Journal of Energy Technology and Environment Vol. 3(4) 2021 pp. 42-52 ISSN-2682-583x

NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

# Performance Evaluation of Pathloss Prediction of Wireless Mobile Network

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**Article Information**

*Article history:*
*Received 04 October 2021*
*Revised 12 October 2021*
*Accepted 20 October 2021*
*Available online 29 Dec. 2021*

*Keywords: Path loss,*
*TEM software,*
*signal strength,*
*COST-231 Hata model.*

https://doi.org/10.37933/nipes.e/3.4.2021.5

**https://nipesjournals.org.ng**


**Abstract**

*This paper presents path loss analysis and computer simulation in selected environments in Akwa Ibom State. The research work was carried out in four environments namely; dense-urban, urban, sub-urban, and non-urban environments. Measurements of path loss were carried out through drive test using TEMS Software. COST231 Hata model was chosen as a reference model because of its peculiarity which makes it useful for predicting signal strength in all environments. It operates with a frequency range that extended to 2100 MHz with a signal strength prediction of up to 10km from the transmitter to the receiver. The system acquired antenna height requirement of 30m to 200m for the transmitter and antenna height of 1m to 10m for the receiver. COST231 Hata model was modified to form a new optimized model. The result obtained shows that the optimized model was found to predict a better path loss with RMSE values of 2.70dB, 1.60dB, 3.12dB, 5.62dB for 2G-900MHz, 2.66dB, 2.70dB, 4.83dB, 5.08dB for 2G-1800MHz and 4.04dB, 2.43dB, 4.48dB, 6.25dB for 3G-2100MHz respectively. In conclusion, it was observed that the RMSE values obtained from the optimized model was lower than those obtained from the predicting model and at the same time, it meets the 6dB standard of the prediction model.*

## 1. Introduction

Path loss is a significant parameter in the investigation and structure of a radio communication system and it is an indispensable job in the remote communication at network level. Path loss or path constriction is an undesirable acquaintance of energy tending to meddle with the best possible gathering and proliferation of the signs during its excursion from transmitter to receiver. The strength of electromagnetic wave diminishes as it engenders through space and this occurs because of losses in path [1]. In wireless communication, the transmitted signal by the electromagnetic waves to receiver suffered from propagation [2]. The signal radiated by a transmitter can also travel along many different paths to a receiver simultaneously. This effect is called multipath. Multipath waves are combined at the receiver antenna. The difference of signal strength from transmitter to receiver antenna is termed as Path Loss (PL). PL at destination is generally determined by the use of different models i.e., stochastic, deterministic and empirical [3]. In remote communication, the losses happened in the middle of transmitter and beneficiary is known as spread path loss. Path loss is the undesirable decrease in power signal which is transmitted. Path loss can be measured in various zone like rural/non-urban, urban, suburban and dense urban with the assistance of proliferation path loss models. Remote communications give great data exchange between versatile gadgets found any place on the planet [4].

Propagation models can be classified mainly into two types namely, fully empirical models and deterministic models. There are some models which have the characteristics of both types. These are known as semi-empirical models, empirical models are based on practically measured data. Since few parameters are used, these models are simple but not very accurate [5]. Some models are categorized as empirical models for macro cellular environment. These include Hata model, Okumura model, and COST-231 Hata model. Extended COST231 Hata model has been approved by the European Cooperation in the field of the scientific and Technical research (COST) to represent higher frequencies [6].

The essential goal of any Global System for Mobile Communication (GSM) service provider is to provide excellent services to her subscribers, which might be impeded by many effects like reflection, refraction, diffraction, scattering and absorption. This introduces path loss to radio communication between the Base Transceiver Station (BTS) of the provider and the mobile unit (MU) of the subscriber. It becomes imperative to constantly investigate and model this path loss which is affected by landscape forms, condition (urban or rural, vegetation and foliage), propagation medium (dry or clammy air), the separation between the transmitter and the receiver and area of antennas [7].

Wireless communication technology is influencing every area of modern life and has encouraged useful researches in nearly all fields of human endeavor. Cellular services are today being used by millions of people worldwide. The growing need for excellent performance of wireless infrastructure, high data rate transmission has resulted in the investigation of propagation mechanisms of higher-order frequencies, with enormous prospects in increasing data rate with respect to higher bandwidth [8]. The gradual loss in power density of an electromagnetic wave as it propagates from the source to the receiver is a problem to network providers. For cellular network to effectively cover a terrain or environment, accurate prediction of the coverage of the radio frequency signal is highly needed. Wave propagation models are essential and very important tools in determining the propagation characteristics for a particular environment [9].

