Path Loss Measurement and Estimation Using Different Empirical Models For WiMax In Urban Area

Gupreet Singh Bola, Gurpreet Singh Saini

Abstract— WiMAX is a wireless access system that offers fixed, nomadic, portable and mobile wireless broadband services. The problem of dimensioning large scale broadband wireless systems is a vital confront in radio network planning. A perfect knowledge of path loss performance is a essential requirement for primary deployment of wireless network and cell planning. In this paper we compare and analyze the path loss by using various propagation models (e.g Cost 231 hata, SUI ,Cost 231 W-I,ECC and Ericsson model) we compared the results by taking different receiver antenna heights in urban area. we also compare and analyze the results by taking different frequencies in urban area in NLOS condition.

Index Terms— Line Of Sight,Non Line Of Sight,Pathloss,Propagation Models,WiMax

1 INTRODUCTION

World interoperability for microwave access (WiMax) is a wireless broadband technology based on IEEE 802.16 standard; This system is based on the Orthogonal Frequency Division Multiplexing (OFDM) and realized broadband data transmission by using a radiofrequency range of 2-11 GHz and 10-66 GHz. WiMax system is a telecommunication technology which enables wireless transmission of voice and data and provide wireless access in urban, suburban, and rural environments, and it has two possible access conditions; Line-of Sight (LOS) condition, and Non-Line of Sight (NLOS) condition. There are two main classes of WiMax systems called fixed WiMax and mobile WiMax. Fixed WiMax is targeted for providing fixed and nomadic services, while mobile WiMax will also provide portable and mobile connectivity. To establish a WiMax network we have to face so many problems. We have to plan everything before installing the site. Path loss calculation is one of the major factor that we have to estimate before installing the site. Propagation models are used widely in network planning, mainly for conducting feasibility studies and during first deployment. They are also very useful for performing interference studies as the deployment proceeds. By combining analytical and empirical methods the propagation models is derived. Propagation models are used for calculation of electromagnetic field strength for the purpose of wireless network planning during preliminary deployment. It describes the signal attenuation from transmitter to receiver antenna as a function of distance, carrier frequency, antenna heights and other significant parameters like terrain profile (e.g. urban, suburban and rural). The empirical models are derived from measurements and observations, while the deterministic models start from the electromagnetic wave equations to determine the received signal power at a particular location. Deterministic models provide a reliable and thorough estimation of the path losses and the channel characteristics, but often require a complete three-dimensional map of the propagation environment. On the other side, empirical approaches offer less accurate but simple prediction methods without the need for specific and detailed information on the terrain type. Although a lot of works in the literature deals with the experimental estimation of path loss for WiMAX systems operating in the 3.5 GHz band, the propagation behavior at 2.5 GHz is not so thoroughly investigated. In this paper we compare and analyze path loss by using different propagation models (i.e. COST 231 Hata model, ECC-33 model, SUI model, Ericsson model and COST 231 Walfish-Ikegami model) in different receiver antenna heights in urban environments in NLOS condition. We compare the results of path loss models by changing operating frequency while the height of receiver antenna is constant. we also take the results by changing the receiver antenna height by taking same frequency for each model.

2.PATH LOSS

The simplest channel is the free space line of sight channel with no objects between the receiver and the transmitter or around the path between them. In this simple case, the transmitted signal attenuates since the energy is extend spherically around the transmitting antenna. For this line of sight (LOS) channel, the received power is given by:

$$P_r = P_t \;[\sqrt{G1}\,\lambda/4\pi d]^2$$

Here, Pt is the transmitted power, G_1 is the product of the transmit and receive antenna field radiation patterns, λ is the wavelength, and d is the distance. Theoretically, the power falls off in proportion to the square of the distance. In practice, the power falls off more quickly, typically 3rd or 4th power of distance. The existence of ground causes some of the waves to reflect and reach the transmitter. These reflected waves may sometime have a phase shift of 180 ° and so may shrink the net received power. A simple two-ray estimate for path loss can be shown to be:

$$P_r = P_t G_t G_r h_t^2 h_r^2/d^4$$

Here, h_t and h_r are the antenna heights of the transmitter and receiver, respectively. Note that there are three main differences from the previous formula. First, the antenna heights have effect. Second, the wavelength is absent and third the exponent on the distance is 4. In general, a common empirical formula for path loss is:

$$P_r = P_t P_o [d_o/d]^{\alpha}$$

Where P_o is the power at a distance d_o and α is the path loss exponent. The path loss is given by:

$$P_L(d)db = P_L(d_o)+10\alpha\log(d/d_o)$$

Here $PL(d_o)$ is the mean path loss in dB at distance d_o

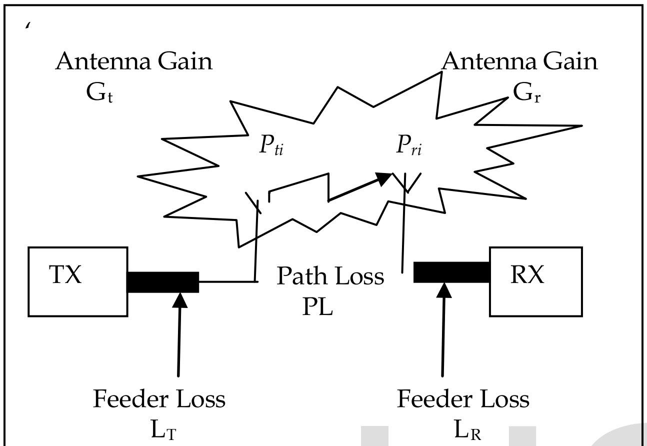

Figure 2.1 Path Loss

3.PROPAGATION MODELS

In this paper, we studied a number of path loss models for predicting the propagation loss for WiMAX. Path loss models play a major role in planning of wireless cellular systems. They represent a set of mathematical equations and algorithms that are used for radio signal propagation prophecy in definite areas. There are three kind of models :

1. Empirical Model
2. Stochastic Model
3. Deterministic Model

In this paper we worked on the Empirical Models as these models are based on data used to predict, not explain a system and are based upon observation and measurement alone. Empirical Model Further Split two parts time dispersive and non-time dispersive.SUI model is one example of time dispersive Model and Cost 231 hata model is example of non-time dispersive model.

3.1 Free Space Model

Path loss in Free Space PL_{FS} defines how much strength of signal is lost during propagation from transmitter to receiver. Free Space Model is diverse on frequency and distance. It is calculated as:

$$PL_{FS} = 32.45+20\log_{10}(d)+20\log_{10}(f) \quad (1)$$

Where, f = Frequency in [MHz]

And d = distance between transmitter and receiver [m]
Power is usually expressed in [dBm]

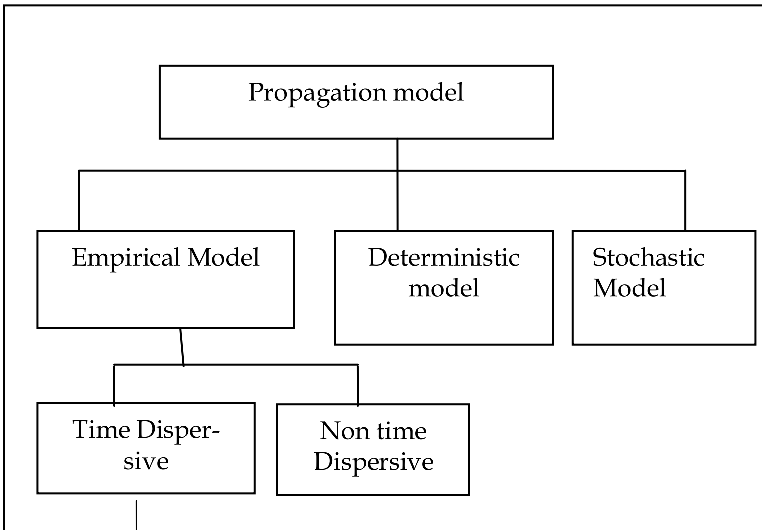

Figure 3.1 Categorize of Propagation Models

3.2 Okumura Model

Okumura Model is the most widely used radiofrequency propagation model for predicting the behavior of cellular transmissions in urban area. This model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection and scattering caused by city structures. This model also has two more varieties for transmission in Suburban and open areas. While dealing with areas, the urban area is sub-grouped as big cities and the medium city or normal built cities. By using Okumura model we can predict path loss in urban area. Median path loss model can be expressed as:

$$PL(db) = L_f + A_{mn}(f,d) - G(h_{te}) - G(h_{re}) - G_{area} \quad (2)$$

Where, PL = Median Path Loss [dB]
L_f = Free Space Path Loss [dB]
$A_{mn}(f,d)$ = Median attenuation relative to free space [dB]
G_{hte} = Base station antenna height gain factor [dB]
G_{hre} = Mobile station antenna height gain factor [dB]
G_{area} = Gain due to type of environment [dB]
f = Frequency [MHz]
h_{te} = Transmitter antenna height [m]
h_{re} = Receiver antenna height [m]
d = Distance between transmitter and receiver [KM]

