Simulation and Analysis of Path Loss Models for WiMax Communication System

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ABSTRACT

(WiMax) is a wireless broadband technology based on IEEE 802.16 standard. WiMax has two potential access conditions; Line-of-Sight condition, and Non-Line of Sight condition. In Non-Line of Sight condition a Path Loss arises when an electromagnetic wave propagates though space from transmitter and receiver. Prediction of WiMax path loss is a fundamental tool for designing any broadband wireless communication system. Several models are available to estimate the path loss, such as: COST 231-Hata model, Hata-Okumura model, COST 231 Walfish-Ikegami (W-I) Model , Stanford University Interim model, and Ericsson model.

In this paper , we aim to simulate the propagation path loss models using MATLAB software. This simulation is done based on the variation of the distance between the base station and the receiver in the range of 0.5 km to 5 km, for different height of the receiver antenna 3, 6, and 10m, within the operating frequencies 2.5 GHz, and 3.5GHz. All simulations carried out separately for urban, suburban, and rural environment. The simulation results of all models are compared and analyzed to identify a suitable model in different environments. The comparison and analyses are done based on the influence of variation of the distance between the transmitter and receiver, the operating frequency, and the receiver antenna height on the path loss prediction.

KEYWORDS: WiMax, path loss, propagation models, NLOS,

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 radio-frequency 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 potential 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 [1].

WiMax systems operating in the frequency range of 2-11 GHz are suitable for communication even in NLOS conditions, when direct visibility between the transmitting and receiving antenna does not exist[1]. In this scenario a Path Loss (PL) arises When an electromagnetic wave propagates though space from transmitter to receiver, the power of signal is decreased due to path distance, reflection, diffraction, scattering, free space loss and absorption by objects of environment. It is also influenced by different environment (urban, suburban, and rural). Variations of transmitter and receiver antenna height also produce losses. Prediction of WiMax path loss (PL) is a fundamental tool for designing any broadband wireless communication system. Several models are available to estimate the path loss, such as: COST 231-Hata model, Hata-Okumura model, COST 231 Walfish-Ikegami (W-I) Model , Stanford University Interim model, and Ericsson model [2].

This paper aims to simulate the propagation path loss models using MATLAB software, this simulation will be done based on the variation of the distance between the base station and the receiver in the range of 0.5 km to 5 km , for different height of the receiver antenna 3, 6, and 10 m, and within operating frequencies 2.5 GHz, and 3.5GHz, all simulations carried out for urban, suburban, and rural environment. The simulation results of all models will be compare and analysis to identify a suitable model in different environments.

2 PATH LOSS MODELS

Path loss models play a significant role in planning of wireless cellular systems. They represent a set of mathematical equations and algorithms that are used for radio signal propagation prediction in certain areas. Propagation path loss models are used for calculation of electromagnetic field strength for the purpose of wireless network planning during preliminary deployment.

Path loss model 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 (urban, suburban and rural).

In this section various path loss models are discussed.

2.1 Free Space Path Loss Model (FSPL)

In telecommunication, free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space, with no obstacles nearby to cause reflection or diffraction. Free-space path loss is proportion to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal.

The equation for FSPL in decibels is [3]:

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

Where :

f is the signal frequency (MHz)

d is the distance from the transmitter (km)

2.2 COST 231 Hata Model

The Hata model is introduced as a mathematical expression to mitigate the best fit of the graphical data provided by the classical Okumura model. Hata model is used for the frequency range of 150 MHz to 1500 MHz to predict the median path loss for the distance d from transmitter to receiver antenna up to 20 km, and transmitter antenna height is considered 30 m to 200 m and receiver antenna height is 1 m to 10 m. To predict the path loss in the frequency range 1500 MHz to 2000 MHz. COST 231 Hata model is initiated as an extension of Hata model.

