Below Rooftop Path Loss Model

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Purpose:

To adopt the recommended below rooftop path loss model for RS-RS, RS-MS and MS-MS link simulation

Introduction

- In this presentation a path loss model is proposed for below rooftop relays in a multihop network, where path loss is dependant on the street layout
  - The model is suitable for below rooftop RS-RS, RS-MS, and MS-MS links
- The model includes an advanced LOS model, which uses an effective road height to take account of the effect of traffic, and a visibility factor which takes account of reduced visibility as range increases along a street
- For NLOS paths the model proposed in ETSI doc. TR 101 112 v3.2.0 (1998-04) is recommended. This is described in the slides, and is also combined with the advanced LOS model.

Advanced LOS Model (1)

In the following reference:-

'Advanced LOS path loss model in microcellular mobile communications', Y.Oda, K.Tsunekawa, M.Hata, IEEE VT-49, No.6, Nov 2000, pp.2121-2125.

an advanced LOS path loss model was presented for below rooftop radio links.

Measurements along streets at 450MHz & 10.7GHz show good agreement with a two-ray model, with an 'effective road height' to account for traffic.

Path loss was seen to be greater beyond a certain distance because of reduced visibility with range along the street. A visibility factor of e^{sr} was used for the path loss model, where s was found to be constant with frequency (s=0.002 at 450MHz and 10.7GHz).

Advanced LOS Model (2)

$$\frac{P_r(r)}{P_t} = -20\log\left(\frac{e^{sr}\,4\pi r D(r)}{\lambda}\right)$$

where,

P_t = Transmit Power (dB)

$P_r(r)$ = Received power (dB)

r = Distance between Tx and Rx antennas

e^{sr} = Visibility factor ($s = 0.002$)

λ = Wavelength

$$D(r) = \begin{cases} 1 & \text{if } r \le r_{bp} \\ \dfrac{r}{r_{bp}} & \text{if } r > r_{bp} \end{cases}$$

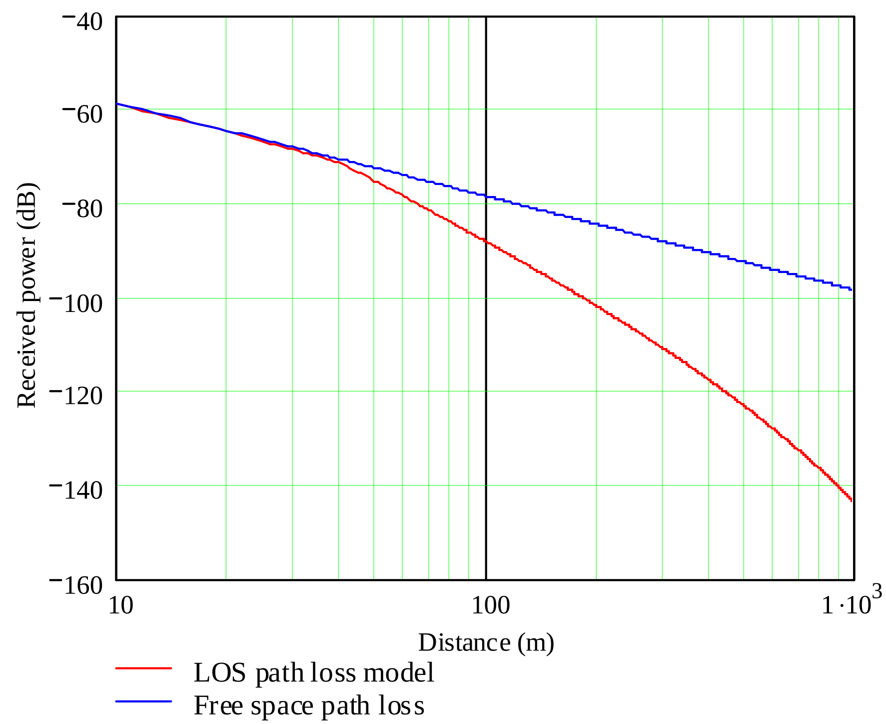
$$r_{bp} = \frac{4(h_t - h_0)(h_r - h_0)}{\lambda} = \text{breakpoint distance}$$

h_t = Height of transmit antenna above the road

h_r = Height of receive antenna above the road

h_0 = Effective road height = 1.0m

LOS path loss at 2GHz. Tx antenna height = 4m, Rx antenna height = 1.5m



Path loss includes visibility factor, effective road height, and breakpoint due to ground reflection.

