Interim Channel Models for G2 MMDS Fixed Wireless Applications

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Purpose:

This is to present work by Stanford University on MMDS channel models with requirements from Sprint.

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Interim Channel Models for G2 MMDS Fixed Wireless Applications

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7 Nov 00

G2 MMDS Scenario*

- Cells are < 4 miles in radius,
- Under-the-eave/window broadbeam directional antennas (8-15ft) at the CPE
- 50-120ft BTS antennas.

* G2 MMDS:Generation2 Multi-channel Multi-point Distribution System

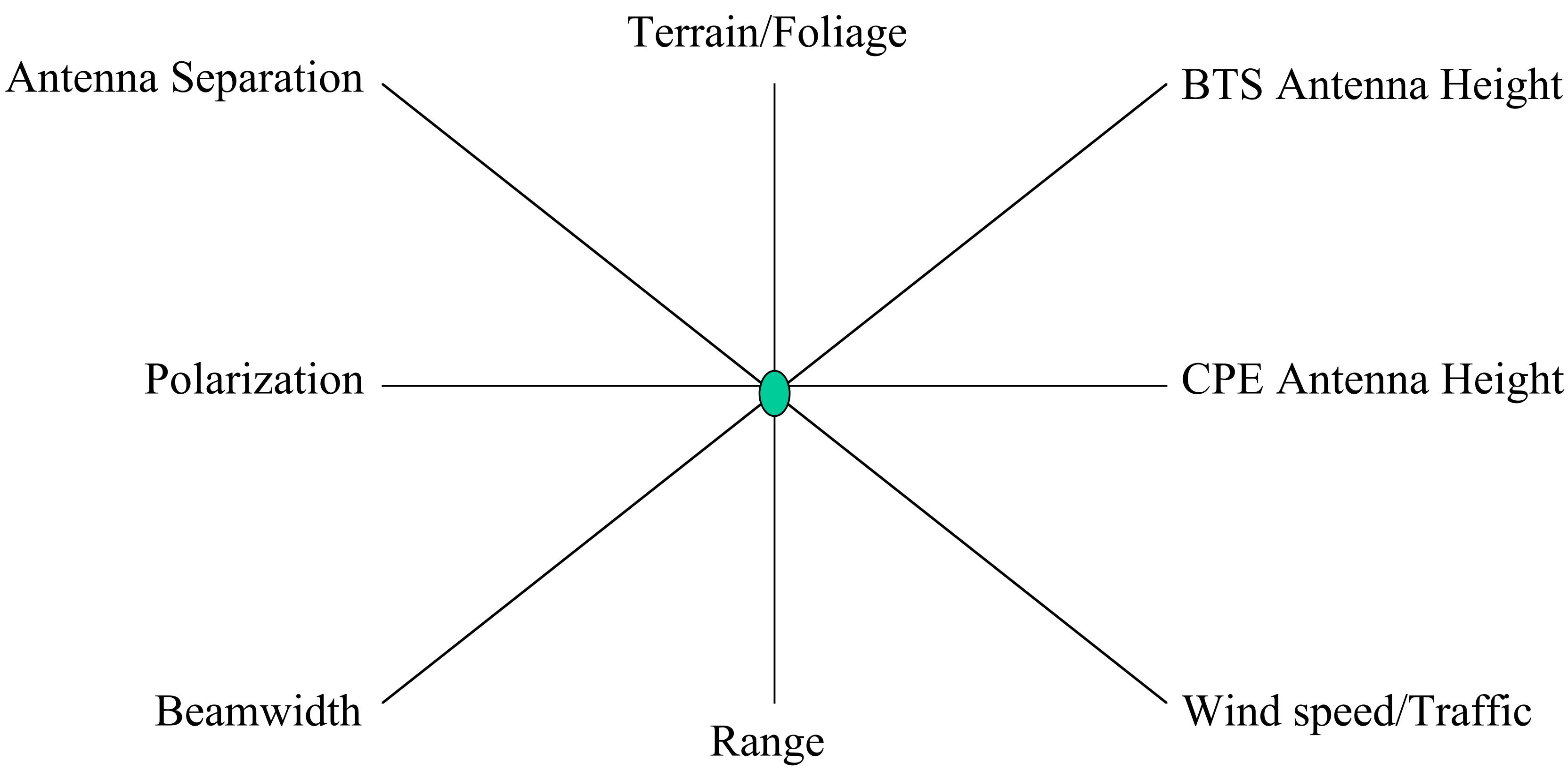
Impairments

- Higher Path Loss (as compared to super cell architecture)
- Fading: Macroscopic (due to shadowing) and Microscopic (due to multipath).
- Co-channel and Adjacent channel Interference
- More severe multipath delay spread
- Doppler spread

