Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Comparison of Propagation Path Loss Models**
Date Submitted	2007-07-06
Source(s)	Yih-Guang Jan, Yang-Han Lee, Hsien-Wei Tseng, Ming-Hsueh Chuang, Jheng-Yao Lin, and Chih-Wei Su Voice: +886-2-2625-2303 E-mail: yihjan@yahoo.com yhlee@ee.tku.edu.tw Institute for Information Industry 7F., No. 218, Sec. 2, Dunhua S. Rd., Taipei City, Taiwan. Department of Electrical Engineering, Tamkang University 151 Ying-chuan Road, Tamsui, Taipei County, Taiwan 25137, R. O. C. [co-authors added here]
Re:	IEEE 802.16m-07/080r2– Call for Comments on Draft 802.16m Evaluation Methodology Document
Abstract	This document contains proposed text for the draft evaluation methodology for IEEE 802.16m technical proposals.
Purpose	For discussion and approval by TGm
Notice	
Release	
Patent Policy	

Comparison of Propagation Path Loss Models

References

[1] Erceg, V., Hari, K. V. S., et al.," Channel Models for Fixed Wireless Applications," Tech. Rep., IEEE 802.16 Broadband Wireless Access Working Group, January 2001.

[2] Wallace, Jon W., Jensen, Michael A., "Modeling the Indoor MIMO Wireless Channel,", *IEEE Trans., on Antenna and Propagation*, Vol., 50, No. 5, May 2002, pp. 591 – 599

[3] Recommendation ITU-R P.1546," Method for Point-to-Area Predictions for Terrestrial Services in the Frequency Range 30 MHz to 3000 MHz," Tech. Rep., International Telecommunication Union, 2001.

[4] COST Action 231," Digital Mobile Radio Towards Future Generation systems, Final report," Tech., Rep., European Communities, EUR 18957, 1999

[5] Hata, M.," Empirical Formula for propagation Loss in Land Mobile Radio Systems," *IEEE Trans. On Vehicular Technology,* Vol. NT-29, Aug. 1980, pp. 317-325.

[6] COST Action 231,"Urban Transmission Loss Models for Mobile Radio in the 900- and 1800 MHz bands (Revision 2), COST231 TD(90) 119 Rev. 2.

[7] Electronic Communication Committee (ECC) within the European Conference of Postal and telecommunications Administration (CEPT), "the Analysis of the Coexistence of FWA Cells in the 3.4 – 3.8 GHz Band," Tech. Report, ECC Report 33, May 2003.

[8] Y. Okumura," Field Strength and its Variability in VHF and UHF Land-mobile Radio-services," Review of the Electrical Communications Laboratory, Vol. 16, September-October, 1968.

1. Introduction

Two types of propagation path loss models, namely time-dispersive and non-time-dispersive, have been extensively studied and examined in the network planning, interference prediction, and network deployment. In the time-dispersive model, it provides the information such as the multi-path time delay spread and their associated power levels (power delay profile). A typical example of this channel model is developed by Erceg. et al. for the IEEE 802.16 working group [1] and Wallace [2]. For the non-time dispersive channel, where the multi-path delay spread is considerably shorter than the signal duration and all multi-path signals arrive at the receiver simultaneously, this channel model is considered in extensively in ITU-R [3], Hata [4,5], COST-231 Hata model [6] , and ECC- 33 Model [7]. All these models predict mean path loss as a function of various parameters, such as the transmitter- receiver distance, antenna height and environment considered. In this contribution we will study and compare the differences between these two types of models especially the COST-231 Hata model, Erceg model and ECC- 33 Model.

2. COST-231 Hata Model

The formulas relating to propagation path loss considered in COST-231 model are listed in the following [6], The median propagation path loss is:

$$L(dB) = 46.3 + 33.9\log f_{MHz} - 13.82\log h_b - a(h_m) + (44.9 - 6.55\log h_b)\log d_{km} - R \quad (1)$$

where

f_{MHz} : the center frequency in MHz (1500………..2000 MHz).

h_b : the effective height of the base station antenna (30,………200m)

h_m : the height of the mobile station antenna

d_{km}: the distance between the base station and mobile (1………..20 km)

R: 0 or 3 dB depending on the environment, it is 0dB in the suburban and rural areas and 3 dB in the urban environment

For various environments we have the following

Urban indoor – large city

R = -3 $a(h_m) = [1.1\log f_{MHZ} - 0.7]h_m - [1.56\log f_{MHz} - 0.8] - 15$ (2)

Urban – large city

R = -3 $a(h_m) = [1.1\log f_{MHZ} - 0.7]h_m - [1.56\log f_{MHz} - 0.8]$ (3)

Urban – small city

R = 0 $a(h_m) = [1.1\log f_{MHZ} - 0.7]h_m - [1.56\log f_{MHz} - 0.8]$ (4)

Suburban

R = 0 $a(h_m) = [1.1\log f_{MHZ} - 0.7]h_m - [1.56\log f_{MHz} - 0.8]$ (5)

