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 values they recommend in three difference indoor environments

Residential	Office	Commercial
28	30	22

Floor Penetration Loss Factor

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

Residential	Office	Commercial
4 *n*	15 + 4 (*n*-1)	6 + 3 (*n* –1)

- This may be less of an issue for us since at this time we are not 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)

$$L_{total} = 40 + 30\log_{10}(10) = 70\ dB$$

- Notice that this is the Link Budget for a Typical Bluetooth Piconet

Shadow Fading

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

Residential	Office	Commercial
8	10	10

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

- Standard makes some comments on how to measure power delay profile.
- Mentions RMS delay spread*.
- Typical values of RMS delay spread.

Residential	Office	Commercial
70 ns	100 ns	150 ns

* 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 Gossip 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.