Channel Model

- Channel Model shall describe
  - Path Loss
  - Multipath Fading and correlation
  - Interference

Channel Has Many Dimensions



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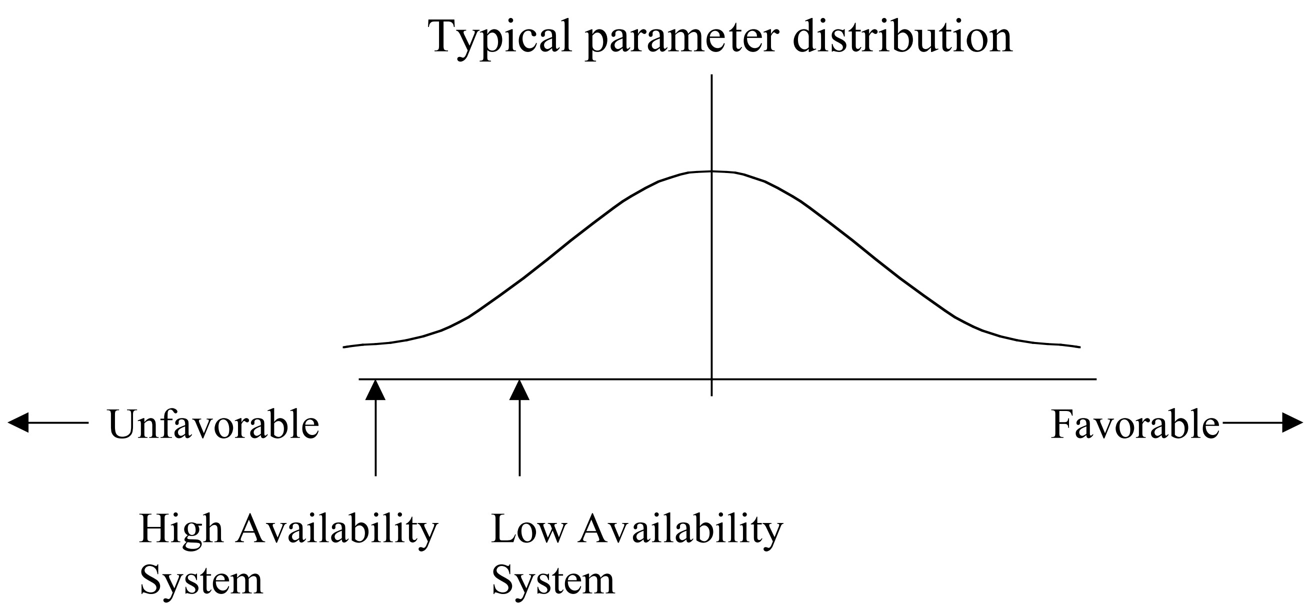
Channel Model Variability

- Channel parameters are RANDOM quantities
- We need Statistical characterization
  – Cumulative Distribution Function (CDF)



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Path Loss Model

- Hata, COST 231 Hata path loss models are for very high BTS and are not suitable for G2 MMDS scenario
- Erceg Model is the appropriate model

G2 MMDS Path Loss Model

Median Path Loss (Erceg model):

$$PL(dB) = A + 10\gamma \log_{10}(d / d_0) + s + \Delta PL_f + \Delta PL_h$$

for $d > d_0$

where

$$A = 20\log_{10}(4\pi d_0 / \lambda)$$ (free space path loss)

$$\gamma = a - bh_b + c/h_b$$, **10** meters < h_b < **80** meters

(mean path loss exponent)

λ is the wavelength

Path Loss Model (contd.)

