Journal of Engineering and Applied Sciences 13 (7): 1907-1918, 2018
ISSN: 1816-949X

Modelling, Simulation and Analysis of Signal Pathloss for 4G Cellular Network Planning

Virginia Chika Ebhota, Joseph Isabona and Viranjay M. Srivastava
Department of Electronic Engineering, Howard College, University of KwaZulu-Natal,
Durban, South Africa

Abstract: In this contribution, the basic propagation loss models which consist of the Hata Model, COST 231 Hata Model, Walfisch-Ikegami Model and Lee Model have been investigated for proper planning of LTE networks in different radio signal propagation environments. Each of the models were studied and compared under the variation of Transmitter-Receiver (T-R) distance, heights of Mobile Station (MS) and Base Station (BS) antenna and transmitting frequency via. extensive computer simulations. The results indicate that path loss increases as the link distance increases due electromagnetic energy spreading and attenuation by different radio propagation mechanisms. As the operating frequency was increase from 1800-2600 MHz, the path loss also increases due to decrease in antenna aperture and decrease in radio signal wavelength. Moreover, we observed a noticeable reduction in path losses as both the transmitter antenna height and receiver antenna height were raised from from 30-70 m and from 1.5-5 m, respectively. Finally, as the receiving antenana height increases, path loss due building roof top to street diffraction reduces.

Key words: LTE network planning, path loss, propagation models, Hata Model, COST 231 Hata Model, Walfisch-Ikegami Model, Lee Model, computer simulations

INTRODUCTION

In wireless radio communication system networks, path loss models are specific mathematical algorithms and models for appraising the radio signal path attenuation loss and coverage area of a Base Station (BS) transmitter. Recent years has mark a rapid increase of number of mobile phones usage and demand for higher data rate by the mobile subscribers worlwide. According to the report by Smith *et al.* (1993), the number of mobile connected devices are expected to exceed the population of the world by the year 2020. The Fourth Generation (4G) mobile systems based on Long Term Evolution (LTE) radio access technology are currently being deployed by mobile network operators to meet the ever increasing subscriber traffic growth and demand for higher data rates. LTE is a wireless broadband technology with scalable bandwidth operation requirement and more complex spectrum arangements of 1.4, 3, 5, 10, 15 and 20 MHz (Talukder *et al*., 2013). It offers high speed for data access for mobile phones and may increase the speed and network capacity by the use of different radio interface. LTE technology is developed by 3rd Generation Partnership Project (3GPP) to meet the users requirement in the telecommunication industry (Ramkumar and Gunasekaran, 2013). LTE is developed to provide access to wider range of communication services which include advanced mobile services that is supported by mobile and fixed networks. With the development of Internet Protocol (IP), LTE is planned to provide support for IP based traffic with end-to-end Quality of Service (QOS). The system is designed to provide the peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink. LTE architecture consists of eNodeB which is evolved node B and User Equipment (UE) nodes. eNodeB acts as a Base Station (BS) and provides several functionalities such as Mobile Management Entity (MME), Radio Resources Management selections, scheduling, etc.

On the other hand, Radio Frequency (RF) network engineers are often confronted with the difficulties that come with a deployment of new technology. Thus, a new radio network interface technology like the LTE needs a different set of distinctive planning tools and algorithm for its effective deployment in different propagation terrains. Of vital importance to the LTE system network deployment is the ability to predict accurately the strength of radio signals from different transmitters in the system. The coverage planning of a cell is imperative in finding the best locations for base stations, so as to build continous coverage according to the planning

Corresponding Author: Virginia Chika Ebhota, Department of Electronic Engineering, Howard College, University of KwaZulu-Natal, Durban, South Africa

requirements. Path loss models are specific mathematical algorithms and models for appraising the radio signal path attenuation loss and coverage area of a Base Station (BS) transmitter. Path Loss (PL) prediction is an important element of system network design in any communication system. Path loss is the difference in Decibel (dB) between the transmitted power from the transmitter and the received power at the reciever. It represents the signal level attenuation as a result of free space propagation, reflection, diffraction and scattering (Pathania *et al.*, 2014). A reliable and accurate prediction model helps in optimizing the coverage area, transmitter power and also gets rid of interference problems of the radio transmitters. Appropriate models must therefore be selected for performance assessment of the field strength and path losss as well as other parameters. This helps the network engineers and planners in optimizing the coverage area and in using the correct transmitting powers. Path loss is also calculated to analyze the link establishment in the telecommunication system. Link establishment can be calculated to the gain and loss of the Transmitter (Tx)/Reciever (Rx) through air medium. In this reesearch, the basic propagation loss models which includes the Hata Model, COST 231 Hata Model, Walfisch-Ikegami Model and Lee Model have been investigated for proper planning of LTE networks in different radio signal propagation environments. Each of the models were studied and compared under the variation of Transmitter-Receiver (T-R) distance, heights of Mobile Station (MS) and Base Station (BS) antenna and transmitting frequency via. extensive computer simulations.

Research background

Propagation loss modelling: During radio wave propagation, signal undergoes various losses as a result of obstacles between the transmitter and the reciever. Considering the transmitter and reciever seperation, received signal power $P_r(d)$ is given as:

$$P_r(d)=\frac{P_tG_tG_r\lambda^2}{(4\pi)^2d^2L} \quad (1)$$

Where:

P_t = The transmitter power

G_t = The transmitter antenna gain

G_r = The receiver antenna gain

L = The system loss factor

d = The link distance between the transmitter and the reciever (m)

In logarithm form, the expression in Eq. 1 can be rewritten as follows:

$$\text{PL (dB)} = -\log_{10}\left[\frac{\lambda^2}{(4\lambda)^2d^2}\right] \quad (2)$$

In more general from, Eq. 2 can be expressed as Eq. 14:

$$\overline{\text{PL}}(\text{dB})=\overline{\text{PL}}\,(\text{d})+10\log_{10}(\frac{\text{d}}{\text{d}_0}) \quad (3)$$

Where:

$\overline{\text{PL}}(\text{dB})$ = Path loss exponent

d = The link distance between the transmitter and the receiver

d_0 = The close-in-reference distance

These are standard formulas used to derive the power gain, transmitter-receiver separation and path loss exponent that are embedded in the wireless technologies (Roslee and Kwan, 2010).

