Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Amendments to the Multi-hop Relay System Evaluation Methodology Document
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Re:	Call for Technical Proposals regarding IEEE Project P802.16j (IEEE 802.16j-06/027)
Abstract	Correction to the path loss models in 802.16j-06/.013r1
Purpose	Address a missing path loss models and some editorial corrections to make the applicability of the models clear in P802.16j-06/13r1 document.
Notice	
Release	
Patent Policy and Procedures	

Amendments to the Multi-hop Relay System Evaluation Methodology Document

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Introduction

The purpose of this document is to propose the following text amendments to the current 802.16j-06/013r1 document to address some of the missing propagation models and editorial comments. They are listed below:

a) Current document does not cover the ART to ART model for urban environment. Since the current ART to ART model (Type D, LOS) is valid only for antenna heights lower than 10 m, it would not be valid for the urban case where average roof top height is larger than 10 m. The new model is described in the document 802.16j-06_xxx(ART-ART CH model for Urban).ppt.

   Proposed Text Change: The text included in Section 2.1.2.6 below should be inserted as Type H model into the 802.16j-06/013r1 document for the urban ART-ART case, with the same section number. The changes to the current section numbers are proposed in (e) below.

b) Current document has no reference on how to model outdoor to indoor, outdoor to inside a tunnel, outdoor to inside a vehicle, and outdoor to underground subways. For that purpose, we propose to include several penetration losses which can be used on top of all the other models, and include them as Type J outdoor to indoor models.

   Proposed Text Change: The Text included in Section 2.1.2.7 below should be inserted into the 802.16j-06/013r1 document for the outdoor-indoor case, with the same section number. The changes to the current section numbers are proposed in (e) below.

c) The type E model does not have adequate parameters to be used for the simulations. In order to have alignment across different simulations we propose to have some parameters specified.

   Proposed Text Change: Proposed Text Change: The Text marked in Blue color included in Section 2.1.2.3 below should be inserted into Type E model description in the 802.16j-06/013r1 document.

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d) The above modifications to the models means several changes are required to Table 3 in Section 2.1.1 and Table 4 in Section 2.1.1.1 of 802.16j-06/013r1.

   Proposed Text Change: Replace Table 3 in Section 2.1.1 of 802.16j-06/013r1 by the Table 1 provided in Section 2.1.1 of this document and change Table 4 in Section 2.1.1.1. of 802.16j-06/013r1 as indicated by blue in Table 2, Section 2.1.1.1 of this document

e) Several headings of the subsections to be changed to reflect the above changes and Type F LOS and NLOS be covered under the same Type F Section as two subsections.

   Proposed Text Changes: We propose to use the titles and section numbers used in this document below as the New section numbers of 802.16j-06/013r1.

Legend for the type of changes:

ABC: Complete changes to a Section or to a Table are marked in BLUE color. These sections should be replaced by the new sections marked in blue. The paragraphs marked in blue are new insertions. Some section headings are changed to reflect the model it represents closely which are marked in blue

ABC: The existing text is in BLACK color.

~~ABC:~~ The deleted text is marked as STRIKETHROUGH in RED color.

~~{ABC}:~~ New editorial comments are in Pink.

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Channel Models

Path-Loss Model

Path-loss Types

The path loss for the IEEE802.16j system contains the basic models for the IEEE802.16-2004 and additional path-loss associated with RS nodes. The path-loss types are listed in **Error! Reference source not found.**

Table 1. Summary Table of Path-loss Types for IEEE802.16j Relay System

Category	Description		Reference
Type A	Macro-cell suburban, ART to BRT for Hilly terrain with moderate-to-heavy tree densities	LOS/NLOS	Section 2.1.2.1
Type B	Macro-cell suburban, ART to BRT for Intermediate path-loss condition	LOS/NLOS	
Type C	Macro-cell suburban, ART to BRT for Flat terrain with light tree densities	LOS/NLOS	
Type D	Macro-cell suburban, ART to ART	LOS	Section 2.1.2.2
Type E	Macro-cell, urban, ART to BRT	NLOS	Section 2.1.2.3
Type F	Urban or suburban, BRT to BRT	LOS	Section 2.1.2.4.1
		NLOS	Section 2.1.2.4.2
Type G	Indoor Office	LOS/ NLOS	Section 2.1.2.5
Type H	Macro-cell Urban, ART to ART	LOS	Section 2.1.2.6
TYPE J	Outdoor to Indoor	NLOS	Section 2.1.2.7