Rural

All rural has $a(h_m) = 0$

Rural indoor (quasi-open)

R = $4.78(\log f_{MHz})^2 - 18.33\log f_{MHz} + 35.94 - 10$

Rural (quasi-open) – countryside

R = $4.78(\log f_{MHz})^2 - 18.33\log f_{MHz} + 35.94$

Rural (open) – desert

R = $4.78(\log f_{MHz})^2 - 18.33\log f_{MHz} + 40.94$

3. IEEE 802.16 Broadband Wireless Group: Erceg Model [2]

Three types of terrains are considered in this model. It considers in Type A the path loss associated with hilly terrain with moderate to heavy foliage environment that will result the maximum pass loss. In Type B model it considers either mostly flat terrains with moderate to heavy tree densities or hilly terrain with light tree densities. In Type C model it results the minimum path loss that associated with the flat terrain with the light tree densities.

The basic path loss follows the following equation:

$$PL = A + 10\gamma \log_{10}(\frac{d}{d_0}) + X_f + X_h + s \quad \text{for } d > d_0$$

where d is the distance between the base station and the mobile station in meters, d_0 is the reference distance, 100m.and s is a log-normally distributed deviation factor to account for the shadowing loss due to trees and other clutters, it has a value in the range of 8.2 – 10.6 dB and

$$A = 20\log_{10}(\frac{4\pi d_0}{\lambda}),$$

$$\gamma = a - b\, h_b + c / h_b$$

The constants a, b and c are given in the following table:

Parameter	Terrain Type A	Terrain Type B	Terrain Type C
a	4.6	4.0	3.6
b (m^{-1})	0.0075	0.0065	0.005
C (m)	12.6	17.1	20

where

h_b : the height of the base station antenna above ground between 10 m to 80 m

X_f is the correction factor for the frequency and for the mobile station antenna height has the form as,

$$X_f = 6.0\log_{10}(\frac{f}{2000})$$

f is the frequency in MHz and

$$X_h = -10.8 \log_{10}(h_m / 2000) \quad \text{for Terrain types A and B}$$

$$= -20 \log_{10}(h_m / 2000) \quad \text{for Terrain type C}$$

4 ECC -33 Model

The ECC -33 path loss model, which is developed by Electronic Communication Committee, is extrapolated from the original measurements by Okumura [8], which were gathered in the suburban areas of Tokyo. In the Okumura model it subdivides the urban areas into two categories, 'large city' and 'medium city' and classifies the suburban areas into 'open' and 'quasi-open' areas. A typical European city is quite different from the environment characteristics in the highly build-up Tokyo, it can be therefore categorized as a 'medium city'.

The basic path loss follows the following equation:

$$PL = A_{fs} + A_{bm} - G_b - G_m$$

Where A_{fs}, A_{bm}, G_b and G_m are the free space propagation loss, the basic median loss, the base station height gain factor and the mobile station height gain factor respectively, and they have the values:

$$A_{fs} = 92.4 + 20\log_{10} d + 20\log_{10} f$$

$$A_{bm} = 20.41 + 9.83\log_{10} d + 7.894\log_{10} f + 9.56[\log_{10} f]^2$$

$$G_b = \log_{10}(h_b/200)\ \{13.958 + 5.8[\log_{10} d]^2\}$$

and

$$G_m = [42.57 + 13.7\log_{10} f][\log_{10} h_m - 0.585]$$

Where, f is the frequency in GHz, d is the distance between the bae station and the mobile station, h_b is the Base station antenna height in meters and h_m is the mobile station antenna height in meters.

4. Example of Propagation Path Loss of the Models

For a wireless communication system with the following parameters is considered to compare the propagation path losses calculated from the proposed three propagation models to reveal the ranges of the pass losses from frequency 1500 MHz – 2000 MHz and the distances from the transmitter to the receiver are from 1 km – 10 km.