- s is a lognormal shadow fading
  - zero mean
  - terrain dependent standard deviation
- h_b is the BTS height in meters
- a, b, c are constants dependent on the terrain category
- d_o is chosen as 100m (reference distance)
- d is the distance from BTS

Correction Terms

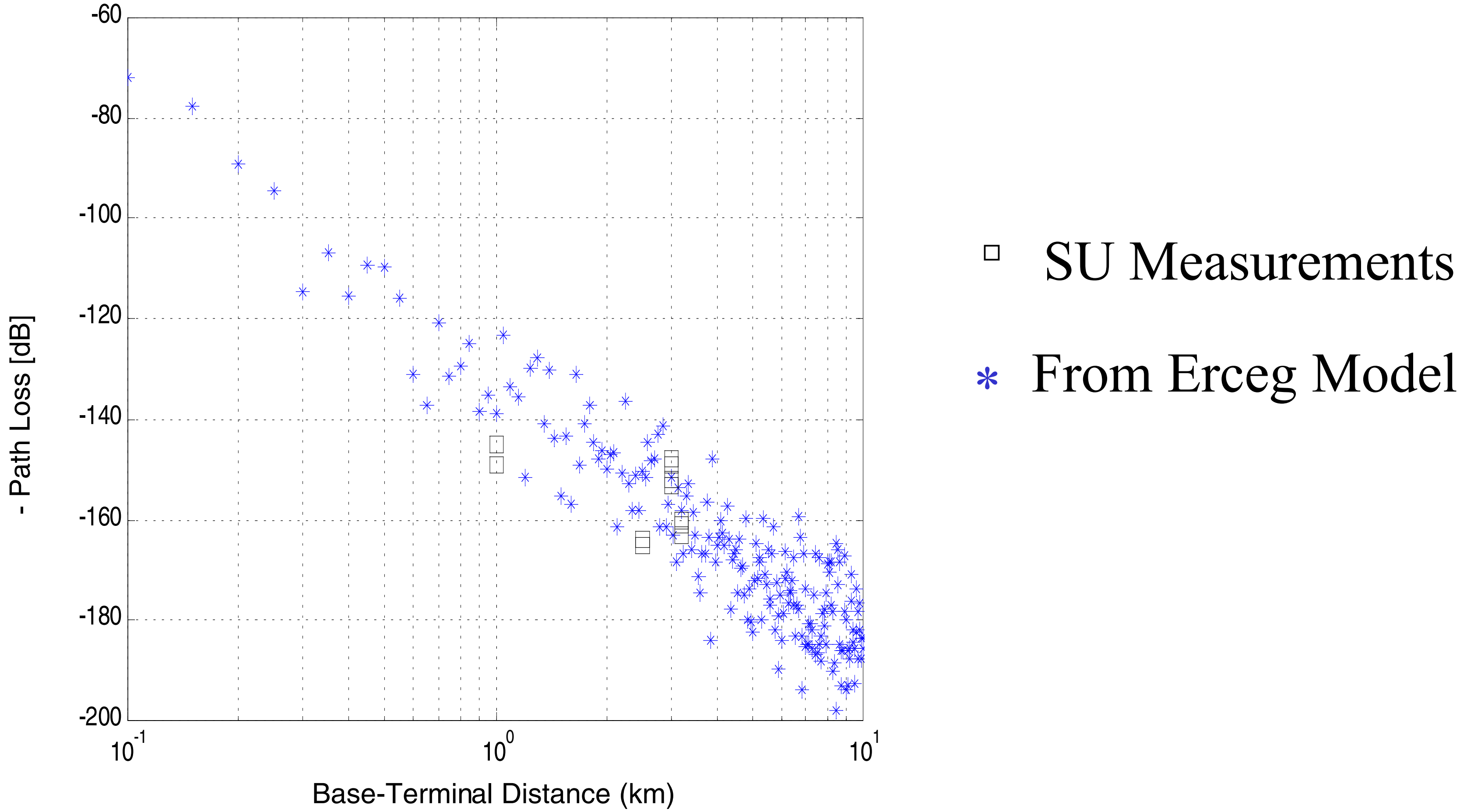
- Frequency correction terms

$$\Delta PL_f = 5.7\log\left(f/2000 \right) \qquad f \text{ in MHz}$$

- CPE height correction term (> 2 meters)

$$\Delta PL_h = -10.8\log\left(h_{CPE}/2 \right) \quad 1 \text{ meter} < h_{CPE} < 8 \text{ meters}$$

Path Loss Scatter Plot



K-Factor

- K-Factor is the ratio of power in the fixed component to the power in the variable component
- It depends upon
  - BTS, CPE heights and beamwidths
  - Distance from the antenna
  - Scattering environment
  - Wind, traffic, season

K-factor Model

- Erceg model for K-factor

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

- F_s is a seasonal factor
  - 1.0; summer (leaves)
  - 2.5; winter (no leaves)
- F_h is the height factor
  - $(h/3)^{0.46}$ (h is the CPE height in meters)

K-factor Model (contd.)

