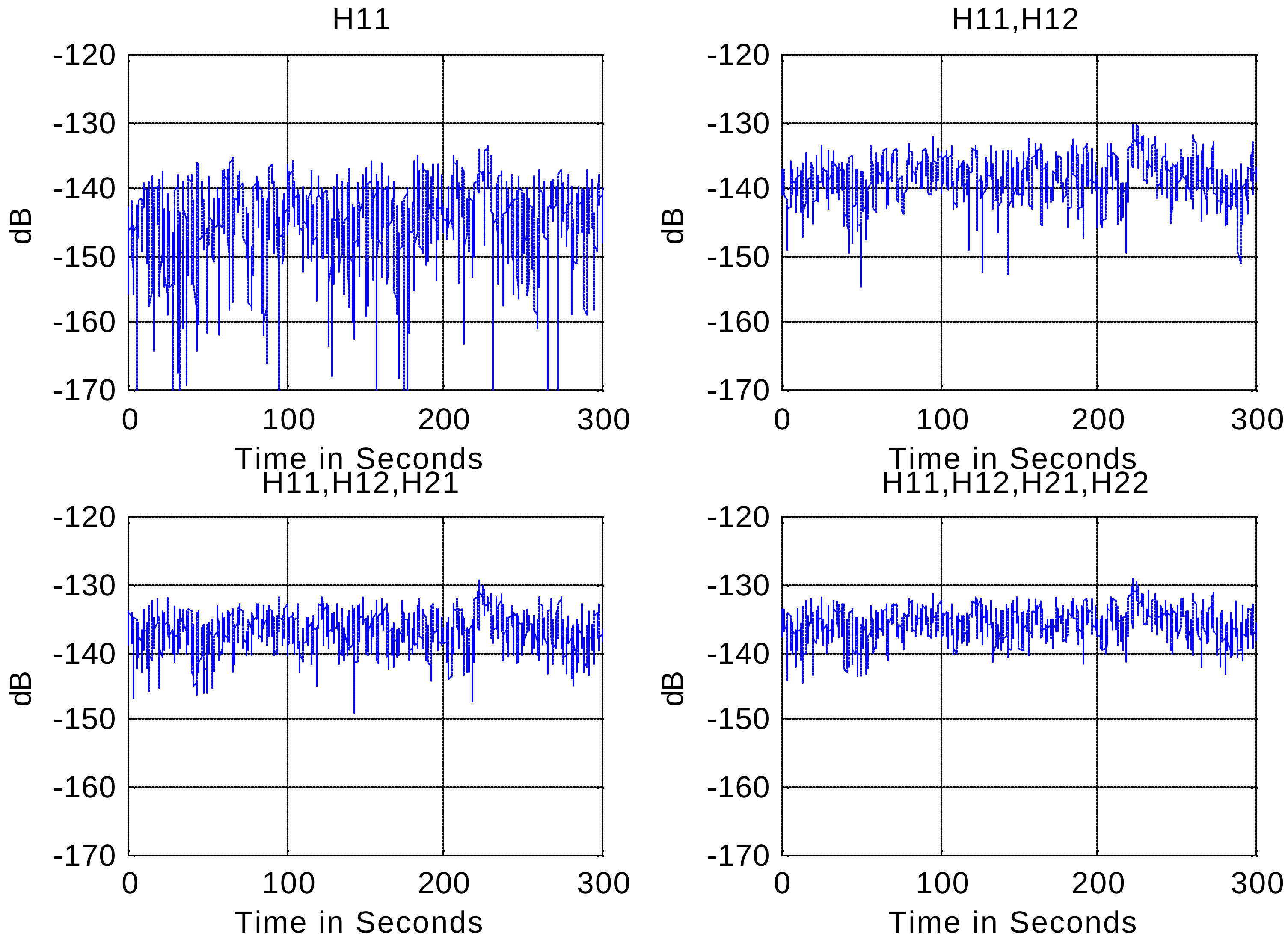
2.4 GHz



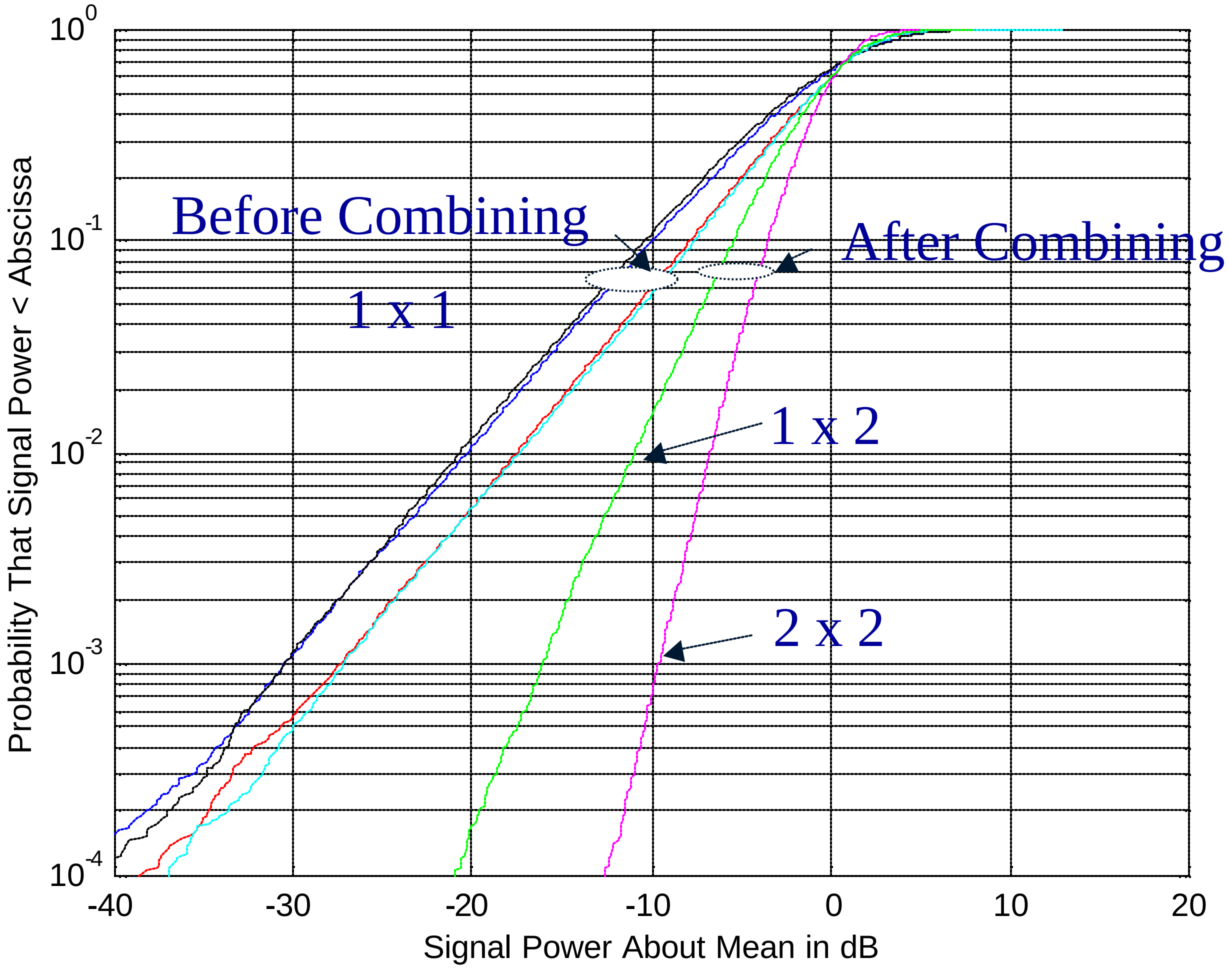
2 x 2 Channel Matrix (Single Tone) - Measured



Effect of Combining - Measured Data



CDF of Tx-Rx Diversity - Measured



Cell Radii for Systems with Different Orders of Diversity

Assumptions: Rayleigh flat fading, BER = 10^{-3} , array gain accounted for, $1/d^4$ propagation, uncorrelated fading.
Source: Theoretical BER vs SNR curves (Proakis, *Digital Communications*)

Diversity Order	Maximum Allowable Path loss	Relative Cell Radius
SISO 1x1	PL	1
SIMO 1x2	PL+13 dB	2.1
MIMO 2x2	PL+16 dB	2.5
MIMO 2x3	PL+19 dB	3.0

Modified SUI (802.16) Channel Models

SUI Channel Model Assumptions

- A cell size of 7km
- BTS Antenna height: 30m
- CPE antenna height: 6m
- BTS Antenna beamwidth: 120 deg
- CPE Antenna Beamwidth: 360 and 30 deg
- Vertical Polarization only

SUI-4

SUI – 4 Channel				
