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

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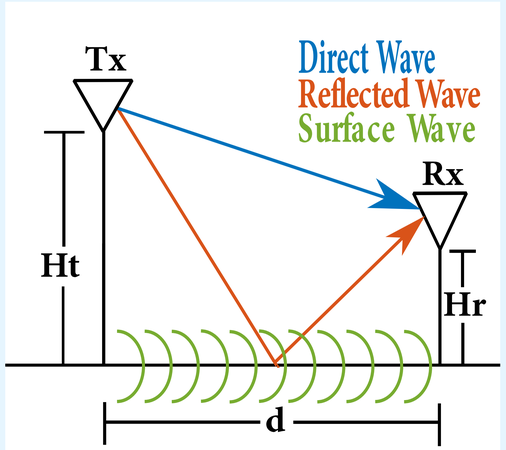
Problem

In the future, wireless sensor networks will be more common and a problem related to this is the antenna placement. In many cases the antennas might be placed near ground and this complicates calculations of the path loss (PL) as different propagation parameters becomes significant.



Test Setup

A measurement campaign was executed with the following parameters.

- 1 Frequency (858 MHz)
- 2 Antenna sets (monopole and patch)
- 2 Polarization (horizontal and vertical)
- 2 Location (outdoor and indoor)
- 4 Rx/Tx heights (from 0.04 to 2.02 m)
- 6 Distances (from 1 to 30 m)

The mean of 10 measurements was found in each point to lessen the effect of uncertainties.

PL Models

Friss free space PL (FSPL):

- Only direct wave
- High heights

Norton surface wave PL (NSPL):

- Only surface wave
- Low heights
- Dependent on surface constants

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

- Direct and reflected wave
- Medium heights

Ground wave PL (GWPL):

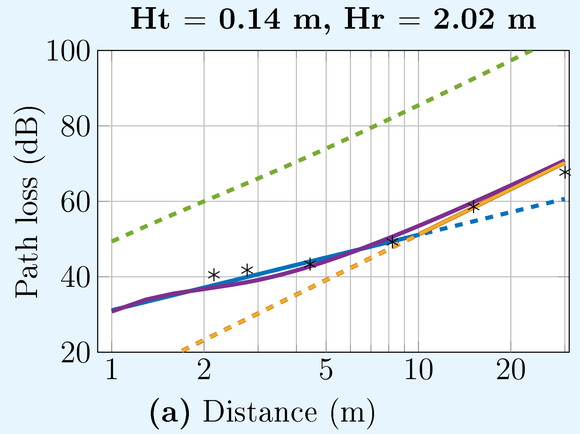
- All waves
- All heights
- Dependent on surface constants

Proposed PL model

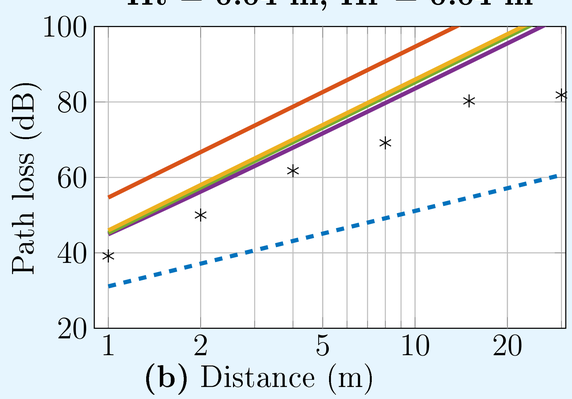
The study found that a combination of the ATRPL and NSPL models, decreases the error from the measurements. The proposed PL model (PPL) is:

$$PPL = \frac{d^4}{h_t^2 h_r^2 + h_0^4} \quad for \quad d > \frac{4\pi \cdot h_t h_r}{\lambda}$$

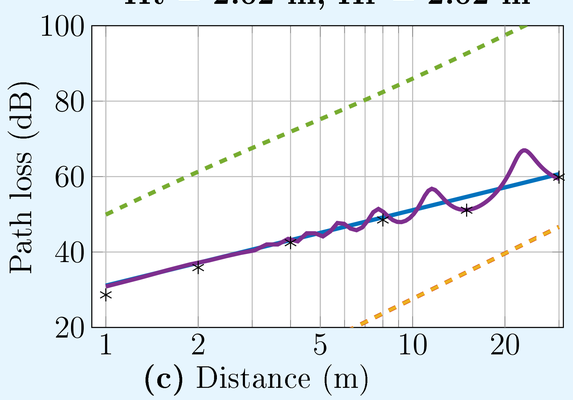
where h_0 is the minimum effective antenna height and depends upon the wavelength and surface constants and λ is the wavelength.



(a) Distance (m)



(b) Distance (m)



(c) Distance (m)

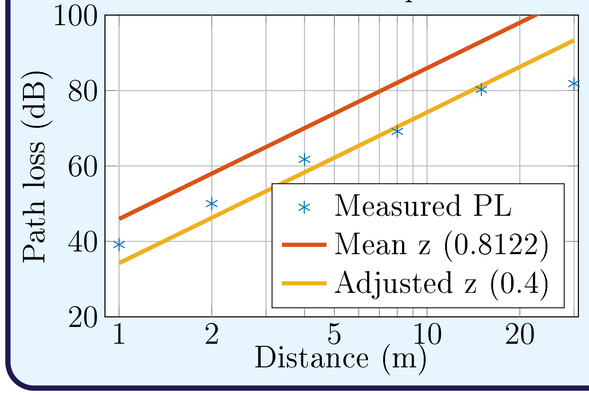
Legend: Points are measured PL, line is FSPL, line is ATRPL, line is NSPL, line is GWPL and line is the PPL. Dashed line means the point is outside the model's coverage area.

Main Findings

The study found that the GWPL was the best method to predict the PL, it is also the most complex model and needs a measurement of the surface constant. The accuracy of the PL models was found to:

Models	MSE	Applicability
FSPL	15.95	35 %
ATRPL	141.58	65 %
GWPL	35.49	100 %
NSPL	230.05	30 %
PPL	60.18	65 %

The PPL also uses the same surface constants as the GWPL. However, not all constants are needed and PPL is more simple to calculate. A change in the surface constant z value, gives rise to a offset in the predicted PL.



Acknowledgements

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References

[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,"