- F_b is the beamwidth factor
  - $F_b = (b/10)^{-0.62}$; (b in degrees)
- K_o and γ are regression coefficients
  - $K_o = 10; \gamma = -0.5$
- u is a lognormal variable
  - zero mean
  - std. deviation of 8.0 dB

K-factor and Reliability

- K-factors are highly variable
- To ensure 99.9% reliability, systems must be designed for zero K-factor (Rayleigh fading)

Delay Spread Model

- Spike-Plus-Exponential Model (Erceg)

$$P(\tau) = A\delta(\tau) + B \sum_{i=0}^{\infty} e^{-i\Delta\tau/\tau_o}\delta(\tau - i\Delta\tau)$$

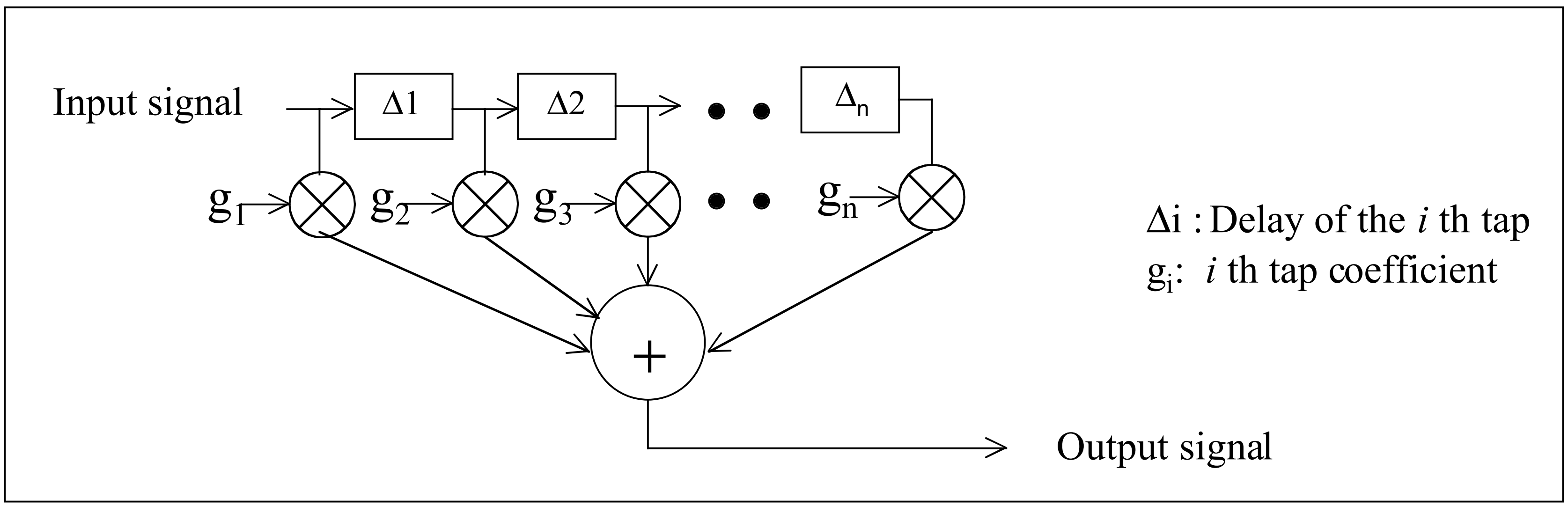
A, *B*, τ_o and $\Delta\tau$ are experimentally determined

$$T_{rms} = \frac{\Delta\tau}{e^{\Delta\tau/2\tau_o} - e^{-\Delta\tau/2\tau_o}}$$

- Good Model for directive antennas

Multipath Fading Model

Modeled by a Tapped Delay Line (TDL)