Note: LOS (Line Of Sight), NLOS (Non Line Of Sight), ART (Above Roof Top), BRT (Below Roof Top)

2.1.1.1 The relationship path-loss models with the relay system usage models

Table 2. Relationship between path-loss and usage models.

Links	Path-loss Type	Applicable Usage Model	Note
BS-RS	Type A/B/C	I, III, IV	Suburban, RS antenna is BRT

	Type D	I, III	Suburban, BS antenna is ART and RS antenna is ART
	Type H	I, III	Urban, BS antenna is ART and RS antenna is ART
	Type E	I, III, IV	Urban, BS antenna is ART and RS antenna is BRT
	TYPE J	II	BS is outdoor and RS is indoor/tunnel
BS-MS	Type A/B/C	I, III, IV	Suburban, BS antenna is ART
	Type E	I, III, IV	BS antenna is ART
	Type J	II	BS is outdoor and MS is indoor/tunnel
RS-RS	Type A/B/C	I, III, IV	Suburban, one RS antenna is ART
	Type D	I, III	Suburban, both RS antennas are BRT
	Type H	I, III	
	Type E	I, III, IV	Urban, One RS antenna is ART and another one is BRT
	Type F	I, III, IV	Both RS antennas are BRT
	Type G	II	Both RS antennas are inside building
	Type J	II	One RS is outside the other inside a bulding/tunnel
RS-MS	Type A/B/C	I, III,	Suburban, RS antenna is ART
	Type E	I, III,	RS antenna is ART
	Type F	I, III, IV	RS antenna is BRT
	Type G	II	Both RS and MS antennas are inside building
	Type J	II	RS is outside and MS is inside or RS is inside and MS is outside

The usage models referenced from IEEE 802.16j-06/015 are:

Ⅰ. Fixed Infrastructure Usage Model

Ⅱ. In-Building Coverage Usage Model

Ⅲ. Temporary Coverage Usage Model

Ⅳ. Coverage on Mobile Vehicle Usage Model

Detailed Path-loss Models

Type-A/B/C (Suburban, ART-to-BRT, LOS/NLOS)

~~Basic IEEE802.16 model~~

The modified IEEE 802.16 path-loss model is recommended for these links which are provided in [9].

Basic IEEE802.16 model is provided below for reference.

$$PL = A + 10 \cdot \gamma \cdot \log_{10}(d/d_0) + \Delta PL_f + \Delta PL_h \quad (1)$$

where d_0=100m and $d>d_0$. $A=20\cdot\log_{10}(4\pi d_0/\lambda)$ and $\gamma=(a - b\cdot h_b + c/h_b)$. λ is the wavelength in meter and h_b is the BS antenna height, which is between 10m and 80m.

Three propagation scenarios are categorized as

Terrain Type A: Hilly terrain with moderate-to-heavy tree densities

Terrain Type B: Intermediate path-loss condition

Terrain Type C: Flat terrain with light tree densities

The corresponding parameters for each propagation scenario are

Table 3. Parameters for the Type A/B/C

Model Parameter	Terrain Type A	Terrain Type B	Terrain Type C
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

Moreover, the correction factors for carrier frequency (ΔPL_f) and receive antenna height (ΔPL_h) are:

$\Delta PL_f = 6 \cdot \log_{10}(f/2000)$ dB (2)

where f is the carrier frequency in MHz.