3.3 COST 231 Hata Model

COST 231 project is the development of the outdoor propagation models for application in urban areas at higher frequencies.It has extended the earlier Hata-Okumura model to support frequencies ranging from 1500 MHz up to 2000 MHz . The main advantage is that it contains corrections for urban, suburban and rural (flat) environments. The basic path loss equation for this COST-231 Hata Model can be expressed as:

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$PL = 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(hb) - ah_m + (49.9 -$

$6.55 \log_{10}(hb)) \log_{10} d + c_m$ (3)

The parameter c_m has different values for different environments like 0 dB for suburban and 3 dB for urban areas and the remaining parameter ah_m defined in urban areas as

$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.79$ for $f > 400$ MHz (4)

The value for ah_m in suburban and rural (flat) areas is given as:

$ah_m = (1.11\log_{10}f - 0.7)h_r - (\log_{10}f - 0.8)$ (5)

3.4 Stanford University Interim (SUI) Model

The 802.16 SUI is an empirical model recommended by 802.16 standardizing committee. The model is an extension of Hata model with correction for frequencies above 1900 MHz. The SUI model describes three types of terrain, they are terrain A, terrain B and terrain C. There is no affirmation about any particular environment. Terrain A can be used for hilly areas with sensible or very dense vegetation. This terrain presents the highest path loss. The basic path loss expression of the SUI model with correction factors is presented as:

$PL = A + 10\gamma \log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + S$ for $d > d_0$ (6)

Where
d = distance between base station and receiver [m]
d_0 = 100 [m]
λ = wavelength [m]
X_f = Correction for frequency above 2 GHz [MHz]
X_h = Correction for receiving antenna height [m]
S = Correction for shadowing [dB]
γ = Path loss exponent

The random variables are taken through a statistical procedure as the path loss exponent γ and the weak fading standard deviation S is defined. The log normally distributed factor S, for shadow fading because of trees and other clutter on a propagations path and its value is between 8.2 dB and 10.6 dB

The parameter A is defined as: $A = 20\log_{10}\left(\frac{4\pi d_0}{\lambda}\right)$ (7)

and the path loss exponent γ is given by :

$$\gamma = a - bh_b + \left(\frac{c}{h_b}\right) \quad (8)$$

where, the parameter h_b is the base station antenna height in meters. This is between 10 m and 80 m. The constants a, b, and c depend upon the types of terrain, that are given in Table 3.4. The value of parameter $\gamma = 2$ for free space propagation in an urban area, $3 < \gamma < 5$ for urban NLOS environment, and $\gamma > 5$ for indoor propagation.

The frequency correction factor X_f and the correction for receiver antenna height X_h for the model are expressed as:

$X_f = 6.0 \log_{10}\left(\frac{f}{2000}\right)$ (9)

$$X_h = \begin{cases} -10.8\log_{10}\left(\frac{h_r}{2000}\right) & for\ terrain\ type\ A\ and\ B \\ -20\log_{10}\left(\frac{h_r}{2000}\right), & for\ terrain\ type\ C \end{cases} \quad (10)$$

where, f is the operating frequency in MHz, and h_r is the receiver antenna height in meter. For the above correction factors this model is extensively used for the path loss prediction of all three types of terrain in rural, urban and suburban environments.

Table 3.4
The parameter values of different terrain for SUI model.