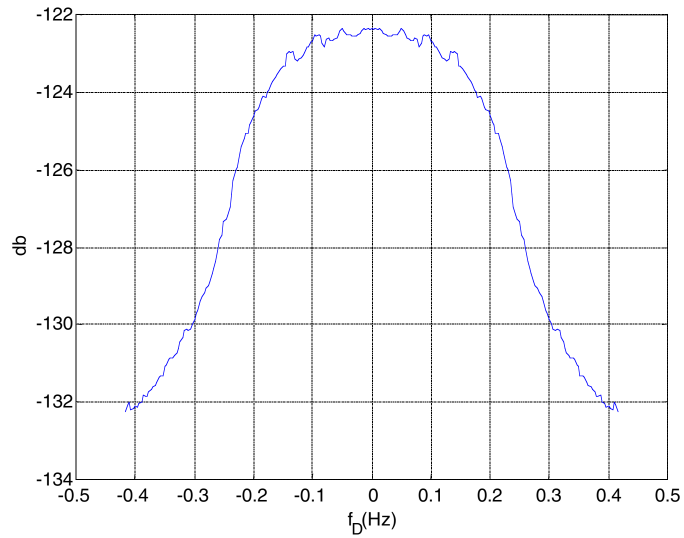


Output signal is a linear combination of
time-shifted, attenuated copies of the input signal

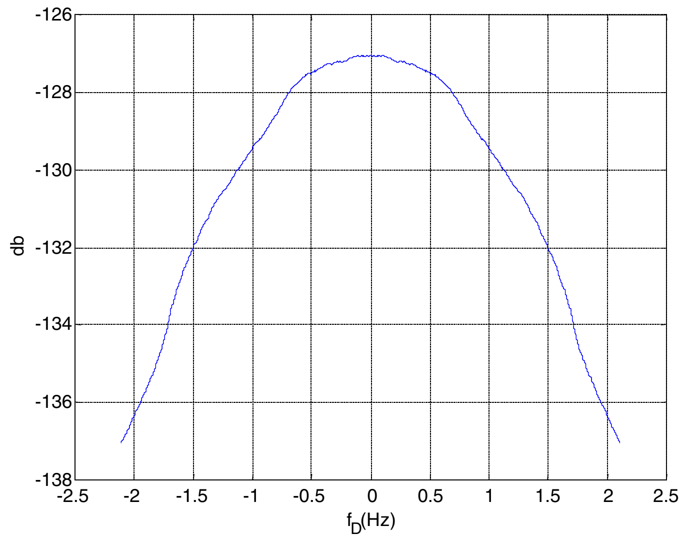
Multipath Fading Model (cont'd)

- Number of taps
- Delay values
- Tap Coefficients (random, uncorrelated)
  - K-Factor
  - Gain
  - Doppler spectrum

Doppler Power Spectrum



Low Wind



High Wind

Rounded Spectrum with f_D~ 0.1Hz- 2Hz

Antenna Correlation

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

- Spacing between antennas
- Height of the antennas
- Beamwidth
- Polarization

Antenna Gain Reduction Factor

- The effective gain of a directional antenna is lower than the actual gain in a scattering environment
- The Gain reduction factor needs to be considered in the link budget

Interference Model

- Co-channel Interference
  - Microscopic fading independent of the primary channel
  - C / I depends on
    - Reuse factor
    - Antenna beamwidth
- Adjacent channel Interference
  - Own system / ITFS channel