To combat wireless channel deficiencies such as poor signal quality, blocked calls, dropped calls and interference problem during conversation, this prompted the study of path loss as one of the possible causes of these problems and also provided models for prediction purposes. Path loss prediction estimation provides an approximation used for the development of models that predicts the signal strength of any given terrain [10].

High data rate transmission has resulted in the investigation of propagation of higher order frequencies and bandwidth. Integration also poses a major challenge in network planning, pilot pollution analysis, implementation and cell parameter evaluation. This paper evaluates path loss prediction of wireless mobile networks in different propagation environments in Akwa Ibom State.

## 2. Methodology

The materials that were used to carry out the drive test in this paper are TEMS Mobiles phones (W995), Global Positioning System (GPS), Test Sims, TEMS software Version 13, Mapinfo software version, Excel Software, MATLAB Simulink, Power Inverters and Laptops.

The investigated areas of study were divided into four environments namely Non-Urban/rural (Obot-Akara) with Longitude 7.6500 and Latitude 5.2667, Suburban (Ikot Ekpene) with Longitude 7.7148 and Latitude 5.1819, Urban (Eket) with Longitude 7.9537 and Latitude 4.63664 and Dense-Urban (Uyo) with Longitude 7.9127 and Latitude 5.037740, respectively. The method adopted for data collection was drive test approach using the TEMS investigation software.

The path loss was evaluated with the use of COST-231 Hata Model [11] and the model was adjusted to obtain an optimized model that was used in these environments. The drive test was accompanied with a portable vehicle furnished with drive testing equipment. This hardware was concentrated with electronic gadgets that interfaces with mobile handsets with SIMs of MTN network provider. All the components (GPS, TEMs, Phones) except the dongle were connected appropriately to the laptop through the Hub to take simultaneous reading in both idle and active mode. The laptop power cord was connected to the car supported inverter for constant electricity supply and the dongle was connected to the laptop through one of its Universal Serial Bus ports. The dongle connected to the laptop gave a license to the TEMS interface on the system and also allowed the accessibility of GPS readings on TEMS interface. However, the next step was to launch the TEMS and the investigation immediately while the cab moves at a speed of not more that 40km/h.

The encrypted voice in the TEMS helped to notifies the technician if there was any changes in the call setup or disconnection. After the successful connection of these tools, the next step was to get the car moving and the drive test commences its operation. The drive testing lasted for one hour and thirty minutes for each of the 12 sites in each environment investigated. Measurements were taken twice in a day for a period of one year and the mean average values of the received signal strength was obtained for analysis.

### 2.1 COST231 Hata Model

COST231 Hata Model is a model that is widely used for predicting path loss in mobile wireless system. The model is designed to be used in the frequency band from 600MHz to 2100MHz and it contains corrections for Urban (UR), Suburban (SU), dense Urban (DU) and rural/non urban (NU) environments. The extended COST231 Hata model uses a propagation equation which is divided into two terms. A first term has a logarithmic dependence on distance, *d*, while a second term is independent of distance. It also includes adjustments to the basic equation to account for Urban, suburban, dense-urban and rural propagation losses.

The general propagation loss in $dB$ is shown in Equation (1).

$$Lp = 46.30 + 33.9 * \log(f) - 13.82 * \log(hm) - a(hm) + (44.9 - 6.55 * \log(hb)) * Cm \quad (1)$$

Where,

$Lp$ is a propagation loss in environment of type $p$, in $dB$ (0: Urban, 1: Suburban, 2: Dense-Urban, 3: Rural).

*f* is the frequency of the transmission in MHz.

hm is the height of the mobile or receiver in meters (1-10m).

*hb* is the height of the base station or transmitter in meters (30-200m).

*d* is the distance between the receiver and the transmitter in kilometers (1-20km).

*a(hm)* is a mobile antenna correction factor which is different for each environment.

Cm is the correction factor which has different value for each environment.

The range of value for the validity of Hata model is:

$$150 \leq f \leq 1500MHz, 30 \leq hb \leq 200m, 1 \leq hm \leq 10m \text{ and } 1 \leq d \leq 20km.$$

Therefore, the values of the height of the mobile and the height of the base station are fixed within the given ranges for the sake of comparison.

Extended COST231 Hata for Urban environment is given in Equation (2).

$$a(hm) = (1.1 * \log(f) - 0.7) * (hm) - (1.56 * \log(f) - 0.8)dB \quad (2)$$

and Cm = 0.

