Recommendation on Time Varying Radio Propagation Channel Models and Study of System Performance for LMDS

IEEE 802.16 (BWA Working Group) Presentation Submission Template (Rev. 8)

Document Number:IEEE 802.16.1pp-00/24
Date Submitted: 2000-07-03

Source:

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Venue: IEEE 802.16 Session #8 PHY Presentation, July 10-14, La Jolla, SanDiego.

Base Document: IEEE 802.16.1pc-00/24 <http://ieee802.org/16/phy/contrib/802161pc-00_24.pdf>

Other Sources: P.Soma, Y.W.M.Chia and L.C.Ong, "Modeling and Analysis of Time Varying Radio Propagation Channel for LMDS" to be appeared in the proceedings of IEEE RAWCON, Sep.10-13, 200, Denvor, Colorado,USA.

Purpose: To provide an input to the PHY task group specific criterion called "robustness to channel impairments – multipath fading"

Welcome…

Recommendation on Time Varying Radio Propagation Channel Models and Study of System Performance for LMDS

By

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Outline

- Introduction to LMDS
- Measurements and Data Processing
- Tapped Delay Line Channel Model
- Study of Path loss and Delay Characteristics
- Simple System Simulation
- Fading Signal Statistical Characteristics
- Conclusion

Introduction

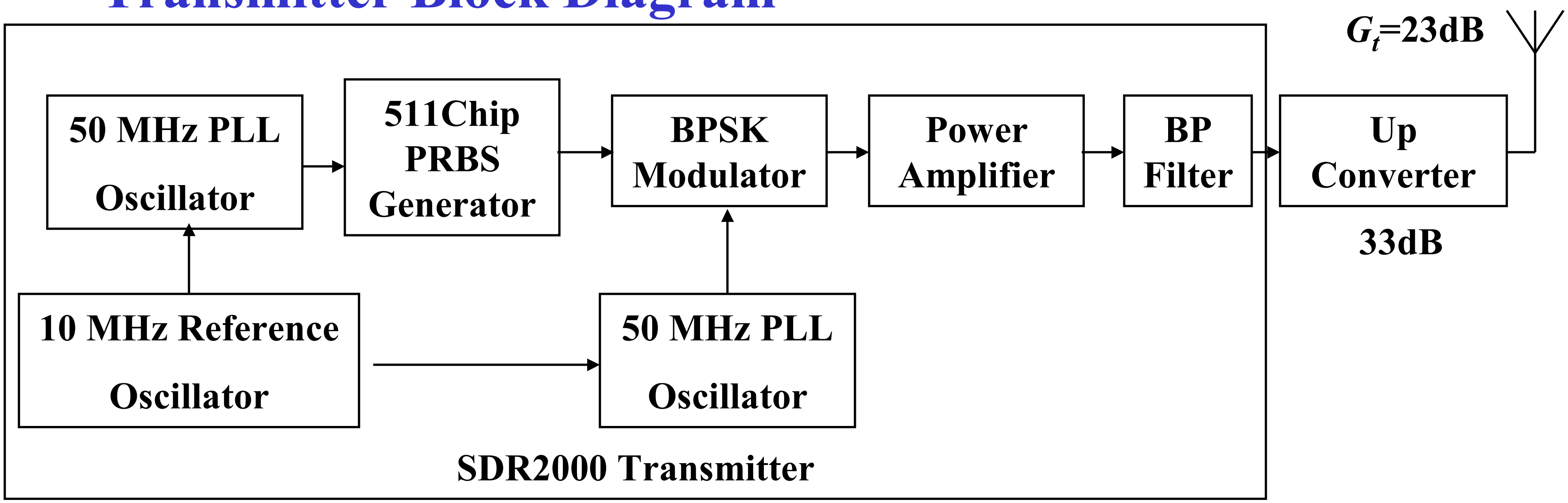
- **Local Multipoint Distribution Service (LMDS)**
  - Last mile solution to provide BWA to fixed networks
  - Operating in the 27.4GHz and higher frequency spectrum
- **LMDS System Architecture**
  - LMDS control centre (LCC)
  - LMDS main co-ordination centre (MCC)
  - LMDS base station
  - LMDS access network (IHDN).
- **Target User Classes**
  - Corporations (large business)
  - Small and Medium-sized Enterprises (SME)
  - Small-Office and Home-Office Users (SOHO)
  - Private Households (HH)

Introduction (*cont…*)

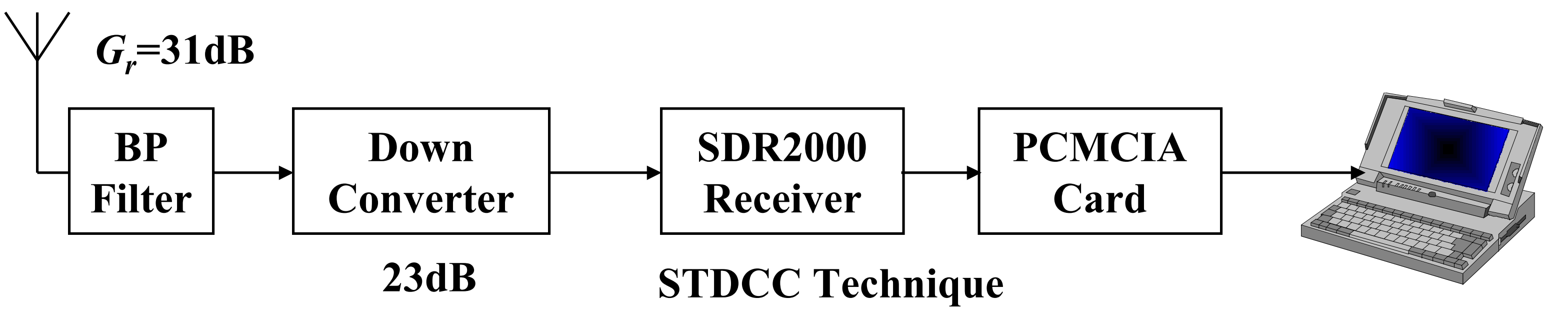
- **Target Services**
  - Voice, one-way video distribution, interactive video, video-on-demand, and real-time video conferencing with high speed internet access.
- **Merits Over Wired Solution**
  - Large bandwidth, high data rates, lower installation cost, ease of deployment, cost-effective network maintenance.
- **Propagation Issues**
  - More favourable compared to mobile comm. system
  - Most susceptible to rain effects (depolarisation, excess loss)
  - Building blockage and vegetative losses reduce coverage
  - Frequency selective fading occurs at high data rates
  - Highly directional antennas at receiver side
  - Accurate channel models are required for the system design

