Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: A statistical model for the UWB indoor channel

Date Submitted: 24 June, 2002

Source: Moe Z. Win, Allcomms Consulting; Dajana Cassioli, RadioLabs, University of Rome Tor Vergata; Andreas F. Molisch, Mitsubishi Electric Research Laboratories

Address MERL Murray Hill 571 Central Avenue Murray Hill, NJ 07974, USA

Voice: +1 908 363 0524, FAX: 908-665-2414 , E-Mail: Andreas.Molisch@ieee.org

Re: [Response to Call for Contributions on Ultra-wideband Channel Models, Doc. IEEE P802.15-02/208r1-SG3a]

Abstract: We establish a statistical model for the ultra-wide bandwidth (UWB) indoor channel based on an extensive measurement campaign in a typical modern office building. Our model is formulated as a stochastic tapped-delay-line (STDL) model of the UWB indoor channel. The averaged power delay profile is modeled by a single exponential decay with a statistically distributed decay constant. The small-scale statistics of path gains follow Gamma distributions whose parameters *m* are truncated Gaussian variables with mean values and standard deviations decreasing with delay. The total received energy experiences a lognormal shadowing around the mean energy given by the path-loss law. The fading of the taps is uncorrelated. Finally, we propose an implementation of the STDL model.

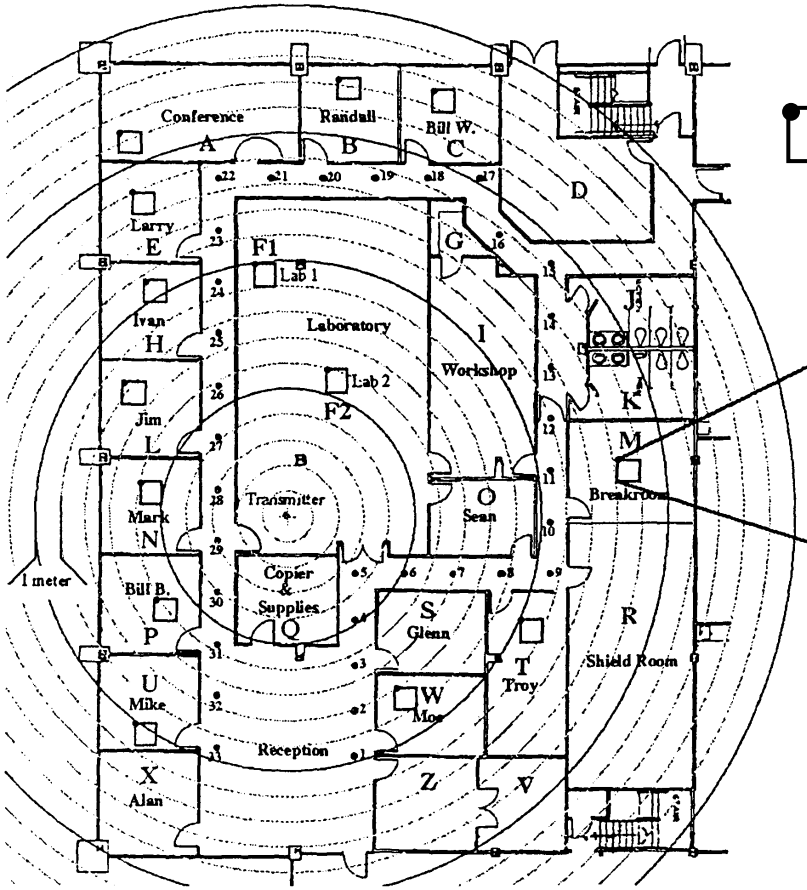
Purpose: [Proposing a multipath model of the UWB indoor channel for the use in the standardization process of the UWB channel model]

A Statistical Model for the UWB Indoor Channel

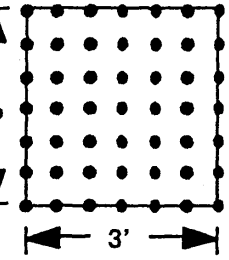
Moe Z. Win, Dajana Cassoli, Andreas F. Molisch