Extended COST231 Hata for Suburban environment is given in Equation (3).

$$L_1 = L_0 - 2(\log\left(\frac{f}{28}\right))^2 - 5.4 \quad (3)$$

Where,

$$a(hm) = (1.1 * \log(f) - 0.7) * (hm) - (1.56 * \log(f) - 0.8)dB \quad (4)$$

and *Cm* = 1.

Extended COST231 Hata for dense-urban environment is given in Equation (5).

$$a(hm) = (3.2 * (\log(11.75 * \mathrm{hm})^2 - 4.97)\mathrm{dB} \quad (5)$$

and *Cm*=3. Extended COST231 Hata for rural environment is given in Equation (6).

$$L_3 = L_0 - 4.78 * (\log(f))^2 + 18.33 * \log(f) - 40.94 \quad (6)$$

(source) [12]

Figure 1 shows the flowchart for the drive test.

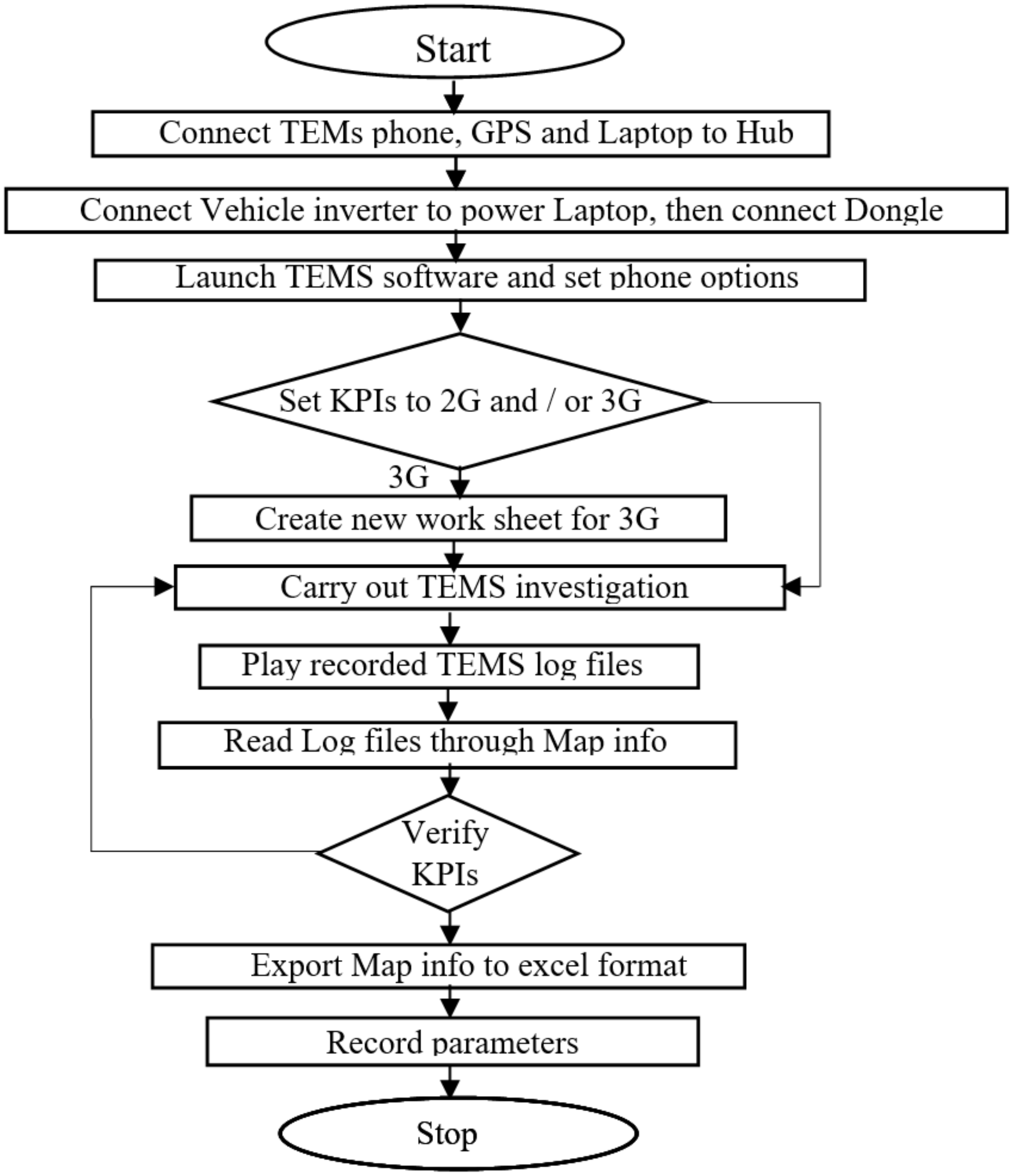


Figure 1: Flow chart for the Drive Test

## 3. Results and Discussion

### 3.1 Results

The results obtained from the experiment was analysed using MATLAB. The field measurements were compared with the model predictions from four different environment namely rural/non-urban, suburban, urban and dense-urban.

