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GUIDELINES FOR USING IMT-ADVANCED CHANNEL MODELS

Introduction

IMT-Advanced channel models were agreed in ITU-R Working Party 5D meeting #3 in Seoul, Korea in October 2008, and confirmed in ITU-R SG 5 meeting in Geneva in November 2008. The channel models were published in Report ITU-R M.2135 [1].

In the same document the channel models for four mandatory and one optional deployment scenario are specified. The simulation cases specify the usage of the corresponding channel models. To make sure that the usage is always uniform, the guidelines given in the attachment are proposed to be applied.

The purpose of this contribution is to provide guidelines to how the models should be interpreted in the different cases. It should be noted that these complementary guidelines are not in any way contradictory to the description in Report ITU-R M.2135.

Proposal

It is proposed that Working Party 5D drafts a channel model evaluation guidelines document with contents as described in this contribution, and that this document is published on the ITU-R IMT-Advanced home page.

¹ This work has been performed in the framework of the CELTIC project CP5-026 WINNER+.

Attachment

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Introduction

Some deployment scenarios specified in [1] match exactly with the corresponding channel model. In other scenarios one or two additional conditions are specified: propagation from outdoor to indoor environment (Outdoor-to-Indoor case) and/or propagation from outdoor to vehicle (Outdoor-to-Vehicle case). For these cases the instructions are needed. In the following, we will specify the following characteristics:

- Path-losses in the Outdoor-to-Indoor and Outdoor-to-Vehicle paths.
- Shadow fading for the different connections.

There is also a proposal for the used channel model parameters for each of these deployment scenarios. Drop concept has been used below. It has been defined in 0. For the purpose of this document it is sufficient to say that the drop is a simulation interval, where all channel model parameters are kept constant, except the fast fading.

Path-loss matters

Deployment scenarios

The following deployment scenarios are mandatory [1]:

Indoor Hotspot (InH), Urban Microcell (UMi), Urban Macrocell (UMa), Rural Macrocell (RMa).

Indoor Hotspot and Urban Microcell outdoor (LOS and NLOS) deployment scenarios match exactly with the corresponding channel models. The InH channel model is not discussed further in this document. The UMi outdoor channel model is unambiguous in 0. Same is true also for the UMi Outdoor-to-Indoor model, but it will be discussed below for completeness and to avoid misunderstandings. In the UMa and RMa deployment scenarios there are only Outdoor-to-Vehicle connections in the evaluation cases and they need to be considered.

Suburban Macrocell (SMa) is an optional deployment scenario. There are two kinds of connections in SMa: Outdoor-to-Vehicle connections for 50 % of the cases and Outdoor-to-Indoor connections for other 50 % of the cases.

Path-loss

Path-loss stands for the mean path-loss. The variable component, shadowing, is modelled as a log-normal random number and is discussed in section 0. Mean and variable components together form the instantaneous path-loss. Excluding the Indoor Hotspot, the following cases for the path-loss can be found:

- Outdoor path-loss
- Outdoor-to-Indoor path-loss and
- Outdoor-to-Vehicle path-loss.

It should be noted that there is always the outdoor part in the Outdoor-to-Indoor and Outdoor-to-Vehicle path-losses. This outdoor part can be line-of-sight (LOS) or non-LOS (NLOS) connection.

Outdoor path-loss

The path-loss for each outdoor deployment scenario can be written as:

$$\begin{aligned} PL_{out} &= PL_{out1}, \text{ for LOS below breakpoint (LOS1),} \\ PL_{out} &= PL_{out2}, \text{ for LOS above breakpoint (LOS2),} \\ PL_{out} &= PL_{out3}, \text{ for NLOS connections.} \end{aligned} \quad (1)$$

These three path-loss formulas for the three different conditions LOS1, LOS2 and NLOS are given in 0 for all the deployment scenarios containing outdoor parts.

Outdoor-to-Indoor path-loss

Outdoor-to-Indoor path-loss for the UMi case is

$$PL = PL_{out}(d_{out} + d_{in}) + PL_{tw} + PL_{in}(d_{in}), \quad (2)$$

where

PL_{out} is the outdoor path-loss from the BS to the UT. One of the three cases has to be selected depending on, if the connection from the BS to the wall next to the UT is LOS1, LOS2 or NLOS. (See the section 0.)