The channel sounding experiment (I)

North



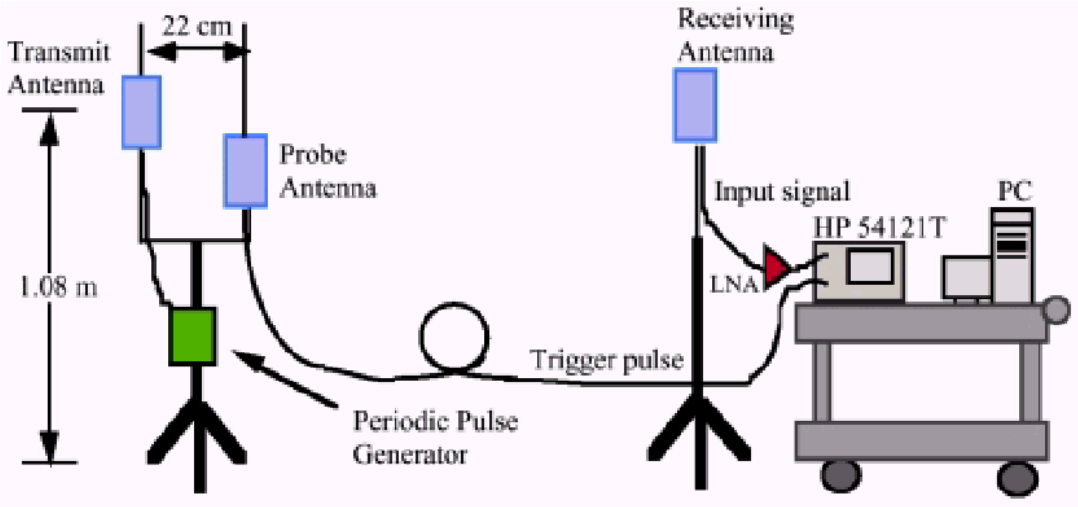
Approximate location of measurements
(dot indicates location of point {1;1})



Measurement Grid

The channel sounding experiment (II)