$\Delta PL_h = -10.8 \cdot \log_{10}(h/2)\ dB$; for Terrain Type A and B (3)

$\Delta PL_h = -20 \cdot \log_{10}(h/2)\ dB$; for Terrain Type C

where h is the MS/RS receive antenna height between 2m and 10m.

Extended IEEE802.16 model

$$PL(dB) = \begin{cases} 20\log\left(\frac{4\pi d}{\lambda}\right) & \text{for } d \le d_0^{'} \\ A + 10\gamma\log\left(\frac{d}{d_0^{'}}\right) + \Delta PL_f + \Delta PL_{ht} & \text{for } d > d_0^{'} \end{cases}$$

where,

$$A = 20\log\left(\frac{4\pi d_0^{'}}{\lambda}\right)$$

$$d_0 = 100m$$

$$d_0^{'} = d_0 10^{-\left(\frac{\Delta PL_f + \Delta PL_{ht}}{10\gamma}\right)}$$

$$\gamma = a - bh_b + \frac{c}{h_b}$$

$$\Delta PL_f = 6\log\left(\frac{f(MHz)}{2000}\right)$$

$$\Delta PL_{ht} = \begin{cases} -10\log\left(\frac{h_t}{3}\right) & \text{for } h_t \le 3m \\ -20\log\left(\frac{h_t}{3}\right) & \text{for } h_t > 3m \end{cases}$$

d = distance between BS and RS

h_b = height of BS

h_t = height of RS

$a = 3.6$

$b = 0.005$

$c = 20$

The parameters for Types A, B and C are same as those of basic model provided in Table 3.
[Editor's note: The above parameter values of a, b and c, provided with the modified equation should be deleted].

Type-D: (Suburban, ART-to-ART. LOS)

This scenario is shown in Figure 1 and Figure 2, where both node antennas are mounted above the rooftops (ART) and they have a LOS between them.

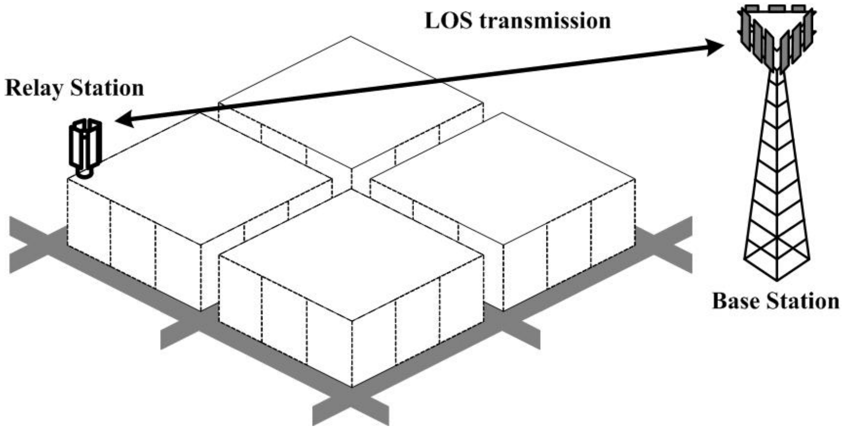

Figure 1. BS-RS link with LOS

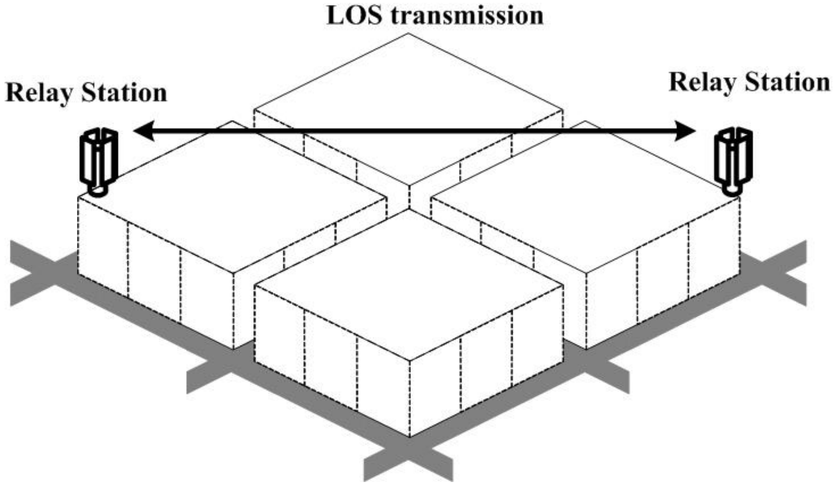

Figure 2. RS-RS LOS link (ART to ART)