This study describes empirical path loss models used in this research. Simulation and comparison of these empirical models were carried out for urban and open areas.

MATERIALS AND METHODS

Hata Model: Hata Model is a developed version of Okumura model that is widely used for prediction of cellular transmission behavior in built up areas. It incorporates the graphical information from Okumura model developed further to realize the effects of reflection, diffraction and scattering caused by structures in urban, suburban and open areas. The model is considered applicable for; frequencies 150-1500 MHz, a distance of 1-20 km from the transmitter, transmitter antenna height ranging from 30-200 m and receiver antenna height ranging from 1-10 m (Singh, 2012).The models for urban, suburban and open areas can be expressed as:

$$\text{PL(dB)}=69.55+26.16\log_{10}f-13.82\log_{10}(h_t)-a(h_r)+(44.9-6.55\log_{10}h_t)\log_{10}d-K \quad (4)$$

Where:

f = Frequency (MHz)

d = Link distance

h_t = Height of the transmitter antenna

$a(h_r)$ = Correction factor for receiver antenna height defined as

$$a(h_r)=(1.1\log_{10}f-0.7)h_r-(1.56\log f-0.8)\text{dB} \quad (5)$$

For open, suburban and small area:

$$a(h_r)=8.29(\log_{10}1.54h_r)^2-1.1 \quad (6)$$

For f<300 MHz:

$$a(h_r) = 3.2(\log_{10} 11.75h_r)^2 - 4.97 \tag{7}$$

For f = 300 MHz for large area:

$$k = 4.78(\log_{10} f)^2 - 18.33\log_{10} f + 40.94 \tag{8}$$

For open area:

$$k = 2(\log_{10}(f)/28)^2 + 5.4 \tag{9}$$

For suburban area and k = 0 for both small and large areas.

COST 231 Hata Model: COST 231 Hata Model is an extension of urban Hata Model based on Okumura Model. This covers an elaborated frequency ranges from 1500-2000 MHz and is appropriate for urban areas with transmitter antenna height of 30-200 m, receiver antenna height of 1-10 m and a link distance of 1-20 km (Khan *et al*., 2012). The COST231 Hata Model for path loss is expressed as follows:

$$\begin{aligned} PL(dB) = {} & 46.3+33.9\log_{10}(f)-13.82\log_{10}(h_t)-ahr+ \\ & (44.9-6.55\log_{10}(h_t))\log_{10}(d)+c_m \end{aligned} \tag{10}$$

Where:

d = The link distance (km)

f = Frequency (MHz)

h_t = Height of transmitter antenna (m)

C_m = The correction parameter (0 dB for open and suburban areas and 3 dB for urban areas)

ah_r = Correction factor for receiver antenna height and is defined as

$$ah_r = 3.2(\log_{10}(11.75h_r))^2 - 4.79 \tag{11}$$

For f >400 MHz (for urban areas):

$$ah_r = (1.11\log_{10}(f)-0.7)h_r - (1.5\log_{10}(f)-0.8 \tag{12}$$

(For suburban and open areas) h_r = height of the receiver antenna (m)

CCIR Model: This is an empirical model which combines the effects of path loss due to free space and path loss generated by terrain. It is made available by CCIR (Comite' Consultatif Internationa, des Radio Communication also known as ITU-R) (Walter, 2006). The CCIR path loss is expressed as follows:

$$\begin{aligned} PL(dB) = {} & 69.55+26.16\log_{10} f-13.82\log_{10}(h_t)-a(h_r)+ \\ & (44.9-6.55\log_{10} h_t)\log_{10} d-B \end{aligned} \tag{13}$$

Where:

h_t = Height of the transmitter antenna (m)

h_r = Height of the receiver antenna (m)

d = The link distance (km)

f = Frequency (MHz)

$$ah_r = (1.1\log_{10} f-0.7)h_r - (1.56\log_{10} f-0.8) \tag{14}$$

% area of building coverage:

$$B = 30-25\log_{10} \tag{15}$$

Equation 12 is equation for Hata Model for suburban and open area propagation conditions, supplemented by correction factor B. B = 0 (for urban area with building coverage of up to 15%):

$$B = 30-25\log_{10} 20 = 2.5\text{ dB} \tag{16}$$

(for 20% building coverage in urban area) CCIR differs from Hata Model in two ways; the effect of coverage area and receiver antenna height.

Walfisch-Ikegami Model: Walfisch-Ikegami (WIM) Model has been shown to be appropriate for measured propagation data between 800-2000 MHz frequencies and a distance of up to 5 km (Seybold, 2005). WIM differentiates between Line of Sight (LOS) and Non Line of Sight (NLOS) propagation scenario. For LOS where the transmitter antenna height is above 30 m with no obstruction between the transmitter and the receiver, the WIM path loss is expressed as:

$$PL(dB) = 42.64+26\log_{10} d+20\log_{10} f \tag{17}$$

Where:

f = Frequency (MHz)

d = Link distance

In NLOS scenario, WIM is more complex but has the ability to stand for more environment and in absence of measurement data, building height (m) may be estimated three times the floor number in addition to 3 m if roof top is pitched instead of being flat. WIM for NLOS fits well for transmitter antenna that is above roof height. WIM for NLOS path loss is expressed as; For urban and suburban area, $L_{rts}+L_{msd}>0$:

$$PL_{NLOS} = \begin{cases} L_{FSL} + L_{rts} + Lmsd \\ L_{FS} \end{cases} \quad (18)$$

Where:

L_{FSL} = Free space path loss
L_{rts} = Roof top to street diffraction
L_{msd} = Multi-screen diffraction loss

$$L_{FSL} = 32.45\_ + 20\log_{10} d + 20\log_{10} f \quad (19)$$

$$L_{rts} = -16 - 10\log_{10}(w) + 10\log_{10} f + 20\log_{10}(\Delta h_r) + L_{ori} \quad (20)$$

$$L_{ori} = -10 + 0.354\ \phi \text{ for } 0 \leq \phi < 35 \quad (21)$$

$$L_{ori} = 2.5 + 0.075(\phi - 35) \text{ for } 35 \leq \phi < 55 \quad (22)$$

$$L_{ori} = 4 - 0.114(\phi - 55) \text{ for } 55 \leq \phi \leq 90 \quad (23)$$

Where; $\phi h_r = h_{roof} - h_r$ and $\phi h_{base} = h_{base} - h_{roof}$

$$L_{msd} = L_{bsh} + k_a + k_d + \log_{10} d + k_f \log_{10} f - 9\log_{10} f - 9\log_{10}(B),\ L_{msd} > 0,\ L_{msd} < 0 \quad (24)$$

$$L_{bsh} = -18\log_{10}(1 + \Delta h_{base}) \text{ for } h_{base} > h_{roof} \quad (25)$$

$$L_{bsh} = o\ h_{base} \leq h_{roof} \quad (26)$$

$$k_a = 54 \text{ for } h_{base} > h_{roof} \quad (27)$$

$$k_a = 54 - 0.8\Delta h_{base} \text{ for } d \geq 0.5\text{km and } h_{base} \leq h_{roof} \quad (28)$$

$$k_a = 54 - 0.8\Delta h_{base}\left(\frac{d}{0.5}\right) \text{ for } d < 0.5\text{km and } h_{base} \leq h_{roof} \quad (29)$$

$$k_d = 18 \text{for } h_{base} > h_{roof} \quad (30)$$

$$k_d = 18 - 15\left(\frac{\Delta h_{base}}{h_{roof}}\right) \text{for } h_{base} \leq h_{roof} \quad (31)$$

$$k_f = -4 + 0.7\left(\frac{f}{925} - 1\right) \quad (32)$$

For suburban area with moderate tree density:

$$k_f = -4 + 1.5\left(\frac{f}{925} - 1\right) \text{ (for urban area)} \quad (33)$$

Where:

d = The link distance
f = Frequency (GHz)
B = Distance between buildings (m)
w = Street width (m)
ϕ = Street orientation

RESULTS AND DISCUSSION

The simulation parameters applied in our study are presented in Table 1. The influence of link distance between the transmitter and the receiver, operating frequency, transmitter antenna height and receiver antenna height were considered for path loss in urban and open area.

Pathloss model perforamce in urban areas: Different simulations were carried out for path loss in urban area at different link distances (1 and 4 km) and varied operating frequency, transmitter and receiver antenna heights, respectively.

Different simulation were carried out for path loss in urban area at different operating frequency (1800-1900 and 2600 MHz) and varied link distances, transmitter and receiver antenna heights, respectively.

Different simulations were carried out for path loss in urban area at different transmitter antenna height (30, 40, 50, 60, 70 m) and varied link distances, receiver antenna heights and operating frequency, respectively.

Different simulations were carried out for path loss in urban area at different receiver antenna height (1.5, 3 and 5 m) and varied link distance, transmitter antenna height and operating frequency.

Analysis of simulation result of urban area

Influence of link distance between the transmitter and the receiver: The results presented in Fig. 1-4 show that path loss increases with increase in distance between the transmitter and the receiver. This is due to electromagnetic energy spreading out in the free space as explained by the inverse square law where:

$$S = P_t \frac{1}{4\pi d^2} \quad (34)$$

Table 1: Simulation parameters

Parameters	Values
Operating frequency (MHz)	1800, 1900, 2600
Transmitter antenna height (ht) (m)	30, 40, 50, 60, 70
Receiver antenna height (hr) (m)	1.5, 3, 5
Building height (hb) (m)	15
Building separation (m)	5
Street width (m)	20
Street orientation angle (degree)	30 for urban area, 40 for suburban area
LTE cell link distance (km)	1, 2, 3, 4, 5

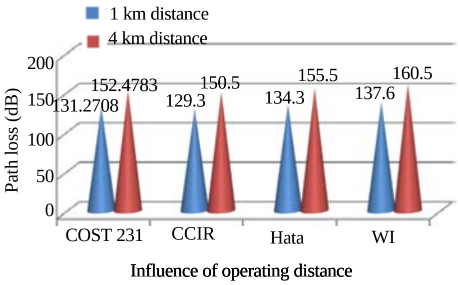

Fig. 1: Performance of the path loss models in urban area at 1 and 4 km link distances, 1800 MHz operating frequency, 30 m transmitter antenna height and 1.5m receiver antenna height

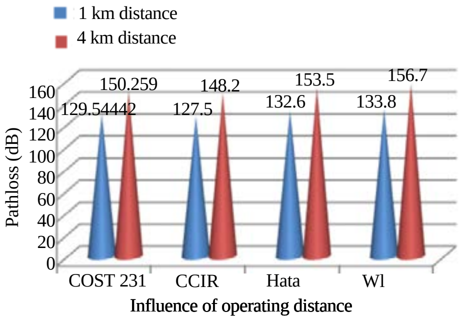

Fig. 2: Performance of THE path loss models in urban area at 1 and 4 km link distances, 1800 MHz operating frequency, 40 m transmitter antenna height and 1.5 m receiver antenna height

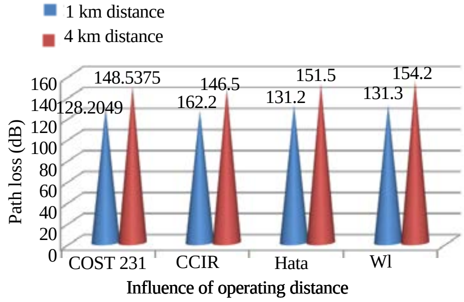

Fig. 3: Performance of the path loss models in urban area at 1 and 4 km link distances, 1800 MHz operating frequency, 50 m transmitter antenna height and 1.5 m receiver antenna height

Where:

S = Power per unit area
d = Distance
P_t = Corresponding isotopically radiated power

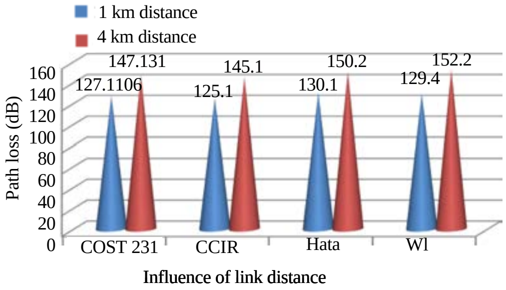

Fig. 4: Performance of the path loss models in urban area at 1 and 4 km link distances, 1800 MHz operating frequency, 60 m transmitter antenna height and 1.5 m receiver antenna height