Table 1indicates the average path loss in 2G-900MHz for the four different environments.

Table 2 shows the average path loss in 2G-1800MHz for the same environments.

Table 3 reveals the average path loss in 3G-2100MHz for four predictions environments.

Table 4 showed the average path loss in 2G-900MHz using optimized model.

Table 5 also reveals the average path loss in 2G-1800MHz using the same optimized model.

Table 6 reveals the average path loss in 3G-2100MHz with the same optimized model.
Table 7 showed the Root Mean Square Error using Optimized Path loss model.
The results of this study revealed that the COST231 Hata model showed a satisfactory performance in the chosen environments based on its RMSE values shown in Table 7 and it was discovered that the Received Signal Strength (RSS) decreases with distance, the power received decreases with the log of distance and Path loss also increases with frequency. This indicate that 3G network experience more path loss than 2G network and Path loss increases from Non-Urban to Sub-Urban to Urban and Dense- Urban, respectively.

**Table 1:** Average Path loss in 2G-900 MHz

| MONTH | Non-Urban | Suburban | Urban | Dense Urban |
|---|---|---|---|---|
| JANUARY | -76.65 | -82.95 | -86.95 | -70.15 |
| FEBRUARY | -77.30 | -86.20 | -88.20 | -69.80 |
| MARCH | -75.10 | -82.30 | -85.35 | -72.45 |
| APRIL | -76.45 | -81.45 | -84.40 | -72.25 |
| MAY | -77.00 | -81.80 | -83.65 | -70.85 |
| JUNE | -75.80 | -85.50 | -87.15 | -72.30 |
| JULY | -75.60 | -79.05 | -86.75 | -72.30 |
| AUGUST | -76.35 | -84.45 | -84.00 | -71.40 |
| SEPTEMBER | -76.30 | -87.25 | -86.50 | -72.15 |
| OCTOBER | -77.40 | -84.95 | -87.80 | -72.05 |
| NOVEMBER | -78.25 | -85.25 | -82.70 | -72.75 |
| DECEMBER | -83.40 | -87.00 | -87.50 | -82.00 |

**Table 2:** Average Path loss for 2G-1800 MHz

| MONTH | Non-Urban | Suburban | Urban | Dense Urban |
|---|---|---|---|---|
| JANUARY | -91.35 | -91.45 | -90.85 | -93.00 |
| FEBRUARY | 92.05 | -96.05 | -94.25 | -90.85 |
| MARCH | -77.05 | -78.35 | -79.75 | -81.45 |
| APRIL | -88.25 | -85.95 | -80.60 | -86.15 |
| MAY | -96.00 | -93.80 | -102.15 | -93.50 |
| JUNE | -86.15 | -83.60 | -84.24 | -83.95 |
| JULY | -83.30 | -81.20 | -85.30 | -78.40 |
| AUGUST | -81.65 | -81.55 | -85.25 | -84.40 |
| SEPTEMBER | -82.20 | -79.80 | -82.80 | -85.90 |
| OCTOBER | -85.00 | -76.10 | -82.45 | -80.05 |
| NOVEMBER | -72.55 | -75.65 | -73.65 | -77.40 |
| DECEMBER | -77.00 | -73.95 | -79.75 | -80.20 |

**Table 3:** Average Path loss for 3G-2100 MHz

| MONTH | Non-Urban | Suburban | Urban | Dense-Urban |
|---|---|---|---|---|
| JANUARY | -93.00 | -82.55 | -93.00 | -91.60 |
| FEBRUARY | -77.35 | -88.85 | -89.25 | -71.85 |
| MARCH | -75.10 | -87.45 | -89.20 | -72.20 |
| APRIL | -76.45 | -87.25 | -88.05 | -72.55 |
| MAY | -77.00 | -89.40 | -90.75 | -70.85 |
| JUNE | -75.30 | -85.60 | -85.65 | -72.05 |
| JULY | -77.65 | -86.15 | -90.55 | -72.30 |
| AUGUST | -76.40 | -87.10 | -90.75 | -71.45 |
| SEPTEMBER | -76.30 | -87.15 | -88.10 | -72.15 |

| | | | | |
|---|---|---|---|---|
| OCTOBERR | -77.80 | -89.70 | -87.55 | -72.45 |
| NOVEMBER | -78.55 | -88.85 | -91.45 | -72.85 |
| DECEMBER | -87.25 | -87.10 | -87.40 | -88.00 |