This model is used to calculate path loss in three different environments like urban, suburban and rural (flat). This model provides simple and easy ways to calculate the path loss. Although the frequency ranges 2.5 GHz and 3.5 GHz is outside of its measurement range, its simplicity and correction factors still allowed to predict the path loss in this higher frequency range. The basic path loss equation for this COST-231 Hata Model can be expressed as [3]:

$$PL = 46.3 + 33.9\, log_{10}(f) - 13.82\, log_{10}(h_b) - ah_m + \left(44.9 - 6.55\, log_{10}(h_b)\right) log_{10}(d) + c_m \qquad (2)$$

Where

d is the distance between transmitter and receiver (km)

f is the frequency (MHz)

h_b is the transmitter antenna height (m), the correction parameter c_m has different values for different environments like 0 dB for suburban and open rural environments and 3 dB for urban areas and the remaining parameter ah_m is defined in urban areas as

$$\mathrm{ah_m} = 3.20\left(\log_{10}(11.75\ \mathrm{h_r})\right)^2 - 4.79 \quad , \text{for f} > 400\ MHz \qquad (3)$$

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

$$ah_m = (1.11\, log_{10}(f) - 0.7)h_r - (1.5\, log_{10}(f) - 0.8) \qquad (4)$$

Where the h_r is the receiver antenna height in meter

2.3 Hata-Okumura Extended Model

One of the most extensively used empirical propagation models is the Hata-Okumura model, which is based on the Okumura model. This model is a well-established model for the Ultra High Frequency (UHF) band. The International Telecommunication Union (ITU) encouraged this model for further extension up to 3.5 GHz . The original Okumura model does not provide any data greater than 3 GHz. Based on prior knowledge of Okumura model, an extrapolated method is applied to predict the model for higher frequency greater than 3 GHz. The tentatively proposed propagation model of Hata-Okumura model is referred to as ECC-33 (Electronic Communication Committee) model. In this model path loss is given by [3]:

$$PL = A_{fs} + A_{bm} - G_b - G_r \qquad (5)$$

Where

$\mathrm{A_{fs}}$ is the free space attenuation (dB)

$\mathrm{A_{bm}}$ is the basic median path loss (dB)

$\mathrm{G_b}$ is the transmitter antenna height gain factor

$\mathrm{G_r}$ is the receiver antenna height gain factor

These factors can be separately described and given by as:

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

$$A_{bm} = 20.41 + 9.83\, log_{10}(d) + 7.894\, log_{10}(f) + 9.56\, [log_{10}(f)]^2 \qquad (7)$$

$$G_b = log_{10}\left(\frac{h_b}{200}\right)(13.958 + 5.8\, [log_{10}(d)]^2) \qquad (8)$$

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

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

for large city

$$\mathrm{G_r} = 0.759\ \mathrm{h_r} - 1.862 \qquad (10)$$

where

d is the distance between transmitter and receiver antenna (km) , f is the frequency (GHz) , h_b is the transmitter antenna height (m) h_r is the receiver antenna height (m), This model is the hierarchy of Okumura-Hata model.

2.4 COST 231 Walfish-Ikegami (W-I) Model

This model is a combination of J. Walfish and F. Ikegami models. The COST 231 project further developed this model. Now it is known as a COST 231 Walfish-Ikegami (W-I) model. This model is most suitable for flat suburban and urban areas that have uniform building height (see Figure 1). Among other models like the Hata model, COST 231 W-I model gives a more precise path loss. This is as a result of the additional parameters introduced which characterized the different environments. It distinguishes different terrain with different proposed parameters. The equation of the proposed model is expressed in [3]:

For LOS condition

$$PL_{LOS} = 42.6 + 26\ log_{10}(d) + 20\ log_{10}(f) \qquad (11)$$

and for NLOS condition

$$\mathrm{PL_{NLOS}} = \begin{cases} \mathrm{L_{FSL} + L_{rts} + L_{msd}} & \text{for urban and suburban} \\ \mathrm{L_{FS}} & \mathrm{L_{rts} + L_{msd}} > 0 \end{cases} \qquad (12)$$