CCIR Model in both distances (1 and 4 km) for varied operating frequency and transmitter antenna height gave the lowest path loss prediction values and Walfisch-Ikegami Model gave the highest path loss prediction values. Illustrating from Fig. 1, CCIR Model at distance of 1 km gave path loss value of 129.30 dB and at distance of 4 km, the path loss value is 150.50 dB. COST 231 Model gave 131.27 dB at 1km distance and 152.48 dB at 4 km distance, Hata Model recorded 134.30 dB at distance of 1 and 155.50 km at distance of 4 km. Wafisch-Ikegami Model gave the highest path loss value of 137.60 dB at 1km distance and 160.50 dB at 4 km distance. A difference of 21.2 dB was recorded by CCIR model as path loss as distance increases from 1km to 4 km and Walfish-Ikegami Model recorded a difference of 22.9 dB. The same trend was observed as the transmitter antenna height increases to 40-60 m as shown in Fig. 2-4.

Influence of operating frequency: As a result of change in the operating frequency from 1800-2600 MHz, an increase in path loss was observed as shown in Fig. 5-8. Frequency dependency of path loss is as a result of frequency dependency of the receiver antenna's aperture where there is fixed antenna gain. How well power from an electromagnetic wave is picked up by antenna is determined by the antenna aperture. As frequency increases, the need to ensure that the receiver antenna gain is intact leads to less energy capture by the antenna which results to increase path loss. From Fig. 5, it is seen that the lowest path loss was recorded by the four models at 1800 MHz operating frequency and the highest path loss at 2600 MHz operating frequency. CCIR Model gave the lowest path loss as 129.30 dB at 1800 MHz, 129.90 dB at 1900 MHz and 133.40 dB at 2600 MHz. COST 231 Model gave 131.27 dB at 1800 MHz, 133.07 at 1900 MHz and 136.68 at 2600 MHz. At 1800 MHz, Hata Model gave 134.0, 134.9 dB at 1900 and 135.5 MHz at 2600 MHz.

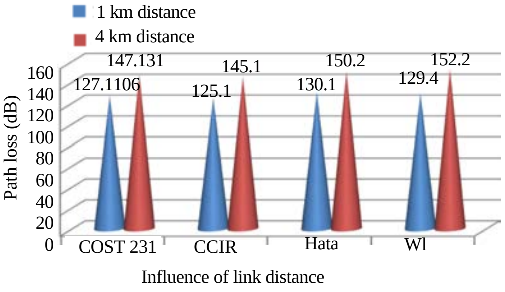

Fig. 5: Performance of the Path loss models in urban area at 1 km link distance, 30 m transmitter and 1.5 m receiver antenna height

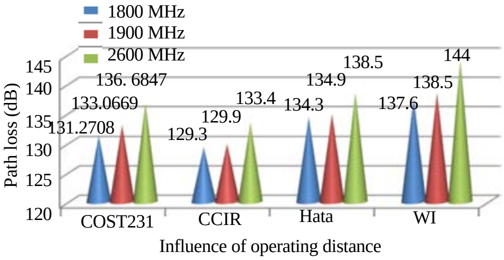

Fig. 6: A comparison of the influence of different operating frequency on path loss in urban area at 4 km link distance, 30 m transmitter and 1.5 m receiver antenna height

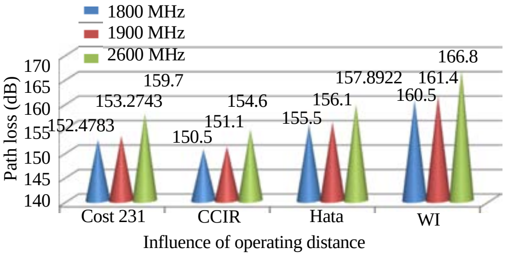

Fig. 7: A comparison of the influence of different operating frequency on path loss in urban area at 1km link distance, 50 m transmitter and 3 m receiver antenna height

Walfisch-Ikegami Model showed the highest path loss with 137.60 dB at 1800 MHz, 138.5 dB at 1900 MHz and 144 dB at 2600 MHz. Similar, trend was also observed in Fig. 6-8, as the operating frequency increases from 1800-2600 MHz.

Influence of transmitter antenna height: Figure 9-12 showed a decrease in path loss as the transmitter antenna height increases. The lowest path loss was recorded by all the four models at 70 m transmitter antenna height and the highest path loss was at 30 m transmitter height. The height of the transmitter antenna is the foundation of base station coverage area. It has been demonstrated by the use of plane earth model that when the antenna height is doubled, it results to 6 dB gain (Lee, 1982). Increase of antenna height result to progressive extension of the distance at which the path loss starts. Illustrating with

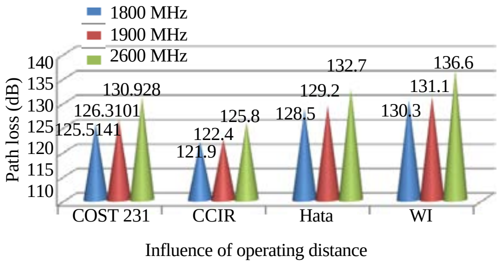

Fig. 8: A comparison of the influence of different operating frequency on path loss in urban area at 4 km link distance, 50 m transmitter and 3m receiver antenna height

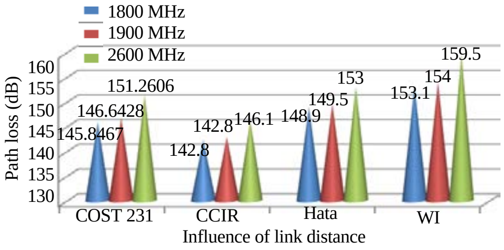

Fig. 9: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in urban area at 1 km link distance, 1.5 m receiver antenna height and 1800 MHz operating frequency

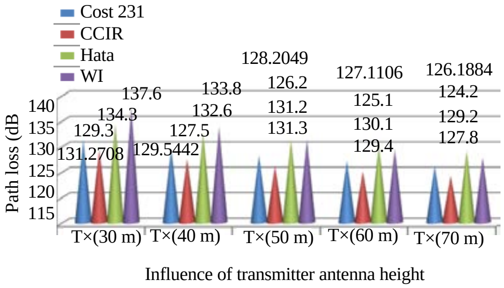

Fig. 10: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in urban area at 4 km link distance, 1.5 m receiver antenna height and 1800 MHz operating frequency

