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Re:	Response to the call for comments on IEEE 802.16j-06/013
Abstract	This contribution captures the harmonization results during the IEEE session#45 Relay TG meeting
Purpose	Proposes the harmonized comments and corresponding change request on the channel models of IEEE 802.16j-06/013
Notice	
Release	
Patent Policy and Procedures	

<http://ieee802.org/16/ipr/patents/notices>.

Harmonized Comments on the Channel Models in IEEE 802.16j-06/013

This contribution captures the harmonized comments on the channel models in IEEE 802.16j-06/013. The proposed change request on the text of IEEE 802.16j-06/013 is shown as following, and the newly added text will be marked in blue color.

---Start of the Text---

2 Channel Models

[Editor's note: adopt the modified IEEE802.16d SUI channel model as baseline [14], and open for further comparison with other models such as the path-loss models in [6]]

2.1 Path-Loss Model

2.1.1 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 Table 1

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

~~Category~~	~~Links~~	~~Description~~		~~Reference~~	~~Note~~
~~Type A~~	~~BS–MS~~	~~Hilly terrain with moderate-to-heavy tree densities~~		~~Section 2.1.2.1~~	~~IEEE 802.16 Type A model~~
~~Type B~~		~~Intermediate path-loss condition~~			~~IEEE 802.16 Type B model~~
~~Type C~~		~~Flat terrain with light tree densities~~			~~IEEE 802.16 Type C model~~
~~Type D~~	~~BS–RS RS–RS~~	~~Both node-antennas (BS/RS) above rooftop~~	~~LOS~~	~~Section 2.1.2.2~~	~~Modified IEEE 802.16 model~~
			~~NLOS~~		
~~Type E~~	~~BS–RS RS–RS RS–MS~~	~~Only one node-antenna (BS/RS) above rooftop~~	~~NLOS~~	~~Section 2.1.2.4~~	~~Modified IEEE 802.16 model~~
~~Type F~~	~~RS–RS RS–MS~~	~~Both node-antennas (BS/RS) below rooftop~~	~~LOS~~	~~Section 2.1.2.5~~	~~Advanced LOS~~
			~~NLOS~~	~~Section 2.1.2.6~~	~~Berg/WiNNER~~
~~Type G~~	~~RS–RS RS–MS~~	~~Indoor Office~~	~~NLOS~~	~~Section 2.1.2.7~~	~~ITU model~~

Category	Description		Reference
Type A	Hilly terrain with moderate-to-heavy tree densities (macro-cell suburban)		Section 2.1.2.1
Type B	Intermediate path-loss condition (macro-cell suburban)		
Type C	Flat terrain with light tree densities (macro-cell suburban)		
Type D	Both node-antennas are ART	LOS	Section 2.1.2.2

Type E	Only one node-antenna is ART	NLOS	Section 2.1.2.3
Type F	Both node-antennas are BRT	LOS/ NLOS	Section 2.1.2.4
Type G	Indoor Office	LOS/ NLOS	Section 2.1.2.5

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

[Editor's note: The linkage with the path-loss models defined in Table 1 and the usage models for the IEEE802.16j is FFS]

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	BS antenna is ART and RS antenna is ART
	Type E	Ⅰ, Ⅲ, Ⅳ	Urban, BS antenna is ART and RS antenna is BRT
BS-MS	Type A/B/C	Ⅰ, Ⅲ, Ⅳ	Suburban, BS antenna is ART
	Type E	Ⅰ, Ⅲ, Ⅳ	BS antenna is ART
RS-RS	Type A/B/C	Ⅰ, Ⅲ, Ⅳ	Suburban, one RS antenna is ART
	Type D	Ⅰ, Ⅲ	Both RS antennas are BRT
	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
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

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

2.1.2 Detailed Path-loss Models

2.1.2.1 Type-A/B/C: ~~BS ↔ MS, BS ↔ MRS, BS ↔ NRS)~~ (Suburban, ART-to-BRT)

Basic IEEE802.16 model

The IEEE 802.16 path-loss ~~and shadow fading~~ model is recommended and given by [14]

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

where d_0=100m and $d>d_0$. $A=20\log_{10}(4\pi d_0/\lambda)$ and $\gamma=(a - b\cdot h_b + c/h_b)$. λ is the wavelength in meter and h_b is the BS ~~base station~~ antenna height, which is between 10m and 80m. ~~"s" is the log-normal shadow fading component in dB.~~ 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 2 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
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
$\Delta PL_h = -20 \cdot \log_{10}(h/2)\; dB$; for Terrain Type C
where h is the MS/RS receive antenna height between 2m and 10m.

