

COMPARISON OF VARIOUS PATH LOSS MODELS FOR WIMAX IN URBAN ENVIRONMENT AT 3.5 GHZ

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Abstract : Fixed Wireless Access (FWA) networks based on WIMAX technology provide efficient packet radio interface enabling high data transmission rates. The accurate prediction of path losses is a crucial element in the first step of network planning. This paper compares various path loss models for mobile as well as fixed wireless systems like WIMAX. This paper begins the introduction to path loss in wireless communication, then various path loss models (Cost-Hata, Erceg, Dual-slope, SU1, Macro model, ECC-33, Hata-Okumura etc) have been compared in urban environment at 3.5 GHz range.

Keywords – WiMAX, Path Loss, Urban area

I. INTRODUCTION

Worldwide Interoperability for microwave access (WiMAX) is the newest wireless broadband Internet technology based on IEEE 802.6 standard. This system is based on Orthogonal frequency division multiplexing (OFDM) and realizes broadband data transmission by using a radio frequency range 2-11 GHz.

In ideal conditions, WiMAX recommends up to 1Gbps (with revised IEEE 802.6m) speeds and range within 50 km in LOS between transmitter and receiver. But in real fields, measurements show far differences from ideal conditions i.e. bit rate of 7-20 Mbps and coverage area between 5-8 km. To reach near optimum goal, researchers identified the following that impair the transmission from transmitter to receiver are path loss, fading, doppler spread, multipath delay spread.

Path loss (PL) arises when an electromagnetic wave propagates through space from one transmitter to receiver. The power of signal is reduced due to path distance, reflection, diffraction scattering, free-space loss and absorption by objects of environment. It is also influenced by different environment (urban, sub-urban & rural). Variations of transmitter and receiver antenna height also produce losses.

PL= power transmitted / power received in Db

In this paper a few path loss models have been studied in section II. Then path loss is estimated for rural environment using MAT Lab. Some parameters used in these models like frequency, distance between AP and CPE, base station height above sea level, height of buildings, width of roads, building separation, road orientation etc have been collected from Ericsson India.

II. PATH LOSS MODELS

A. Free Space Path Loss Model

Path loss in free space *PLFSPL* defines how much strength of the signal is lost during propagation from transmitter to receiver. FSPL is diverse on frequency and distance. The calculation is done by using the following equation:

$$L_{FS} = 32.45 + 20 \log(d) + 20 \log(f)$$

where,

f : Frequency (MHz)

d : Distance between transmitter and receiver (m)

Power is usually expressed in decibels (dBm).

B. COST-231 Hata Model

A model that is widely used for predicting path loss in mobile wireless system is the COST-231 Hata model [1]. It was devised as an extension to the Hata-Okumura model [2], [3]. The COST-231 Hata model is designed to be used in the frequency band from 500 MHz to 2000 MHz. It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has seen it widely used for path loss prediction at this frequency band. The basic equation for path loss in dB is [1],

$$PL = 46.3 + 33.9 + \log_{10}(f) - 13.82 \log_{10}(h_b) - a_h m + (44.9 - 6.55 \log_{10}(h_b)) \log_{10} d + c_m$$

(1)

where, f is the frequency in MHz, d is the distance between AP and CPE antennas in km, and h_b is the AP antenna height above ground level in meters. The parameter c_m is defined as 0 dB for suburban or open environments and 3 dB for urban environments. The parameter $a_h m$ is defined for urban environments as [4]

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$$a h_m = 3.20 (\log_{10} (11.75 h_r))^2 - 4.97 \quad (2)$$

for f > 400MHz

and for suburban or rural (flat) environments,

$$a h_m = (1.1 \log_{10} f - 0.7) h_r - (1.5 \log_{10} f - 0.8) \quad (3)$$

where, h_r is the CPE antenna height above ground level. Observation of (1) to (3) reveals that the path loss exponent of the predictions made by COST-231 Hata model is given by,

$$n_{COST} = (44.9 - 6.55 \log_{10}(h_b))/10. \quad (4)$$

To evaluate the applicability of the COST-231 model for the 3.5 GHz band, the model predictions are compared against measurements for three different environments namely, rural (flat), suburban and urban.

