

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

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16gr751
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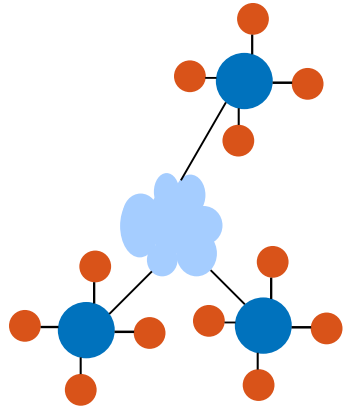
Proposed PL model

Model fit

The z parameter

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- ▶ Wireless Sensor Networks
 - ▶ Commercial
 - ▶ Military
- ▶ Focus
 - ▶ Accuracy
 - ▶ Applicability
 - ▶ Simplicity



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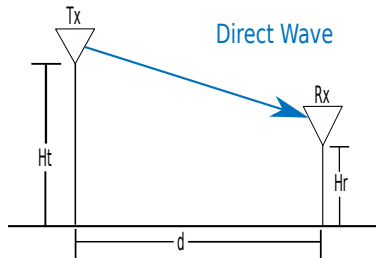
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Friss free space PL (FSPL):

- Only direct wave
- High heights

Conditions:

- No Multipath
- $d \gg \lambda$



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

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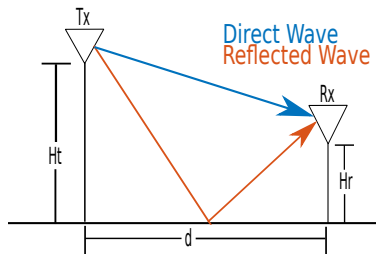
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Approximated two-ray ground-reflection PL (ATRPL):

- ▶ Direct and reflected wave
- ▶ Medium heights

Conditions:

- ▶ No obstacles
- ▶ Plane surface
- ▶ $d > \frac{4\pi \cdot h_t h_r}{\lambda}$



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

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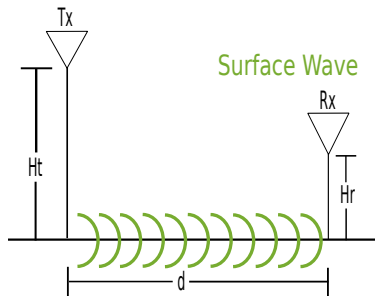
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Norton surface wave PL (NSPL):

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

Conditions:

- ▶ No obstacles
- ▶ Plane surface
- ▶ $h_t, h_r > \lambda$



$$L_p = \left(d \cdot \left| \frac{\lambda}{2\pi z} \right|^{-1} \right)^4 \quad (1)$$

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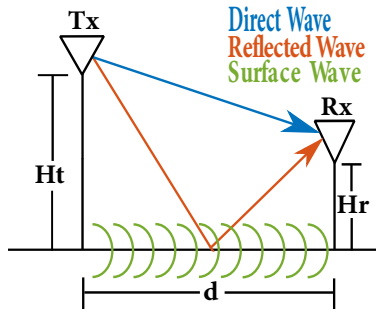
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Ground wave PL (GWPL):

- ▶ All waves
- ▶ All heights
- ▶ Dependent on surface constants

Conditions:

- ▶ No obstacles
- ▶ Plane surface



$$L_p = \left(\frac{4\pi d}{\lambda} \right)^2 \cdot \left| \underbrace{1}_{\text{Direct wave}} + \underbrace{Re^{j\Delta}}_{\text{Reflected wave}} + \underbrace{(1-R)Ae^{j\Delta}}_{\text{Surface wave}} \right|^{-2} \quad (2)$$

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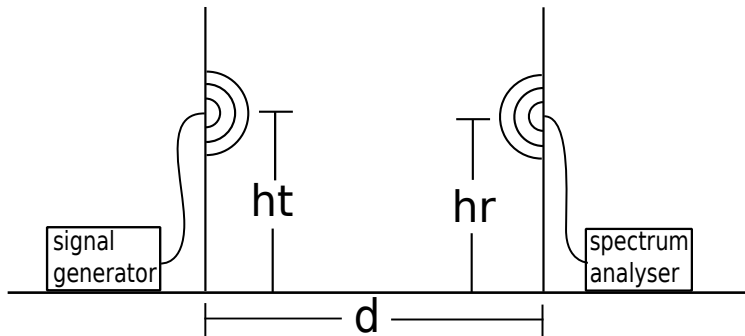
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- ▶ 1 Frequency (858 MHz)
- ▶ 2 Antenna sets (monopole and patch)
- ▶ 2 Polarization (horizontal and vertical)
- ▶ 2 Location (outdoor and indoor)
- ▶ 4 Rx/Tx heights (from 0.04 to 2.02 m)
- ▶ 6 Distances (from 1 to 30 m)