**Table 4:** Average Optimized Path loss for 2G-900 MHz

| Distance | Non-Urban | Sub-Urban | Urban | Dense-Urban |
|---|---|---|---|---|
| 0.50 | -42.67 | -51.92 | -52.08 | -42.42 |
| 1.00 | -45.08 | -54.00 | -55.08 | -43.42 |
| 1.50 | -51.58 | -58.08 | -61.58 | -46.17 |
| 2.00 | -54.67 | -62.58 | -66.17 | -51.42 |
| 2.50 | -61.75 | -67.67 | -72.33 | -52.58 |
| 3.00 | -63.50 | -70.17 | -74.17 | -55.33 |
| 3.50 | -64.92 | -74.50 | -77.00 | -61.25 |
| 4.00 | -71.42 | -77.50 | -78.75 | -62.75 |
| 4.50 | -72.58 | -80.17 | -83.08 | -65.42 |
| 5.00 | -73.25 | -83.67 | -86.17 | -70.67 |
| 5.50 | -80.50 | -87.75 | -90.33 | -73.67 |
| 6.00 | -83.42 | -91.83 | -93.75 | -78.50 |
| 6.50 | -89.25 | -93.75 | -96.17 | -81.33 |
| 7.00 | -91.17 | -98.25 | -98.50 | -83.00 |
| 7.50 | -93.67 | -100.17 | -100.17 | -89.50 |
| 8.00 | -95.25 | -102.50 | -101.42 | -91.58 |
| 8.50 | -98.83 | -104.00 | -104.17 | -95.08 |
| 9.00 | -100.33 | -104.25 | -106.00 | -99.33 |
| 9.50 | -102.08 | -105.83 | -109.42 | -101.58 |
| 10.00 | -106.75 | -111.67 | -111.92 | -105.75 |

**Table 5:** Average Optimized Path loss for 2G-1800MHz

| Distance | Non-Urban | Suburban | Urban | Dense Urban |
|---|---|---|---|---|
| 0.50 | -55.42 | -56.50 | -56.83 | -56.83 |
| 1.00 | -60.42 | -59.33 | -61.42 | -60.75 |
| 1.50 | -63.67 | -63.08 | -64.25 | -64.08 |
| 2.00 | -65.92 | -66.00 | -68.50 | -66.75 |
| 2.50 | -70.17 | -69.08 | -70.50 | -69.75 |
| 3.00 | -74.08 | -70.00 | -74.00 | -72.42 |
| 3.50 | -76.08 | -73.50 | -76.42 | -75.25 |
| 4.00 | -78.17 | -74.50 | -79.67 | -77.67 |
| 4.50 | -81.33 | -76.58 | -81.92 | -81.08 |
| 5.00 | -83.83 | -81.00 | -84.33 | -83.33 |
| 5.50 | -86.75 | -83.33 | -86.00 | -86.08 |
| 6.00 | -89.17 | -87.00 | -89.00 | -89.17 |
| 6.50 | -91.50 | -89.83 | -92.33 | -90.58 |
| 7.00 | -94.25 | -93.50 | -93.75 | -93.92 |
| 7.50 | -96.50 | -96.42 | -96.83 | -97.00 |
| 8.00 | -99.08 | -99.50 | -100.25 | -99.92 |
| 8.50 | -100.67 | -102.58 | -102.42 | -103.08 |
| 9.00 | -103.92 | -104.33 | -104.67 | -105.75 |
| 9.50 | -106.33 | -105.83 | -107.92 | -107.50 |
| 10.00 | -110.33 | -110.50 | -110.75 | -111.17 |