where

$\mathrm{L_{FSL}}$ is the free space loss

$\mathrm{L_{rts}}$ is the roof top to street diffraction

$\mathrm{L_{msd}}$ is the multi-screen diffraction loss

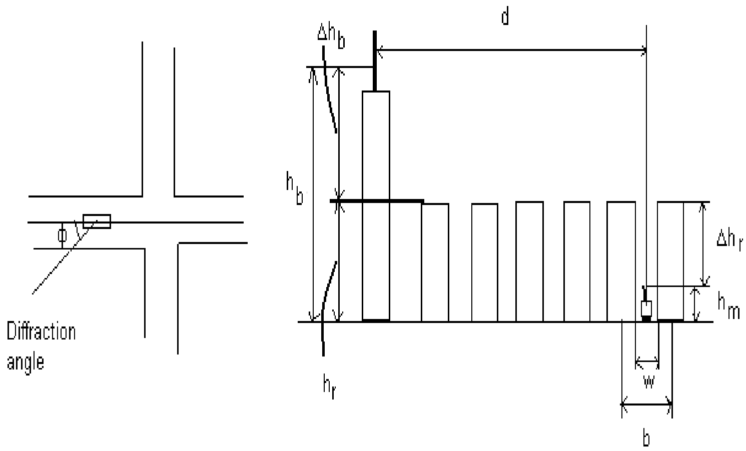


Figure 1. Diffraction angel and urban scenario

free space loss

$$\mathrm{L_{FSL}} = 32.45 + 20\ \log_{10}(\mathrm{d}) + 20\ \log_{10}(\mathrm{f}) \qquad (13)$$

roof top to street diffraction (see Figure 1) [4]:

$$\mathrm{L_{rts}} = \begin{cases} -16.9 - 10\log_{10}(\mathrm{w}) + 10\log_{10}(\mathrm{f}) \\ +20\log_{10}(\Delta \mathrm{h_m}) + \mathrm{L_{ori}} & \text{, for } \mathrm{h_{roof}} > \mathrm{h_m} \\ 0 \end{cases} \qquad (14)$$

where

$$\mathrm{L_{ori}} = \begin{cases} -10 + .354\ \phi & \text{for } 0 \le \phi < 35 \\ 2.5 + 0.075\ (\phi - 35) & \text{for } 35 \le \phi < 55 \\ 4 - 0.114\ (\phi - 55\ ) & \text{for } 55 \le \phi \le 90 \end{cases} \qquad (15)$$

Note that

$\Delta h_m = h_{roof} - h_m$

$\Delta h_{base} = h_{base} - h_{roof}$

The multi-screen diffraction loss is

$$L_{msd} = \begin{cases} L_{bsh} + k_a + k_d \, log_{10}(d) + k_f \, log_{10}(f) \\ -9 \, log_{10}(f) - 9 log_{10}(B) \quad , \quad L_{msd} > 0 \\ 0 \qquad\qquad\qquad\qquad\qquad L_{msd} < 0 \end{cases} \tag{16}$$

Where

$$L_{bsh} = \begin{cases} -18 \, log_{10}(1 + \Delta h_{base}) & h_{base} > h_{roof} \\ 0 & h_{base} \leq h_{roof} \end{cases} \tag{17}$$

$$k_a = \begin{cases} 54 & for \;\; h_{base} > h_{roof} \\ 54 - 0.8 \, \Delta h_{base} \\ , for \;\; d \geq 0.5 \, km \, and \;\; h_{base} \leq h_{roof} \\ 54 - 0.8 \, \Delta h_{base} \left(\frac{d}{0.5}\right) \\ , for \;\; d < 0.5 \, km \, and \;\; h_{base} \leq h_{roof} \end{cases} \tag{18}$$

$$k_d = \begin{cases} 18 & h_{base} > h_{roof} \\ 18 - 15 \left(\frac{\Delta h_{base}}{h_{roof}}\right) & h_{base} \leq h_{roof} \end{cases} \tag{19}$$

For suburban or medium size cities with moderate tree density

$$k_f = -4 + 0.7 \left(\frac{f}{925} - 1\right) \tag{20.a}$$

and for metropolitan – urban

$$k_f = -4 + 1.5 \left(\frac{f}{925} - 1\right) \tag{20.b}$$

Where

d is the distance between transmitter and receiver antenna (m)

f is the frequency (GHz)

B is the building to building distance (m)

w is the street width (m)

ϕ is the street orientation angel with respect to direct radio path (degree)

2.5 Stanford University Interim (SUI) Model

IEEE 802.16 Broadband Wireless Access working group proposed the standards for the frequency band below 11 GHz containing the channel model developed by Stanford University, namely the SUI models. This prediction model come from the extension of Hata model with frequency larger than 1900 MHz. The correction parameters are allowed to extend this model up to 3.5 GHz band. In the USA, this model is defined for the Multipoint Microwave Distribution System (MMDS) for the frequency band from 2.5 GHz to 2.7 GHz [5].