Measurements and Data Processing

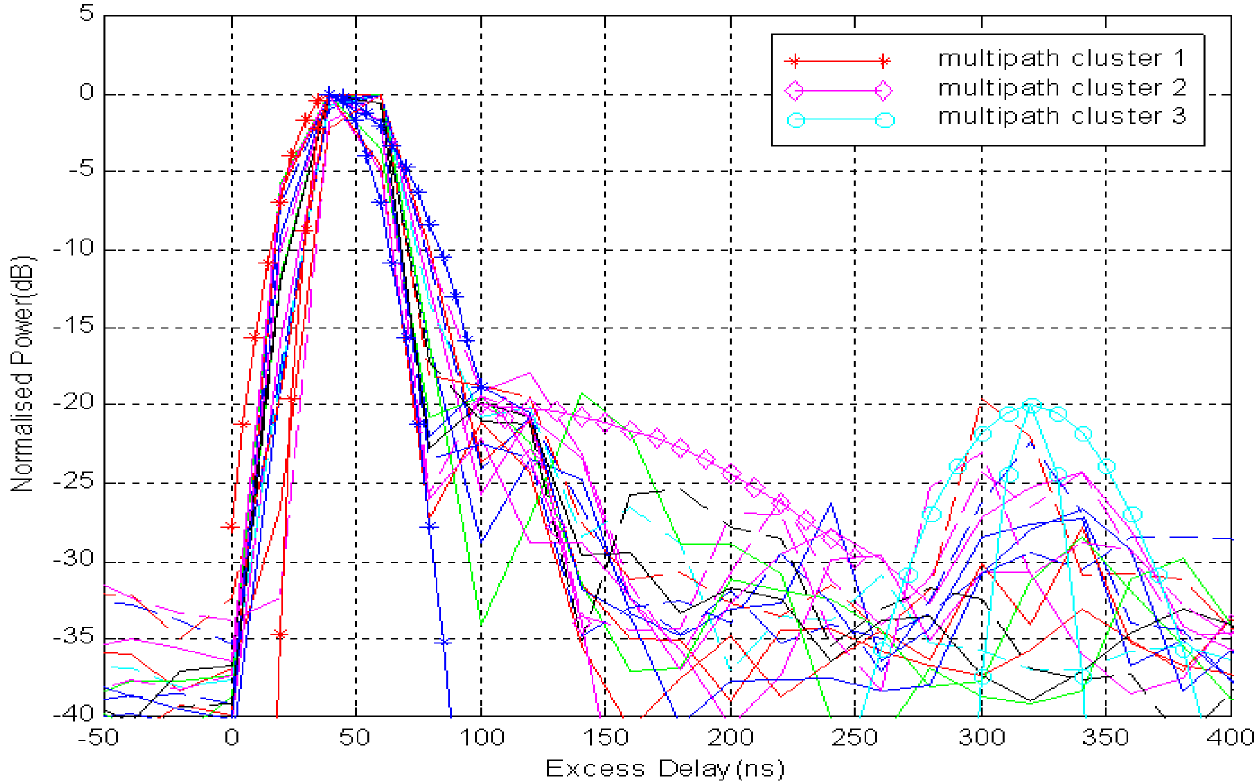
- **Transmitter Block Diagram**



- **Receiver Block Diagram**

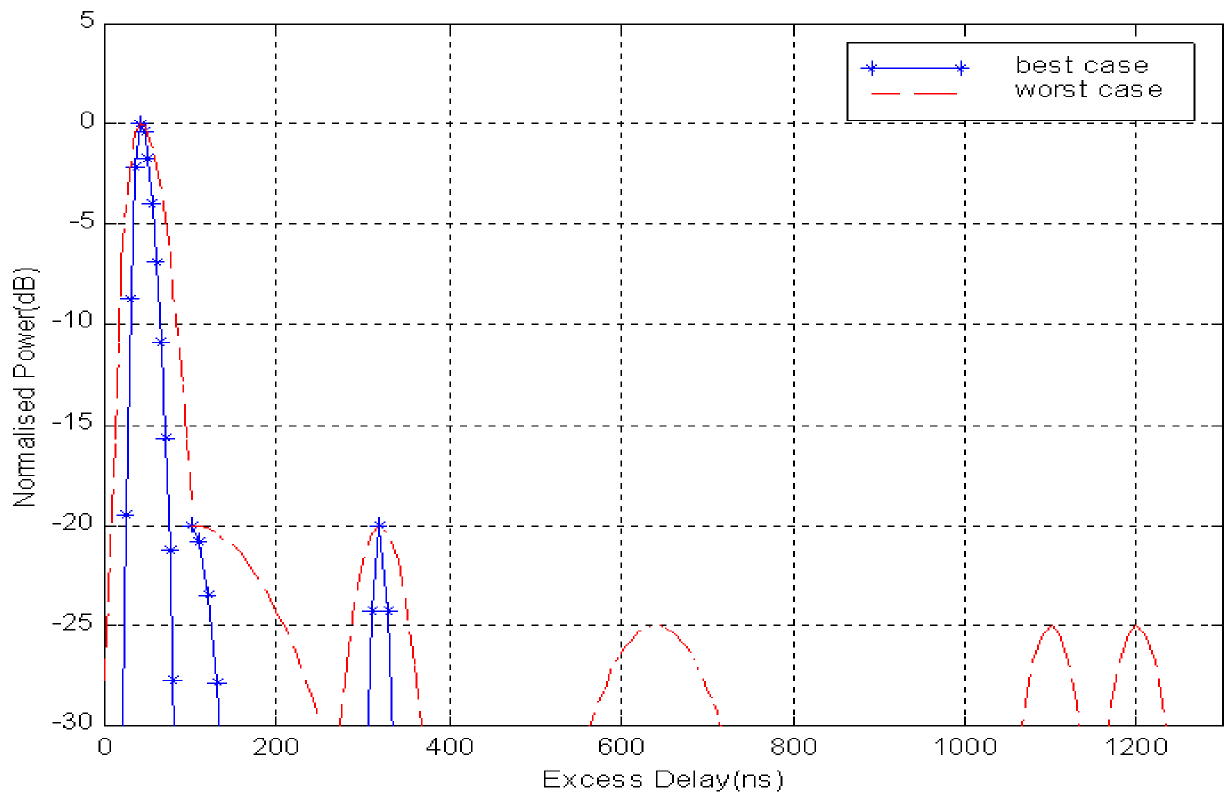


Typical Urban Environment



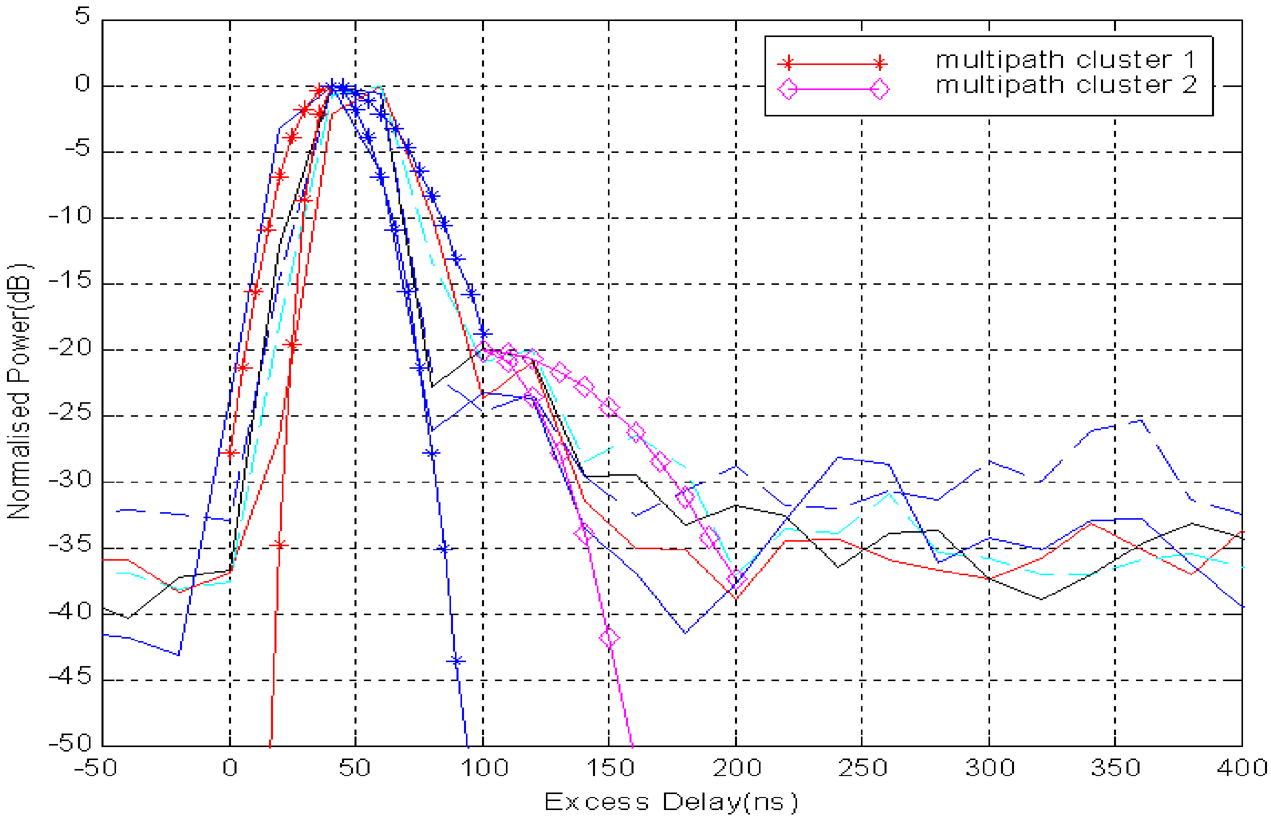
- Normalised power delay profiles approximated with our model.
- Slight variation for different locations.
- Average excess delay varies in the range of 50 - 70ns
- RMS delay spread is in the range of 20 - 80ns.

High dense Urban Environment



