

Below Rooftop Path Loss Model

Document Number:

IEEE C802.16j-06/010

Date Submitted:

2006-05-01

Source:

Dean Kitchener, Mark Naden

deank@nortel.com

Voice: +44 1279 403118

Nortel, London Road

Harlow, Essex, CM17 9NA

Wen Tong, Peiyong Zhu, Gamini Senarnath, Hang Zhang, David Steer, Derek Yu

wentong@nortel.com

pyzhu@nortel.com

613 763 1315

613 765 8089

Nortel, 3500 Carling Avenue

Ottawa, On K2H 8E9 Canada

Mike Hart

Mike.Hart@uk.fujitsu.com

Fujitsu Laboratories of Europe Ltd.

Hayes Park Central

Hayes End, Middx., UK, UB4 8FE

Sunil Vadgama

Sunil.Vadgama@uk.fujitsu.com

Fujitsu Laboratories of Europe Ltd.

Hayes Park Central

Hayes End, Middx., UK, UB4 8FE

Venue:

IEEE 802.16 Session #43, TelAviv, Israel

Base Document: N/A

Purpose:

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

Notice:

This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release:

The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.

IEEE 802.16 Patent Policy:

The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <<http://ieee802.org/16/ipr/patents/policy.html>>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <<mailto:chair@wirelessman.org>> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <<http://ieee802.org/16/ipr/patents/notices>>.

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

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

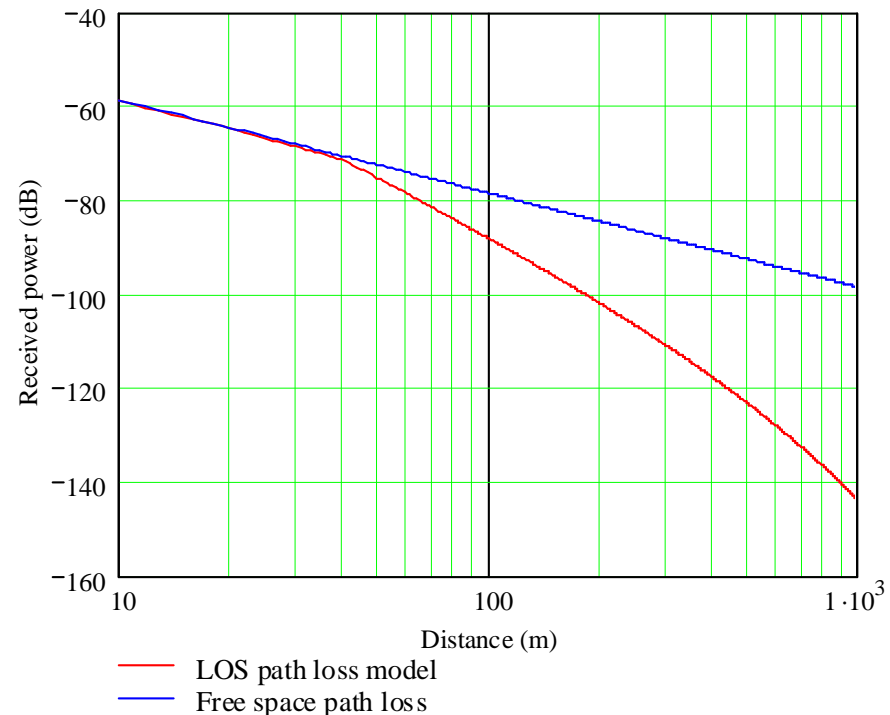
$$r_{bp} = \frac{4(h_t - h_0)(h_r - h_0)}{\lambda} = \text{breakpoint distance}$$

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

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

where,

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

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

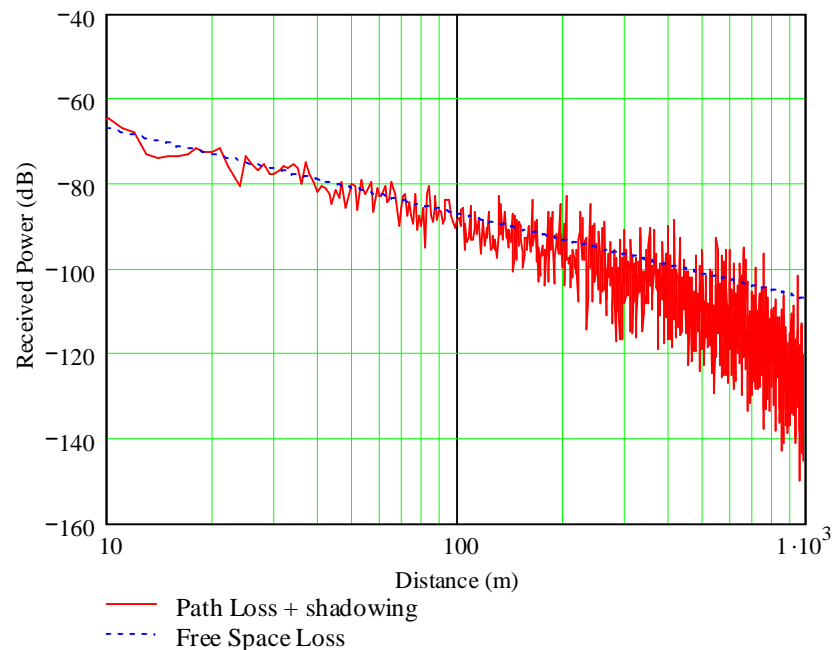
$P_{fs}(r)$ = Free Space path loss (dB)