	Tap 1	**Tap 2**	**Tap 3**	**Units**
Delay	0	1.5	4	µs
Power (omni ant.)	0	-4	-8	dB
90% K-fact. (omni)	0	0	0	
75% K-fact. (omni)	1	0	0	
Power (30^o ant.)	0	-10	-20	dB
90% K-fact. (30^o)	1	0	0	
75% K-fact. (30^o)	5	0	0	
Doppler	0.2	0.15	0.25	Hz

Antenna Correlation: $\rho_{ENV} = 0.3$
Gain Reduction Factor: GRF = 4 dB
Normalization Factor: $F_{omni} = -1.9218$ dB, $F_{30°} = -0.4532$ dB

Terrain Type: B
Omni antenna: $\tau_{RMS} = 1.257$ µs
overall K: K = 0.2 (90%); K = 0.6 (75%)
30° antenna: $\tau_{RMS} = 0.563$ µs
overall K: K = 1.0 (90%); K = 3.2 (75%)

Discussion and Conclusions

For multi-cell BWA deployments:

- K = 0 (Rayleigh fading) must be assumed for robust system design
- Excess delay spread values vary from 0 - 20 µs
- Antenna Gain Reduction Factors (GRF) must be accounted for in link budgets
- Diversity combining dramatically improves coverage/reliability of any system