The base station antenna height of SUI model can be used from 10 m to 80 m. Receiver antenna height is from 2 m to 10 m. The cell radius is from 0.1 km to 8 km. The SUI model describes three types of terrain, they are terrain A, terrain B and terrain C. There is no declaration about any particular environment. Terrain A can be used for hilly areas with moderate or very dense vegetation. This terrain presents the highest path loss, and it is considered as a dense populated urban area. Terrain B is characterized for the hilly terrains with rare vegetation, or flat terrains with moderate or heavy tree densities. This is the intermediate path loss scheme. This model is considered for suburban environment. Terrain C is suitable for flat terrains or rural with light vegetation, here path loss is minimum.

The basic path loss expression of The SUI model with correction factors is presented as [5]:

$$PL = A + 10\,\gamma\,log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s \quad , \quad for \quad d > d_0 \qquad (21)$$

where

d is the distance between BS and receiving antenna (m)

d_0 is the reference distance 100 (m)

λ is the wavelength (m)

X_f is the frequency correction factor for frequency above 2 GHz

X_h is the correction factor for receiving antenna height (m)

s is the correction for shadowing (dB), and γ is the 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 [5]:

$$A = 20\,log_{10}\left(\frac{4\,\pi\,d_0}{\lambda}\right) \qquad (22)$$

and the path loss exponent γ is given by [1]:

$$\gamma = a - b\,h_b + \left(\frac{c}{h_b}\right) \qquad (23)$$

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 1 [5]. 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 .

Table 1. 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	0.0050
$c\ (m)$	12.6	17.1	20.0
S	10.6	9.6	8.2

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

$$X_f = 6.0\,log_{10}\left(\frac{f}{2000}\right) \qquad (24)$$

For terrain type A and B

$$X_h = -10.8\,log_{10}\left(\frac{h_r}{2000}\right) \qquad (25.a)$$

for terrain type C

$$X_h = -20.0\,\,log_{10}\left(\frac{h_r}{2000}\right) \qquad (25.b)$$

Where

f is the operating frequency (MHz)

h_r is the receiver antenna height (m)

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.

2.6 Ericsson Model

To predict the path loss, the network planning engineers are used a software provided by Ericsson company is called Ericsson model [6]. 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 [5]:

$$PL = a_0 + a_1\, log_{10}(d) + a_2\, log_{10}(h_b) + a_3\, log_{10}(h_b)\, log_{10}(d) - g_1(hr) + g_2(f) \quad (26.a)$$

Where $g_1(hr)$ and $g_2(f)$ are given by :

$$g_1(hr) = 3.2(log_{10}(11.75\, h_r)^2) \quad (26.b)$$

$$g_2(f) = 44.49\, log_{10}(f) - 4.78\, (log_{10}(f))^2 \quad (26.c)$$

and parameters

f is the frequency (MHz)

h_b is the transmission antenna height (m)

h_r is the receiver antenna height (m)

The default values of the parameters (a_0, a_1, a_2 and a_3) for different terrain are given in Table 2 [7].

Table 2. Values of parameters for Ericsson model

Environment	a_0	a_1	a_2	a_3
Urban	36.2	30.2	12.0	0.1
Suburban	43.20	68.93	12.0	0.1
Rural	45.95	100.6	12.0	0.1

3 RESULTS and DISCUSSION

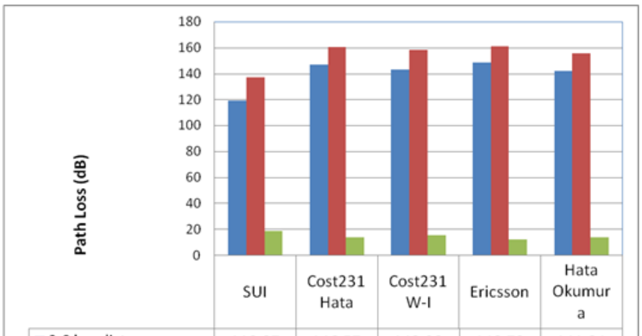
The simulation parameters in our study are presented in Table 3

