IEEE P802.15 Working Group for Wireless Personal Area Networks™

Overview of ITU-R P.1238-1 “Propagation Data and Prediction Methods for Planning of Indoor Radiocommunication Systems and Radio LAN in the Frequency Band 900 MHz to 100 GHz”
Why Review ITU P.1238-1?

- We need a model of the RF Channel for the Coexistence Model
- ITU is an *International Standard* on Indoor Radio Propagation
- TG2 can review the standard and decide if it is applicable to the Coexistence Model
Outline of ITU P.1238-1

1 Introduction
2 Propagation Impairments
3 Path Loss Models
4 Multipath Delay Spread Models
5 Effect of Antenna Polarization
6 Effect of Location of XMTR and RCVR
7 Effect of Building Material
8 Effect of Moving Objects
Propagation Impairments

• Reflection from and Diffraction around Objects
• Transmission Loss through walls, floors and other obstacles
• Channeling of Energy in Corridors
• Motion of Persons and Objects in the room
Impact of these Propagation Impairments

- Path Loss
- Temporal and Spatial Variation of Path Loss
- Multipath Effects
- Polarization Mismatch
Site-General Path Loss Model

• Path Loss Formula

\[ L_{total} = 20 \log_{10}(f) + N \log_{10}(d) + L_f(n) - 28 \]

• \( N \) Distance Power Loss Coefficient
• \( f \) Frequency (MHz)
• \( d \) Distance (m) between nodes \((d > 1)\)
• \( L_f \) Floor Penetration Loss Factor (dB)
• \( n \) Number of Floors Penetrated \((n > 0)\).
Site-General Path Loss Model

- If we let $f = 2500$ MHz then for our case the formula simplifies to,

$$L_{total} = 40 + N \log_{10}(d) + L_f(n)$$
Distance Power Loss Coefficient

• If we were in Free Space then the “distance power loss coefficient” would be 20.
• However, indoors it is worse due to the environment.
• They give values at several frequencies. One case is 1.8-2.0 GHz.
• The value does not depend heavily on the frequency.
Distance Power Loss Coefficient

• Here is the value of the *distance power loss coefficient* they recommend in three different indoor environments:

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<th>Residential</th>
<th>Office</th>
<th>Commercial</th>
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<tr>
<td></td>
<td>28</td>
<td>30</td>
<td>22</td>
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Floor Penetration Loss Factor

- They also give recommendations for the Floor Penetration Loss Factor.

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<tr>
<td></td>
<td>$4n$</td>
<td>$15 + 4(n-1)$</td>
<td>$6 + 3(n-1)$</td>
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- This may be less of an issue for us since at this time we are not yet considering multi-floor facilities.
Example of Path Loss Model

- 10 meter range \((d = 10)\)
- All on a single floor \((n = 0)\)
- Office Environment \((N = 30)\)

\[
L_{total} = 40 + 30 \log_{10}(10) = 70 \text{ dB}
\]

- Notice that this is the Link Budget for a Typical Bluetooth Piconet
Comments on Path Loss Formula

• The formula for Path Loss represents the average or *mean path loss*. The actual value of the path loss fluctuates about that mean value.

• One of the factors that causes this variation is Shadow Fading.

• Another factor that causes this variation is Multipath Fading.
Shadow Fading

- Additional Fading can occur due to Shadowing of the RF signal.
- Shadow Fading statistics are Lognormal with the following Standard Deviation (dB).

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<td></td>
<td>8</td>
<td>10</td>
<td>10</td>
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Multipath Delay Spread

- Multiple Paths result in a time delay spread in the channel.
- A rough estimate of the delay spread can be obtained from the dimensions of the room and the fact that RF waves travel one meter in approx. 3.3 ns.
- These delayed signals form a time-varying linear filter.
Multipath Delay Spread

- The Standard makes some comments on how to measure power delay profile.
- It also mentions RMS delay spread*.
- Typical values of RMS delay spread.

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<td></td>
<td>70 ns</td>
<td>100 ns</td>
<td>150 ns</td>
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* The RMS delay spread is the standard deviation of the power delay profile (see T. Rappaport, *Wireless Communications*).
Statistical Multipath Delay Spread Models

• Introduces the Wide-Sense Stationary Uncorrelated Scattering (WSSUS) Model.

• Replace real scattering paths with only a few uncorrelated multipath components, in the model.

• Combine unresolved multipath components, of similar path length.
Statistical Multipath Delay Spread Models

- The formula for the Multipath channel impulse response is,

$$h(t) = \sum_{n=1}^{N} \sqrt{p_n} g_n(t) \delta(t - \tau_n)$$

- $p_n$ is the receive power for the $n^{th}$ multipath component.

- $g_n(t)$ is a Complex Gaussian Time Varying Process combining multiple paths.
Effect of Antenna Polarization

- Circularly polarized antenna can reduce RMS delay spread.
- Directional antennas can reduce RMS delay spread.
Effect of Motion of Objects in the Room

• The movement of persons and objects within the room can cause temporal variation in the indoor propagation characteristics.

• Apart from people in the vicinity of the antennas or in the direct path, the movement of people in the office has a negligible effect on the propagation characteristics.
Effect of Motion of Objects in the Room

- Measurements at 1.7 GHz indicate that a person into the path of a LOS signal causes 6 to 8 dB drop in received power level.
- At 900 MHz measurements show a signal strength reduction of 4 to 7 dB when the terminal is held at the waist and 1 to 2 dB when held near the head.
Effect of Motion of Objects in the Room

- When the antenna is lower than about 1 meter (like in a desktop computer or laptop) the LOS path may be shadowed by people moving in the vicinity of the terminal.
- Measurements at 37 GHz in an indoor lobby show fades of 10 to 15 dB.
Summary

- I recommend using the ITU specification for indoor path loss.
- More detail is needed for the Multipath delay spread model.
- Likely we will need to use the WSSUS multipath delay spread model.
- Effects of antenna will be hard to model.
- May need to model shadow fading due to obstruction of LOS path.
Where to get ITU P.1238

- You can get a copy of ITU P.1238 on the web at,
  www.itu.int/itudoc/itu-r/rec/p/1238-1.html