Journal of Applied Engineering, Technology and Management (JAETM)

ANALYSIS ON PREDICTION OF PATH LOSS FOR MOBILE NETWORK IN JNEC, DEWATHANG AT 1800 MHz

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Abstract— As the mobile cellular subscription is constantly increasing, the demand for good network and data traffic, remains to be high. In order to achieve that, proper network planning is important to enhance reliable mobile network and optimization. Path loss modelling is extensively used in the initial feasibility studies for the proper deployment of telecommunication. Prediction of path loss helps to indicates the field strength of the radio propagation. Path loss is the weakening of signal strength during propagation and can be determined by using different models. Largely affected by the complex terrain, buildings, trees, generally, the path loss is caused by reflection, refraction and diffraction. The evaluation is performed at 1800 MHz frequency which is the operating band of Long-Term Evolution (LTE) 4G network service in the region. A comparative study is done between different types of path loss models used in LTE networks in MATLAB. Analysis of path loss for irregular terrain in the region is also being simulated using Radio-mobile. With this study, a person can predict the mobile signal quality and a proper network can be planned.

Keywords—Pathloss, LTE network, Radio propagation, Diffraction, Terrain

I. INTRODUCTION

Every year the number of mobile users, data traffics and wireless telecommunication services are increasing, which leads to an increase in desire for next-generation services by mobile users. The number of mobile devices are expected to surpass the population of the world as reported in [1]. Therefore, there has always been a need for a communication system that can tackle such growth. To overcome the demands of mobile subscribers, there is a rapid need for proper network coverage prediction.

Long Term Evolution (LTE) was one system to provide a higher data rate for an ever-increasing population. One of the advanced features of LTE called Relaying can be used to enhance efficiency through increasing capacity, extending cell coverage and throughput [2-5]. Relays would be the cost-efficient solution to replace base stations in the future. The successful deployment of relay stations requires an understanding of cellular coverage and prediction of path loss in the network. For this reason, engineers need to rely on propagation models, estimation of signal strength and need to have knowledge on path loss between the base station and a relay. The prediction for a good network coverage is limited by the environmental conditions and these lead to the evaluation of overall network quality for a good efficient and reliable coverage [3, 6-9]. It also enables the planning of transmitted power and quality of service [10]. It is impossible to avoid the effect of path loss in mobile communication.

When an electromagnetic signal propagates through space from transmitter to receiver, there is a decrease in the received power of these signals. The decreasing of the received power of a signal is called path loss [2-7]. There are many phenomena like absorption, scattering, coupling cable loss, refraction, diffraction and reflection, which affect path loss. Reflection is the change in the direction of a wave when there is a mismatch between materials through which the wave is travelling. Attenuation is caused when the energy is absorbed or propagated through the medium. Diffraction occurs when there is bending of radio waves around the edges of an object. The amount of bending depends on the wavelength of the light and the size of the opening. The bending will be negligible when the opening is much greater than the wavelength of light. Scattering is a process when the waves hit the rough surfaces, the moving particle is forced to deviate. It occurs due to structural inhomogeneities, compositional fluctuations and non-uniformities [3-4, 11]. Apart from these, path loss also depends on environment landscape, weather conditions, transmitter-receiver distance and height of the antenna. These processes lead to a multipath effect in which there may be two or more paths for a signal to reach the destination [10-11]. It can cause constructive and destructive interference and phase shifting, depending on the increase or decrease of the resultant signal level.

In Bhutan, there was a significant increase in demand for mobile data. Telecommunication company Bhutan Telecom (BT) launched LTE in Thimphu on October 24, 2013. 4G service operates in 1800Mhz with Frequency Division Duplex (FDD) technology [12]. This is the most widely used band in Southeast Asian countries in which smartphones are readily available in the region [13]. There is an exponential number of people using mobile data and accessible to 4G technologies, in the small country of Bhutan. BT started 4G services through 70 sites in Thimphu, Paro, Wangdue Phodrang, Punakha and Phuentsholing [14]. After that, the service was provided to other dzongkhags. Before 4G service came to Samdrup Jongkhar, there was a problem with the B-mobile network. Officials said that the increasing number of users caused the network problem [15].