For this link the modified IEEE 802.16d channel model is recommended as presented in this section. There are three categories for this model, as shown in the previous section, where each category represents a different environment. The most benign category (category C) is chosen for this scenario to allow for the fact that the relays in this case are assumed to have been deployed with a good LOS back to the BS. The model is equal to the free space path loss up to a breakpoint, which is determined by the transmission frequency and the relay antenna height. Beyond the breakpoint, the path loss exponent increases, and this is to account for the fact that LOS probability will decrease with distance from the BS. This factor is also important for multi-cell simulations for interference calculations.

$$PL(dB)=\begin{cases}20\log\left(\frac{4\pi d}{\lambda}\right) & \text{for } d\le d_0^{'}\\ A+10\gamma\log\left(\frac{d}{d_0^{'}}\right)+\Delta PL_f+\Delta PL_{ht} & \text{for } d>d_0^{'}\end{cases}$$

where,

$$A=20\log\left(\frac{4\pi d_0^{'}}{\lambda}\right)$$

$$d_0=100m$$

$$d_0^{'}=d_0 10^{-\left(\frac{\Delta PL_f+\Delta PL_{ht}}{10\gamma}\right)}$$

$$\gamma=a-bh_b+\frac{c}{h_b}$$

$$\Delta PL_f=6\log\left(\frac{f(MHz)}{2000}\right)$$

$$\Delta PL_{ht}=\begin{cases}-10\log\left(\frac{h_t}{3}\right) & \text{for } h_t\le 3m\\ -20\log\left(\frac{h_t}{3}\right) & \text{for } h_t>3m\end{cases}$$

d = distance between BS and RS

h_b = height of BS

h_t = height of RS

$a=3.6$

$b=0.005$

$c=20$

Note that the MS/RS height correction factor is Okumura's correction factor.

Type-E: (Urban ART-to-BRT, NLOS)

For the urban NLOS case which is shown as the examples in Figure 4 and 5, the COST 231 Walfisch-Ikegami model is recommended and given in [14].

(Editor's Note: The text of COST 231 Walfisch-Ikegami model is in the Appendix A of [14])

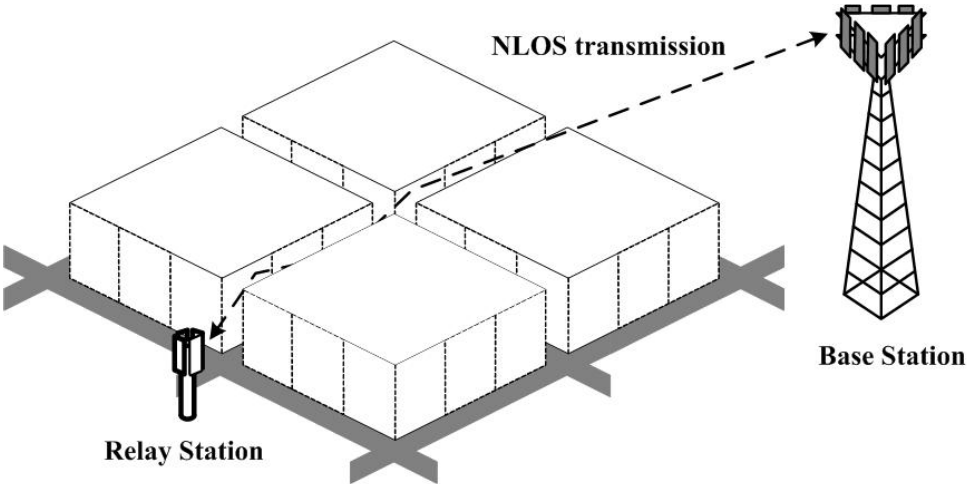

Figure 3, BS-RS NLOS (ART to BRT)