Table 3. Simulation parameters

Parameter	Value
Transmitter antenna height	40 m in urban environment 30 m in suburban environment 20 m in rural environment
Receiver antenna height	3 – 12 m
WiMax cell (BS) distance	0.5 – 5 km
Operating frequency	2.5 GHz, and 3.5 GHz
Building to building distance	50 m
Average building height	15 m
Street width	25 m
Street orientation angle	30° in urban environment 40° in suburban environment
Correction for shadowing	8.2 dB in urban 9.6 dB in suburban 10.6 dB in rural

3.1 Path Loss in Urban Area

A comparison between simulation results for urban environment in different BS distance (2, and 5 km) and at 6 m receiver antenna height is shown in Figure 2 at 2.5 GHz.



	SUI	Cost231 Hata	Cost231 W-I	Ericsson	Hata Okumura
2.0 km distance	118.87	146.57	142.98	148.72	141.84
5.0 km distance	137.24	160.26	158.1	160.8	155.32
Difference in Path Loss	18.37	13.69	15.12	12.08	13.48

Figure 2. A comparison of results for urban area at 6 m receiver antenna height and 2.5 GHz

Figure 3 shows a comparison of simulation results for urban environment in different operating frequency (2.5, and 3.5 GHz) and at distance of 3 km and 6m of receiver antenna height, and Figure 4 shows a comparison of

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results for urban environment in different receiver antenna height (6 m, and 10 m) and at distance of 5 km and 3.5 GHz operating frequency.

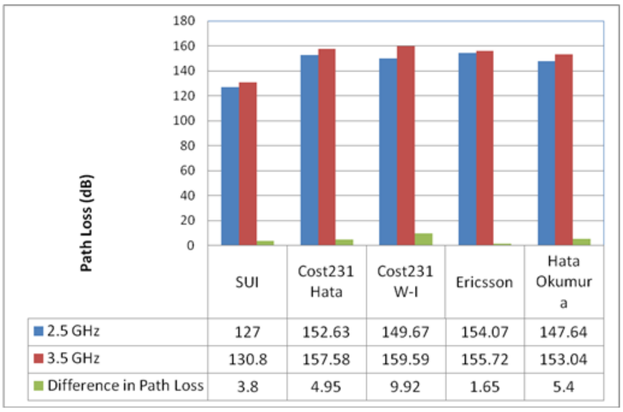

Figure 3. A comparison results for urban environment at 3 km distance and 6 m of receiver antenna height

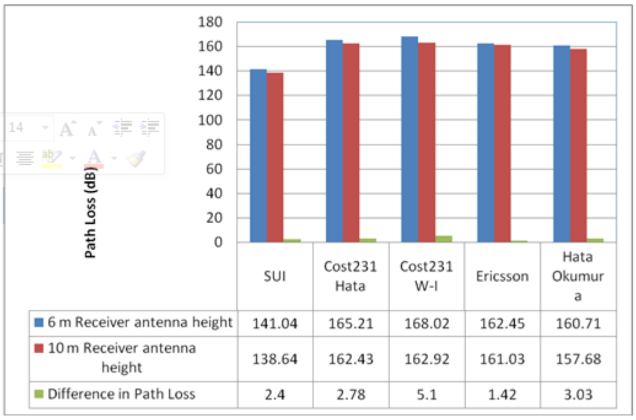

Figure 4. A comparison of results for urban environment in at distance of 5 km and 3.5 GHz operating frequency

Analysis of Simulation Results of Urban Area

a) Influence of distance

From the presented results in Figure 2, we note that , in both distances (2km, and 5km), the SUI model shows the lowest path loss prediction (118.87 dB, and 137.24 dB), and the Ericsson model provides the highest path loss values (148.72 dB, and 160.8 dB). Due to changing of the distance from 2 km to 5 km, the SUI model has a highest effect, where its loss is increased by (18.37 dB), but the Ericsson model showed a lowest influence, where its predication loss is increased by (12.08 dB).