Lognormal shadowing σ

$$\sigma(r) = \sigma_u \left[1 - e^{-\frac{\left| P(r) - P_{fs}(r) \right|}{4}} \right] + 1.5$$

where,

$\sigma_u = 6.5\text{dB}$, giving a maximum standard deviation of 8dB

$P(r) =$ Mean path loss (dB)

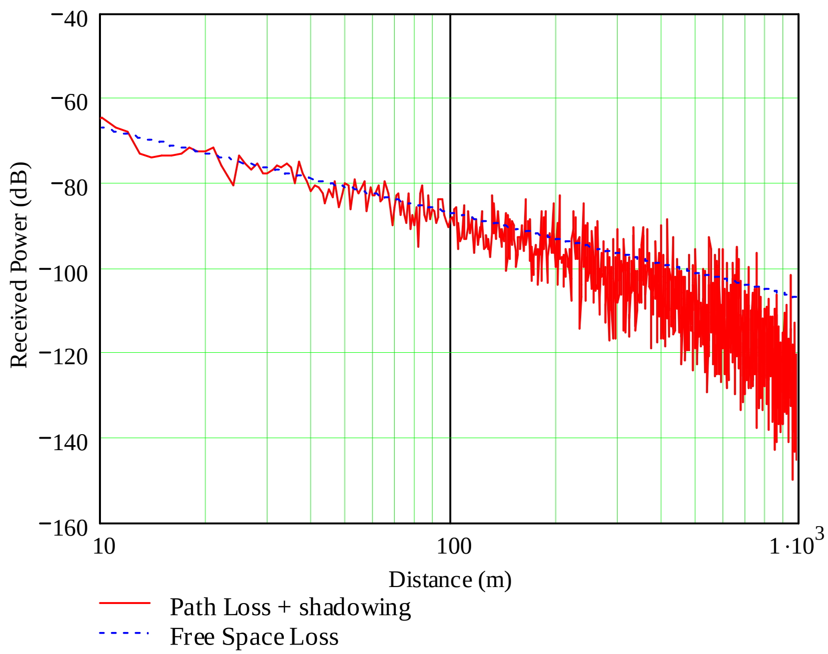
$P_{fs}(r) =$ Free Space path loss (dB)

Lognormal shadowing is dependent on the excess path loss over free space. The function has a constant offset of 1.5dB, where this takes account of variations due to the ground reflection even at very short distances (derived from 2-ray model). The function approaches a maximum value of 8dB as the excess loss increases.

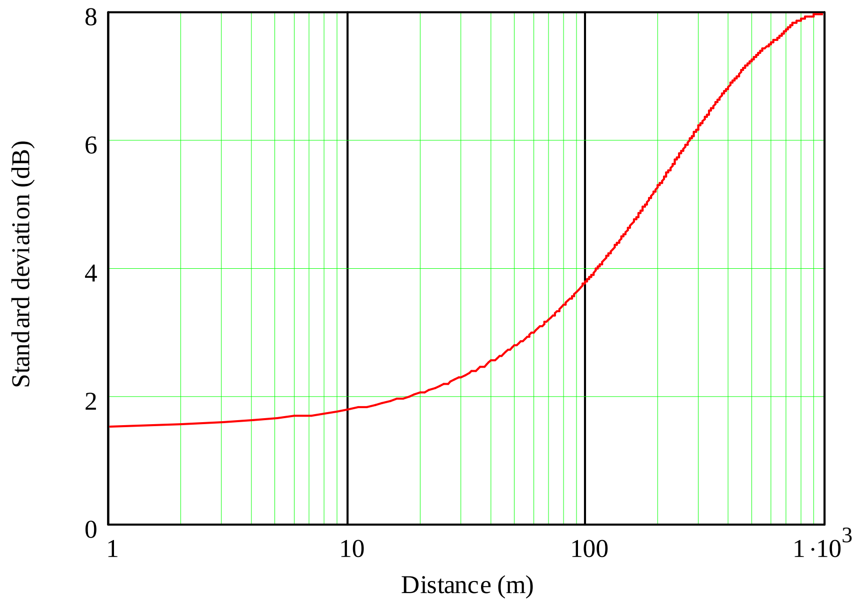
Since below rooftop shadowing is so dependent on the street layout and obstructions within the street the shadowing for different relays can be considered to be independent. MOSAIC could be used to model the spatial variation of the shadowing for a given link with an appropriate decorrelation distance.

Example of lognormal shadowing – LOS path

Transit link LOS model plus shadowing



Variation of lognormal standard deviation with distance



The shadowing model ensures that the path loss + shadowing is not overly optimistic or pessimistic for short distances.