PL_{tw} is through-wall penetration loss (20 dB)

$PL_{in} = \alpha d_{in}$ is the path-loss inside the building, α is the attenuation coefficient (0.5)

d_{in} is the indoor distance from wall to the UT and d_{out} is the distance from the base station to the wall next to the UT.

The penetration loss PL_{tw} describes the attenuation through the wall and the indoor path-loss PL_{in} describes the extra path-loss caused by the indoor conditions.

In the scenario SMa PL_{in} has been set to zero for simplicity. Then the equation reads:

$$PL = PL_{out}(d) + PL_{tw} \quad (3)$$

where the explanations are given in (2). Now PL_{out} must be calculated by using one of the three outdoor formulas for SMa depending on, if the connection between the BS and the wall next to the UT is LOS1, LOS2 or NLOS. d is the Euclidean distance between the BS and UT.

In both the equations the formula for the PL_{out} must be selected according to the conditions: First LOS/NLOS condition has to be randomly drawn according to LOS probability (see 0).

Then, if the LOS condition is encountered, the below or above break-point formula has to be used depending on the distance from the BS to the wall of the building.

For UT located in indoor, the indoor segment length from UT to the wall is determined by drawing a random number between 0 and 25 (m). ITU UMi scenario required min distance ($d_{out} + d_{in}$) is 10 m. It is possible to generate the indoor segment length d_{in} to exceed the distance from the BS to UT ($d_{out} + d_{in}$). Explicitly, this phenomenon should be avoided. Therefore the distance from UT to wall should be specified as below:

d_{in} = distance from wall to UT (in the LOS direction towards the Base Station site), assumed uniformly distributed between 0 and 25 m for distances from UT to BS above 25m.

d_{in} = distance from wall to UT (in the LOS direction towards the Base Station site), assumed uniformly distributed between 0 and ($d_{out} + d_{in}$) for distances from UT to BS below 25m.

Outdoor-to-Vehicle path-loss

Exactly the same equation as in (3) is valid for the Outdoor-to-Vehicle connections, provided that the through-wall penetration loss is replaced with the Vehicle Penetration Loss PL_v :

$$PL = PL_{out} + PL_v \quad (4)$$

where PL_{out} must be calculated by using one of the three outdoor formulas for the deployment scenario depending on the propagation conditions. (See the section 0.) The Vehicle Penetration Loss is modelled with a lognormal random number. PL_v in the equation is the mean value of it, 9 dB 0.

Line of Sight probability

Line of Sight (LOS) probability is given in the table A1-3 in 0. It specifies the probability of LOS condition for the outdoor connections as function of distance. This LOS probability applies also for the Outdoor-to-Indoor and Outdoor-to-Vehicle connections as regards the outdoor path. For Outdoor-to-Indoor connections the LoS probability should be calculated based on the distance from the base station site to the penetration point of the building wall, i.e., $P_{LOS} = P_{LOS}(d_{out})$. Note that the statement (*for outdoor users only*) for the UMi case in Table A1-3 in [1] may be misleading. The outdoor LOS / NLOS condition for each connection shall be drawn according to this probability.

Shadow fading

Shadowing in the outdoor and Outdoor-to-Indoor connections is modelled as a log-normal shadow fading and it has been specified in 0. Shadowing can be described by one zero-mean log-normal random variable, the standard deviation of which has been given in Table A1-7 of 0.

Shadowing in the Outdoor-to-Vehicle connections has two random components: i) The basic log-normal shadow fading described above and related to the outdoor path and ii) the additional shadow fading connected to the vehicle penetration loss. Also the latter is log-normal and the standard deviation is 5 dB as given in 0.

Shadowing for the Outdoor connections

The shadow fading for the Outdoor connections is modelled to be independent between different Base Stations sites.

$$PL_{inst} = PL + X_l \quad (5)$$

where PL_{inst} is the instantaneous path-loss, PL is the mean path-loss and X_l is the ordinary shadow fading random variable.

In cases, where the instantaneous path-losses to one UT from several, say N , Base Stations sites have to be calculated, the different random variables X_{ln} for all N connections are modelled independent. All have the same standard deviation that is given in 0 for the different environments. On the contrary the random variables from different UTs to a single Base Station site are correlated. The shadow fading has exponentially distance dependent correlation between two UTs 0.

Shadowing for the Outdoor-to-Indoor connections

The shadow fading for the Outdoor-to-Indoor (O2I) connections can be calculated similarly as for the outdoor connections. The correct shadow fading standard deviation from Table A1-7 of 0 has to be applied.