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

3.5 Hata-Okumura extended model or ECC-33 Model

One of the most extensively used empirical propagation models is the Hata-Okumura model which is based on the Okumura model..The International Telecommunications Union (ITU) extended original model to frequencies up to 3.5 GHz. The cautiously proposed propagation model of Hata-Okumura model with report is referred to as ECC-33 model. In this model path loss is given by :

$PL = A_{fs} + A_{bm} + G_b - G_r$ (11)

A_{fs} = free space attenuation [dB]
A_{bm} = basic median path loss [dB]
G_b = transmitter antenna height gain factor
G_r = receiver antenna height gain factor

These factors can be separately described and given by as:

$A_{fs} = 92.4 + 20 \log_{10}(d) + 20 \log_{10}(f)$ (12)

$A_{bm} = 20.41 + 9.83 \log_{10}(d) + 7.894 \log_{10}(f) + 9.56[\log_{10}(f)]^2$ (13)

$$G_b = \log_{10}\left(\frac{h_b}{200}\right)\{13.958 + 5.8[\log_{10}(d)]^2\} \quad (14)$$

When dealing with gain for medium cities, the G_r will be expressed as:

$$Gr = [42.57 + 13.7\log_{10}(f)][\log_{10}(h_r) - 0.585] \quad (15)$$

for large city $G_r = 0.759h_r - 1.862$ (16)

3.6 COST 231 Walfish-Ikegami Model (WI)

This is the COST 231 proposed Walfisch and Ikigami combined model. 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 regard to the direct radio path (φ). The model has separate equations for Line of Sight (LOS) and Non LOS (NLOS) conditions. The equation of the proposed model is expressed as:
For LOS condition

$$PL_{LOS} = 42.6 + 26\log(d) + 20\log(f) \quad (17)$$

And For NLOS condition

$$PL_{NLOS} = \begin{cases} L_{FSL} + L_{rts} + L_{msd} & for\ urban\ and\ suburban \\ L_{FS} & if\ L_{rts} + L_{msd} > 0 \end{cases} \quad (18)$$

where L_{FSL} is the free space loss, L_{rts} the roof-to-street diffraction and scatter loss, and L_{msd} the multi screen diffraction loss.

Where

$$L_{rts} = -8.8 + 10\log_{10}(f) + 20\log_{10}(\Delta h_{Mobile}) - 10\log_{10}(w) + L_{ori} \quad (19)$$

L_{ori} = street orientation function

$$L_{msd} = L_{bsh} + k_a + k_d\log_{10}(d) + k_f\log10(f) - 9\log_{10}(b) \quad (20)$$

Where

$$L_{bsh} = \begin{cases} -18log_{10}(1 + \Delta h_{base} & h_{base} > h_{roof} \\ 0 & h_{base} \le h_{roof} \end{cases} \quad (21)$$

$$Kf = -4 + 1.5(f/925 - 1) \quad (22)$$

3.7 Ericsson Model

To predict the path loss, the network planning engineers are used a software provided by Ericsson company is called Ericsson model. This model also stands on the modified Okumura-Hata model to allow room for changing in parameters according to the propagation environment. Path loss according to this model is given by :

$$PL = a_0 + a_1.\log_{10}(d) + a_2.\log_{10}(h_b) + a_3.\log_{10}(h_b).\log_{10}(d) - 3.2(\log_{10}(11.75h_r)^2) + g(f) \quad (23)$$

where

$$g(f) = 44.49\log_{10}(f) - 4.78(\log_{10}(f))^2 \quad (24)$$

The default values of these parameters (a_0, a_1, a_2 *and* a_3) for different terrain are given in Table 3.7

Table 3.7
Values of parameters for Ericsson model

Enviornment	a_o	a_1	a_2	a_3
Urban	36.2	30.2	12.0	0.1
Suburban	43.20	68.63	12.0	0.1
Rural	45.95	100.6	12.0	0.1

The value of parameter a_0 and a_1 in suburban and rural area are based on the Least Square (LS) method.

4. Simulations And Results

In our first calculation, we fix our operating frequency at 3.5 GHz. 5km of distance is considered between transmitter and receiver, transmitter antenna height we choose is 35 m. we considered 3 different antenna heights i.e. 3 m, 6 m and 9 m. In our second computation we fix the receiver antenna height at 9 m and take the results by changing the frequency i.e. 2.7 GHz, 3.0 GHz and 3.3 GHz .Distance between the transmitter and receiver remains same i.e. 5km. Transmitter height is also same i.e. 35 m. In our paper we concentrate on NLOS condition. We exploited Free Space Model (FSL) as our reference model in all comparisons. Table 4.1 shows the parameter we use in our simulation.