Below rooftop NLOS model

Berg model – incorporating Advanced LOS model

$$\frac{P_r(R)}{P_t} = -20\log\left(\frac{4\pi d_n D\left(\sum_{j=1}^{n} r_{j-1}\right)\prod_{j=1}^{n} e^{s r_{j-1}}}{\lambda}\right)$$

$R = \sum_{j=1}^{n} r_{j-1} =$ Distance along streets between Tx and Rx

$r_j =$ Length of the street between nodes j and $j+1$ (there are $n+1$ nodes in total)

$$r_{bp} = \begin{cases} r_0 \ \text{if}\ r_0 \le \dfrac{4(h_t - h_0)(h_r - h_0)}{\lambda} \\ \dfrac{4(h_t - h_0)(h_r - h_0)}{\lambda} \ \text{if}\ r_0 > \dfrac{4(h_t - h_0)(h_r - h_0)}{\lambda} \end{cases}$$

$$D(R) = \begin{cases} 1 \ \text{if}\ R \le r_{bp} \\ \dfrac{R}{r_{bp}} \ \text{if}\ R > r_{bp} \end{cases}$$

The distance d_n is the 'illusory' distance and is defined by the recursive expression,

$k_j = k_{j-1} + d_{j-1} q_{j-1}$

$d_j = k_j r_{j-1} + d_{j-1}$

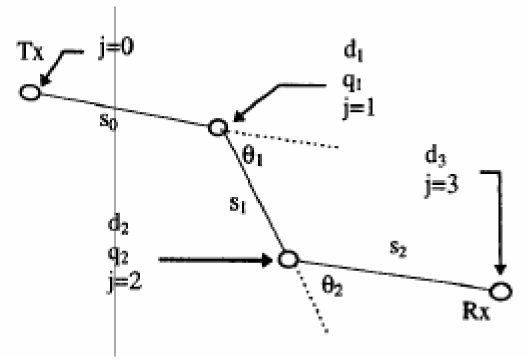
with $k_0 = 1$ and $d_0 = 0$

$$q_j(\theta_j) = \left(\theta_j \frac{q_{90}}{90}\right)^{\nu}$$

$\theta_j =$ Angle between streets at junction j

$q_{90} = 0.5$, and $\nu = 1.5$

Based on the Berg microcellular model, modified to include visibility factors on each street, and effective road height to calculate LOS breakpoint distance.



Recommended NLOS below rooftop model

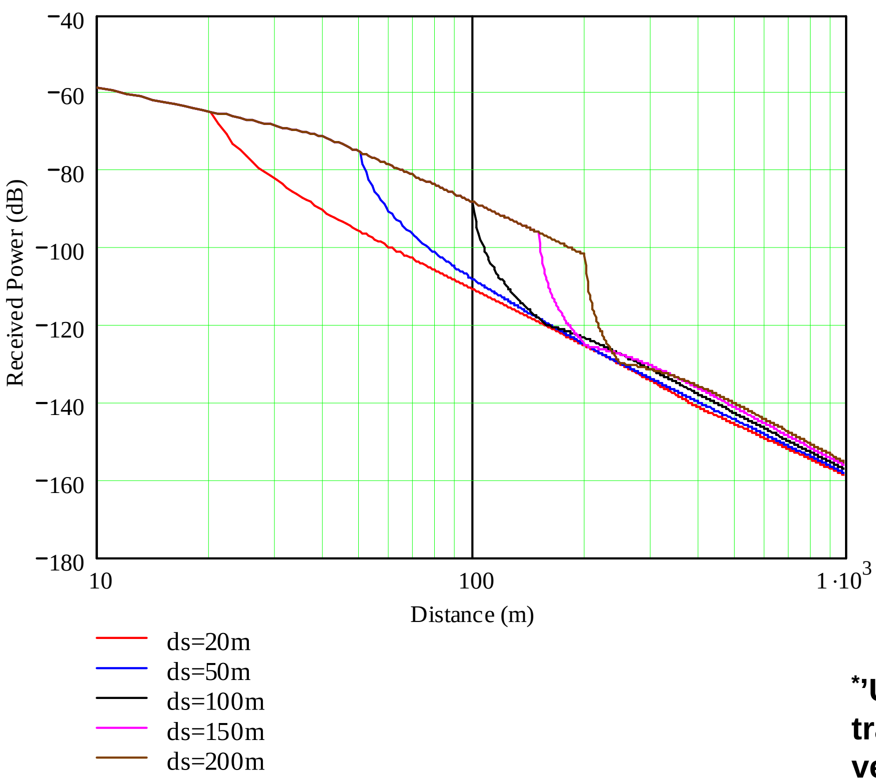
Modified Berg model combined with ETSI over-the-rooftop model

$$P(r) = \min(\text{Modified Berg model, over-rooftop model})$$

$$P(R) = 24 + 45\log(d + 20)$$

ETSI Over-the-rooftop model* (valid at 2GHz)