II. PROPAGATION PATH LOSS MODELS

The propagation path loss models can be broadly categorized into empirical and deterministic [4]. In deterministic models, the received signal is determined using the electromagnetic wave propagation theories. It can be more accurate as it often uses the 3-D map of the environment. It requires detailed information about the locations and dimensions for every obstacle [9, 11]. Obstacles can be trees, buildings and mountains. The extent of the coverage area is to be determined instead of the location covered by the network designer. So, this way is more complex. Empirical models are those based on observations and measurements. It is not as accurate as compared to deterministic [6]. There can be many factors like terrain profiles, frequency, antenna heights and received signal strength which affect the propagation of the signal. In empirical, these parameters are used by taking statistical considerations to calculate the path loss. The empirical method can be used to replicate similar environmental conditions by taking original measurements [1-9].

2.1 Free space model

The free space propagation model is an ideal scenario whereby the channel has no obstacles. The propagated wave transmits without reflection, absorption and refraction [1, 5]. It is a basic path loss model which is used as a reference. Assuming the signal is radiated in 360° with a fixed power in all directions, the power flux transmitted can be:

$$P_t = P_d . 4\pi d^2 \tag{1}$$

where P_d is the power at a distance d from antenna and P_t is the transmitted power. Power received P_r by the antenna can be calculated using power density, a wavelength of received signal λ and antenna aperture A_e.

 ISSN (PRINT): 2707-4978 & (ONLINE): 2789-0848

$$A_e = \frac{\lambda^2}{4\pi} \quad (2)$$

$$P_r = P_d . A_e \quad (3)$$

Substituting equations (1) and (2) in equation (3).

$$P_r = \frac{P_t . \lambda^2}{(4\pi d)^2} \quad (4)$$

Loss can be calculated from transmitted and received power:

$$L_p = P_t - P_r \quad (5)$$

Substituting equations (1) and (4) in equation (5) and re-arranging:

$$L_p(dB) = 20log_{10}4\pi + 20log_{10}d - 20log_{10}\lambda \quad (6)$$

2.2 SUI model

The Stanford University Interim (SUI) model was developed in 2007 under IEEE802.16 wireless access group. The correction factors were available for the model. It can be used for the frequency of 1.9Ghz, base station height between 10m to 80m and mobile station height range from 2m to 10m. Three most common terrain types can be used in this model [2, 3, 16]:

A. Hilly terrain with moderate to heavy tree densities and maximum path loss.
B. Hilly terrain with light tree density or mostly flat with modest to heavy tree density and moderate path loss.
C. Mostly flat with light trees density and have less path loss.

The equation for SUI model is as follows:

$$PL_{SUI} = A + 10\gamma \log\left(\frac{d * 1000}{d_o'}\right) + \Delta PL_f + \Delta PL_h \quad (7)$$

where $d > d_o$, d is the distance between the transmitter and receiver in [m] and $d_o = 100[m]$.

$$A = 20\log\left(\frac{4\pi d_o'}{\lambda}\right) \quad (8)$$

$$d_o' = d_o 10^{-\left(\frac{\Delta PL_f + \Delta PL_h}{10\gamma}\right)} \quad (9)$$

$$\gamma = a - bh_b + \frac{c}{h_b} \quad (10)$$

$$\Delta PL_f[dB] = 6\log\left(\frac{2000}{f}\right) \quad (11)$$

$$\Delta PL_h[dB] = -10\log\left(\frac{h_r}{3}\right) for\ h_r \leq 3 \quad (12)$$

where f is the operating frequency in Mhz, γ is the path loss exponent, h_r is the receiving antenna height in m, h_b is the transmitting antenna height in m, $\Delta PL_f[dB]$ is the correction factor for frequency and $\Delta PL_h[dB]$ is the correction factor for receiving antenna height. *a, b* and *c* are constants and they depend on the terrain type as given in Table 01.

2.3 COST 231-Hata model

It is the modification of Hata model and COST 231 projects (European cooperation of scientific and technical research). This model was applicable from 1.5 to 2Ghz. The path loss depends on the frequency, distance, height of the receiver and transmitter antenna. Its application of correction factors for different terrain,

Table 01: Parameter for Terrain type A/B/C [2].