- Probe pulses: approximately derivate of Gaussian; 2ns duration



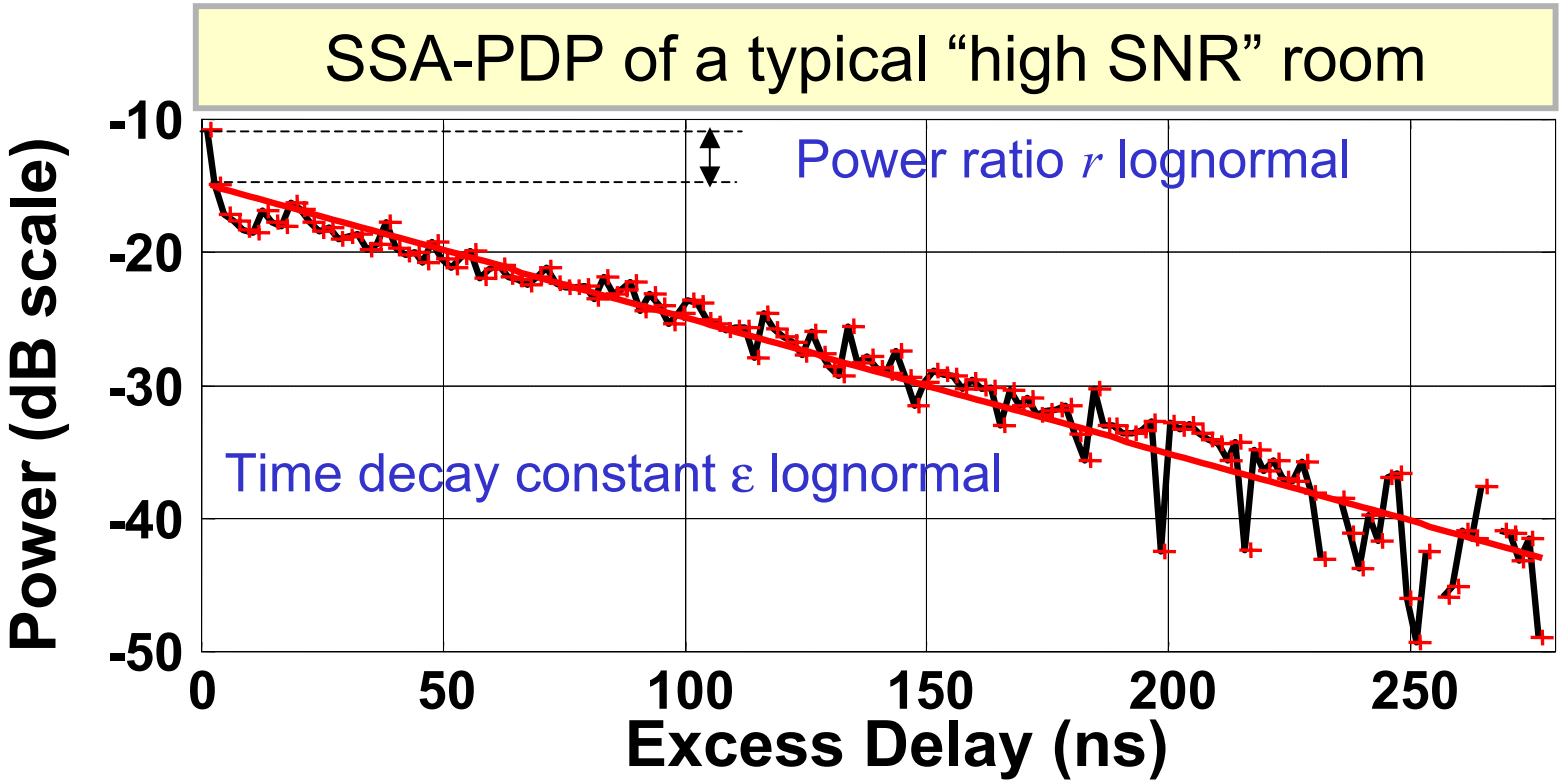
Data processing

- Absolute propagation delays
- Power delay profile (PDP)
- Noise reduction
- Local PDPs
- Small Scale Averaged PDP (SSA-PDP)

Basic model structure

- Small-scale effects
  - Impulse response changes when RX moves half a wavelength
  - Averaging squared impulse response over room $\rightarrow$ SSA-PDP
- Large-scale effects
  - SSA-PDP changes from room to room

