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

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Purpose: To provide an input to the PHY task group specific criterion called “robustness to channel impairments – multipath fading”
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Recommendation on Time Varying Radio Propagation Channel Models and Study of System Performance for LMDS

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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**

  50 MHz PLL Oscillator → 511Chip PRBS Generator → BPSK Modulator → Power Amplifier → BP Filter → Up Converter

  SDR2000 Transmitter

  $G_r=23\text{dB}$

- **Receiver Block Diagram**

  BP Filter → Down Converter → SDR2000 Receiver → PCMCIA Card

  $G_r=31\text{dB}$

  23dB

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

<table>
<thead>
<tr>
<th>Case (i)</th>
<th>Peak time, $\tau_p$ (ns)</th>
<th>Attenuation factor, $\alpha_i$</th>
<th>Decay factor, $\beta_i$</th>
<th>Excess delay $\tau$ (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>1.0</td>
<td>$\beta_1$</td>
<td>0 – 40</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>1.0</td>
<td>$\beta_2$</td>
<td>40 – 100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>0.1</td>
<td>$\beta_3$</td>
<td>100 – 250</td>
</tr>
<tr>
<td>3</td>
<td>320</td>
<td>0.1</td>
<td>$\beta_4$</td>
<td>250 – 400</td>
</tr>
<tr>
<td>4</td>
<td>640</td>
<td>0.056</td>
<td>1</td>
<td>560 – 720</td>
</tr>
<tr>
<td></td>
<td>1100</td>
<td>0.056</td>
<td>5</td>
<td>1060 – 1140</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>0.056</td>
<td>5</td>
<td>1160 – 1240</td>
</tr>
</tbody>
</table>

Table 2. Classification of propagation channel

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Urban1</th>
<th>Urban2</th>
<th>Suburban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_k$ (dB)</td>
<td>-10 – 6</td>
<td>-10 – 6</td>
<td>-5 – 3</td>
<td>-5 – 3</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>20 – 100</td>
<td>20 – 100</td>
<td>50 – 120</td>
<td>50 – 120</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>6 – 20</td>
<td>6 – 20</td>
<td>10 – 25</td>
<td>10 – 25</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>0.5 – 10</td>
<td>0.5 – 10</td>
<td>1 – 10</td>
<td>0</td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>5 – 50</td>
<td>5 – 50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\tau_{max}$ (ns)</td>
<td>1240</td>
<td>400</td>
<td>250</td>
<td>100</td>
</tr>
</tbody>
</table>
**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.

\[
L_{env} = 20 \log (0.25/d_{kms})
\]

![Graph showing Environment Loss Vs Distance](image)
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.
• 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.
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.
Measurements show 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.

**ccdf of RMS Delay Spread**

- Probability that abscissa is exceeded
- RMS delay spread (ns)

- Urban1
- Urban2
- Suburban
- Rural
- Measurements
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
- $h(t, \tau)$ - 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, $\sigma^2 = m_s^2 + 2m_sm_c$
- K-factor $= m_c / m_s$

\[ m_s = m - \sqrt{m^2 - \sigma^2} \]
\[ m_c = m - m_s \]
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 40.5\( \mu \)s of observation time
  - correspond to 4 samples
- Provision of 10 dB fade margin increases this period to 243.3\( \mu \)s
  - correspond to 25 samples indicating the slow fading behaviour

\[ lcr_n = N_r/(T_0 f_{\text{max}}) \]
Normalised Average Fade Duration (ADF)


dfn = cdf/lcr

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

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