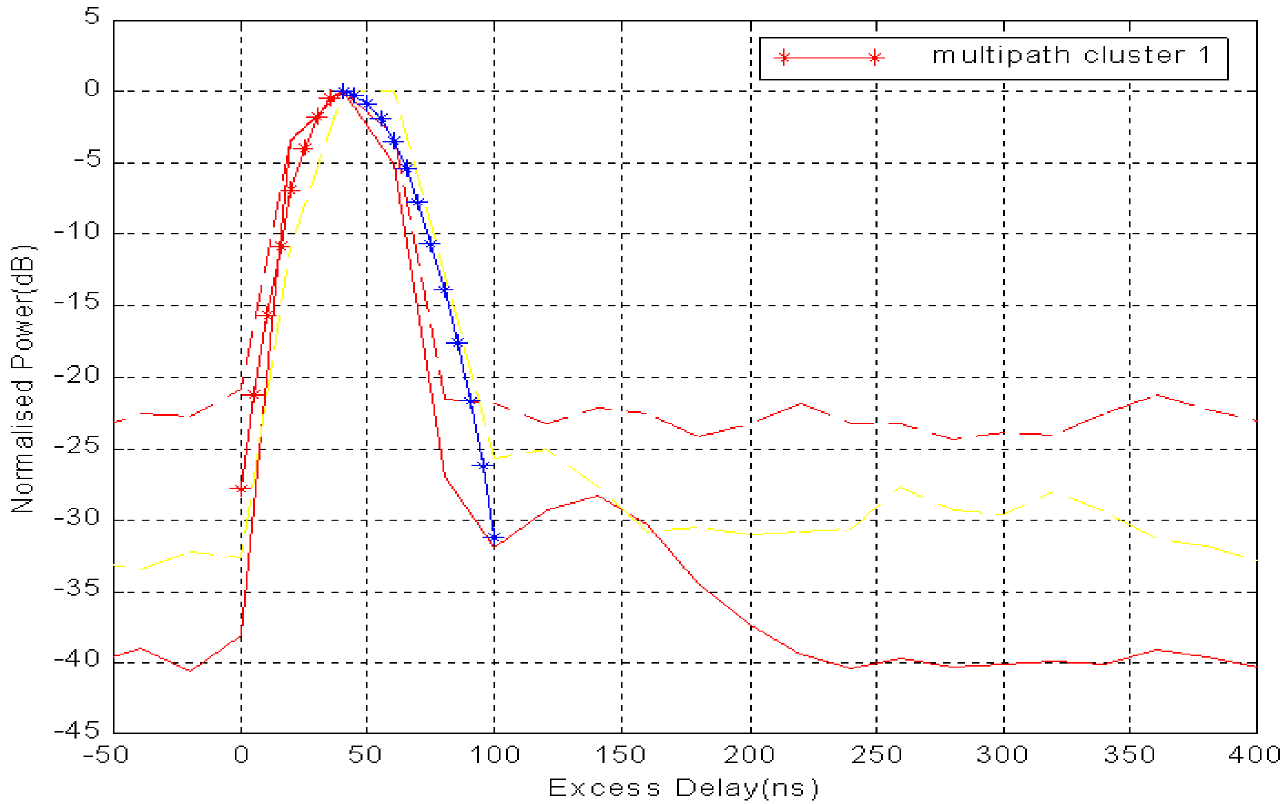
- Normalised power delay profiles for worst case urban environment.
- Longer delayed multipath clusters are 25dB weaker.
- Average excess delay is in the range of 70 - 110ns
- RMS delay spread is in the range of 80 - 155ns

Typical Suburban Environment



- Normalised power delay profiles for typical suburban environment.
- Longer delayed multipath clusters are 25dB weaker.
- Average excess delay is in the range of 40 - 50ns
- RMS delay spread is in the range of 10 - 20ns