C. ECC-33 Path Loss Model

The original Okumura experimental data were gathered in the suburbs of Tokyo [3]. The authors refer to urban areas subdivided into ‘large city’ and ‘medium city’ categories. They also give correction factors for ‘suburban’ and ‘open’ areas. Since the characteristics of a highly built-up area such as Tokyo are quite different to those found in typical European suburban areas, use of the ‘medium city’ model is recommended for European cities [5], [6]. Although the Hata- Okumura model [2] is widely used for UHF bands its accuracy is questionable for higher frequencies. The COST-231 model extended its use up to 2 GHz but it was proposed for mobile systems having omni-directional CPE antennas sited less than 3 m above ground level. A different approach was taken in [7], which extrapolated the original measurements by Okumura and modified its assumptions so that it more closely represents a FWA system. The path loss model presented in [7], is referred to here as the ECC-33 model. The path loss is defined as,

$$PL = A_{fs} + A_{bms} - G_b - G_r \quad (5)$$

where, A_{fs} , A_{bms} , G_b and G_r are the free space attenuation, the basic median path loss, the BS height gain factor and the terminal (CPE) height gain factor. They are individually defined as,

$$A_{fs} = 92.4 + 20 \log_{10}(d) + 20 \log_{10}(f) \quad (6)$$

$$A_{bms} = 20.41 + 9.83 \log_{10}(d) + 7.984 \log_{10}(f) + 9.56 [\log_{10}(f)]^2 \quad (7)$$

$$G_b = \log_{10}(h_b/200) \{13.958 + 5.8 [\log_{10}(d)]^2\} \quad (8)$$

and for medium city environments,

$$G_b = [42.57 + 13.7 \log_{10}(f)] [\log_{10}(h_r) - 0.585] \quad (9)$$

where, f is the frequency in GHz, d is the distance between AP and CPE in km, h_b is the BS antenna height in meters and h_r is the CPE antenna height in meters. The medium city model is more appropriate for European cities whereas the large city environment should only be used for cities having tall buildings. It is interesting to note that the predictions produced by the ECC-33 model do not lie on straight lines when plotted against distance having a log scale. For the sake

of completeness, the path loss gradient at 2km will be compared with the path loss predicted by other models. The predictions using the ECC-33 model with the medium city option are compared with the measurements taken in suburban and urban environments.

D. COST Walfisch-Ikegami Model

This is the COST 231 proposed Walfisch and Ikegami combined model [8]. This gives a better path loss prediction. Characteristics of urban environment such as, height of buildings (h_{roof}) in m, width of roads (w) in m, building separation (b) in m, and road orientation with respect to the direct radio path (φ). In our analysis we have used 10m for h_{roof} , 12m for w , 20m for b and 630 for φ . The model has separate equations for Line of Sight (LOS) and Non LOS (NLOS) conditions. Equation (10) gives the equation for NLOS conditions, which we used in our analysis.

$$PL_{NLOS}(dB) = L_{FS} + L_{rts}(w_r, f, \nabla h_m, \varphi) + L_{MSD}(\nabla h_t, h_t, d, f, b_s) \quad (10)$$

L_{FS} gives free space loss, which is defined in (13), L_{rts} gives the Roof-to-street loss (14), and L_{MSD} is the multiple screen diffraction loss (16). ∇h_m is given by (11) and ∇h_t is given by (12).

$$\nabla h_m = h_t - h_{roof} \quad (11)$$

$$\nabla h_t = h_t - h_{roof} \quad (12)$$

where h_t gives base station height (m) and h_{roof} gives the height of the building (m).

$$L_{FS} = 32.4 + 20 \log_{10}(d) + 20 \log_{10}(f_c) \quad (13)$$

$$L_{rts} = -8.8 + 10 \log_{10}(f_c) + 20 \log_{10}(\nabla h_m) - 10 \log_{10}(w) + L_{ori} \quad (14)$$

In the above equation h_m gives the CPE height in m and L_{ori} is the street orientation function which depends on φ . We used the function (10) for this.

$$L_{ori} = 4.0 - 0.114(\varphi - 55) \text{ since } 550 \leq \varphi \leq 900 \quad (15)$$

$$L_{MSD} = L_{bsh} + k_a + k_q \log_{10}(d) + k_f \log_{10}(f) - 9 \log_{10}(b) \quad (16)$$

In equation (16), L_{bsh} is given by (17), K_a is 54, K_d is 18, and K_f is given by (18).

$$L_{bsh} = -18 * \log_{10}(1 + \nabla ht) \quad (17)$$

$$K_f = -4 + 0.7((f_c/925) - 1) \quad (18)$$

E. Erceg Model

This was developed by Erceg et al. and the experimental data were taken in several suburban areas in New Jersey and around Seattle, Chicago, Atlanta, and Dallas. The base antenna heights were in the range from 12 to 79 m [9]. This has categorized three different terrain categories. The maximum path loss category is hilly terrain with moderate-to-heavy tree densities (Category A), the minimum path loss category is mostly flat terrain with light tree densities (Category C) and the middle category can be characterized as either mostly flat terrain with moderate-to-heavy tree

densities, or hilly terrain with light tree densities (Type B). This model is recommended by IEEE 802.16 Broadband Wireless Access Working Group [10]. The Path Loss in dB is given by equation (19),

$$PL = A + 10\gamma \log_{10} \left(\frac{d}{d_0} \right) + X_f + s \text{ for } d > d_0 \quad (20)$$

where, A gives decibel path loss at distance d_0 (21), γ gives path loss exponent (22) and s is the shadowing component given by (23).