Model parameter	**Terrain A**	**Terrain B**	**Terrain C**
a	4.6	4	3.6
b $[m^{-1}]$	0.0075	0.0065	0.005
c $[m]$	12.6	17.1	20

makes it one of the most used path loss prediction methods [1-3, 17]. The COST Hata equation is given by:

$$PL_{COST\ 231-HATA} = A + B\log(d) + C_m - a(h_r) \quad (13)$$

$$A = 43.3 + 33.9\log(f) - 13.83\log(h_b) \quad (14)$$

$$B = 44.9 - 6.55Log(h_b) \quad (15)$$

For small to medium cities:

$$a(h_r) = (1.1\log(f) - 0.7)h_r - (1.56\log(f) - 0.8) \quad (16)$$

where *f* is the frequency in MHz, h_b is the transmitter antenna height and h_r the receiver antenna height in m, *d* is the distance between the transmitter-receiver in Km and a(h_r) is receiver antenna height correction factor. C_m is the correction factor. It is 0 dB for the suburban area and 3 dB for the metropolitan area.

2.4 Lee model

It became popular because the parameters were easily adjustable to the environment with the help of added calibration field measurements. Hence, more accuracy could be achieved with this model. The operating frequency was extended up to 2Ghz [2, 13, 18, 19]. The Lee model path loss equations were given as:

$$PL_{Lee} = PL_O + mlog\left(\frac{d}{d_o}\right) - H_T + H_R \quad (17)$$

(18)

$$H_T = 15\log\left(\frac{h_t}{h_{tref}}\right)$$

$$H_R = 10\log\left(\frac{h_r}{h_{rref}}\right) \quad (19)$$

PL_O = Path loss reference at distance d_o in [dB]

$$PL_O(f) = PL_o(f_o) + 20\log\left(\frac{f}{f_o}\right) \quad (20)$$

where m is Slope in m [dB/decade], d is transmitter-receiver separation in m, d_o is the reference distance in km [$d_o = 1.609km$], h_t is transmitter antenna height in m, h_{tref} is reference transmitter antenna height in m, h_r is receiver antenna height in m and h_{rref} is reference receiver antenna height in m. Slope 'm' values are given in Table 02 and it remains the same for all frequencies which are different than the reference frequency f_o.

Table 02: Intercept and slope values for different environments for Lee model [2]

Terrain types	**PL_o[dB] @ f_o = 900Hz**	**m [db/decade]**
Open area	95	43.5
Sub-urban	107.7	38.4
Urban	116	36.8

2.5 Knife-edge diffraction model

The model is a combination of two ray path loss and knife-edge diffraction losses. It considers irregular terrain where the transmitting and receiving antenna is located at different hill heights. An obstruction between antennas blocks the line-of-sight (LOS) path. An obstruction can be a mountain, hill, trees, building and tower. Depending on the number of obstructions, the number of edge diffraction can be considered. In this paper, we have considered only single knife-edge diffraction. The obstructed object height tends to increase as the distance increases [7, 20]. For these sorts of irregular terrain, the path loss in JNEC campus is calculated using Radio mobile software. With the help of the software, latitude, longitude, ground elevation, the distance between stations, losses can be known.

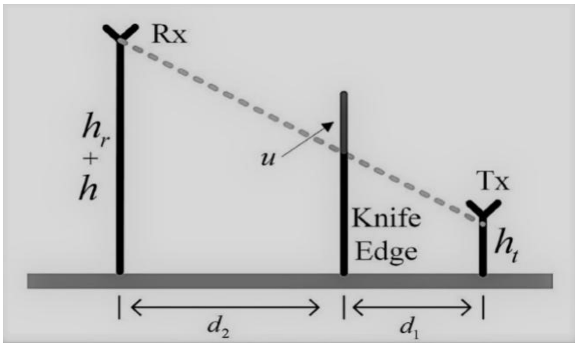

Figure 01: Knife-edge diffraction model

The formula to calculate path loss for the irregular terrain [7] is given as;

$$PL = 40log_{10}(d) - 20log_{10}(h_t) - 20log_{10}(h_r + h) + 20log_{10}\left(\left|\frac{\sqrt{2}}{2}\int_v^{\infty} e^{-j(\frac{\pi}{2})t^2} dt\right|\right), \quad (21)$$

$$v = u\sqrt{\frac{2(d_1 + d_2)}{\lambda d_1 d_2}}, \tag{22}$$

$$h = (h_t + g_t) - g_r \tag{23}$$

where, as shown in Figure 01, d is the distance between the transmitting antenna and the receiving antenna, h_t is the height of the base station, h_r is the height of receiving antenna, h is the hill height of transmitting antennas, v is knife-edge diffraction loss, h_t is transmitter ground elevation, g_t is the transmitting antenna ground elevation and g_r is receiving antenna ground elevation. To calculate the height of the hills, the difference between the two-ground elevation needs to be considered [7].