b) Influence of operating frequency

By observing the results shown in Figure 3, we see that in both cases of frequencies (2.5 GHz, and 3.5 GHz) the SUI model gives the lowest path loss prediction (127.00 dB, and 130.8 dB); the Ericsson model predicts the highest path loss (154.07 dB) at frequency of 2.5 GHz, and the Cost 231 W-I model showed the highest path loss (159.59 dB) at operating frequency of 3.5 GHz. The effect of the changing of frequency from 2.5GHz to 3.5GHz is more remarkable for the COST 231 W-I model where the loss is increased by (9.92 dB), but it has not much influence for the Ericsson model where the increasing of the loss is (1.65 dB).

c) Influence of receiver antenna height

From the presented results in Figure 4, we note that , in both antenna heights (6m, and 10m), the SUI model provides the lowest path loss values (141.04 dB, and 138.64 dB), and the Cost 231 W-I model shows the highest path loss (168.02 dB, and 162.92 dB).

Due to changing of the antenna height from 6m to 10m, the Cost 231 W-I model has a highest effect, where its loss is decreased by (5.1 dB), but the Ericsson model showed a lowest and not much influence, where its predication loss is decreased by (1.42 dB), and the other models have not much influence.

3.2 Path Loss in Suburban Area

The comparison between simulation results for different models in suburban environment for different BS distance (2, and 5 km) at 6 m receiver antenna height and 2.5 GHz are shown in Figure 5.

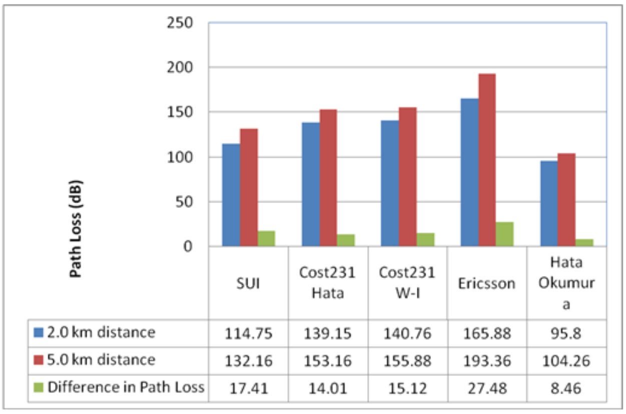

Figure 5. A comparison of simulation results for suburban area at 6 m receiver antenna height and 2.5 GHz

Figure 6 shows a comparison of simulation results for suburban environment in different operating frequency (2.5, and 3.5 GHz), at distance of 3 km and 6m of receiver antenna height.

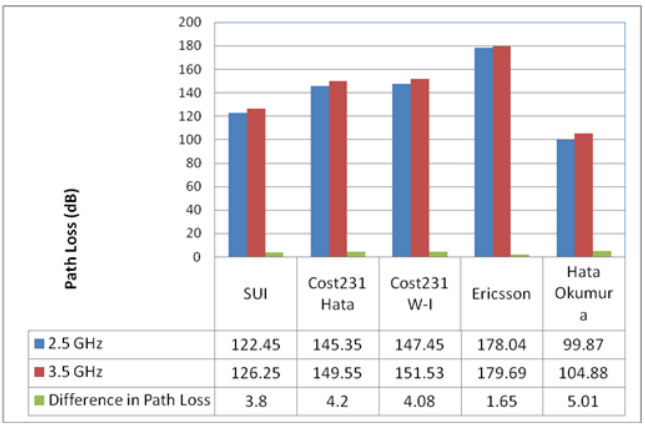

Figure 6. A comparison of results for suburban area at distance of 3 km and 6m of receiver antenna height.

Figure 7 shows a comparison between results for suburban environment in different receiver antenna height (6, and 10m) at 3 km distance and 3.5 GHz.