**Table 6:** Average Optimized Path loss for 3G-2100 MHz.

| Distance | NU | SU | UR | DU |
|---|---|---|---|---|
| 0.50 | -116.26 | -118.95 | -121.72 | -118.98 |
| 1.00 | -126.52 | -129.31 | -132.19 | -129.58 |
| 1.50 | -132.51 | -135.37 | -138.32 | -135.78 |
| 2.00 | -136.77 | -139.67 | -142.67 | -140.18 |
| 2.50 | -140.07 | -143.42 | -146.04 | -143.64 |
| 3.00 | -142.77 | -145.73 | -148.79 | -146.39 |
| 3.50 | -145.05 | -148.03 | -151.12 | -148.74 |
| 4.00 | -147.03 | -150.03 | -153.14 | -150.79 |
| 4.50 | -148.77 | -151.79 | -154.92 | -152.59 |
| 5.00 | -150.33 | -153.36 | -156.51 | -154.20 |
| 5.50 | -151.74 | -154.79 | -157.95 | -155.66 |
| 6.00 | -153.03 | -156.09 | -159.26 | -156.99 |
| 6.50 | -154.21 | -157.28 | -160.47 | -158.21 |
| 7.00 | -155.31 | -158.39 | -161.59 | -159.35 |
| 7.50 | -156.33 | -159.42 | -162.63 | -160.44 |
| 8.00 | -157.28 | -160.38 | -163.61 | -161.39 |
| 8.50 | -158.18 | -161.29 | -164.53 | -162.32 |
| 9.00 | -159.03 | -162.14 | -165.39 | -163.19 |
| 9.50 | -159.83 | -162.95 | -166.21 | -164.02 |
| 10.00 | -160.59 | -163.72 | -166.98 | -164.80 |

Table 7: Root Mean Square Error (RMSE) using Optimized Model

| Environment | 2G-900 MHz | 2G-1800 MHz | 3G - 2100 MHz |
|---|---|---|---|
| NU | 2.70 | 2.66 | 4.04 |
| SU | 1.60 | 2.70 | 2.43 |
| UR | 3.12 | 4.83 | 4.48 |
| DU | 5.62 | 5.08 | 6.25 |

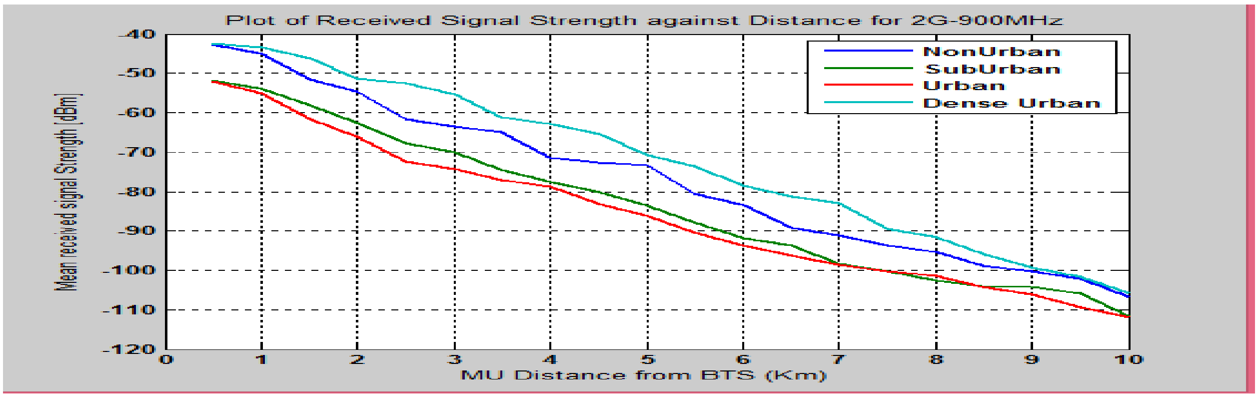


**Figure 2:** Average Received Signal Strength for 2G – 900MHz

Figure 2 shows the graph of received signal strength against distance. It is observed that as the distance increases from the BTS, the signal strength deceases in all cases with urban having the least signal strength for all distances due to the terrain. Again, it is also indicated that as the distance decreases from the BTS, the signal strength increases with urban having the least signal strength.