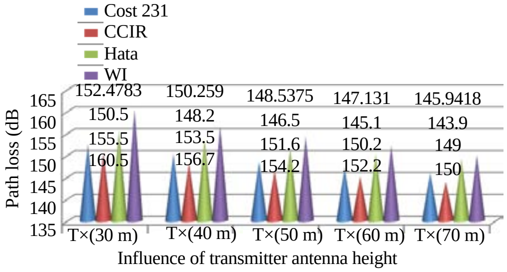

Fig. 11: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in urban area at 1 km link distance, 1.5 m receiver antenna height and 2600 MHz operating frequency

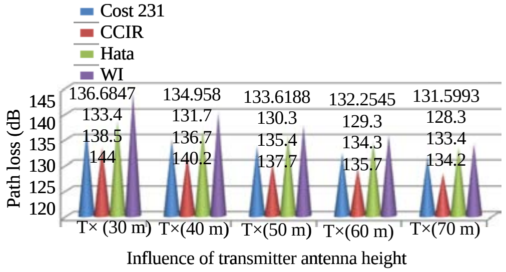

Fig. 12: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in urban area at 4 km link distance, 1.5 m receiver antenna height and 2600 MHz operating frequency

Fig. 9, CCIR Model gave the least path loss as 129.30 dB at 30 m, 127.50 dB at 40 m, 126.20 dB at 50 m, 125.10 dB at 60 m and 124.20 dB at 70 m transmitter antenna heights. COST 231 Model gave 131.27 dB at 30 m, 129.54 dB at 40 m, 128.20 dB at 50 m, 127.11 dB at 60 m and 126.19 dB at 70 m transmitter antenna heights. Hata Model gave 134.30 dB at 30 m, 132.6 dB at 40 m, 131.20 dB at 50m, 130.10 dB at 60 m and 129.20 dBat 70 m transmitter antenna heights. Walfisch-Ikegami Model gave the highest path loss as 137.6 dB at 30 m, 133.80 dB at 40 m, 131.30 dB at 50 m, 129.40 dB at 60 m and 127.80 dB at 70 m transmitter antenna heights. Figure 10-12 also follows similar trend.

Influence of receiver antenna height: At varied link distance, operating frequency and transmitter antenna height, we observed that path loss decreases with increase in the receiver antenna height as shown in Fig. 13-16 for all the four considered models. This is because the loss as a result of rooftop to street diffraction is expected to reduce at higher receiving antenna height.

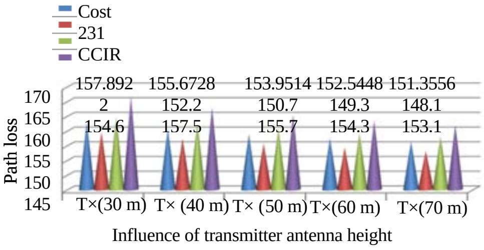

Fig. 13: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in urban area at 1km link distance, 30m receiver antenna height and 1800 MHz operating frequency

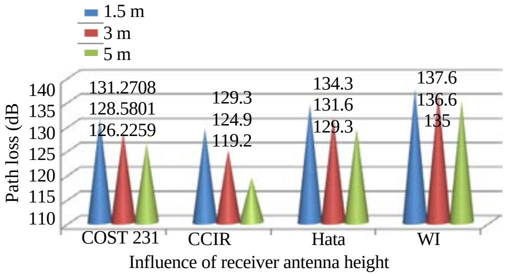

Fig. 14: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in urban area at 4km link distance, 30 m receiver antenna height and 1800 MHz operating frequency

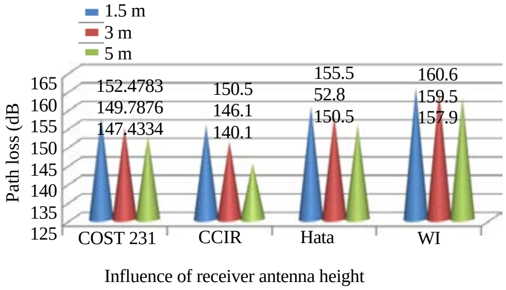

Fig. 15: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in urban area at 1km link distance, 30 m receiver antenna height and 1900 MHz operating frequency

From Fig. 13, CCIR Model gave the lowest path loss prediction values as 129.30 dB at 1.5 m, 124.90 dB at 3 m and 119.2 dB at 5 m receiver antenna heights. COST 231 Model gave 131.27 dB at 1.5 m, 128.58 at 3 m and 126.23 dB at 5 m receiver antenna heights. Hata Model gave 134.30 dB at 1.5 m, 131.6 dB at 3 m and 129.30 dB at 5 m receiver antenna heights. Walfisch-Ikegami gave the highest path loss values as 137.60 dB at 1.5 m, 136.60 dB at 3 m and 135 dB at 5 m receiver antenna heights. The same trend was observed in Fig. 14-16.

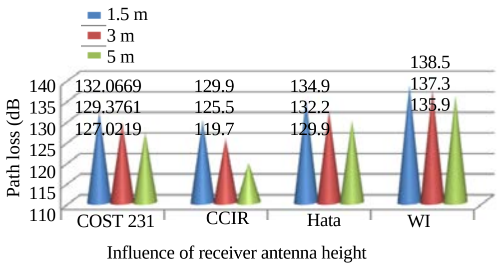

Fig. 16: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in urban area at 4 km link distance, 30 m receiver antenna height and 1900 MHz operating frequency

Pathloss Model perforamce open area: Different simulations were carried out for path loss in open area at different link distances (1 and 4 km) and varied operating frequency, transmitter and receiver antenna heights, respectively.

Different simulations were carried out for path loss in open area at different operating frequency (1800, 1900 and 2600 MHz) and varied link distances, transmitter and receiver antenna heights, respectively.

Different simulations were carried out for path loss in open area at different transmitter antenna heights (30, 40, 50, 60, 70 m) and varied link distances, receiver antenna heights and operating frequency.

Different simulations were carried out for path loss in open area at different receiver antenna heights (1.5, 3 and 5 m) and varied link distances, transmitter antenna height and operating frequency.