Stanford University Interim (SUI) Generic Channel Models for G2 MMDS

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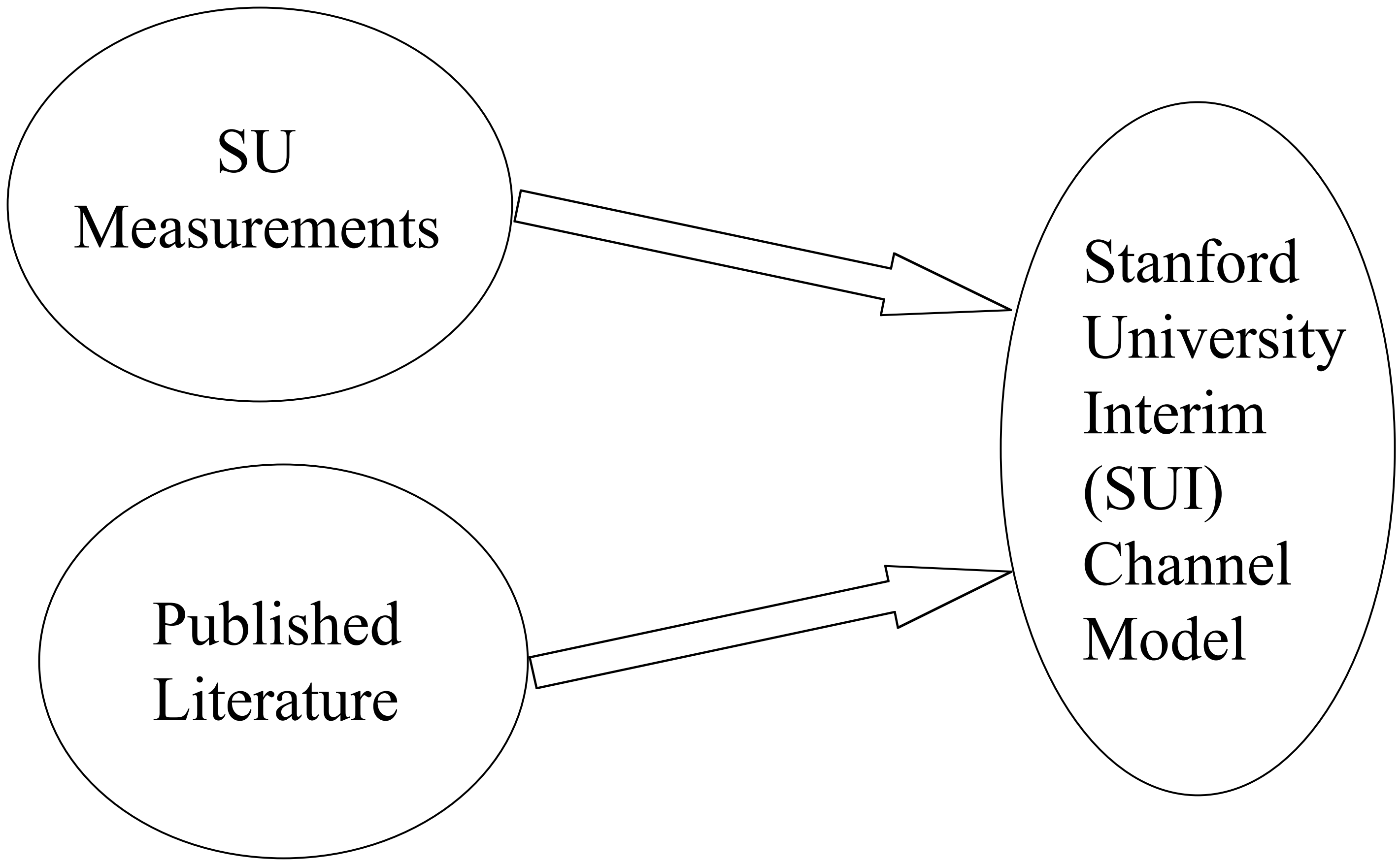
Channel Modeling



Rationale for SUI Channel Models

- Many parameter combinations possible
- We picked 6 models related to deployment and Terrain scenarios typical of CONUS

Terrain	SUI Model
C Flat/Light Tree Density	SUI-1, SUI-2
B Flat/Moderate Tree Density	SUI-3, SUI-4
A Hilly/Moderate to Heavy Tree Density	SUI-5, SUI,6

