Development of a Simple Near-Ground Path Loss Model Verified by Measurements

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Problem

In the future there will be used more wireless sensor networks to different task and many nodes in these networks, can be placed at low heights, where communication between nodes get worse, as the path loss (PL) increases as the multipath waves can no longer be ignored. This will effect the link budget, when designing the antennas.

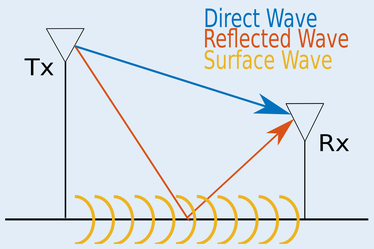

Figure 1: The different waves effecting the PL

Test setup

A measurement campaign were designed with given different parameters. By knowing system gains and losses, the PL can be calculated. For the test setup there where these different parameters;

- 2 Antenna sets at 858MHz (monopole and rectangular patch)
- 2 Polarization (horizontal and vertical)
- 2 Location (parking lot and school gym)
- 4 different height for the antennas (0.04, 0.14, 0.36 and 2.02 m)
- 6 distances between antennas (1, 2, 4, 8, 15 and 30 m)

In each point, 10 measurements were performed and the mean hereof were found, to lessen the effect of small scale fading.

PL Models

Friss free space PL (FSPL):

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^2$$

- Do not take into account any reflections.
- Do not work at low heights.
- Is not affected of height changes, as long as it do not go to low.

Approximated two-ray ground-reflection PL (ATRPL):

$$L_p = \left(\frac{d^2}{h_t h_r}\right)^2$$

- Take a single reflection into account, reflected from the nearest surface.
- Do not work at higher heights.
- Is affected of changes in heights of the antennas.

Norton surface wave PL (NSPL):

$$L_p = \left(\frac{d}{\left|\frac{\lambda}{2\pi z}\right|}\right)^4$$

- Takes into into account the surface wave, which comes from the ground absorbing the wave and repuls it again.
- Only works at low heights.
- Is not affected of height changes, as long as it do not go to high.

Ground wave PL (GWPL):

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^2 \cdot \left|1 + Re^{j\Delta} + (1-R)Ae^{j\Delta}\right|^{-2}$$

- Takes into account all the reflections from ATRPL and NSPL.
- Works at all heights.
- Is affected of height changes.

New proposed PL model

Comparison

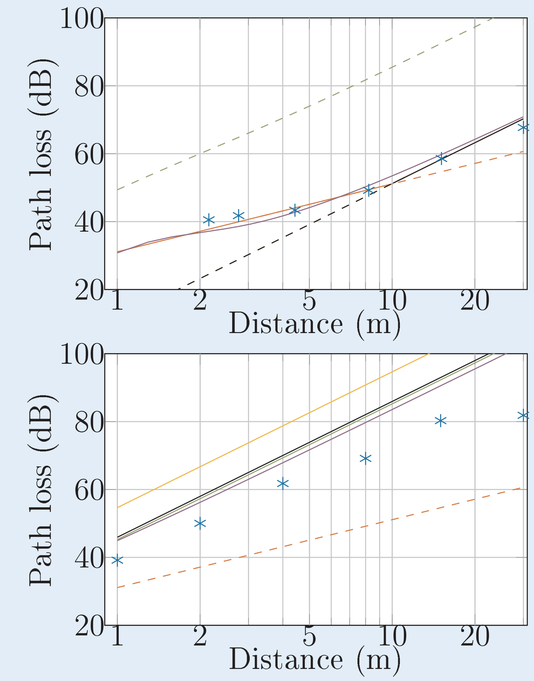

Figure 2: Comparison between the different PL model. At the top, the Tx and Rx height are 0.14 and 2.02 m and at the bottom, both are 0.04 m
The points are the measured PL, The red is FSPL, the blue is ATRPL, the yellow is NSPL, the purple is GWPL and the black is the NPPL.

Acknowledgements

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Reference

[1] K. Bullington, "Radio Propagation at Frequencies Above 30 Megacycles,"
[2] P. K. Chong and D. Kim, "Surface-Level Path Loss Modelling for Sensor Networks in Flat and Irregular Terrain,"