Analysis of simulation results in open area

Influence of link distance between the transmitter and the receiver: Figure 17-20 showed a increase in path loss as the distance between the transmitter and the receiver increases due to electromagnetic energy spreading out in the free space. Hata Model in both distances (1 and 4 km) for varied operating frequency and transmitter antenna heights gave the lowest path loss prediction values and Walfisch-Ikegami Model gave the highest path loss prediction values. Illustrating with Fig. 17, Hata Model gave 102.30 dB at 1 km distance, 123.50 dB at 4 km distance while Walfisch-Ikegami Model gave 137.60 dB at 1 km distance and 160.50 dB at 4 km distance. CCIR Model gave 129.30 dB at 1 km distance and 150.50 dB at 4 km distance while COST 231 Model gave 127.64 dB at 1 km distance and 148.85dB at 4km distance. Figure 18-20 follow similar trend. The huge different in changing effect in Hata prediction values for urban and open areas shows the suitability of Hata Model for open area path loss prediction than urban area.

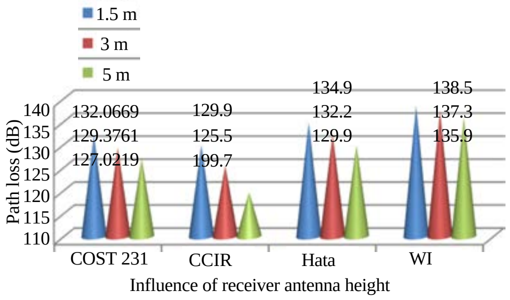

Fig. 17: Performance of the path loss models in open area at 1 and 4 km link distances, 1800 MHz operating frequency, 30 m transmitter antenna height and 1.5 m receiver antenna height

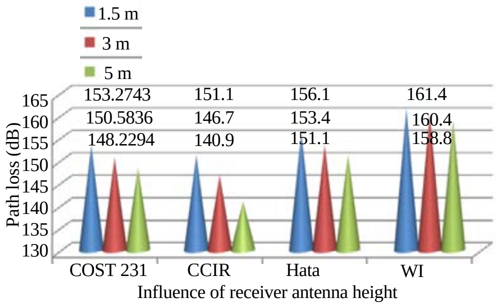

Fig. 18: Performance of the path loss models in open area at 1 and 4 km link distances, 1800 MHz operating frequency, 40 m transmitter antenna height and 1.5 m receiver antenna height

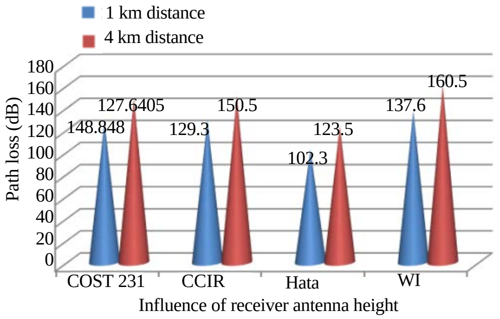

Fig. 19: Performance of the path loss models in open area at 1 and 4 km link distances, 1800 MHz operating frequency, 50 m transmitter antenna height and 1.5 m receiver antenna height

Influence of operating frequency: Path loss increases with increase in operating frequency as recorded by the four models in Fig. 21-24. This is as a result of frequency dependency of the receiver antenna's aperture where there is fixed antenna gain. From Fig. 21, Hata Model gave the lowest path loss prediction values as 102.30 dB at 1800, 102.60 at 1900 and 104.30 at 2600 MHz. COST 231 Model gave 127.64 dB at 1800 MHz, 128.36 dB at 1900 MHz and 132.54 dB at 2600 MHz while CCIR

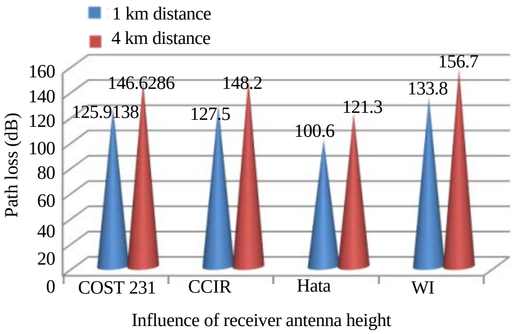

Fig. 20: Performance of the path loss models in open area at 1 and 4 km link distances, 1800 MHz operating frequency, 60 m transmitter antenna height and 1.5 m receiver antenna height

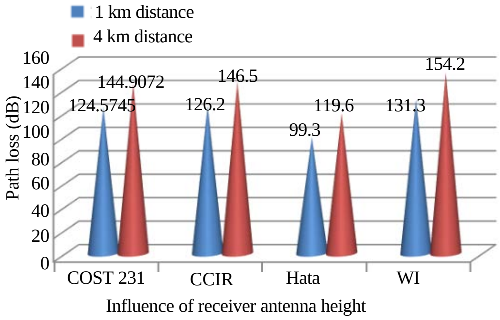

Fig. 21: A comparison of the influence of different operating frequency on path loss in open area at 1km link distance, 30 m transmitter and 1.5 m receiver antenna height

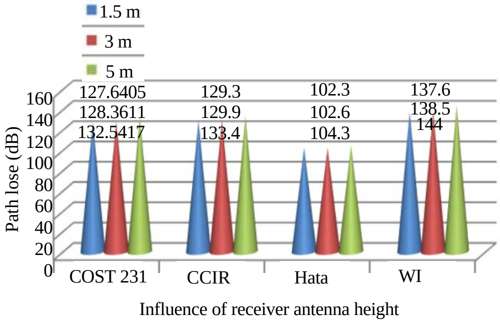

Fig. 22: A comparison of the influence of different operating frequency on path loss in open area at 4 km link distance, 30 m transmitter and 1.5 m receiver antenna height

Model gave 129.30 dB at 1800 MHz, 129.90 dB at 1900 and 133.40 at 2600 MHz. Walfisch-Ikegami gave the highest path loss value as 137.6 dB at 1800 MHz, 138.50 dB at 1900 MHz and 144 dB at 2600 MHz. Similar trend was observed in Fig. 22-24.The effect of change in frequency is more remarkable from 1900- 2600 MHz in all the models where loss is increased by 5.5 dB in Walfisch-Ikegami Model, 3.5 dB in CCIR Model, 4.2 dB in COST 231 Model and 1.7 dB in Hata Model.