Large-scale behavior



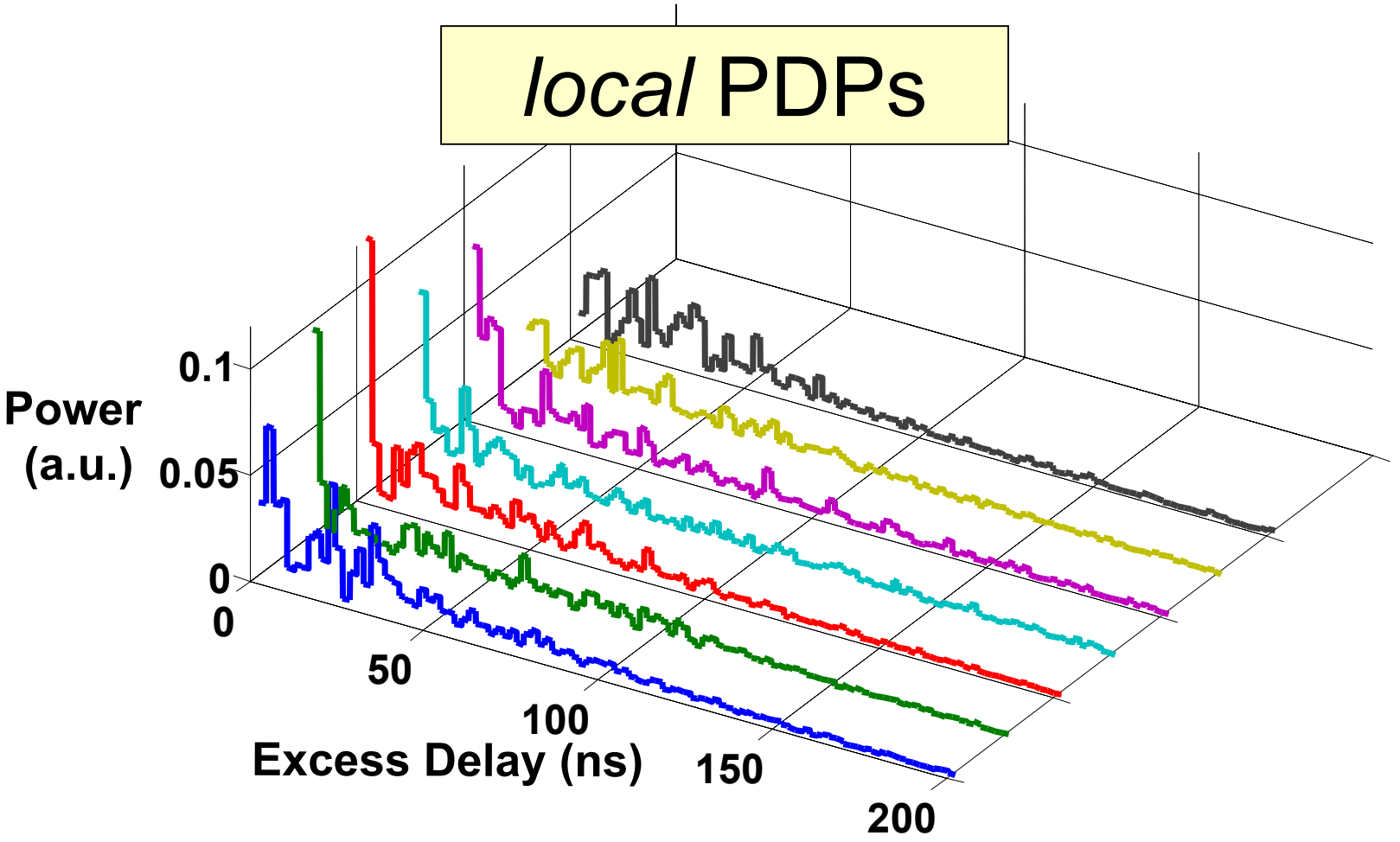
Path Loss and Shadowing

- Path Loss power law: model makes no suggestions concerning path loss model
- Shadowing: Total average gain is Lognormal distributed

Large scale fading

Global parameters ➡ $\overline{G}_{\text{tot}}$ and $\overline{G}_k$	
Path Loss	From other models
Shadowing	$\overline{G}_{\text{tot}} \approx \text{Logn}(PL; 4.3\,\text{dB})$
Exponential time-decay of the average energy gains $\overline{G}_k$	$\varepsilon \approx \text{Logn}(16.1; 1.27\,\text{dB})$ $r \approx \text{Logn}(-4\text{dB}; 3\,\text{dB})$

Small- scale statistics



Small-scale fading statistics

- Power within each bin is Gamma-distributed (Nakagami field strength)
- m-factors are random variables (truncated Gaussian)
- Both mean and variance decreases with delay
- Fading of delay bins is uncorrelated
- Phases: uniformly distributed

Stochastic Tapped-Delay-Line Model

GLOBAL PARAMETERS $\Rightarrow \overline{G}_{\text{tot}}$ and $\overline{G}_k$	
Path Loss	From other models
Shadowing	$\overline{G}_{\text{tot}} \sim \mathcal{L}_{\mathcal{N}}(-PL;\, 4.3)$
Decay Constant	$\varepsilon \sim \mathcal{L}_{\mathcal{N}}(16.1; 1.27)$
Power Ratio	$r \sim \mathcal{L}_{\mathcal{N}}(-4;\, 3)$