Shadowing for the Outdoor-to-Vehicle connections

In the case of Outdoor-to-Vehicle (O2V) connections, there are two shadowing components. One for the outdoor connection, the other for the shadow fading connected to the vehicle penetration. The additional shadow fading connected to the vehicle penetration is modelled to be fully correlated between the connections of one UT and different Base Stations. The reason is that the variation is due to the differences between different vehicles. Then the instantaneous path-loss for the BS n is:

$$PL_{inst,n} = PL_n + X_{1n} + X_{2n} \quad (6)$$

where $PL_{inst,n}$ is the instantaneous path-loss (constant over one drop) for the link n , PL_n is the mean path-loss, X_{1n} is the outdoor shadow fading related random variable and X_{2n} is the vehicle penetration related shadow fading random variable for link n . X_{2n} is equal for all links terminating to the same UT (or vehicle).

Now X_{1n} is independent for links from one UT to different Base Stations, as described in section 0. On the other hand X_{2n} has the same value for all Base Stations connected to the same UT. This means that for the Outdoor-to-Vehicle connections, the two shadow fading components have to be calculated separately. X_1 is an independent random variable specified in the 0. X_{2n} is fully correlated random variable between any UT and all the Base Stations associated to it.

Note that the above interpretation is based on the understanding that the variation in the O2V loss comes from the differences between the different vehicles that has been noted in the references 0, 0, 0.

Path-loss summary

The summary table for the path-loss and shadow fading formulas for the Outdoor-to-Indoor and Outdoor-to-Vehicle connections is given in table 1.

TABLE 1

Path-loss and shadow fading parameters for the Outdoor-to-Indoor and Outdoor-to-Vehicle connections.

Scenario	Path loss (dB)	Shadow fading std of X_1 (dB)	Shadow fading std of X_2 (dB)	Outdoor channel model and propagation condition
UMi O2I	$PL = PL_{out1}(d_{out} + d_{in}) + 20 + 0.5 d_{in} + X_1$	7	N.A	LOS1
	$PL_{out2}(d_{out} + d_{in}) + 20 + 0.5 d_{in} + X_1$	7	N.A	LOS2
	$PL_{out3}(d_{out} + d_{in}) + 20 + 0.5 d_{in} + X_1$	7	N.A	NLOS
UMa O2V	$PL = PL_{out1} + 9 + X_1 + X_2$	4	5	LOS1
	$PL_{out2} + 9 + X_1 + X_2$	4	5	LOS2
	$PL_{out3} + 9 + X_1 + X_2$	6	5	NLOS
RMa O2V	$PL = PL_{out1} + 9 + X_1 + X_2$	4	5	LOS1
	$PL_{out2} + 9 + X_1 + X_2$	4	5	LOS2
	$PL_{out3} + 9 + X_1 + X_2$	8	5	NLOS
SMa O2I	$PL = PL_{out1} + 20 + X_1$	4	N.A.	LOS1
	$PL_{out2} + 20 + X_1$	4	N.A	LOS2
	$PL_{out2} + 20 + X_1$	8	N.A	NLOS
SMa O2V	$PL = PL_{out1} + 9 + X_1 + X_2$	4	5	LOS1
	$PL_{out2} + 9 + X_1 + X_2$	4	5	LOS2
	$PL_{out3} + 9 + X_1 + X_2$	8	5	NLOS

Path-loss calculation for Outdoor-to-Vehicle and Outdoor-to-Indoor paths

Assume that the locations of the BSs and the UTs are given as well as the deployment scenarios. It is also assumed that the fact whether UT is located indoors or in vehicle has been determined. Further, it is assumed that the BS to UT distances are known. Then the instantaneous path-losses for O2I and O2V paths can be calculated as follows:

Instantaneous path-loss for O2I and O2V paths can be calculated as follows:

Mean path-loss:

- 1 For the UMi O2I case: determine the indoor segment length by drawing a random number between 0 and 25 (m). Calculate the outdoor segment length.
- 2 Determine the LOS condition from BS to the building wall or vehicle, where the UT is located, using LOS probability given in Table A1-3 in [1].
- 3 If the condition is LOS, calculate the outdoor part using LOS1 or LOS2 formula depending on whether the distance is below or above the break-point distance. Otherwise use the NLOS formula. (Note that in the UMi case the outdoor part contains also the length of the indoor segment.)
- 4 For the UMi case: calculate the indoor path-loss and sum to the outdoor path-loss.