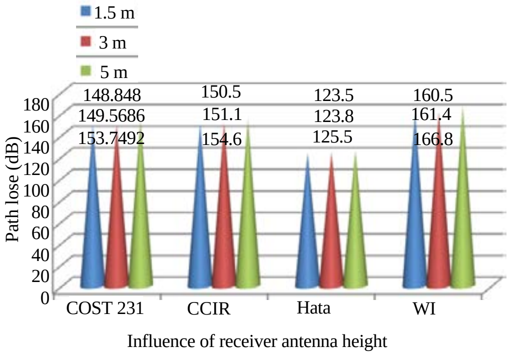

Fig. 23: A comparison of the influence of different operating frequency on path loss in open area at 1km link distance, 50 m transmitter and 3 m receiver antenna height

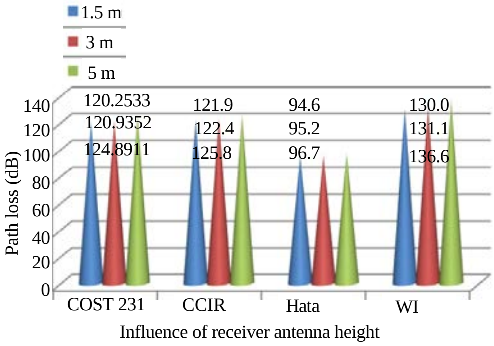

Fig. 24: A comparison of the influence of different operating frequency on path loss in an open area at 4 km link distance, 50 m transmitter and 3 m receiver antenna height

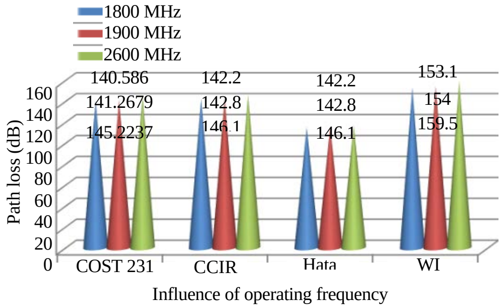

Fig. 25: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in open area at 1 km link distance, 1.5 m receiver antenna height and 1800 MHz operating frequency

Influence of transmitter antenna height: Figur 25-28 showed a decrease in path loss as the transmitter antenna height increases in all varied link distances, operating frequency and receiver antenna heights. From Fig. 25, Hata Model gave the lowest path loss prediction value as 102.30 dB at 30 m, 100.60 dB at 40 m, 99.30 dB at 50 m, 98.20 dB at 60 m and 97.20 dB at 70 m transmitter antenna heights. Walfisch-Ikegami Model gave the highest path loss prediction value as 137.60 dB at 30 m, 133.80 dB at 40 m, 131.30 dB at 50 m, 129.40 dB at 60 m and 127.80 dB at 70 m transmitter antenna heights. COST 231 Model gave 127.64 dB at 30 m, 125.91 dB at 40 m, 124.57 dB at 50 m, 123.48 dB at 60 m and 122.56 dB at 70m while CCIR Model gave 129.30 dB at 30 m, 127.50 dB at 40 m, 126.20 dB at 50 m, 125.10 dB at 60 m and 124.20 dB at 70 m transmitter antenna heights. Figure 26-28 also show the same trend as path loss decreases with the increase in the transmitter antenna height.

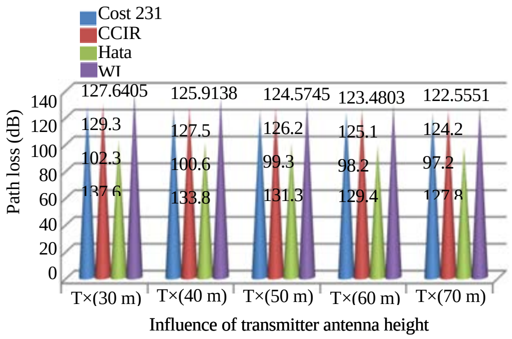

Fig. 26: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in open area at 4 km link distance, 1.5 m receiver antenna height and 1800 MHz operating frequency

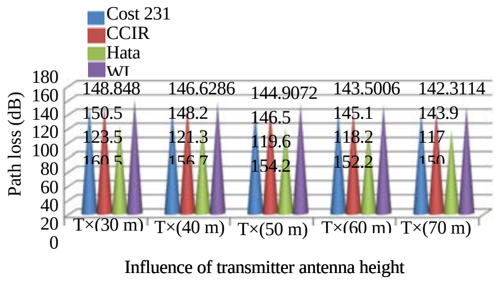

Fig. 27: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in open area at 1km link distance, 1.5 m receiver antenna height and 2600 MHz operating frequency

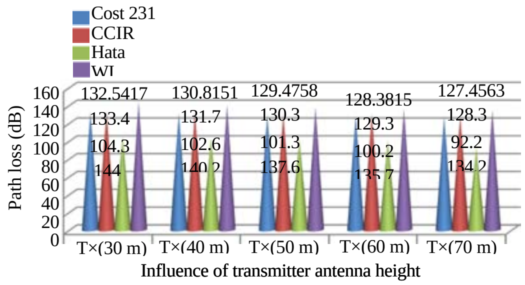

Fig. 28: A comparison of the influence of transmitter antenna height (30, 40, 50, 60 and 70 m) on path loss in open area at 4 km link distance, 1.5 m receiver antenna height and 2600 MHz operating frequency

Influence of receiver antenna height: Figure 29-32 showed a decrease in path loss as the receiver antenna height increases. This is because of reduction in the loss

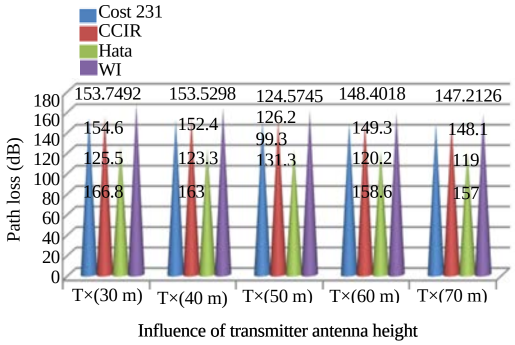

Fig. 29: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in open area at 1 km link distance, 30 m receiver antenna height and 1800 MHz operating frequency