Table 4.1
Simulation Parameter

Parameters	**Values**
Base Station Transmitter Power	43dBm
Mobile Transmitter Power	30dBm
Transmitter Antenna Height	35 m
Receiver Antenna Height in case 1	3 m, 6 m, 9 m
Receiver Antenna Height in case 2	9m
Operating Frequency in case 1	3.5GHz
Operating Frequency in case 2	2.7 , 3.0and3.3GHz
Distance Between TX and RX	5km
Street Orientation Angle	**30^0**
Correction For Shadowing	10.6 dB
Building To Building Distance	50 m
Average Building Height	15m

4.1 Path loss simulation with different receiver antenna height.

The results for different models for different antenna heights are shown in Figure 4.1,4.2 and 4.3.

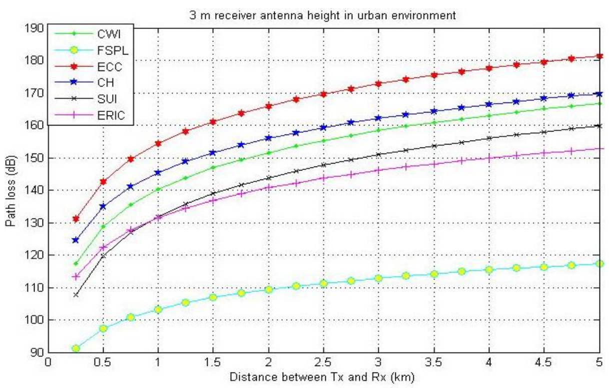

Figure 4.1 Path loss for 3m receiver antenna height

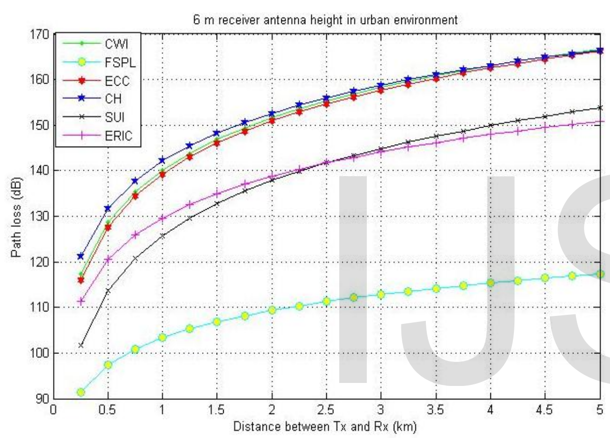

Figure 4.2 Path loss for 6m receiver antenna height

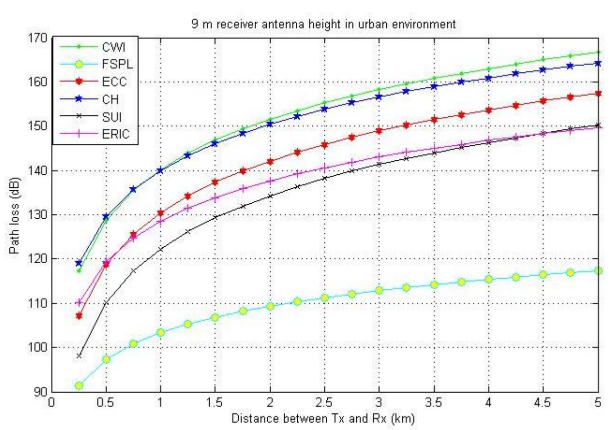

Figure 4.3 Path loss for 9m receiver antenna height

We have summarized the path loss data in Table 4.2. we have consider these values at 5km Tx-Rx distance. From the values mentioned in Table 4.2 it is clear that with the change in receiver antenna height the path loss values changes.