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.

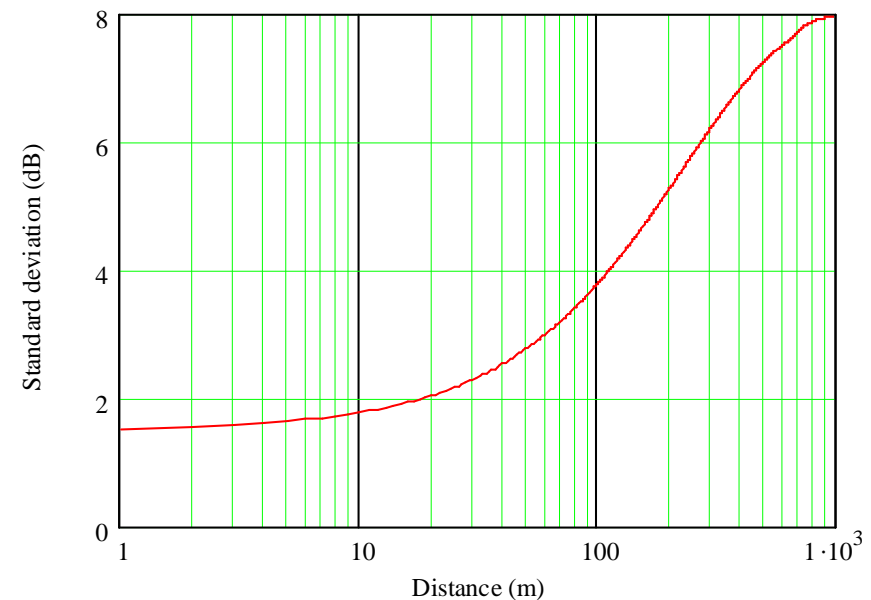
Since below rooftop shadowing is so dependent on the street layout and obstructions within the street the shadowing for different relays can be considered to be independent. MOSAIC could be used to model the spatial variation of the shadowing for a given link with an appropriate decorrelation distance.

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

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

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

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

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

$$D(R) = \begin{cases} 1 & \text{if } R \leq r_{bp} \\ \frac{R}{r_{bp}} & \text{if } R > r_{bp} \end{cases}$$

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

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

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

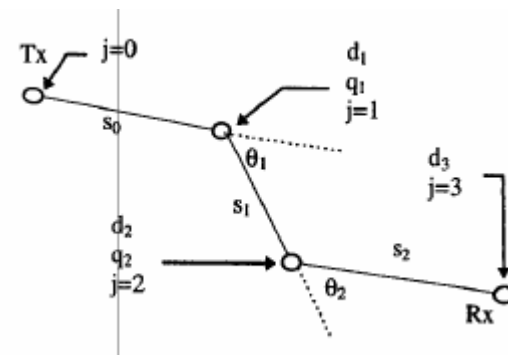
with $k_0 = 1$ and $d_0 = 0$

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

θ_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.