Typical Rural Environment



- High SNR values (up to 35dB) in some cases.
- Longer delayed multipath clusters are not present.
- Average excess delay is less than 30 - 40ns
- RMS delay spread is less than 10ns

Tapped Delay Line Channel Model

- Impulse response completely describes the radio channel:
  - represented by a tapped delay line model at any time, t_k

$$h(t_k, \tau) = c_k \sum_{n=0}^{N-1} m(\tau_n)\delta(t_k - \tau_n) e^{-j(\omega_c \tau_n + \phi)}$$

  - τ *is the* excess delay, n is tap index and N is the total number of taps.
  - $m(\tau)$ gives the tap gains of various multipath delayed components
  - c_k models the time varying nature of IR (based on measurements)
  - ϕ is the uniform random phase in the range of $[0,2\pi)$

- Tap gain distribution is given by,

$$m(\tau_n) = \alpha \exp\left\{ -\beta \left(\frac{\tau_n - \tau_p}{100} \right)^2 \right\}$$

Summary of Channel Model

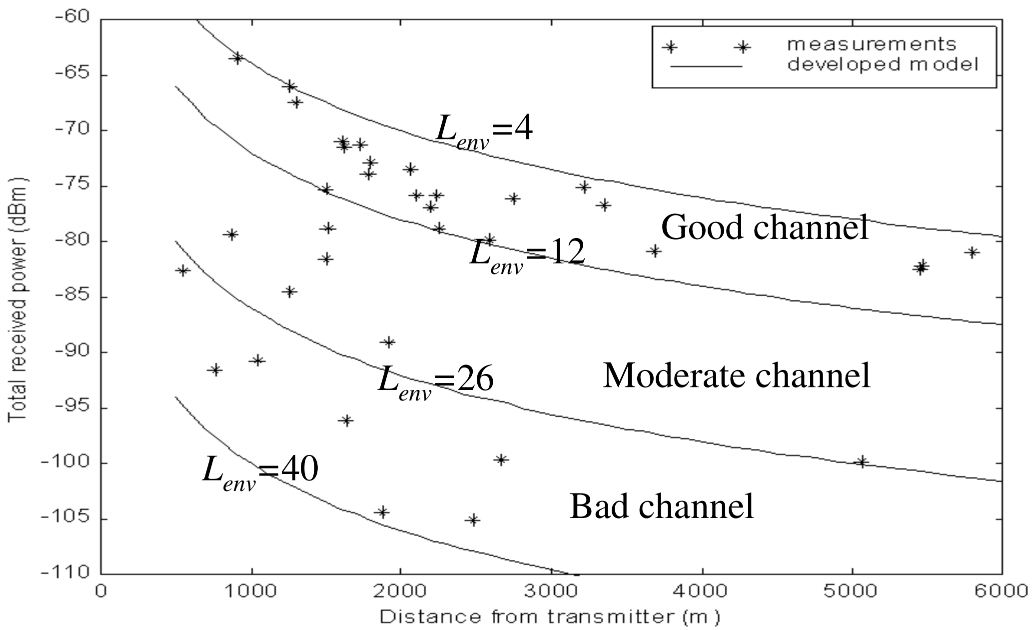
Table 1. Summary of channel model parameters

Case (i)	Peak time, τ_p (ns)	Attenuation factor, α_i	Decay factor, β_i	Excess delay τ (ns)
1	40 40	1.0 1.0	β_1 β_2	0 – 40 40 – 100
2	100	0.1	β_3	100 – 250
3	320	0.1	β_4	250 – 400
4	640 1100 1200	0.056 0.056 0.056	1 5 5	560 – 720 1060 – 1140 1160 – 1240

Table 2. Classification of propagation channel

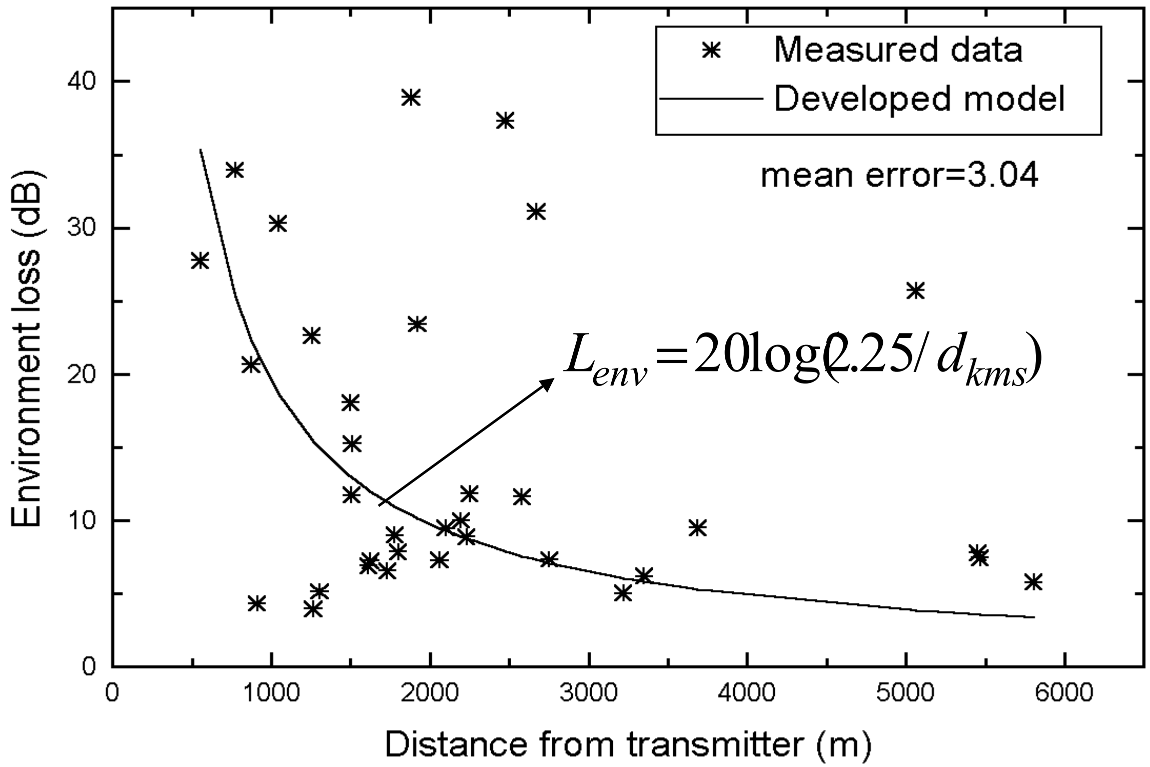
Parameter	Urban1	Urban2	Suburban	Rural
c_k (dB)	-10 – 6	-10 – 6	-5 – 3	-5 – 3
β_1	20 – 100	20 – 100	50 – 120	50 – 120
β_2	6 – 20	6 – 20	10 – 25	10 – 25
β_3	0.5 – 10	0.5 – 10	1 – 10	0
β_4	5 – 50	5 – 50	0	0
τ_{max} (ns)	1240	400	250	100