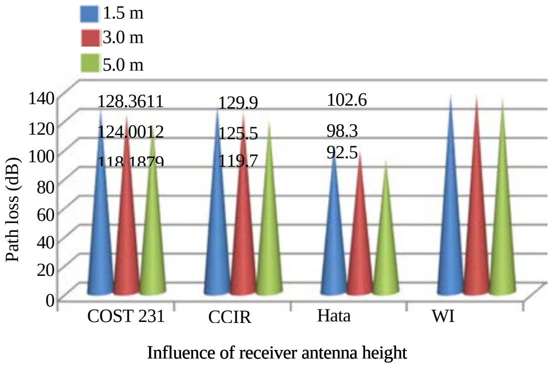

Fig. 30: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in open area at 4 km link distance, 30 m receiver antenna height and 1800 MHz operating frequency

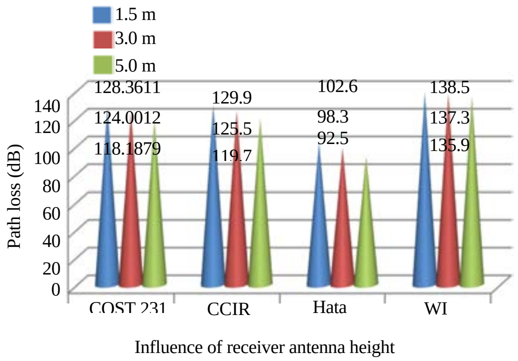

Fig. 31: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in open area at 1 km link distance, 30 m receiver antenna height and 1900 MHz operating frequency

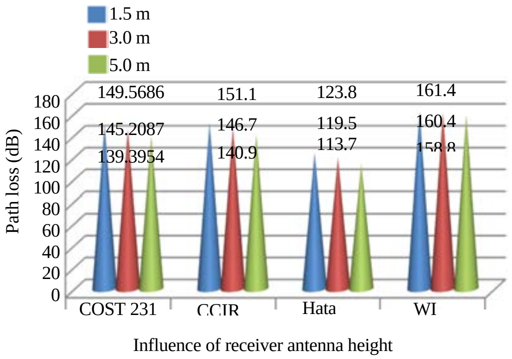

Fig. 32: A comparison of the influence of receiver antenna height (1.5, 3 and 5 m) on path loss in an open area at 4 km link distance, 30 m receiver antenna height and 1900 MHz operating frequency

due rooftop to street diffraction as the receiver antenna height increases. In Fig. 29, Hata Model gave the lowest path loss as 102.30 dB at 1.5 m, 98 dB at 3 m and 93.20 dB at 5 m receiver antenna heights while Walfisch-Ikegami Model gave the highest path loss prediction value as 137.60 dB at 1.5 m, 136.6 dB at 3 m and 135 dB at 5 m receiver antenna heights. COST 231 Model gave 127.64 dB at 1.5 m, 123.31 dB at 3 m and 117.56 dB at 5 m receiver antenna height while CCIR Model gave 129.30 at 1.5, 124.90 dB at 3 m and 119.20 dB at 5 m receiver antenna heights. The same trend is observed in Fig. 30-32 where path loss reduces as the receiver antenna height increases.

CONCLUSION

In this research, four basic large scale radio signal propagation loss models which includes Hata Model, COST 231 Hata Model, Walfisch-Ikegami Model and Lee Model have been studied and analyzed via simulation to aid effective LTE network planning. The simulation and analyses were performed to find out the impact of varying MS antenna height, BS antenna height and the T-R separation on LTE radio network deployment in urban, suburban and open areas. In urban area, CCIR model showed the lowest path loss at different distance operating frequencies, different transmitter and receiver antenna heights while Walfisch-Ikegami Model gave the highest path loss. Also, the least path loss was recorded by the four considered path loss models at 1800MHz operating frequency while at 2600 MHz operating frequency, path loss increased rapidly. In open area, Hata Model showed the least path loss at different distance variations, different operating frequencies and different transmitter and receiver antenna heights while Walfisch-Ikegami Model showed the highest path loss. CCIR fitted in more among other considered path loss models for prediction of path loss in urban area while Hata Model shows superiority over other considered models for path loss prediction in open area. However, no particular path loss model showed superiority over other models in both urban and open area at all simulated propagation conditions.

REFERENCES

Khan, I., T.C. Eng and S.A. Kamboh, 2012. Performance analysis of various path loss models for wireless network in different environments. Intl. J. Eng. Adv. Technol., 2: 161-165.

Lee, W.C., 1982. Mobile Communications Engineering. 2nd Edn., McGraw-Hill Professional, New York, USA., Pages: 371.

Pathania, P., P. Kumar and B.S. Rana, 2014. Performance evaluation of different path loss models for broadcasting applications. Am. J. Eng. Res., 3: 335-342.

Ramkumar, J. and R. Gunasekaran, 2013. A new path loss model for LTE network to address propagation delay. Intl. J. Comput. Commun. Eng., 2: 413-416.

Roslee, M.B. and K.F. Kwan, 2010. Optimization of Hata propagation prediction model in suburban area in Malaysia. Prog. Electromagnet. Res. C., 13: 91-106.

Seybold, J.S., 2005. Introduction to RF Propagation. John Wiley & Sons, Hoboken, New Jersey, USA., Pages: 329.

Singh, Y., 2012. Comparison of okumura, hata and COST-231 models on the basis of path loss and signal strength. Intl. J. Compu. Appl., 59: 37-41.

Smith, R.P., D. Li, D.W. Francis, J. Chappuis and A.W. Neumann, 1993. Experimental study of the relationship between the free energy of Adhesion and the repulsive force between a particle and a solidification front. J. Colloid Interface Sci., 157: 478-484.

Talukder, Z.H., S.S. Islam, D. Mahjabeen, A. Ahmed and S. Rafique *et al.*, 2013. Cell coverage evaluation for LTE and WiMAX in wireless communication system. World Appl. Sci. J., 22: 1486-1491.

Walter, D., 2006. RF Path Loss & Transmission Distance Calculations. Technical Memorandum, Alaska, USA.,.