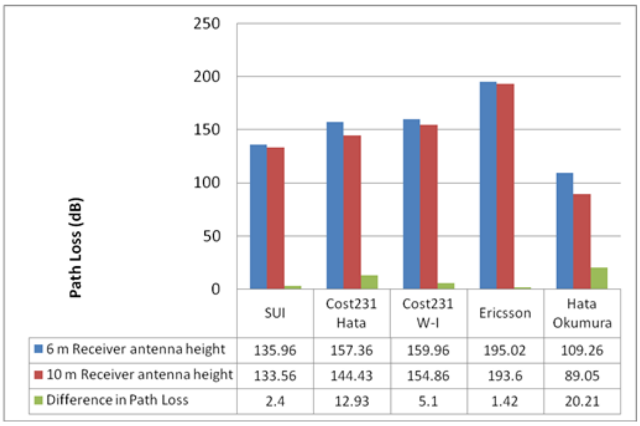

Figure 7. A comparison of simulation results for suburban environment at 5 km distance and 3.5 GHz

Analysis of Simulation Results of Suburban Area

a) Influence of distance

From the presented results in Figure 5, we note that , in both distances (2km, and 5km), the Hata Okumura model shows the lowest path loss prediction (95.8 dB, and 104.26 dB), and the Ericsson model provides the highest path loss values (165.88 dB, and 193.36 dB). Due to changing of the distance from 2 km to 5 km, the SUI model has a highest effect, where its loss is increased by (17.41 dB), but the Hata Okumura model showed a lowest influence, where its predication loss is increased by (8.46 dB).

b) Influence of operating frequency

By observing the results shown in Figure 6, we see that in both cases of frequencies (2.5 GHz, and 3.5 GHz) the Hata Okumura model gives the lowest path loss prediction (99.87 dB, and

104.88 dB), and the Ericsson model predicts the highest path loss (178.04 dB, 179.69 dB). The effect of the changing of frequency from 2.5GHz to 3.5GHz is more remarkable for the Hata Okumura model where the loss is increased by (5.01 dB), but it has not much influence for the Ericsson model where the increasing of the loss is (1.65 dB).

c) Influence of receiver antenna height

From the presented results in Figure 7, we note that , in both antenna heights (6m, and 10m), the Hata Okumura model provides the lowest path loss values (109.26 dB, and 89.05 dB), and the Ericsson model shows the highest path loss (195.02 dB, and 193.60 dB).

Due to changing of the antenna height from 6m to 10m, the Hata Okumura model has a highest effect, where its loss is decreased by (20.21 dB), but the Ericsson model showed a lowest and not much influence, where its predication loss is decreased by (1.42 dB).

3.3 Path Loss in Rural Area

A comparison between simulation results for different models in rural environment in different distance (2, and 5 km), at 6 m receiver antenna height and 2.5 GHz is shown in Figure 8, Figure 9 shows a comparison of simulation results for rural environment in different operating frequency (2.5, and 3.5 GHz), at distance of 3 km and 6m of receiver antenna height, and Figures 10 shows a comparison between simulation results for rural environment in different receiver antenna height (6, and 10m) and at 5 km distance and 3.5 GHz.

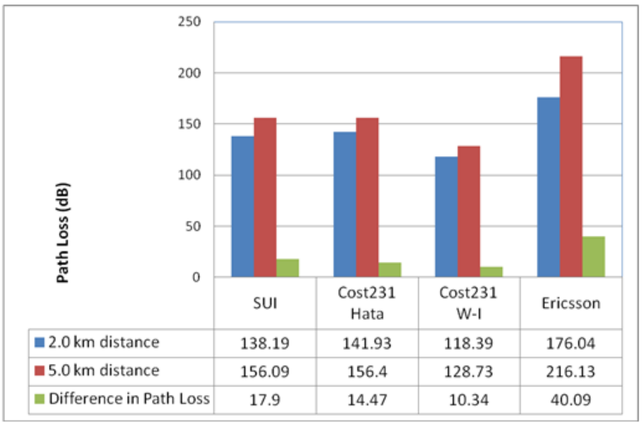

Figure 8 A comparison of simulation results for rural area at 6 m receiver antenna height and 2.5 GHz

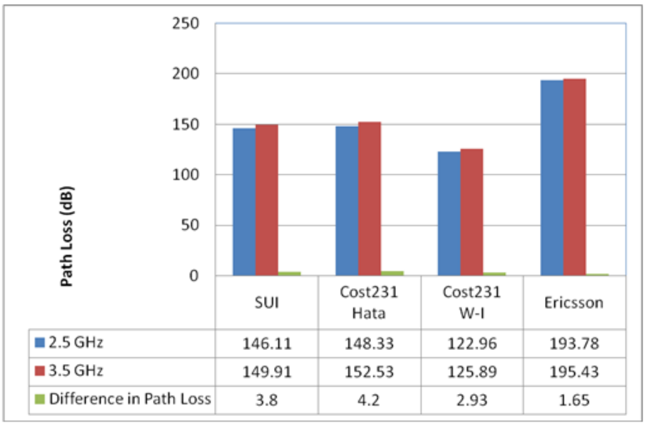

Figure 9 A comparison of results for rural area at distance of 3 km and 6m of receiver antenna height.