Total Received Power Vs Distance



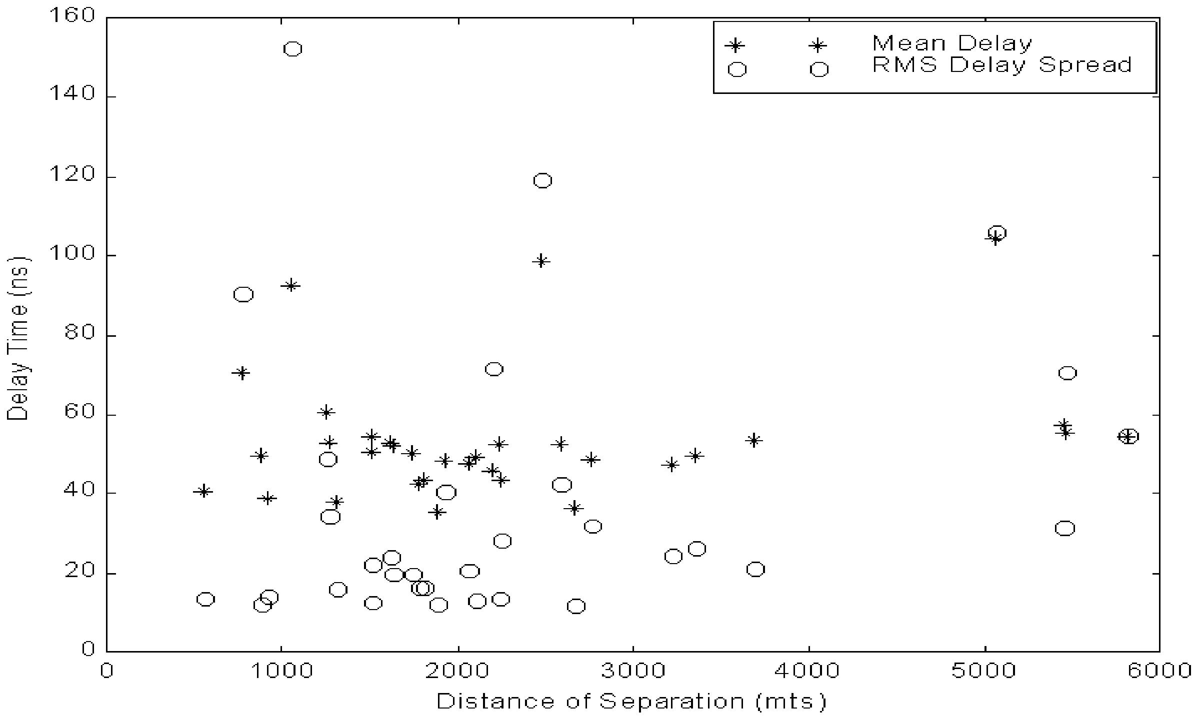
- Total received power(dB), $P_r = P_t + G_t + G_r - 32.44 - 20\log(f_{GHz} d_m) - L_{ex}$
- Excess path loss (dB), $L_{ex} = P_t + G_t + G_r - 32.44 - 20\log(f_{GHz}) + L_{env}$
- Good channel $\Rightarrow 4 \leq L_{env}(dB) < 12$
- Moderate channel $\Rightarrow 12 \leq L_{env}(dB) < 26$
- Bad channel $\Rightarrow 26 \leq L_{env}(dB) < 40$

Environment Loss Vs Distance



- Additional loss caused by climatic conditions, multipath and shadowing effects from surrounding buildings, foliage etc.,
- Dominant effect at lower distance of separation.
- Link margin has to be provided to compensate this excess loss.

Delay Characteristics



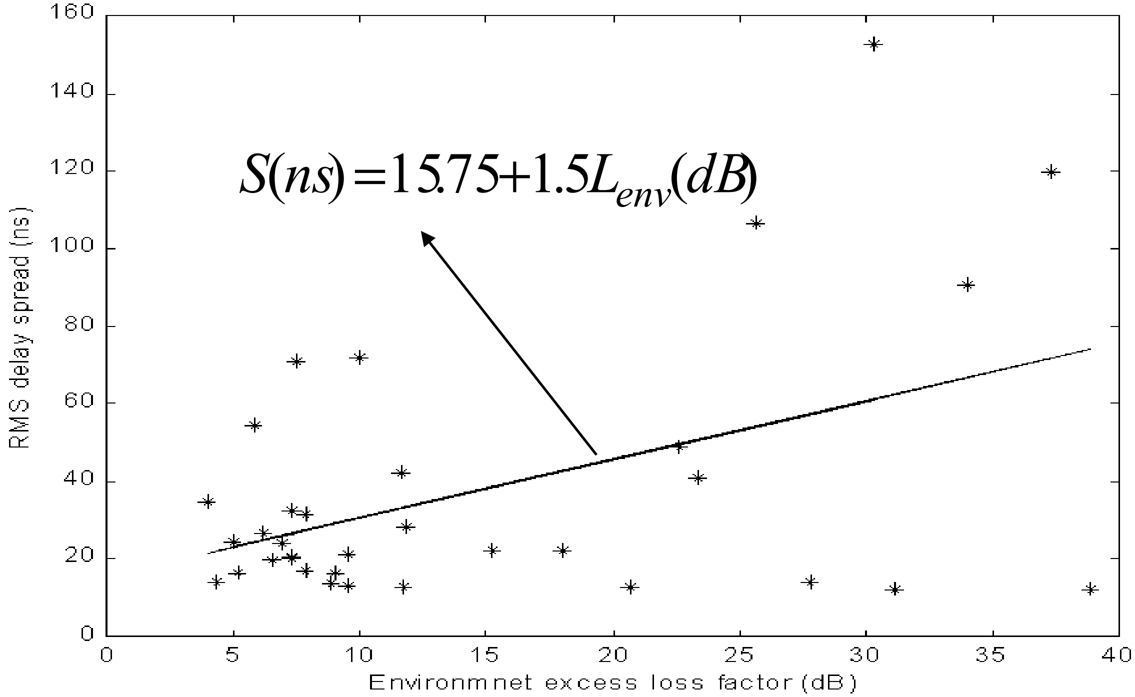
• High delay values are due to the presence of significant multipath components

• Also depends on the received signal to noise ratio.

• Useful in the design of equaliser and selection of suitable data rate.