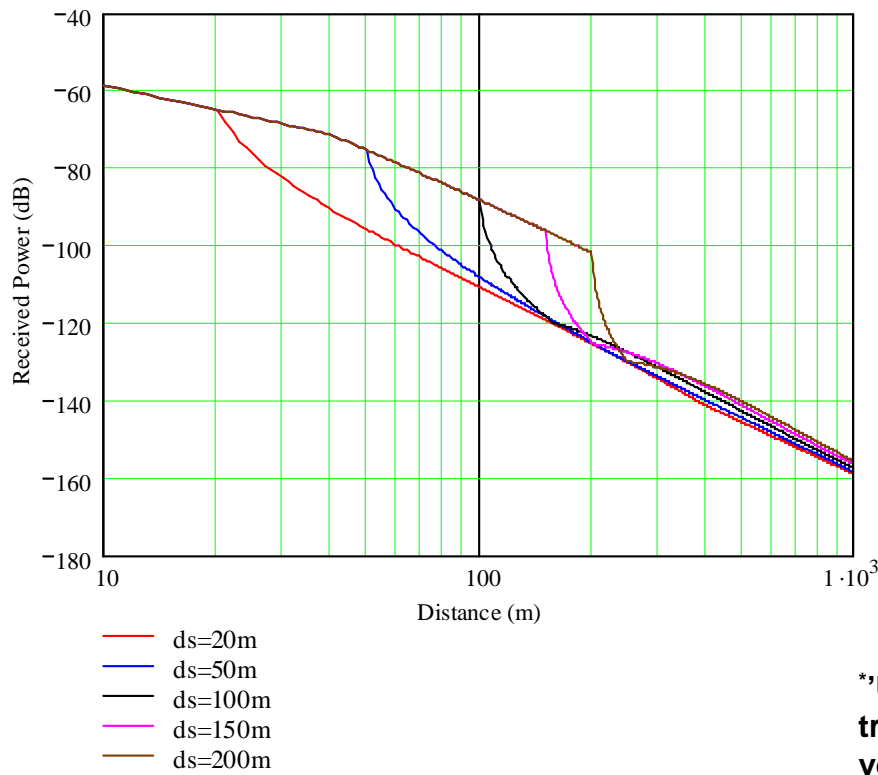
Recommended NLOS below rooftop model

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

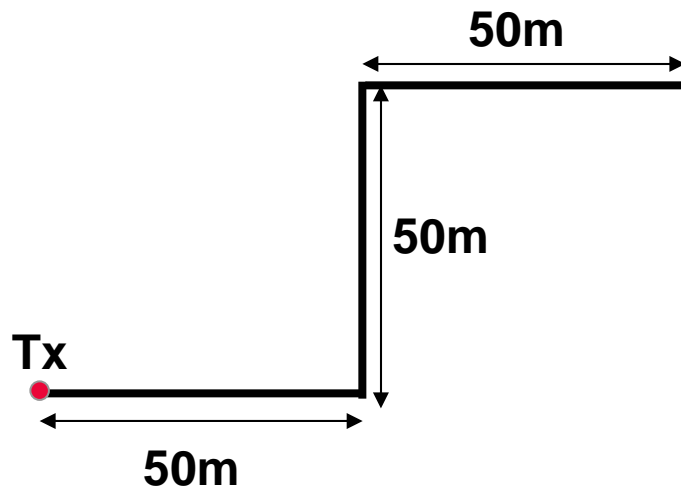


The pathloss is the minimum of the modified Berg model and the ETSI over-the-rooftop model. Example results are shown on the left at 2GHz for a side street at 90° to the main street, and with the Tx at different distances from the junction.

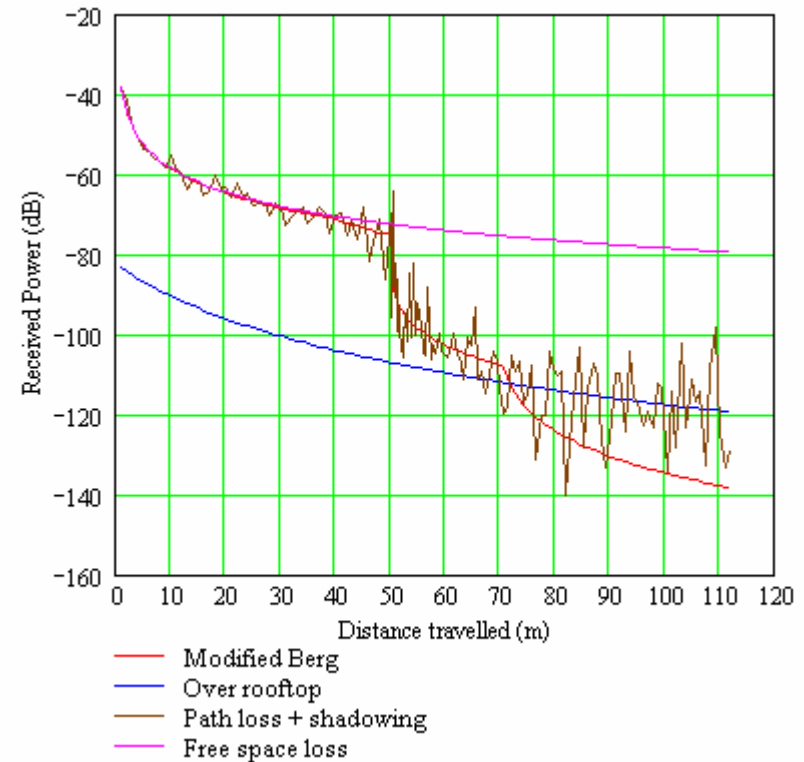
*'UMTS; Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0)', ETSI doc. TR 101 112 v3.2.0 (1998-04)

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