Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Comments on C802.16j_045 – Path loss and shadowing (update)
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Re:	Response to a call for contributions for the Relay TG 80216j-06/006.pdf
Abstract	Comments on C802.16j_045 – Path loss and shadowing
Purpose	To clarify the path loss and shadowing modeling misses proposed in C802.16j_045
Notice	
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Multi-hop System Evaluation Methodology

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Introduction

This memo provides some comments on a submission to IEEE 802.16j on path loss models .

Path Loss Models

IEEE 802.16d Model

In the subscriber antenna height correction factor for the Category C environment of the model is given as:-

$$20\log h/2 \text{ dB} \qquad (1)$$

which agrees with the term given in . However, in this term is referenced back to the work of Okumura . Okumura found that path loss increased at a rate of 10dB/decade for mobile heights below 3m, but increased at a rate of 20dB/decade for heights above 3m (eg. see). Therefore, the correct mobile antenna height correction factor for Category C environments should be:-

$$PL_{ht} \quad \begin{matrix} 10\log\dfrac{h}{3} & \text{for } h \quad 3m \\ 20\log\dfrac{h}{3} & \text{for } h \quad 3m \end{matrix} \qquad (2)$$

For the IEEE 802.16d model the reference mobile antenna height was 2m, and so the above equation does increase the path loss at the reference height by 10log(2/3) = 1.76dB. This could easily be subtracted as a constant in the path loss equation. The point is that the Okumura equations for mobile antenna height correction capture the correct *variation* of path loss with mobile antenna height. The Okumura mobile antenna height correction factor was the recommendation given in . In addition, it was shown in that when the frequency correction factor and the antenna height correction factor are used, a modified breakpoint needs to be used in order to prevent discontinuities in the path loss occurring at the reference distance of 100m. This is detailed in . This also allows the model to become a two slope model, such that below the breakpoint distance the model simply reverts to the free space path loss. This allows it to be used for ranges less than the breakpoint distance.

ITU Indoor Office Test Environment

The path loss model for this case is given in as:-

$$PL = 37 + 30\log d + 18.3n^{((n+2)/(n+1)-0.46)} \quad (3)$$

This equation is supposed to be the model that comes from . However, the equation in is given as:-

$$PL = 37 + 30\log d + 18.3n^{\left(\frac{n+2}{n+1}-0.46\right)} \quad (4)$$

Therefore, equation (3), which is given in , is incorrect. The correct equation is equation (4).

This equation is derived from the more general form given below,using a default set of parameters (see):-

$$Pl = P_{fs} + P_c + \sum k_{wi}P_{wi} + n^{\left(\frac{n+2}{n+1}-b\right)} P_f \quad (5)$$

where,

$$P_{fs} = 20\log\left(\frac{4\pi d}{\lambda}\right) \quad \text{Free space path loss} \quad (6)$$

P_c = Constant loss (normally set to 37dB)
k_{wi} = Number of penetrated walls of type i
n = Number of penetrated floors
P_{wi} = Loss of wall type i
P_f = Loss between adjacent floors

By comparing equations (4) and (5) it can be seen that the free space path loss (6) has been absorbed into the constant terms of the equation by setting the frequency to 2GHz. In , this fact is overlooked, and it is proposed that the frequency correction factor used for the IEEE 802.16d model (equation (7)) can be added to equation (3) to account for frequency variations. However, the frequency correction factor used for IEEE 802.16d ***combines*** with the free space path loss term to give a total $f^{2.6}$ dependence. Consequently, it is incorrect to simply add equation (7) to equation (3). The correct approach would be to add equation (7) to the full equation given in (5), so that once again frequency variation is determined by the ***combination*** of the free space path loss and equation (7).