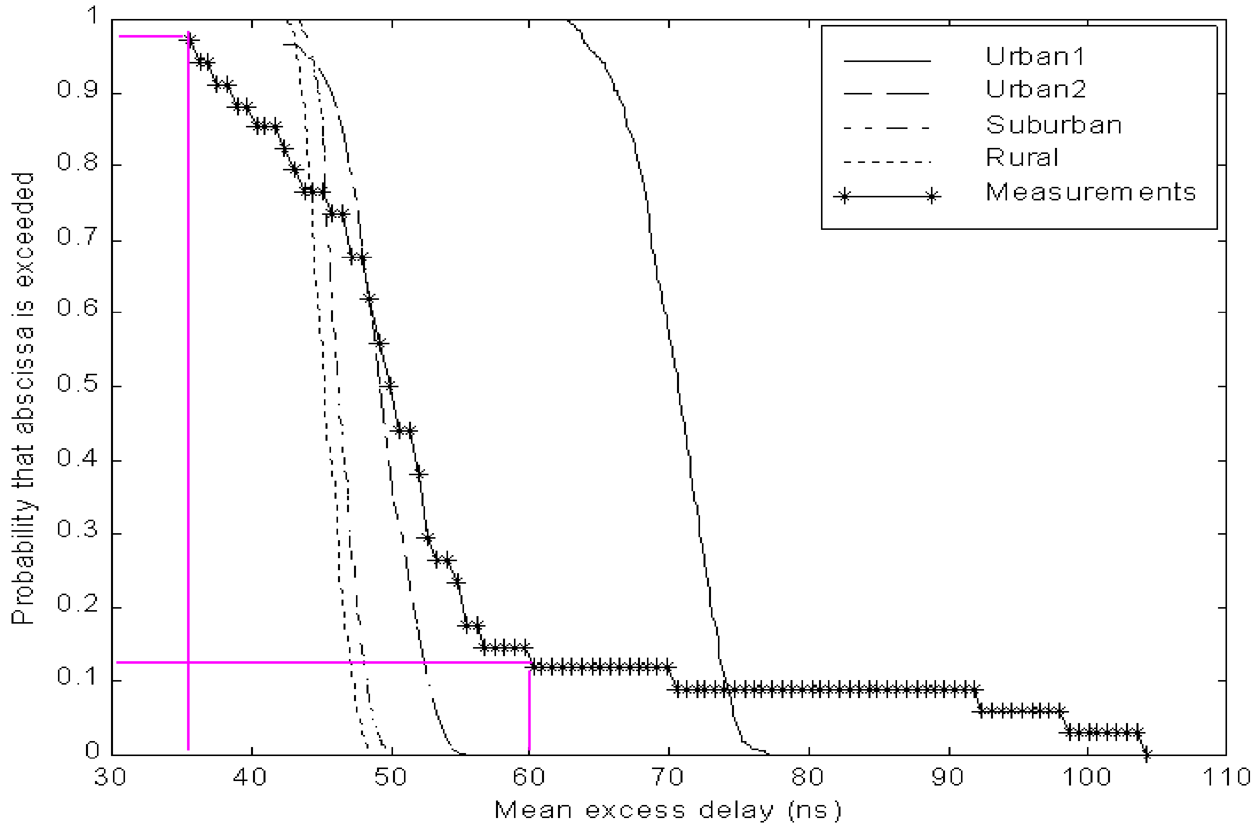
• For normalised delay spreads (bit rate* *S*) of 0.6 or higher irreducible errors tend to occur.

Delay Spread Vs Excess Loss



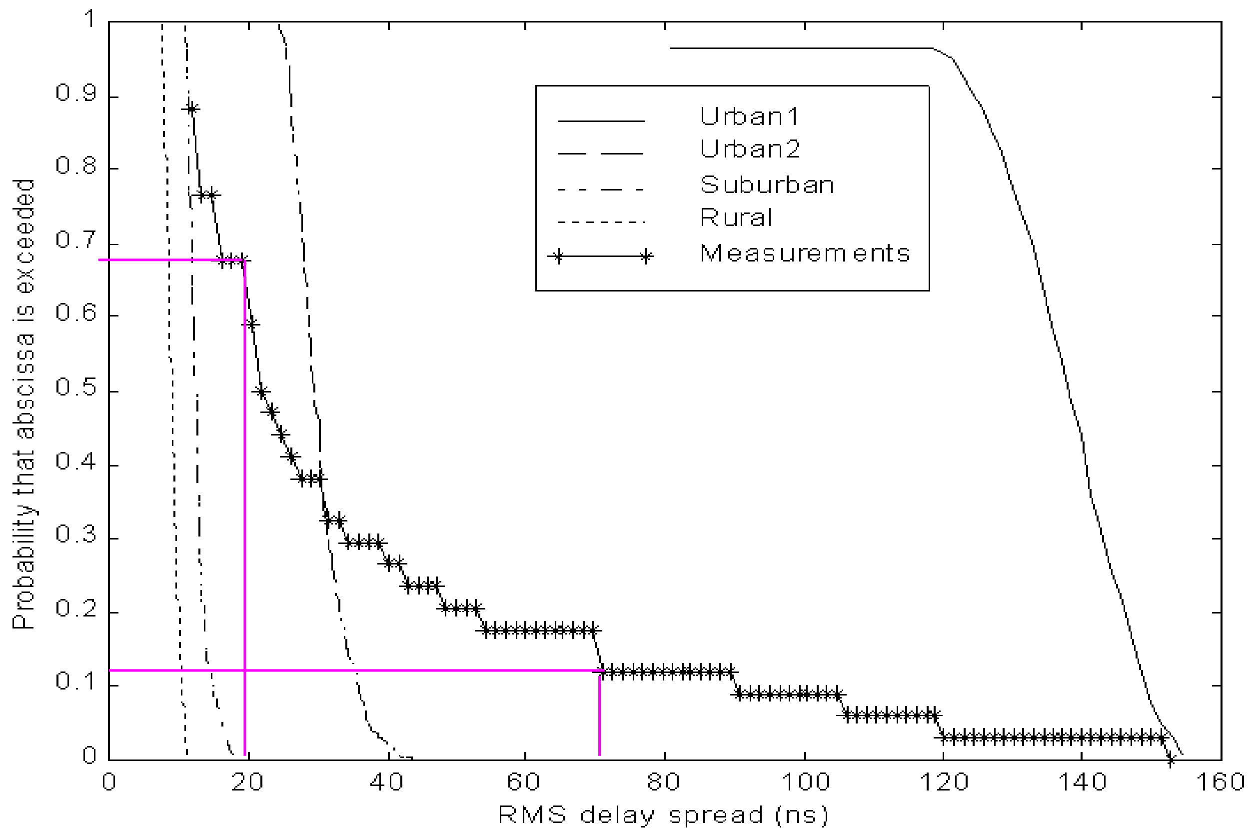
- Low excess loss and low delay spread corresponds to a less dispersive and less attenuated good channel.
- High delay spread but less excess path loss corresponds clear LOS receiver locations at larger distance.
- High delay spread and high excess loss corresponds to the partially blocked nearer receiver locations surrounded by high rise buildings.