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Distance	1 m	2 m	4 m
PL	(34.7 ± 1.6) dB	(41.4 ± 1.4) dB	(49.0 ± 1.7) dB

Distance	8 m	15 m	30 m
PL	(57.3 ± 2.1) dB	(66.1 ± 2.5) dB	(72.3 ± 2.3) dB

$h_t \setminus h_r$	0.04 m	0.14 m	0.36 m	2.02 m
0.04 m	(63.7 ± 5.2) dB	(60.7 ± 5.1) dB	(55.4 ± 4.7) dB	(52.4 ± 3.8) dB
0.14 m	(60.7 ± 5.1) dB	(58.1 ± 5.2) dB	(53.4 ± 4.5) dB	(50.2 ± 3.2) dB
0.36 m	(55.4 ± 4.7) dB	(53.4 ± 4.5) dB	(49.0 ± 2.9) dB	(47.6 ± 4.8) dB
2.02 m	(52.4 ± 3.8) dB	(50.2 ± 3.2) dB	(47.6 ± 4.8) dB	(44.4 ± 3.1) dB

Gym	Parking lot	Monopole	Patch
(52.4 ± 1.8) dB	(54.6 ± 2.2) dB	(55.6 ± 2.0) dB	(51.4 ± 2.0) dB

Vertical	Horizontal
(51.8 ± 1.9) dB	(55.1 ± 2.1) dB

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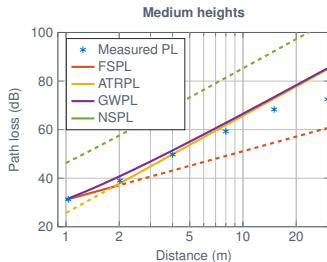
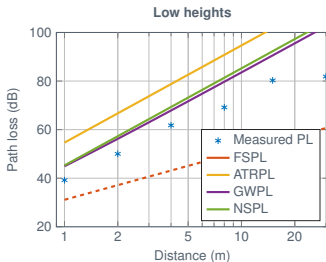
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$$PPL = (ATRPL^{-1} + NSPL^{-1})^{-1}$$

$$PPL = \frac{d^4}{h_t^2 h_r^2 + h_0^4}$$

Model fit

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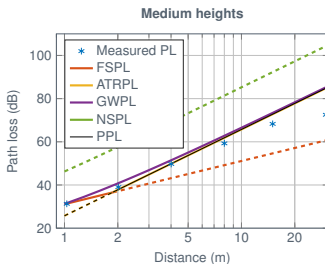
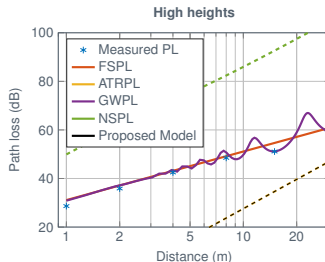
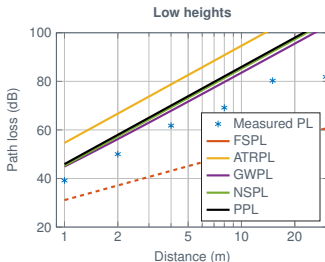
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Models	MSE	Applicability
FSPL	15.95	35 %
ATRPL	141.58	65 %
GWPL	35.49	100 %
NSPL	230.05	30 %
PPL	60.18	65 %

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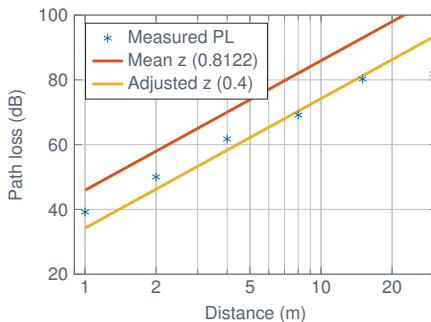
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$$Z_V = \frac{\sqrt{\epsilon_0 - \cos^2 \theta}}{\epsilon_0}$$

$$Z_H = \sqrt{\epsilon_0 - \cos^2 \theta}$$



Questions



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