$$PL_f = 6\log\left(f(MHz)/2000\right) \quad (7)$$

Recommended urban microcell

For this case the WINNER channel models are recommended in . However, the LOS model for WINNER is not a two-slope model, whereas it is well known that the path loss for this scenario fits well to a two-slope model with a breakpoint of:-

$$d_{bp} = \frac{4h_t h_r}{\lambda} \quad (8)$$

where,
h_r = Height of receiver
h_t = Height of transmitter
A better model is proposed in and .
Also, the WINNER NLOS path loss model proposed in only has a path loss component which is the ‘round-the-streets’ component. A much better approach is to use a model of the form given in , which takes the minimum of the ‘round-the-streets’ and the ‘over-the-rooftop’ component. In fact, both simulations and measurements have shown that once a street corner has been turned the ‘over-the-rooftop’ component quickly becomes the dominant component. This is shown in .

Urban macro cell

In the WINNER channel model is recommended for this case. It is shown in that this is not a good model. It is based on the COST 231 Hata model and compared to measured results this has been found to be optimistic. The IEEE 802.16d path loss model gives better results.

LOS fixed stations

For this scenario in it is assumed that the BS and RS are both above rooftop and a WINNER path loss model is recommended. This model is only a few dB above the free space loss, and it is assumed that there is a LOS path between the BS and the RS. However, in a multicell simulation the RS would be deployed to give a LOS to the wanted BS only. Neighbouring BS's would be unlikely to have a LOS to the RS, and so a different path loss model is required to give a better estimate of the interference. It is proposed in and that the IEEE 802.16d path loss model would be a good model to use, as this gives a reasonably similar path loss to the WINNER channel model up to 1km, but beyond that it is much more realistic for longer range NLOS interfering BS's.

Shadowing

Standard Deviation

In , the standard deviation of the shadowing for each scenario is expressed as a constant value. This does not take into account any variations with frequency, and also does not make any allowances for the standard deviation when the path loss model approaches the free space path loss.

In it is recommended that an equation due to Okumura should be used for determing the lognormal shadowing standard deviation at different frequencies, where equations are given for urban and suburban environments, and these are for above-rooftop to below-rooftop links (BS-MS, BS-RS, RS-RS NLOS). The frequency dependence of the standard deviation for below-rooftop links and for indoor environments is T.B.D.

Another important consideration with regard to shadowing is that the model should not generate excessively low path loss values, such that the path loss becomes significantly lower than the free space path loss. For example, when a path loss model intersects the free space loss curve, if the standard deviation of the shadowing was 8dB, then a shadowing sample of -2 would result in a path loss value which was 16dB lower than the free space path loss! This is obviously not observed in practice. Therefore, in it is proposed that the standard deviation should be determined using an equation that is dependent on the excess path loss over free space. The equation then ensures that the standard deviation of the shadowing decreases as the median path loss approaches the free space loss curve. It increases up to a maximum value (eg. determined by Okumura's equation) as the median path loss diverges away from the free space loss curve.

These two effects should be included when modeling shadowing; frequency dependence of the standard deviation, and variation with the excess path loss over free space.

1.1 Correlated Shadowing

In section 3.1 of a model is given which allows for spatially correlated lognormal shadowing samples to be generated. The model is well known, and is specified in 1.1. Each consecutive lognormal sample is generated from a distribution whose mean and variance are dependant on the correlation at a separation distance x. As x decreases the variation from the previous sample becomes more restricted, which results in correlated lognormal shadowing. However, the variation is not continuous and the model is therefore 'noisy'. A better model which results in a continuous variation is given in 1.1, where this is based on a sum of sinusoids approach. The model is dependant on the absolute (x,y) location of the mobile in the cell, so that for a given instance of the model each location in the cell has a specific lognormal value.

In section 3.2 of a model is given for correlating the lognormal shadowing from two different BSs at a given mobile location. This is a simple model which is dependant only on the angle between the BSs. Again, a better model is presented in 1.1, where this model is dependant on the angle between the BSs, the 1/e spatial decorrelation distance of the shadowing, and the ranges of the two BSs to the mobile location. This results in a more realistic model for the BS correlations.

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