Parametric View of SUI Channel models

K: Low

Delay Spread

Doppler

	Low	Moderate	High
Low	SUI-3		SUI-6
High		SUI-4	SUI-5

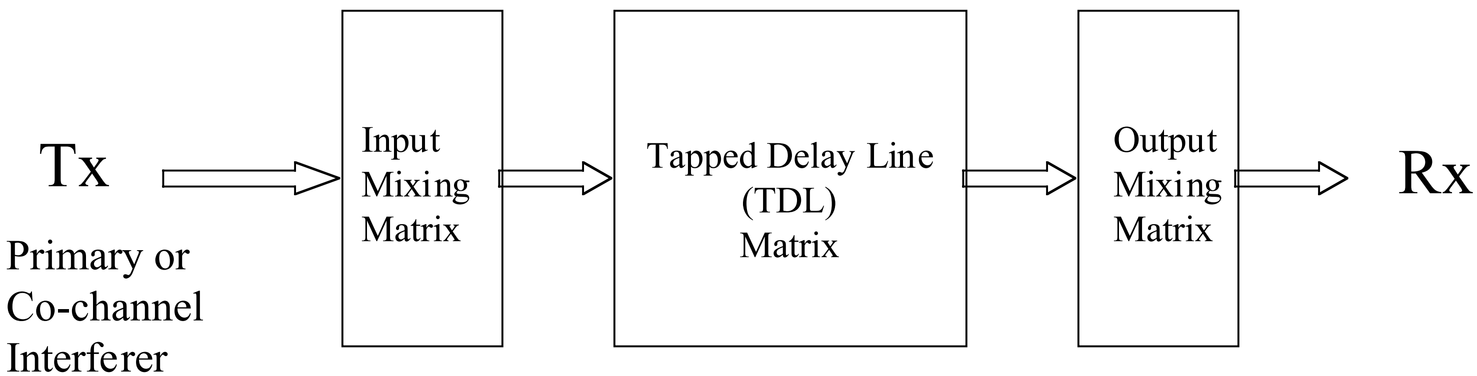
K: Moderate/High

Delay Spread

Doppler

	Low	Moderate	High
Low	SUI-1,2		
High			

SUI Channel Structure



- A generic channel structure for a MIMO (2x3) channel (SISO, SIMO are subsets of this structure)
- The mixing matrices correlate the signals at Tx and Rx
- TDL matrix introduces fading. Each TDL has 3 taps
- Antenna correlations are assumed to be the same everywhere

Model Assumptions

- A cell size of 4 miles (6.4 km)
- BTS Antenna height: 50ft
- CPE antenna height: 10ft
- BTS Antenna beamwidth: 120 deg
- CPE Antenna Beamwidth: 50 deg
- Vertical Polarization only

SUI-1 Channel

Terrain Category C

Ant Corr = 0.7				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	0.4	0.8	μs
Power (P)	0	-15	-20	dB
K factor	18	0	0	
Doppler (D)	0.4	0.4	0.4	Hz

- RMS Delay Spread = 0.1 μs, Overall K = 10

SUI-2 Channel

Terrain Category C

Ant Corr = 0.5				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	0.5	1	μs
Power (P)	0	-12	-15	dB
K factor	10	0	0	
Doppler (D)	0.4	0.4	0.4	Hz

- RMS Delay Spread = 0.2 μs, Overall K = 5

SUI-3 Channel

Terrain Category B

Ant Corr = 0.25				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	0.5	1	μs
Power (P)	0	-5	-10	dB
K factor	0	0	0	
Doppler (D)	0.4	0.4	0.4	Hz

- RMS Delay Spread = 0.3 μs

SUI-4 Channel

Terrain Category B

Ant Corr = 0.25				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	2	4	μs
Power (P)	0	-4	-8	dB
K factor	0	0	0	
Doppler (D)	1	1	1	Hz

- RMS Delay Spread = 1.3 μs

SUI-5 Channel

Terrain Category A

Ant Corr = 0.25				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	5	10	μs
Power (P)	0	-5	-10	dB
K factor	0	0	0	
Doppler (D)	2	2	2	Hz

- RMS Delay Spread = 3 μs

SUI-6 Channel

Terrain Category A

Ant Corr = 0.25				
	Tap 1	Tap2	Tap3	
Delay (Δ)	0	14	20	μs
Power (P)	0	-10	-14	dB
K factor	0	0	0	
Doppler (D)	0.4	0.4	0.4	Hz

- RMS Delay Spread = 5.2 μs

Summary

- Interim Channel Models presented for G2 MMDS scenario
- SUI Channel Models developed based on measurements and published literature
- 6 typical channels presented

Example: 3 Taps vs 6 Taps

Comparison of Frequency responses

Frequency Response (dB)

3-taps

Dly = [0 2 5] µs

Gain = [0 -4 -10] dB

Frequency

Frequency Response (dB)

6-taps

Dly = [0 1 2 3 4 5] µs

Gain = [0 -2 -4 -6 -8 -10] dB

Frequency