- 5 For the O2I cases: sum the wall penetration loss, PL_{tw} (20 dB) to the outdoor path-loss .
6 For the O2V case: sum the vehicle penetration loss, PL_v (9 dB) to the outdoor path-loss.

Random variations:

- 7 Draw the random variable X_{1n} representing the ordinary shadowing and sum to the path-loss. The standard deviation for each deployment scenario is given in Table A1-7 of 0 and section 2.4 of this document. The random variables X_{1n} are independent.
8 For the O2V connections: draw the random variable X_{2n} and sum to the path-loss including X_{1n} . The standard deviation for each deployment scenario is given in Table 8-2 of 0 and section 2.4 of this document. The random variables X_{2n} are equal for all Base Stations connected to same UT but independent for connections to different UT:s and represent the shadowing of vehicle penetration.
9 Repeat 1 – 8 for all O2I/O2V connections in the simulation.

Channel model parameters

For the mandatory InH and UMi channel models all the parameters have been specified in 0.

For the mandatory UMa and RMa channel models, use the path-loss and shadow fading parameters given above. Other channel model parameters (than path-loss and shadowing) in the UMa and RMa environments shall be used according to the conditions in the outdoor path: use LOS parameters for LOS outdoor conditions and NLOS parameters for NLOS outdoor conditions also in the O2V cases.

For the optional SMA channel model the same rule is applied both in the O2I and O2V cases.

Antenna effects

Antenna patterns according to [1] have been used. The filed pattern is three dimensional, although the channel model itself is two dimensional. Down-tilt can be applied by calculating the antenna elevation angle at the base station from the geometry and calculating the antenna gain using this figure together with the azimuth angle. Note that the Indoor BS antennas are assumed omnidirectional as well as all the UT antennas, which means that the elevation effects of them can be neglected.

Implementation of IMT-Advanced channel model

Implementation guidelines

The reference implementation [3] has been updated to include the modifications presented in this document. Following updates have been performed:

- For the O2I case SMA (optional):
 - Add the building penetration loss to the path-loss formula.
 - Check that the LOS1 / LOS2 / NLOS condition is interpreted correctly in the path-loss calculations.
 - Use the channel parameters given in 0 for the specified propagation condition (LOS/NLOS) and generate the channel coefficients.
- For the O2V cases UMa, RMa (mandatory) and SMA (optional):
 - Add the vehicle penetration loss to the path-loss formula.
 - Add the lognormal random variable (X_2 above) with a standard deviation of 5 dB to the instantaneous path-losses. Ensure that the random variable is fully correlated (constant) within the connections to the same UT.

- Check that the LOS1 / LOS2 / NLOS condition is interpreted correctly in the path-loss calculations.
- Use the channel parameters given in 0 for the specified propagation condition (LOS/NLOS) and generate the channel coefficients.

Implementation issues

- 1 To clarify the implementation steps, in [1], section 1.3.2.1, page 34, step 6, the following text should be added after (eq.12). (For LOS case only.)

In the case of LOS condition an additional specular component is added to the first cluster. Power of the single LOS ray is

$$P_{1,LOS} = \frac{K_R}{K_R + 1}$$

and the cluster powers are not like in (12), but

$$P_n = \frac{1}{K_R + 1} \frac{P'_n}{\sum_{n=1}^N P'_n} + \delta(n-1)P_{1,LOS},$$

where $\delta(\cdot)$ is Dirac's delta function and K_R is the Ricean K-factor defined in Table A1-7 converted to linear scale. Note! These power values are used *only* in equations (13) and (14) of M.2135, but *not* in equation (20).

- 2 Shadowing standard deviation for LOS connections in RMa and SMa channel model for distances lower and higher than the breakpoint distance are equal in Table A1-7, but partly different in Table A1-2 of [1]. We propose to use the equal standard deviations of Table A1-7 for simplicity.
- 3 In [1], section 1.3.2.1, page 38, step 10b) there is description of an alternative method to generate fading channel coefficients with so called correlation matrix based method. There is specified that "Unique covariance matrices are determined for each drop and radio link based on the parameters defined in the previous steps". We propose to clarify that also unique Doppler spectra must be determined for each drop and radio link based on the parameters defined in the previous steps.

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