III. RESULTS AND DISCUSSION

Comparative analysis was done for different path loss models at 1800 Mhz. In the first case, the distance between the antennas is varied for the fixed base station height. In the second case, base station height is varied for constant distance. In case three, the path loss is calculated with the consideration of irregular terrain. Following Table 03 shows the simulation parameters used to calculate the different path loss shown in Table 04.

Table 03: Simulation Parameters

Parameters	Values
Height of transmitting antenna (BS)	37 m
Height of receiving antenna (mobile)	1.5 m
Operating frequency	1800 Mhz
Distance between transmitting and receiving antennas.	1.5 km
Environment	Suburban
Terrain type	Terrain B
City type	Medium city

Table 04: Path loss values at a different distance

Distance [km]	Path loss [dB]			
	SUI model	COST 231-hata model	LEE model	Free space model
0.2	276.9	313.6	20.9	176.5
0.3	284.4	319.7	27.66	186.1
0.6	297.1	330.1	39.22	192.1
0.9	304.5	336.2	45.98	195.6
1.2	309.8	340.5	50.78	198.1
1.5	313.9	343.9	54.5	200.1

3.1 Variation of T-R distance keeping fixed base station height

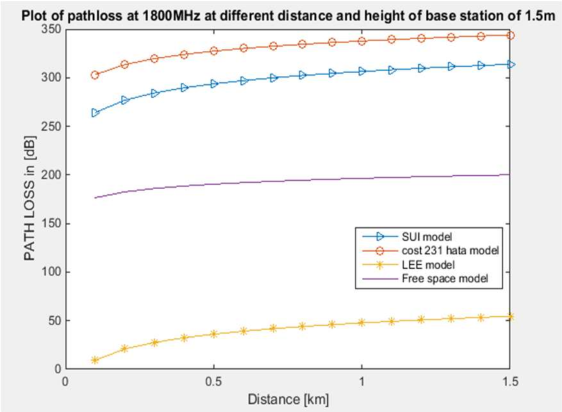

Figure 02: Path loss performance

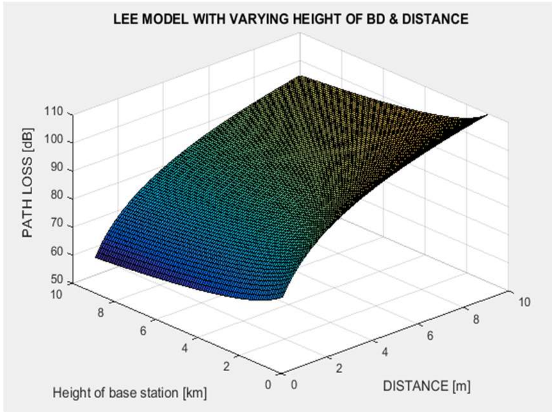

Figure 03: Mesh plot of Lee model

From Figure 02, it is being observed that there is a clear trend of increase in the path loss as the distance between the transmitting and receiving antenna is increased. From the graph it is showing that Lee model has the lowest path loss values among all other models. However, in Lee model the type of the terrains is not considered. For JNEC, suburban terrain is appropriate considering its hilly terrain with light tree densities. Hence. this makes SUI model more appropriate for the prediction of path loss in JNEC with its moderate path loss values.

3.2 Variation of base station height keeping fixed T-R distance

From figure 03, 04 and 05, it is showing that there is a clear trend of decreasing path loss values when the height of the transmitting antenna is increased. Among the three graphs, it is clear that in SUI model, the path loss reduces steeply with raising height of antenna compared to another model. The other models including Lee and COST 231-hata model, the path loss decreases gradually with increasing base station.