ccdf of Average Excess Delay



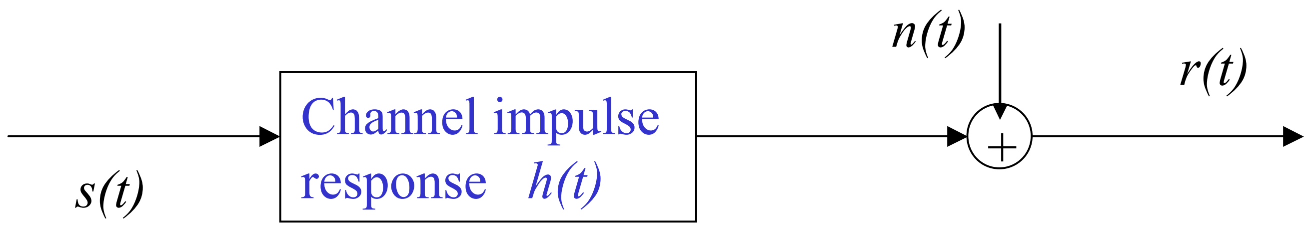
- Measurements shows that around 98 percent of the locations have average delay more than 35ns
- However, only 11 percent of the locations have average delay more than 60ns.

ccdf of RMS Delay Spread



- Measurements shows that around 68 percent of the locations have delay spread more than 20ns (bit duration of our measurement system)
- However, only 11 percent of the locations have average delay more than 70ns.

Simple System Simulation



- Total received signal at an observation time t_k is given by,

$$r(t) = s(t) \otimes h(t,\tau) + n(t)$$

  - *s(t)* - any specified transmitted signal
  - *n(t)* - AWGN signal
  - *h(t, τ)* - time varying radio channel complex impulse response represented by the tapped delay line model

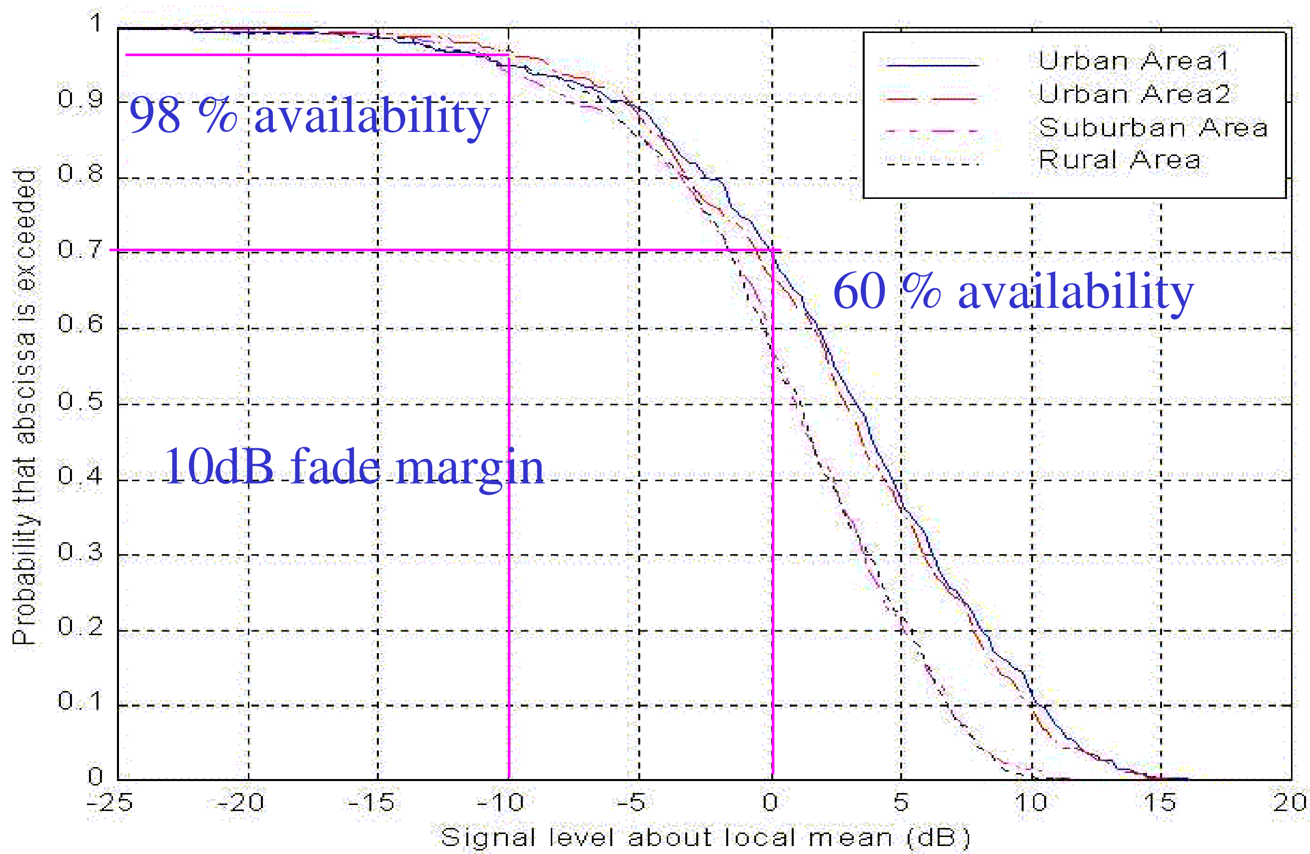
- Rician K-factor Evaluation
  - Local mean, $m = m_s + m_c$
  - Variance, $\sigma^2 = m_s^2 + 2\, m_s m_c$
  - K-factor = m_c / m_s