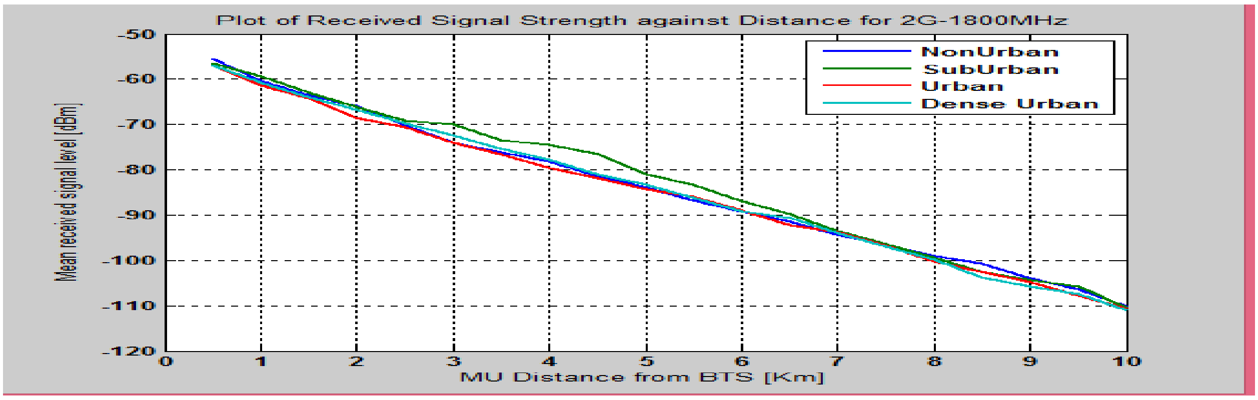


**Figure 3:** Average Received Signal Strength for 2G – 1800MHz

Figure 3 shows the average received signal strength for 2G- 1800MHz for the various environments under study. The graph shows that urban has the least signal strength for all distances while sub urban has the highest signal strength due to the terrain.

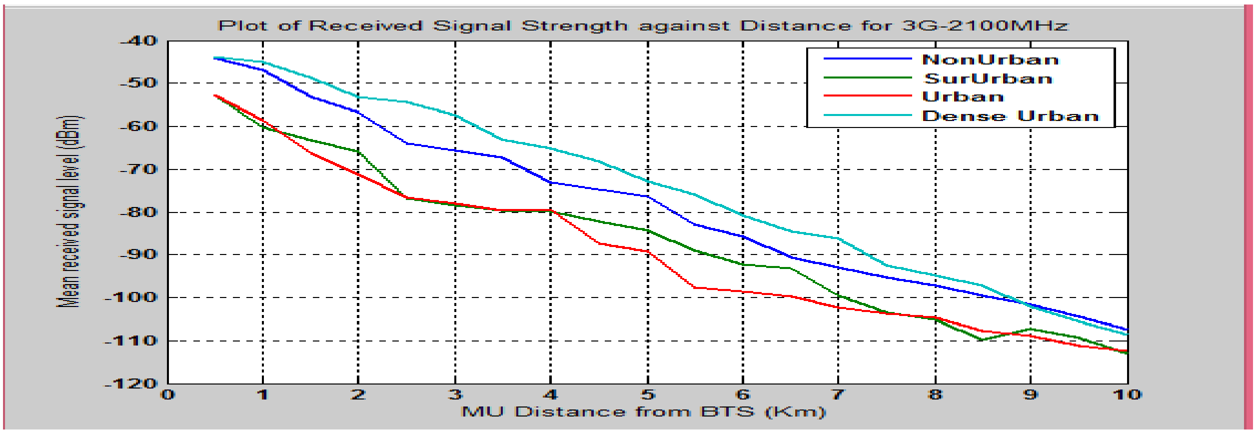


**Figure 4:** Average Received Signal Strength for 3G – 2100MHz

Figure 4 shows the average received signal strength for 3G-2100MHz. It is observed that as the distance from the base station increases, the received signal strength decreases with urban having the least value. Also, when the distance from the base station decreases, the received signal strength increases.