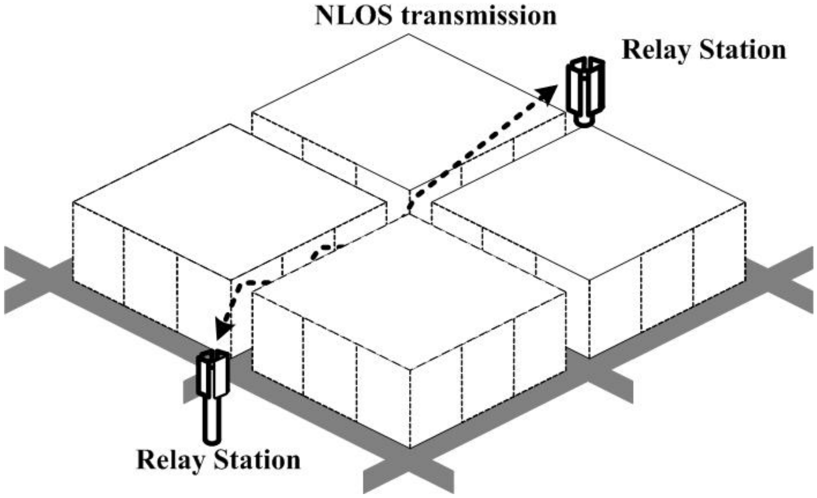

Figure 4. RS-RS NLOS (ART to BRT)

Parameter values to be used for this model are provided below. The use of these values is not mandatory.

Building spacing, b = 60m (this is the spacing between building centres)
Street width, w = 12m (this is the spacing between building faces)
Street orientation = 90 degrees
Average rooftop height, hroof = 25m

An alternative is using WINNER model, which is given as:

$$PL(d)=38.4+35\log_{10}(d) \text{ dB} \quad \textit{for } 50\text{m} < d < 5\text{km}$$

where d is the distance in meter and the carrier frequency is 5GHz.

Type-F: (BRT-to-BRT)

Both LOS and NLOS models are provided separately below for this case.

[Editor's note: Two subsections 2.1.2.4.1 and 2.1.2.4.2 are to replace 2.1.2.4 and 2.1.2.5 in the original document}

LOS version:

For this scenario we assume that both node antennas are located below the rooftop, and that they are located on the same street.

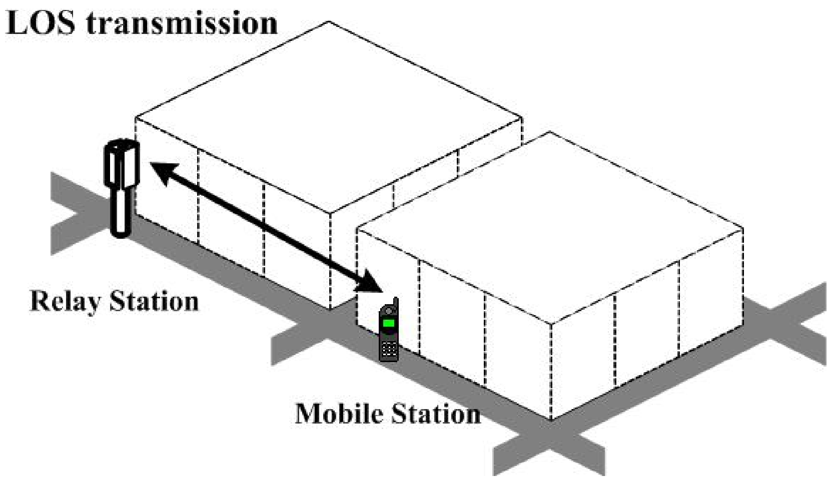

Figure 5. RS-MS LOS Scenario

For this case an advanced LOS model is recommended. This is a two-slope model, where the breakpoint is dependant on the relay and MS antenna heights. However, the effect of traffic is taken into account by defining an effective road height, which reduces the relay and MS heights. In addition, a visibility factor is included which reduces the path loss further as distance increases, and this factor accounts for the fact that LOS decreases with distance along a street. The model is given below:-