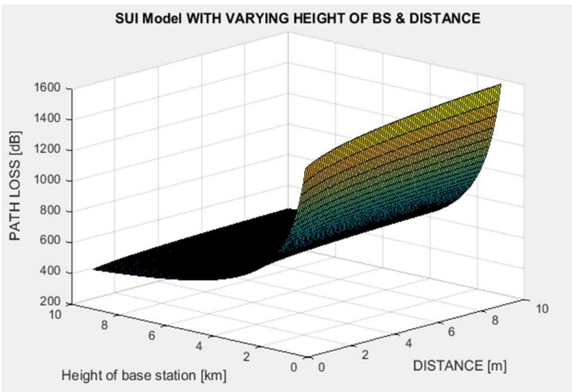

Figure 04: Mesh plot of SUI model

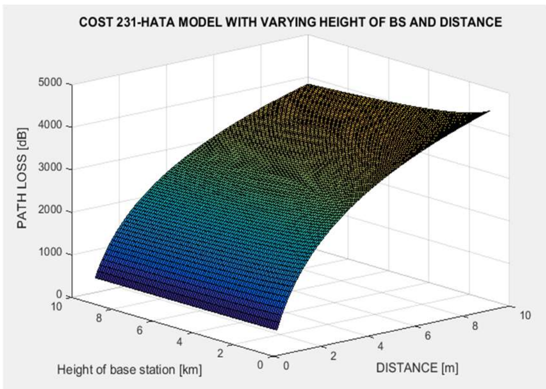

Figure 05: Mesh plot of COST-231 Hata model

Table 05: Path loss values at different height of transmitter

Height of base station [m]	Path loss [dB]		
	SUI model	Cost 231 Hata model	LEE model
10	399.8	352.4	63.02
20	344.1	347.9	58.5
30	323.1	345.3	55.86
40	310.7	343.4	53.99
50	301.7	341.9	52.54

3.3 Consideration of irregular terrain

Comparing Figure 07 and 08, it's observed that the path loss decreases gradually at the receiver placed at self-catering hostel whereas the path loss decreases abruptly when the receiver is placed at IT building. The main reason behind it is that the distance between the base station and receiver station at IT building is more than the receiver station placed at self-catering where more the distance, it consists more of trees and building in between making the signal lose its strength due to signal diffraction and fading.

Figure 06: GPS map of JNEC campus

From the calculation, we observed that the path loss is inversely proportional to the obstructed height above the LOS for the irregular land pattern. The path loss has been calculated for five different locations between the base station and receiving station. IT building and self-catering hostel of JNEC campus were found to have maximum and minimum path loss respectively.

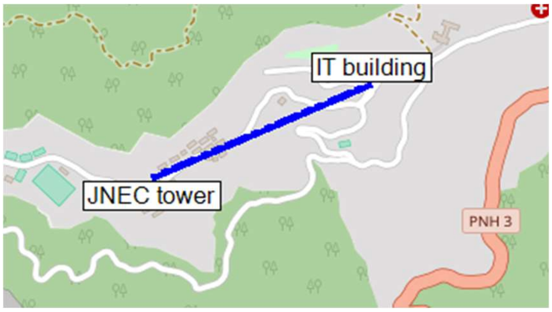

Figure 07: Shows the open street map of IT building (JNEC)

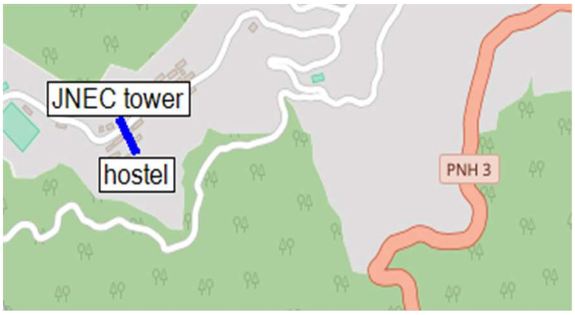

Figure 08: Shows the open street map of self catering block (JNEC)

Table 06: Calculated path loss for different areas in JNEC

Locations	**Receiver ground elevation[m]**	**Transmitter ground elevation[m]**	**Hill height [m]**	**Distance [m]**	**Path loss [dB]**
IT block	852.7	884.2	68.5	695	67.42
ECE building	873.3	884.2	47.9	305	47.9
Administration block	859.1	884.2	62.1	630	66.56
Self-catering block	870.1	884.2	51.1	100	36.28
Sports complex	883.7	884.2	37.5	253	55.1

IV. CONCLUSION

The comparison between the various models including SUI model, COST 231-hata model and LEE model were done at the operating frequency of 1800MHz. Among these models, SUI model was found appropriate for the prediction of path loss in JNEC campus. This path loss was calculated without the consideration of the terrain profile and geographical parameters. For the irregular terrains, with the help of Radio mobile software, the path loss is predicted accordingly for the different receiving mobile stations which include IT building, ECE block, self-catering hostel, sports complex and administration block. Impact of rain, multipath effect, ground elevation and humid conditions can be considered for the study in the future.