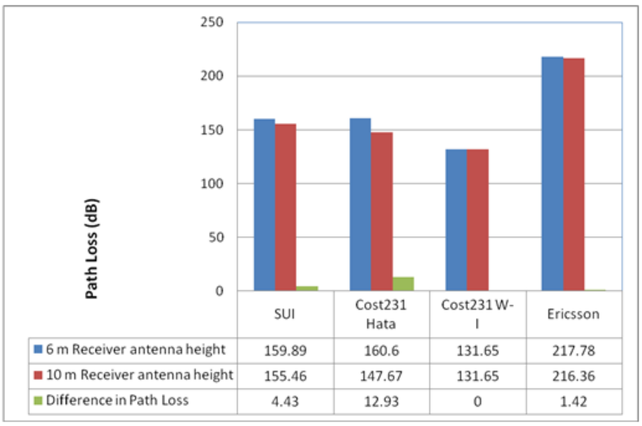

Figure 10 A comparison of simulation results for rural environment at 5 km distance and 3.5 GHz

Analysis of Simulation Results of Rural Area

a) Influence of distance

From the presented results in Figure 8, we note that , in both distances (2km, and 5km), the Cost 231 W-I model shows the lowest path loss (118.39 dB, and 128.73 dB), and the Ericsson model provides the highest path loss values (176.04 dB, and 216.13 dB). Due to changing of the distance from 2 km to 5 km, the Ericsson model has a huge effect, where its loss is increased by (40.097 dB), but the Cost 231 W-I model showed a lowest influence, where its predication loss is increased by (10.34 dB).

b) Influence of operating frequency

By observing the results shown in Figure 9, we see that in both cases of frequencies (2.5 GHz, and 3.5 GHz) the Cost 231 W-I model gives the lowest path loss prediction (122.96 dB, and 125.89 dB), and the Ericsson model predicts the highest path loss (193.78 dB, and 195.43 dB). The effect of the changing of frequency from 2.5GHz to 3.5GHz is more remarkable for the COST 231 Hata model where the loss is increased by (4.20 dB), but it has not much influence for the Ericsson model where the increasing of the loss is (1.65 dB).

c) Influence of receiver antenna height

From the presented results in Figure 10, we note that , in both antenna heights (6m, and 10m), the Cost 231 W-I model provides the lowest path loss values (131.65 dB, and 131.65 dB), and the Ericsson model shows the highest path loss (217.78 dB, and 216.36 dB). Due to changing of the antenna height from 6m to 10m, the Cost 231 Hata model has a highest effect, where its loss is decreased by (12.93 dB), the Ericsson model showed a lowest and not much influence, where its predication loss is decreased by (1.42 dB). Because the Cost 231 W-I does not depending on the receiver antenna height the difference in path loss is (0 dB).

4 CONCLUSIONS

In this paper, we have presented the simulation results for path loss prediction for various propagation models under different propagation conditions, in urban, suburban, and rural environments. The simulation results were compared and analyzed based on the influence of variation of propagation conditions, distance, frequency and receiver antenna height, on the path loss prediction.

Based on our simulation results, we conclude that , under three propagation conditions the SUI model gave the lowest path loss in urban environment. In suburban environment, the Hata-Okumura model showed the lowest value of path loss, while in rural environment the Cost231 W-I showed the lowest path loss prediction compared to other models. Therefore, there is no single model is acceptable for all environments.

From point of view of the influence of variation of propagation conditions, we found that, the Hata-Okumura model had the lowest changing in path loss values due to change of distance, especially in suburban environment. Due to change of operating frequency, and receiver antenna height, the Ericsson model has the lowest difference in path loss prediction in urban, suburban, and rural environments.

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