Extended IEEE 802.16 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

$a = 3.6$

$b = 0.005$

$c = 20$

2.1.2.3 Type-D~~: BS ↔ RS,~~ LOS (ART-to-ART)

This scenario ~~is~~ shown ~~in~~ as the examples in Figure 1 and Figure 3, where both node ~~the BS and RS~~ antennas are mounted above the rooftops (ART) and they have a LOS between them.

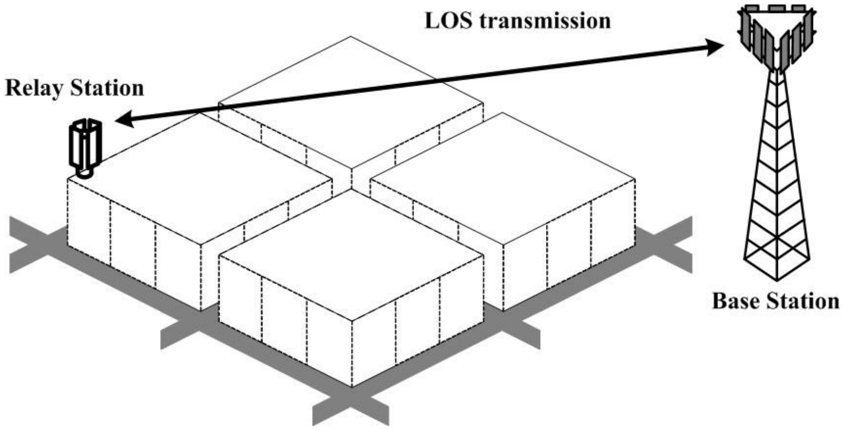

Figure 1 BS-RS link with LOS~~/NLOS~~

(Editor's note: Figure3 is moved to following location)

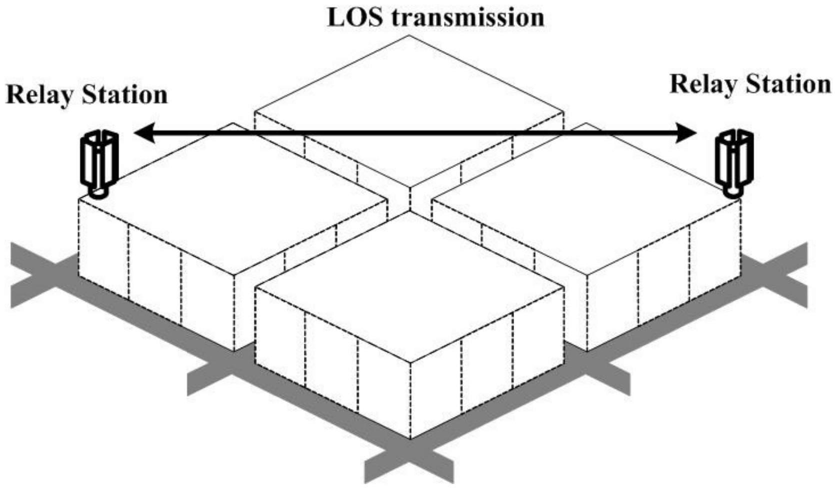

Figure 2 RS-RS LOS link (ART to ART)

For this link the ~~a~~ modified IEEE 802.16d channel model is recommended, as presented in the following. ~~in section 2.1.2.1.~~ 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. ~~The relay will only be deployed to try to give LOS back to the 'wanted' BS. Interfering BSs (at greater distance) will most likely not have a LOS back to the BS, and the path loss model will account for this.~~

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

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.