Table 4.2
Path Loss Estimate at 5km distance

Propagation Model	Tx antenna height(m)	Path Loss at 3m (dB)	Path Loss at 6m (dB)	Path Loss at 9m (dB)
Free Space Loss	35	118	118	118
ECC-33	35	182	167	158
Cost 231 Hata	35	170	167	165
Ericsson	35	152	150	149
Cost 231 W-I	35	168	167	167
SUI	35	160	152	150

4.2 Path loss simulation with different frequcies.

The results for different models for different frequencies are shown in figure 4.4,4.5 and4.6.In this prediction we fix the receiver antenna height i.e. 9m

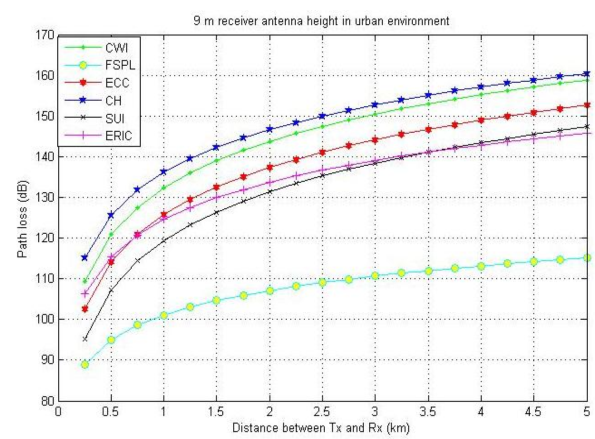

Figure 4.4 Path loss for 2.7Ghz frequency

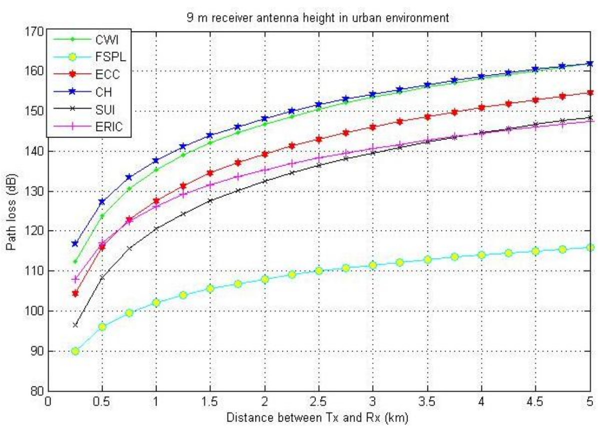

Figure 4.5 Path loss for 3.0 Ghz frequency

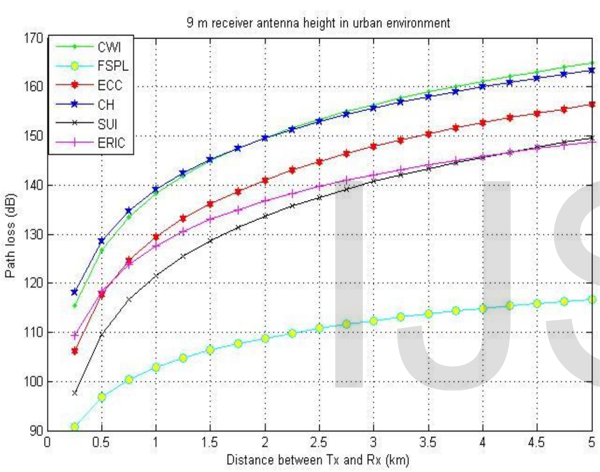

Figure 4.6 Path loss for 3.3 Ghz frequency

Table 4.3 shows the summarize data at 5km distance when the receiver antenna height is fixed i.e. 9m and the value of frequency is changing.

Table 4.3
Parth loss Estimate using different frequencies

Propagation Model	Rx Antenna Height(m)	Path Loss at 2.7GHz Frequency (dB)	Path Loss at 3.0GHz Frequency (dB)	Path Loss at 3.3GHz Frequency (dB)
Free Space Loss	9	118	118	118
ECC-33	9	152	155	157
Cost 231 Hata	9	160	162	163
Ericsson	9	145	148	148
Cost 231 W-I	9	158	162	162
SUI	9	148	149	149

5. Conclusion

Our analysis signifies that all empirical models experiences higher path loss due to the multipath and NLOS environment in urban area. We can see the Ericsson model showed the lowest path loss when the receiver antenna height is 9m.It is also concluded that there is a slight change in the path loss when we change the operating frequency. but this change in path loss is less as compared to the results we have taken w.r.t the receiver antenna height. The ECC model showed the highest path loss when the receiver antenna height is 3m.Cost 231 W-I model showed the similar results on each receiver antenna height and frequencies .Among all the ECC model showed the largest variation in path loss at three different receiver antenna heights and different frequencies.

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BIBLEOGRAPHY

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