SSA-PDP

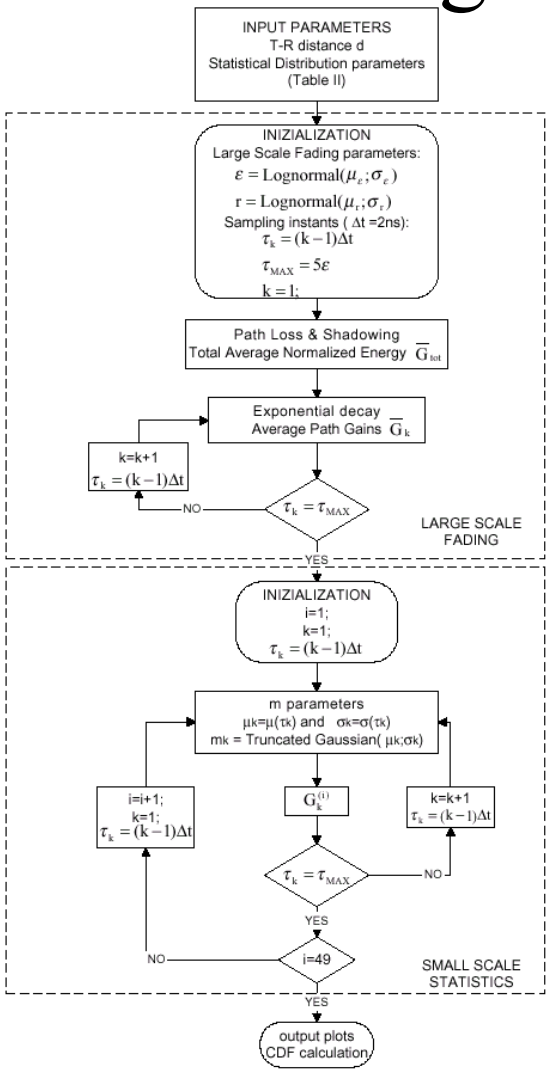
$$\overline{g}(\tau) = \sum_{k=1}^{N_{\text{bins}}} \overline{G}_k \delta(\tau - \tau_k)$$

LOCAL PARAMETERS $\Rightarrow G_k$	
Energy Gains	$G_k \sim \Gamma(\overline{G}_k;\, m_k)$
m values	$m_k \sim \mathcal{T}_N\left(\mu_{\text{m}}(\tau_k);\, \sigma^2_{\text{m}}(\tau_k)\right)$ $\mu_{\text{m}}(\tau_k) = 3.5 - \frac{\tau_k}{73}$ $\sigma^2_{\text{m}}(\tau_k) = 1.84 - \frac{\tau_k}{160}$

$$g(t) = \sum_{k=1}^{N_{\text{bins}}} G_k \delta(t - \tau_k)$$

Local PDP

Simulation algorithm



Summary

- Evaluation of UWB indoor measurement campaign to derive channel model
- Distinction between large-scale and small-scale effects
- Exponential power delay profiles with stronger first path
- Nakagami small-scale statistics in every delay bin
- Decay constants, power ratios, Nakagami parameters, are statistically distributed
- Simple implementation recipe, MatLab simulation program will be made available

Some references

- D. Cassioli, M. Z. Win and A. F. Molisch, "A statistical model for the UWB indoor channel", *in the Proceedings of IEEE VTC Spring 2001*.
- D. Cassioli, M. Z. Win and A. F. Molisch, "The ultra-wide bandwidth indoor channel: from statistical model to simulations", *to appear in the JSAC special issue "Channel and propagation models for wireless system design" of Aug. 2002*. Preprint version.
- D. Cassioli, M. Z. Win, F. Vatalaro and A. F. Molisch, "Performance of low-complexity Rake reception in a realistic UWB channel", *in the Proceedings of the ICC 2002*.

These papers can be downloaded at http://www.radiolabs.it