2.1.2.4 ~~Type-D: RS ↔ RS, LOS (ART to ART)~~

~~For this scenario we assume that both relays are deployed above the rooftops, and they are deployed such that a LOS exists between them. Note that interfering relays at greater distances will not necessarily have a LOS path, and so the model proposed in section 2.1.2.2 can be used.~~

2.1.2.1 ~~2.1.3.4~~ Type-E~~: BS ↔ RS,~~ Urban NLOS (ART-to-BRT)

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])
~~This scenario is shown illustrated in Figure 3, where in this case the BS antenna is mounted above the rooftops and the relay antenna is mounted below the rooftop (BRT).~~

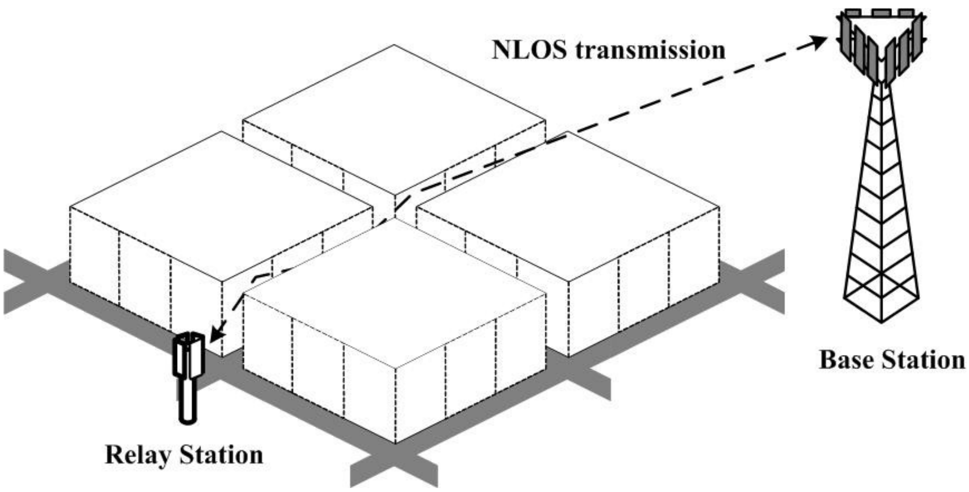

Figure 3 BS-RS NLOS (ART to BRT)

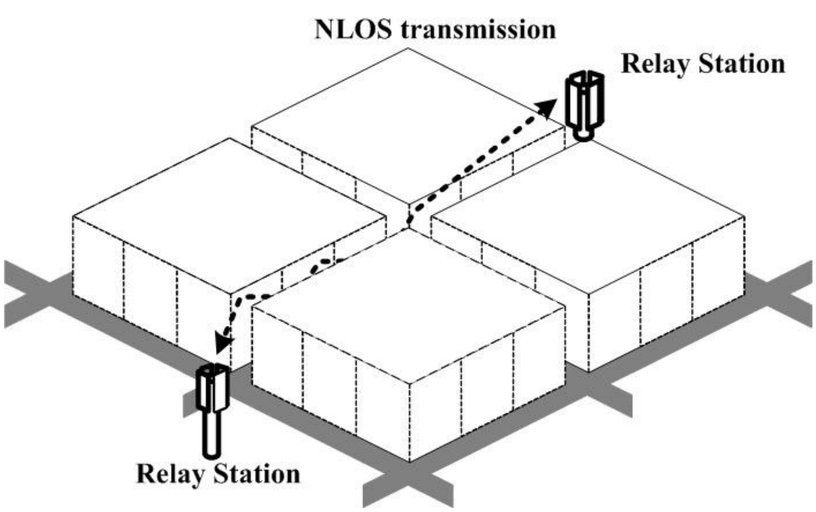

Figure 4 RS-RS NLOS (ART to BRT)

~~For this case the link is like a standard macro-cellular link, except that the relay antenna height is likely to be higher than the height of a typical MS. Consequently, the section 2.1.2.1 is a good model for this case, where all three categories (A, B, and C) are now applicable to cover different environments. The model includes a MS antenna height correction factor, and it includes a frequency correction factor.~~

~~The model is identical to that given in section 2.1.2.1 except for the following changes to allow for three different environment types: see [6]~~

~~Category A: Hilly terrain with moderate-to-heavy tree densities~~
~~Category B: Mostly flat terrain with moderate-to-heavy tree densities, or hilly terrain with light tree densities~~
~~Category C: Flat terrain with light tree densities~~

$$PL_{ht} \quad \begin{matrix} 10.8\log \dfrac{h_t}{2} & \text{Categories A \& B} \\ 10\log \dfrac{h_t}{3} & \text{Category C}, h_t \quad 3 \\ 20\log \dfrac{h_t}{3} & \text{Category C}, h_t \quad 3 \end{matrix}$$

2.1.2.2 Type-E: RS ↔ RS, NLOS (ART-to-BRT)

This scenario is similar to the BS-MS link, where it is assumed that one relay is mounted above the rooftop and one relay is mounted below the rooftop. Therefore, the model proposed in section 2.1.2.2 can be used.