$$PL(dB) = 20\log\left(\frac{e^{sr} 4\pi r D(r)}{\lambda}\right)$$

where,

$r =$ distance between Tx and Rx

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

$\lambda =$ Wavelength

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

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

$h_t =$ Height of transmitter above ground

$h_r =$ Height of receiver above ground

$h_0 =$ Effective road height $= 1.0m$

Note, for the distance between RS-RS or RS-MS less than 10m case, the free-space model is used.

For this scenario, the alternative WINNER path-loss model can be used:

$PL(d)$=22.7 $\log_{10}(d)$+41.0 dB for 10m < d <650m

where d is the distance in meter and the carrier frequency is 5 GHz

NLOS version (Type-F: BRT-to-BRT)

For this scenario both nodes antenna heights are below rooftop and they are located on different streets.

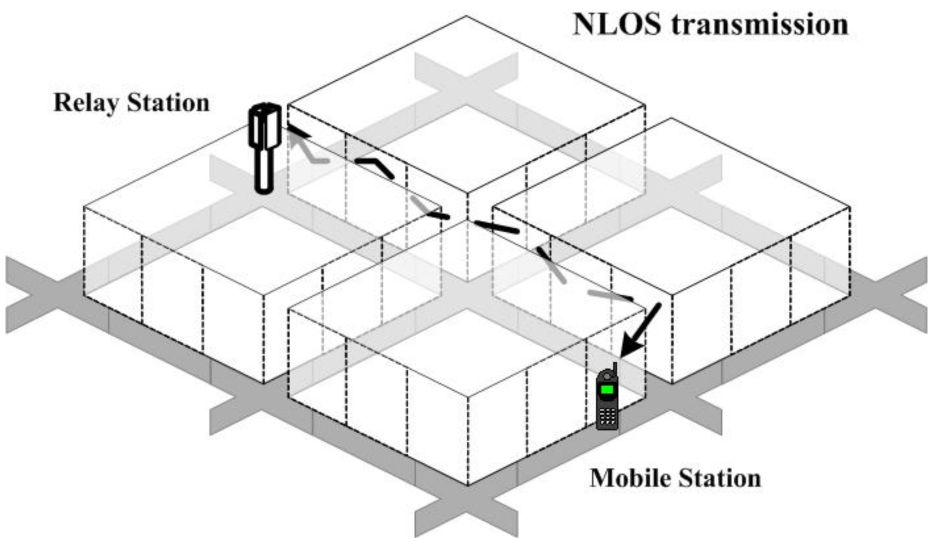

Figure 6. RS-MS NLOS scenario

For this case, the model takes the minimum of an over-the-rooftop component and a round-the streets component. The round-the-streets component is based on a model by Berg, although this has been modified to be compatible with the advanced LOS model (see section 2.1.2.6), such that the visibility factor is included, and the effective road height to give the correct breakpoint in the first street section. The full model is shown below:

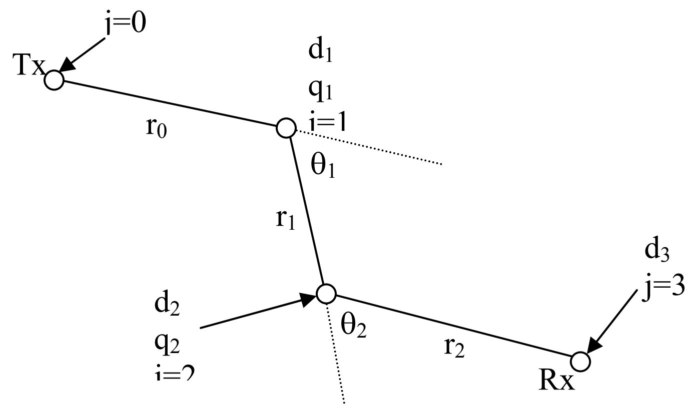

Figure 7. Geometry of street sections used for Berg model

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

$R = \sum_{j=1}^{n} r_{j-1}$ = 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 $d_0 = 0$

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

θ_j = Angle between streets at junction j

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

$PL_{over\_the\_rooftop}(dB) = 24 + 45\log(r_{Eu})$

r_{Eu} = Euclidean distance between Tx and Rx

$PL(dB) = \min\left(PL_{Berg}(dB), PL_{over\_the\_rooftop}(dB)\right)$

Note that the one-street turn corner modeling is recommended for the most of case.

For this scenario the alternative WINNER path-loss model (for 5GHz) can be used:

$PL = 65 + 0.096 \cdot d_1 + (28-0.024 \cdot d_1) \cdot \log_{10}(d_2)$ *dB for* $10\text{m} < d_1 < 550\text{m}$ and $w/2 < d_2 < 450\text{m}$

where d_1 is the distance along the main street in meters, d_2 is the distance for perpendicular street, w is the street width, and the carrier frequency is 5 GHz

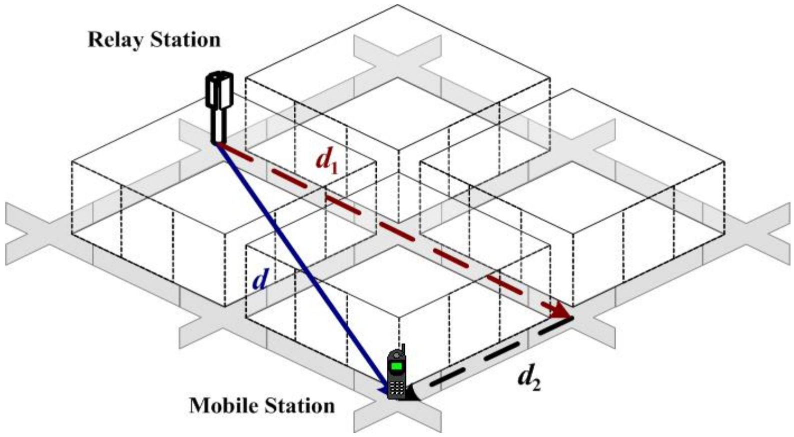

Figure 8. The alternative model for RS-MS NLOS scenario

Type-G Indoor Office Environment path-loss Model

The path-loss model for indoor environment is:

$$PL = 37 + 30 \cdot \log_{10}(d) + 18.3 \cdot n^{((n+2)/(n+1)-0.46)}\ dB \qquad (4)$$

where d is the distance in meters and n is the number of floors in the path.

For Type-G Indoor Office Environment scenario the alternative WINNER path-loss model can be used:
For LOS case:

$PL(d)$=18*log10 (d)+46.8 dB for 3m < d < 100m

For NLOS case:

$PL(d)$=36.8*log (d)+38.8 dB for 3m < d < 100m

Where d is in meters and the carrier frequency is 5GHz.

Type H Urban ART to ART model

The model is based on the COST 231 Walfisch-Ikagami pathloss model, modified to remove the rooftop to street diffraction component (*Lrts*).