. Base station antenna height = 50 m

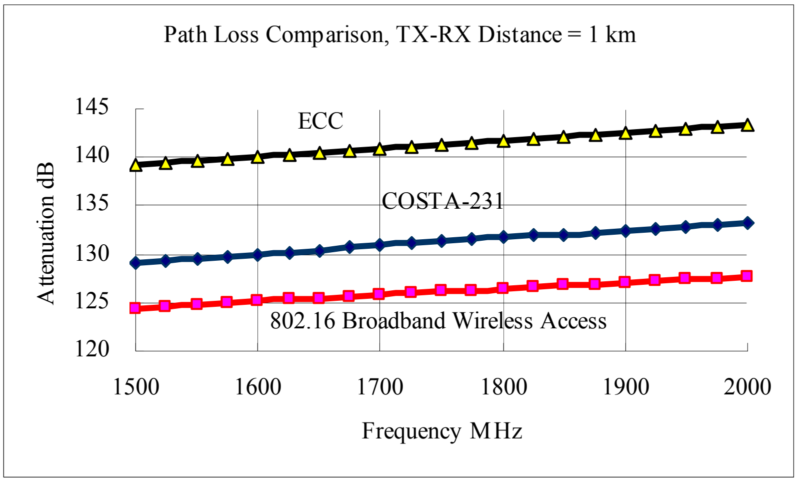
. Mobile station antenna height = 2 m

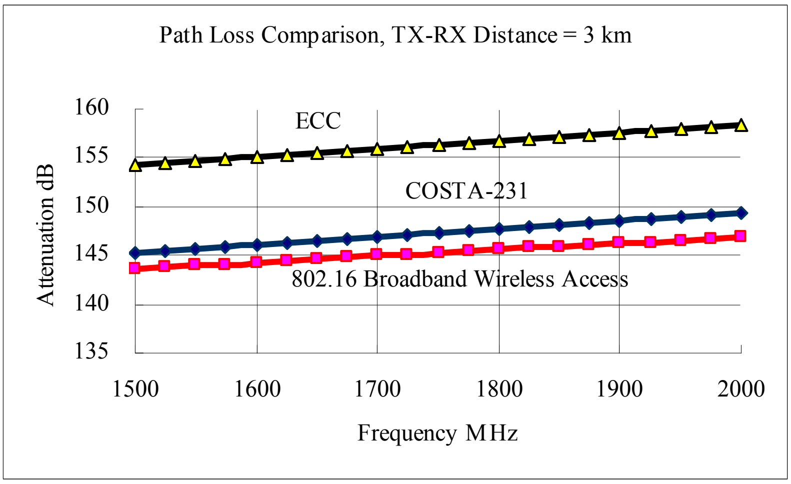
. Erceg model: Type B terrain

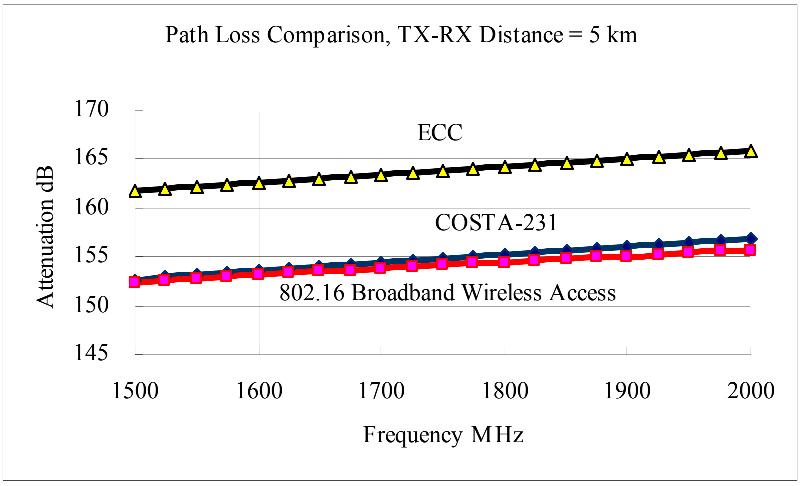
d_0 = 100 m

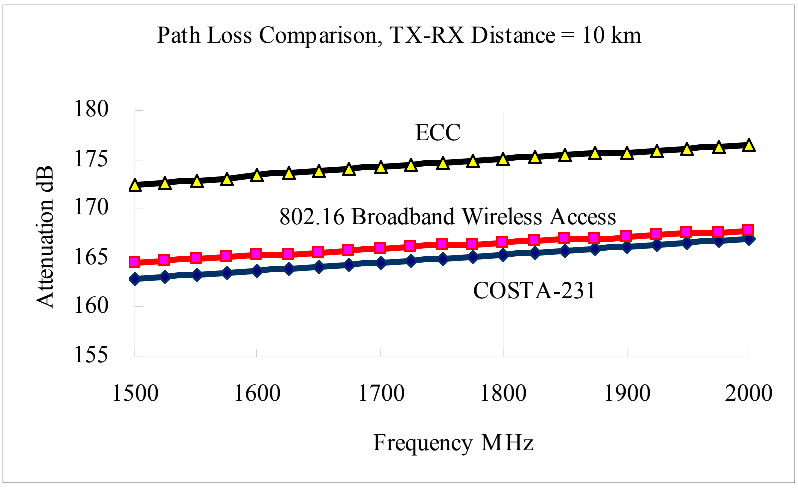
shadow loss = 9 dB

. COST-231**:** R = 0 dB




Path Loss Comparison, TX-RX Distance = 3 km
Attenuation dB
160
155
150
145
140
135
ECC
COSTA-231
802.16 Broadband Wireless Access
1500
1600
1700
1800
1900
2000
Frequency MHz


Path Loss Comparison, TX-RX Distance = 5 km
Attenuation dB
170
165
160
155
150
145
ECC
COSTA-231
802.16 Broadband Wireless Access
1500
1600
1700
1800
1900
2000
Frequency MHz


Path Loss Comparison, TX-RX Distance = 10 km
Attenuation dB
180
175
170
165
160
155
ECC
802.16 Broadband Wireless Access
COSTA-231
1500
1600
1700
1800
1900
2000
Frequency MHz