COST Walfish-Ikegami Model for antennas below roof-top

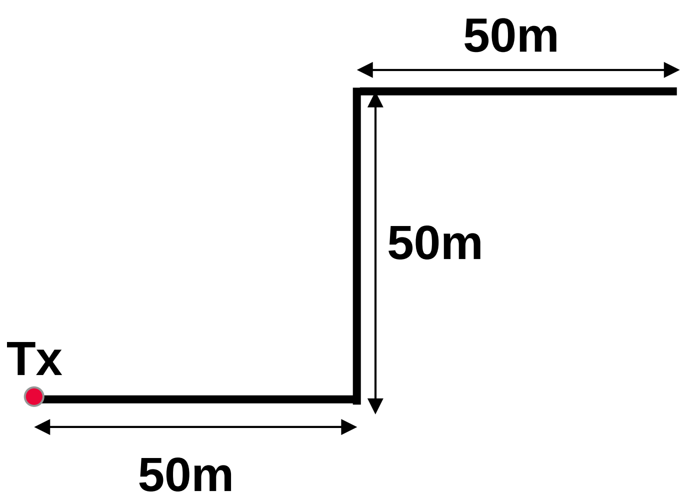


The pathloss is the minimum of the modified Berg model and the ETSI over-the-rooftop model. Example results are shown on the left at 2GHz for a side street at 90° to the main street, and with the Tx at different distances from the junction.

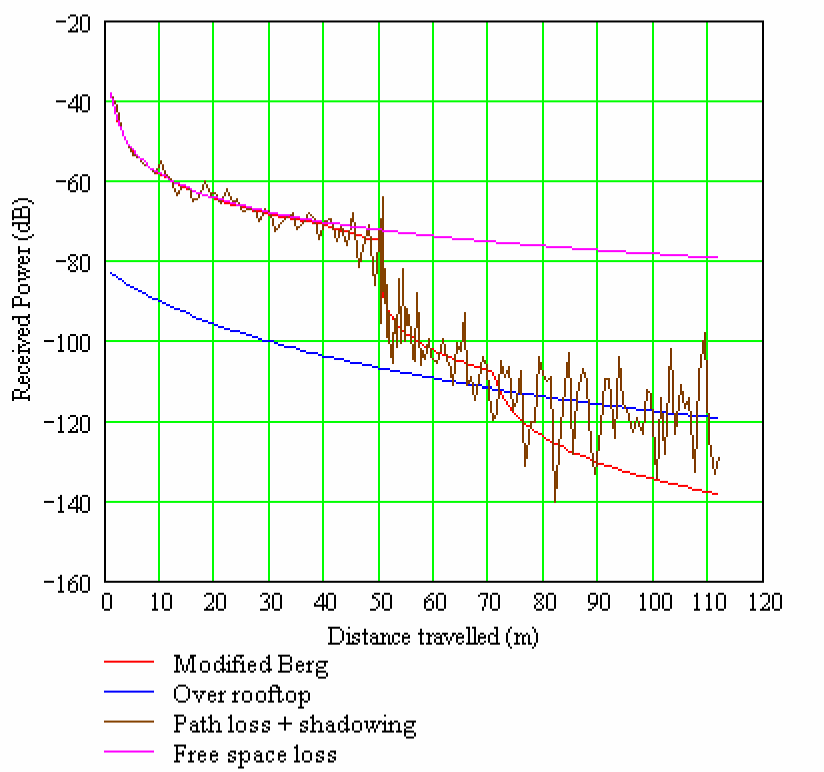
***'UMTS; Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0)', ETSI doc. TR 101 112 v3.2.0 (1998-04)**

Example path in regular street grid

Route traversed by receiver



Path loss versus LOS range for NLOS route



Example showing a NLOS case including the point where the over-the-rooftop received power begins to exceed the power received by propagation around the streets.

Summary

- This contribution has presented a path loss model for below rooftop, which is recommended to use for RS-RS, RS-MS, or MS-MS radio links.
- The LOS part of the model is based on a two ray path loss model
  - An effective road height is employed to take account of the effect of traffic on the breakpoint
  - A visibility factor is used to account for decreasing visibility with range along the street
- The NLOS model takes the minimum of the Berg path loss model (modified to include a visibility factor), and an over-the-rooftop path loss component
- A distance dependant lognormal shadowing standard deviation is proposed