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

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

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

2.1.3.4 .5 Type-F: RS ↔ MS, LOS (BRT-to-BRT)

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

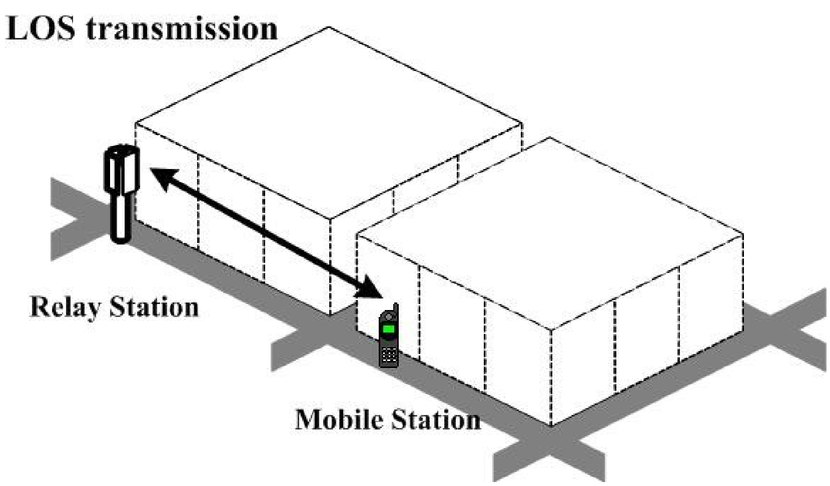

Figure 5– RS-MS LOS Scenario

For this case an advanced LOS model is 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:-

$$PL\ dB \quad 20\log \frac{e^{sr}\, 4\ \ rD\ r}{}$$

where,

r distance between Tx and Rx

e^{sr} Visibility factor s 0.002

Wavelength

$$D\ r \quad \begin{matrix} 1 & r & r_{bp} \\ \frac{r}{r_{bp}} & r & r_{bp} \end{matrix}$$

$$r_{bp} \quad \frac{4\ h_t \quad h_0\ \ h_r \quad h_0}{}$$

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

2.1.2.3 Type-F~~: RS ↔ MS,~~ NLOS (BRT-to-BRT)

For this scenario the both node antenna ~~RS and MS antenna~~ heights are below rooftop and they are located on different streets.

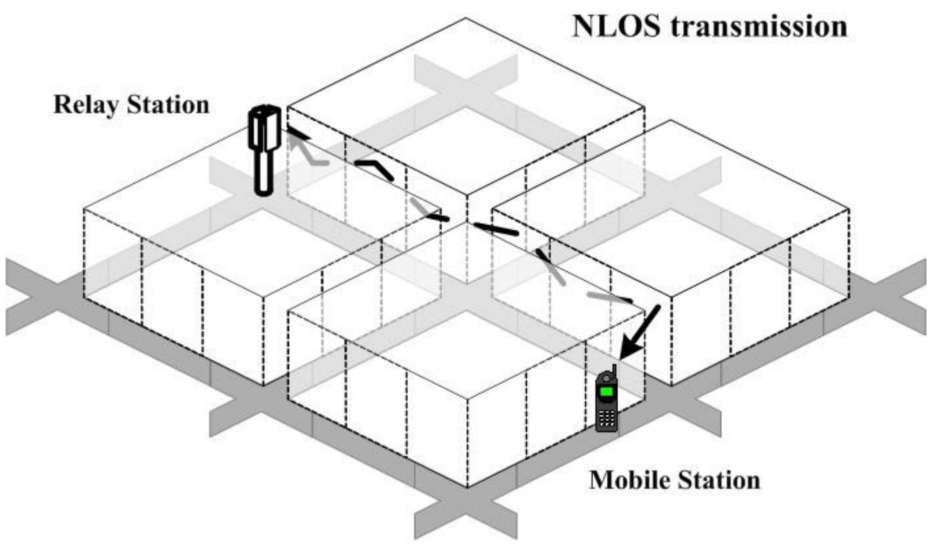

Figure 6 RS-MS NLOS scenario

For this case, the model takes 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, such that the visibility is included, and the effective road height to give the correct breakpoint in the first street section. The full model is shown below:

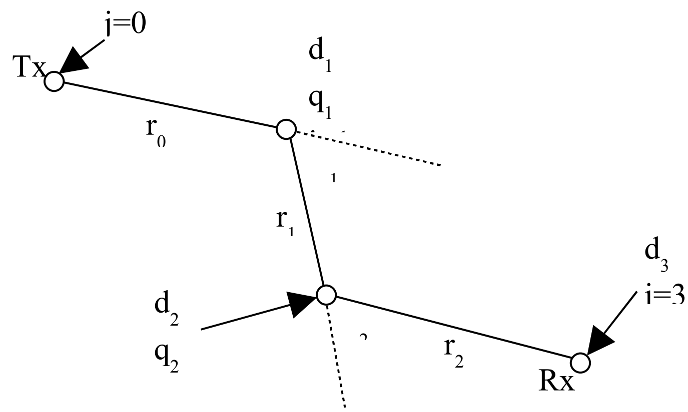

Figure. 8 ~~2-7~~ – Geometry of street sections used for Berg model

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

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

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

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

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 $d_0 = 0$

$$q_j(\theta_j) = \theta_j \frac{q_{90}}{90}$$

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 ~~Type-F NLOS~~ scenario, the alternative WINNER path-loss model can be used:

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

where d_1 is the distance along the main street in meter~~, which is valid from 10m to 550m~~. d_2 is the distance for perpendicular street~~, which is valid from w/2m to 450m~~. w is the street width, and the carrier frequency is 5 GHz

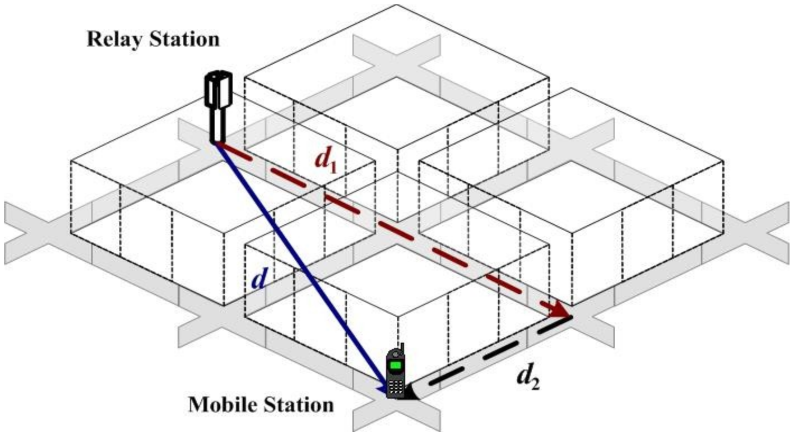

Figure 8 The alternative model for RS-MS NLOS scenario

2.1.2.4 Type-G Indoor Office Environment path-loss Model

[Editor: The indoor model is FFS, the default model is shown in this section]

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.

2.1.2.5 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.

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

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.

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

2.2 Shadowing modeling

The level of shadow fading (in dB) is usually simulated by dropping a normal distributed random variable, this refers to typical log-normal shadow fading model. However, the correlation of the propagation environment for different observation time or different radio links can not be presented if the simulator drops these variables independently. The standard deviation of the shadowing is introduced in Section 2.2.1 and two types of correlation models for shadow fading are introduced in this section 2.2.2

2.2.2 Standard deviation of the shadowing

The typical values based on WINNER models of the standard deviation for lognormal shadowing is listed in Table 3,

Table 3 Standard Deviation Values

	Type-A	Type-B	Type-C	Type-D		Type-E		Type-F		Type-G	
				~~LOS~~	~~NLOS~~	~~LOS~~	~~NLOS~~	LOS	NLOS	LOS	NLOS
Std (dB)	10.6	9.6	8.2	~~1.5~~ 3.4	~~[4.5]~~	~~[FFS]~~	~~[FFS]~~ 8.0	~~[FFS]~~ 2.3	~~[FFS]~~ 3.1	~~[12]~~ 3.1	3.5

5 References

[15] IST-2003-507581 WINNER D5.4 v1.4, “Final Report on Link Level and System Level Channel Models”, November 2005. https://www.ist-winner.org/

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