$$A = 20 \log_{10} \left(\frac{4\pi d_0}{\lambda} \right) \quad (21)$$

In this λ gives the wavelength in m.

$$\gamma = a - b h_b + c / h_b \quad (22)$$

The parameter h_b is the base station antenna height in meters ($80m \geq h_b \geq 10m$), χ is a zero-mean Gaussian variable of unit standard deviation $N[0,1]$ and a, b, c and σ_γ are constants for each terrain category given by Table 1.

$$s = \gamma \sigma \quad (23)$$

Table 1 Numerical values of Erceg Model Parameters

Model Parameter	Terrain Type A	Terrain Type B	Terrain Type C
A	4.6	4.0	3.6
B	0.0075	0.0065	0.0050
C	1.26	17.1	20.0
σ_γ	0.57	0.75	0.59
h_b	10.6	9.6	82
σ_s	2.3	3.0	1.6

F. Hata-Okumura Model

This model is best suited for large cell coverage (distances up to 100 km) and it can extrapolate predictions in the 150 - 1500 MHz band. Also this is the widely used model for most of the signal strength predictions in macrocellular environment [2], [3]. Although, its frequency band is outside the band of Fixed WiMAX, its simplicity has made it to be used widely in propagation predictions. The path loss equation is given by (2).

$$PL_{urban} = 69.55 + 26.16 \log_{10}(f_c) - 13.82 \log_{10}(h_b) - a(h_m) + [44.9 - 6.55 \log_{10}(h_b)] \log_{10}(d) \quad (24)$$

f_c is the operating frequency in MHz, h_b and h_m are the BTS antenna height and the CPE height in m, d is the distance from BTS to CPE in km and $a(h_m)$ is the Correction factor for mobile unit antenna height in dB.

$$a(h_m) = 3.2 (\log_{10}(11.75 h_m))^2 - 4.97 \quad (25)$$

III. RESULTS

The following graphs represent the variation of path loss with distance between transmitter and receiver. The base station height has been kept constant at 30m.

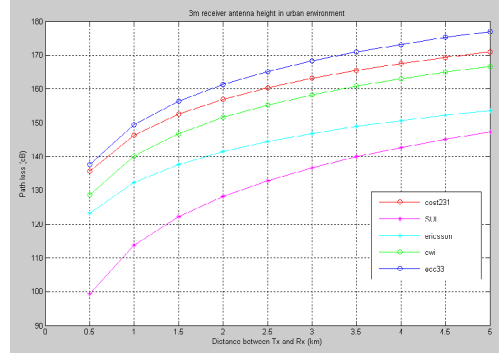


Figure1: 3m Receiver Antenna Height

Figure1 shows graph showing plots for 3m receiver antenna height and SUI path loss model gives minimum path loss among compared path loss models for specified conditions.

Figure2 and 3 shows graph showing plots for 6m and 10m resp. receiver antenna height and SUI path loss model gives minimum path loss among compared path loss models for specified conditions.

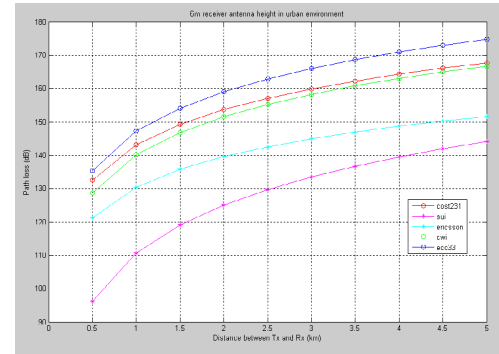


Figure: 6m Receiver Antenna Height

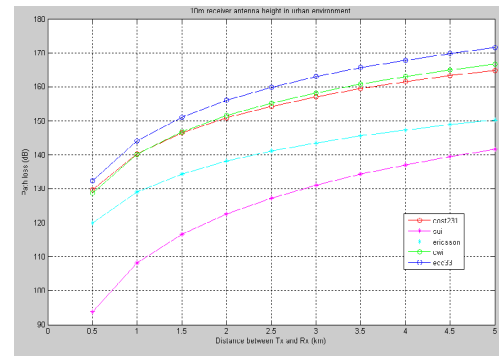


Figure: 10m Receiver Antenna Height

IV. CONCLUSION

Propagation models are needed not only for installation guidelines, but they also play a key part in any analysis or design that strives to mitigate interference. For urban environment, SUI path loss model has shown the minimum path loss among compared path loss models under specified conditions.

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