$\Longrightarrow$

$$m_s = m - \sqrt{m^2 - \sigma^2}$$

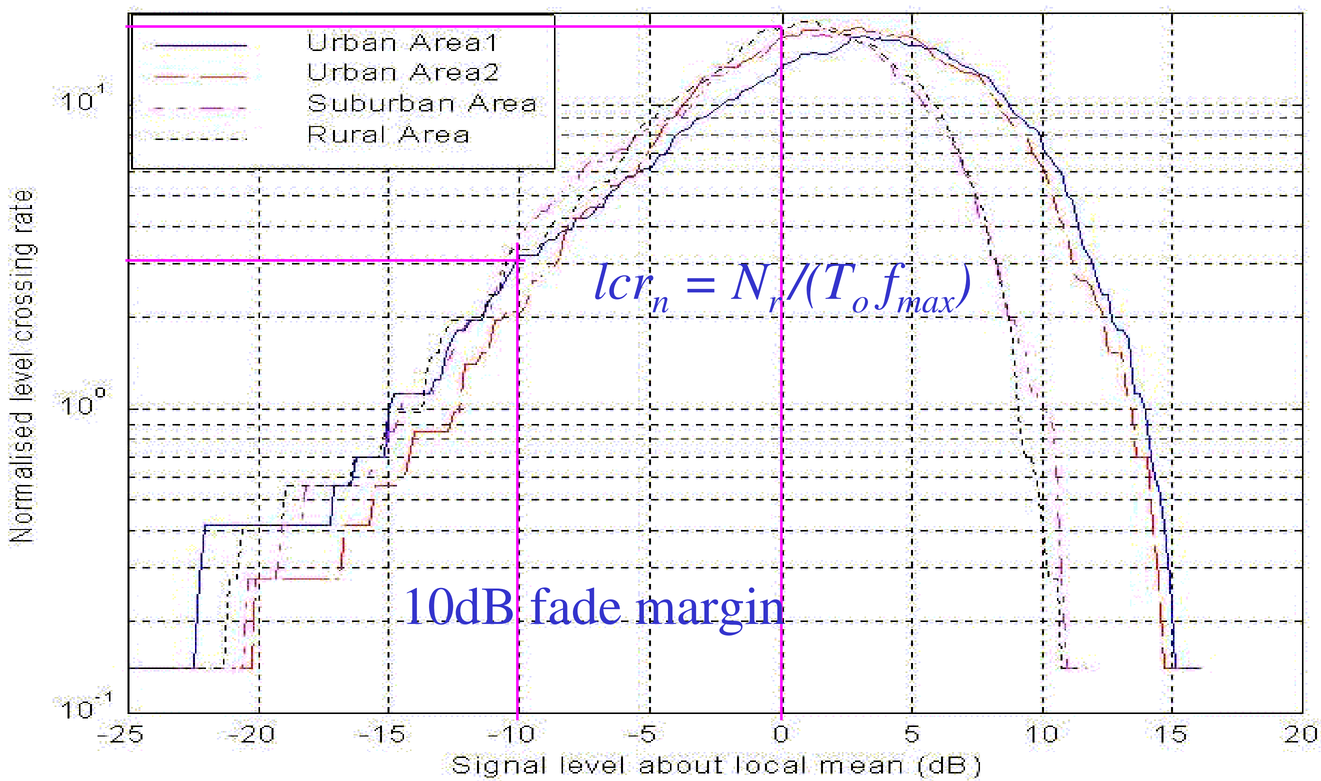
$$m_c = m - m_s$$

Cumulative Distribution Function (*cdf*)



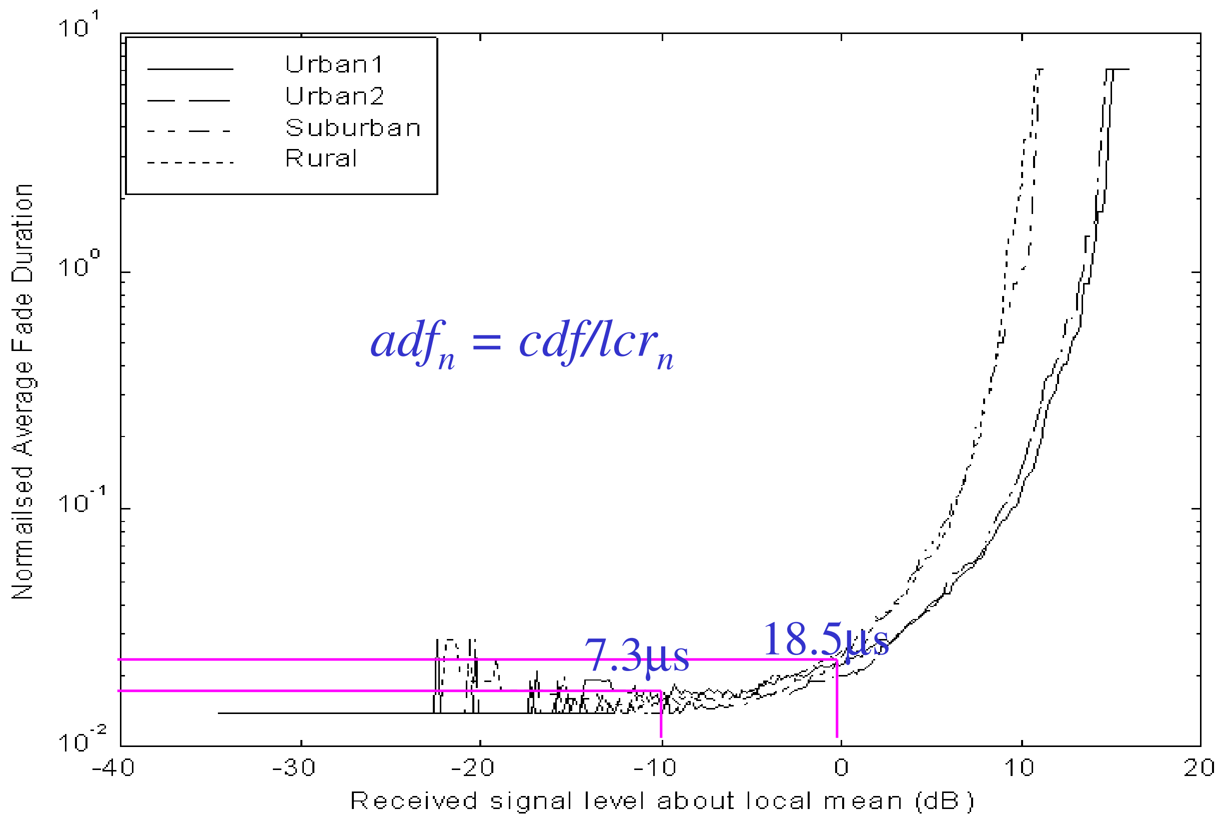
- Signal lies above the local mean only for 60% of the observation time.
- Provision of 10 dB fade margin increases the availability of signal above the threshold to 98% of the observation time
- Time variations are not much dependent on type of channel.

Normalised Level Crossing Rate (*LCR*)



- *lcr* is defined as the rate at which signal lies below a threshold.
- Signal crosses the local mean once for every 40.5µs of observation time
  - correspond to 4 samples
- Provision of 10 dB fade margin increases this period to 243.3µs
  - correspond to 25 samples indicating the slow fading behaviour

Normalised Average Fade Duration (*ADE*)



- Average fade duration (*afd*) determine how long the signal lies below a given threshold, on average.
  - determine the number of bits that may be lost during a fade
  - together with *lcr* , it helps to predict burst of errors.

Conclusion

- Introduction to LMDS
- Measurements and data processing
- Tapped delay line channel model
- Path loss and delay characteristics
- Simple system simulation
- Study of fading signal statistical characteristics

Characteristic	Urban1	Urban2	Suburban	Rural
lcr_{-10dB}	3.22	2.1	3.78	3.36
afd_{-10dB}	0.015	0.014	0.015	0.015
Mean Delay (ns)	70.41	48.08	46.41	45.41
Delay Spread (ns)	134.57	30.32	12.75	9.05
CorrBW (MHz)	5.0	9.46	14.0	14.91
K-Factor (dB)	10.13	10.38	14.28	14.86