The basic transmission loss is composed of two terms: free space loss (*L0*) and multiple screen diffraction loss (*Lmsd*)

$$L = \begin{cases} L_0 + L_{msd} & \text{for } L_{msd} > 0 \\ L_0 & \text{for } L_{msd} \le 0 \end{cases}$$

The free space loss is given by:

$$L_0(dB) = 32.4 + 20\log(d/km) + 20\log(f/MHz)$$

The multiple screen diffraction term represents the propagation over multiple rooftops and this is given by the following expression:

$$L_{msd} = L_{bsh} + k_a + k_d \log\left(\frac{d}{km}\right) + k_f \log\left(\frac{f}{MHz}\right) - 9\log\left(\frac{b}{m}\right)$$

The term *Lbsh* describes the dependence of the loss on the height of the BS antenna

$$\Delta h_{Base} = h_{Base} - h_{Roof}$$

$$L_{bsh} = \begin{cases} -18\log\left(1 + \frac{\Delta h_{Base}}{m}\right) & \text{for } h_{Base} > h_{Roof} \\ 0 & \text{for } h_{Base} \le h_{Roof} \end{cases}$$

Here, hBase is the Base station antenna height, hRoof is the average rooftop height and b is the Building separation (building centre-to-building centre).

The term ka represents the increase of the path loss for base station antennas below the rooftops of the adjacent buildings.

$$k_a = \begin{cases} 54 & \text{for } h_{Base} > h_{Roof} \\ 54 - 0.8\frac{\Delta h_{Base}}{m} & \text{for d} \ge 0.5\text{km and } h_{Base} \le h_{Roof} \\ 54 - 0.8\frac{\Delta h_{Base}}{m}\frac{d/km}{0.5} & \text{for d} < 0.5\text{km and } h_{Base} \le h_{Roof} \end{cases}$$

The terms terms *kd* and *kf* control the dependence of the multi-screen diffraction loss on distance and radio frequency, respectively. They can be evaluated using the following expressions.

$$k_d = \begin{cases} 18 & \text{for } h_{Base} > h_{Roof} \\ 18 - 15\frac{\Delta h_{Base}}{h_{Roof}} & \text{for } h_{Base} \le h_{Roof} \end{cases}$$

$$k_f = -4 + 1.5\left(\frac{\text{f/MHz}}{925} - 1\right)$$

Type J: Outdoor to Indoor, tunnels, in-vehicle and subway model

This is modelled by incorporating a penetration loss factor to the previous base models (Type A, B, C, D, E, F, H). The following are the recommended penetration losses for various cases.

Outdoor to indoor : 12 dB mean, lognormal distribution with a standard variation of 8 dB . Ref xx]
{Editor's note: the following reference should be included under references.
Ref [xx]: *Section 1.1.2., p.25 of Rec. ITU-R M.1225 }*
Outdoor to in-vehicle: 6 dB mean value, a lognormal distribution having a standard deviation of 3 dB.
Outdoor to tunnels: 12 dB mean value, lognormal distribution with a standard deviation of 8 dB.
Subways: Use a penetration loss of *PU* as per the following equation similar to multi-floor indoor case, in Section 2.1.2.5. A lognormal variation of 6 dB is to be used.

$$PU = 18.3 \cdot n^{((n+2)/(n+1)-0.46)}\ dB$$

Where n is the number of floors below the ground. N = 1 for the ground floor. N=2 for the next level down etc.

LOS Probability

In path-loss Type-F and Type-G, the radio link may be either LOS (Line-Of-Sight) or NLOS (Non Line-Of-Sight).

For Type-F, both node-antennas are below rooftop. Therefore, the following equation for LOS probability [15] can be considered in simulation.

$$P_{LOS}(d) = \begin{cases} 1 & d \le 15m \\ 1-\left(1-\left(1.56-0.48\cdot\log_{10}(d)\right)^3\right)^{1/3} & d > 15m \end{cases}$$

where $d = \sqrt{d_1^2 + d_2^2}$, and d_1 and d_2 are like in Figure 9.

For Type-G, indoor office environment, the following equation for LOS probability [15] should be considered when simulation.

$$P_{LOS}(d) = \begin{cases} 1 & d \le 2.5m \\ 1-0.9\cdot(1-(1.24-0.61\cdot\log_{10}(d))^3)^{1/3} & d > 2.5m \end{cases}$$