REFERENCES

[1] E. Ubom, V. E. Idigo, A. Azubogu, C.O. Ohaneme and A. Leonard, “Path loss Characterization of Wireless Propagation for South – South Region of Nigeria,” International Journal of Computer Theory and Engineering, vol. 3, no. 3, pp. 360-364, June 2011.

[2] M. Hamid and I. Kostanic, “Path loss model for LTE and LTE-A Relay Stations,” Universal Journal of Communication and Network, vol. 1 (4), pp. 119-126, December 2013.

[3] A. Zreikat, and M. Dordevic, “Performance Analysis of Path loss Prediction Models in Wireless Mobile Networks in Different Propagation Environments,” Proceesings of Third World Congress on Electrical Engineering and Computer Systems and Science (EECSS'17) Rome, Italy, pp. 103-110, June 2017.

[4] C. Levis, J. T. Johnson and F. Teizeira, "Radio wave propagation physics and application," 1st ed., Wiley, 2003.

[5] K. Mella, "Theory, Simulation and Measurement of Wireless Multipath Fading Channels," Norwegian University of Science and Technology, pp. 04-18, May 2007. [Online]. Available: https://researchpapers4scolars.files.wordpress.com/2015/06/masteroppgave.pdf

[6] E. Ercceg and K. V. S. Hari, "An empirical based path loss model for wireless channel in sub urban environment", IEEE Journal of selected area in communication, vol. 17, pp. 1205-1212, 1999.

[7] J. Zang, and X. Wang, "Measurements and Modeling of Path Loss over Irregular Terrain for Near-Ground and Short-Range Communications," Progress in Electromagnetic Research M, vol. 57, pp. 55-62, 2017

[8] N. Gerald and Ezeagwu, "Path loss Prediction for GSM Mobile Networks for Urban Region of ABA, South-East Nigeria," International Journal of Computer Science and Mobile Computing, Vol.3, Issue 2, February 2014.

[9] A. Adeyemi, A. Oluwadamilola, A. Aderemi and I. Francis "A Performance Review of the Different Path Loss Models for LTE Network Planning," Proceedings of the World Congress on Engineering, vol. 1, July 2014. [Online]. Available: 10.13140/2.1.4654.5283.

[10] I. Joseph and C. C. Konyeha, "Urban Area Path loss Propagation Prediction and Optimization," IOSR Journal of Applied Physics, vol. 3, issue 4, pp. 08-18, March 2013.

[11] S. A. Mawjoud, "Path Loss Propagation Model Prediction for GSM Network Planning," International Journal of Computer Applications, vol. 8, no. 7, 2013.

[12] Bhutan Telecom Limited, "2G/3G/4G (LTE)," [Online]. Available: https://www.bt.bt/bt-services/2g-3g-4g-lte/

[13] D. Tshomo, "BT launches 4G in five dzongkhags", Kuensel, 2017 [Online]. Available: https://kuenselonline.com/bt-launches-4g-in-five-dzongkhags/

[14] K. Wangchuk, "BT launches 4G services in 16 dzongkhags," Kuensel, 2017. [Online]. Available: https://kuenselonline.com/bt-launches-4g-services-in-16-dzongkhags/

[15] N. Shabbir, M. T. Sadiq, H. Kashif and R. Ullah, "Comparison of Radio Propagation models for LTE network," International Journal of Next-Generation Networks, vol.3, no.3, pp. 27-41, Sep.2011.

[16] J. Biebuma and B. Omijeh, "Path loss model using GIS," International Journal of Engineering and Technology, vol. 3, no.3, pp. 269-275, March 2013.

[17] M. Nisirat, S. Alkhawaldeh, M. Ismail and L. Nissirat, "Hata based propagation loss formula using terrain criterion for 1800 MHz," International journal of Electronics and Communications, Page 855-859, March 2012.

[18] H. K. Hoomod, I. Al-Mejibli and A. I. Jabboory, "Analyzing Study of Path loss Propagation Models in Wireless Communications at 0.8 GHz," Journal of Physics: Conference Series, 2018.

[19] M. Ekpenyong J. Isabona and E. Ekong, "On Propagation Path Loss Models For 3-G Based Wireless Networks: A Comparative Analysis," Georgian Electronic Scientific Journal: Computer Science and Telecommunications, no. 2, pp. 74-84, 2010.

[20] P. Pathania, P. Kumar and S. Rana, "Performance Evaluation of different Path loss models for broadcasting applications," American Journal of Engineering Research, vol. 03, issue 04, pp-335-342, 2014.