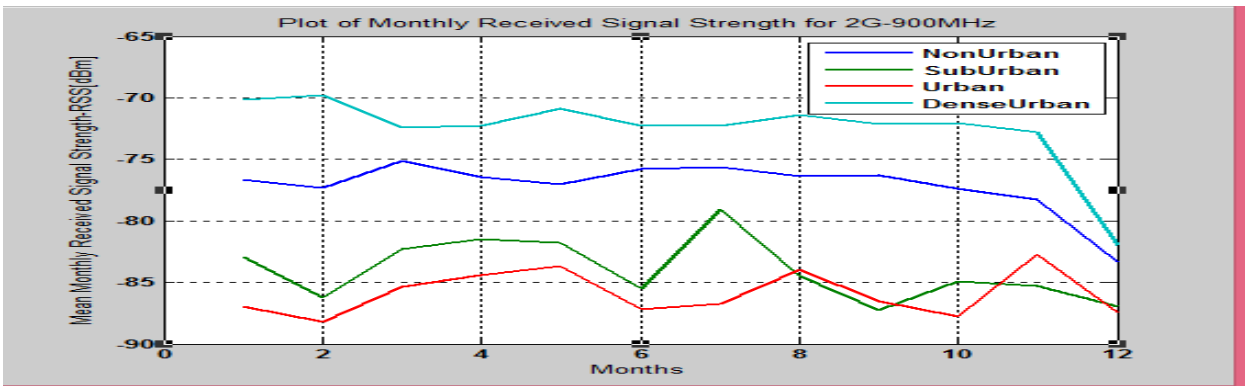

**Figure 5**: Monthly Received Signal Strength for 2G–900MHz

Figure 5 shows the monthly received signal for 2G-900MHz. It is observed that different months have varying signal strength due to seasonal changes with urban having the least signal strength and dense-urban having the highest signal strength.

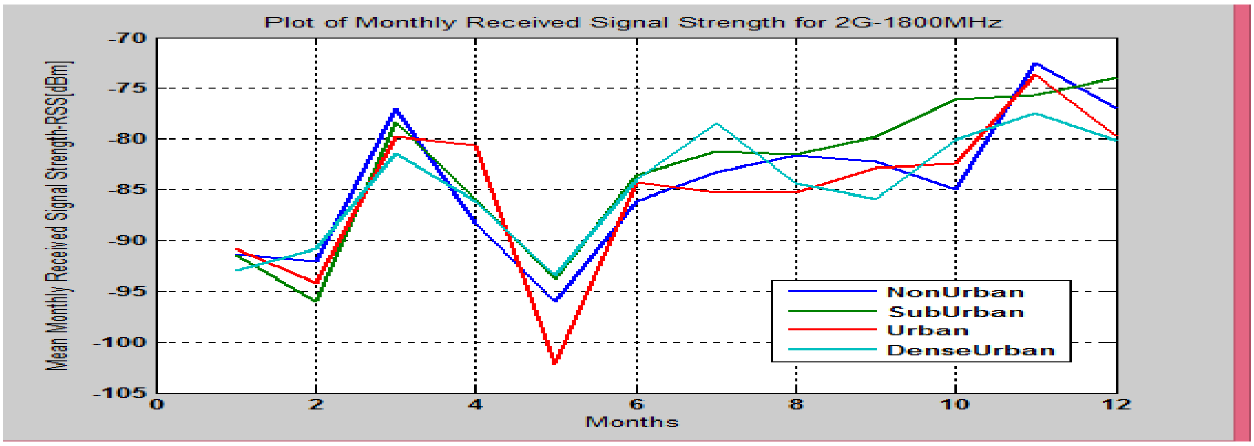


**Figure 6:** Monthly Received Signal Strength for 2G – 1800MHz

Figure 6 shows the monthly variation of received signal strength for 2G-1800MHz. It is observed that variation in weather conditions have negative effects in the received signal strength for all environments.

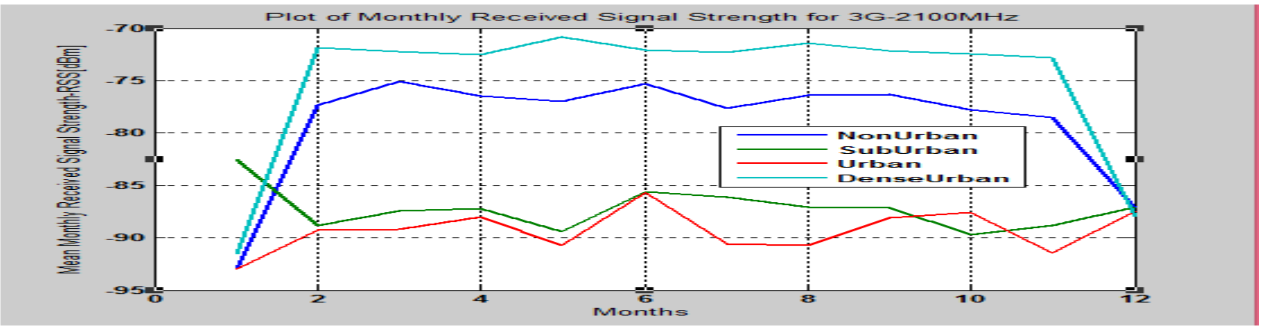


**Figure 6:** Monthly Received Signal Strength for 3G – 2100MHz

Figure 6 shows the monthly received signal strength for 3G-2100MHz. It is observed that urban has the least signal strength in all the months due to environmental factors and the signal strength is different in all months due to seasonal variations.

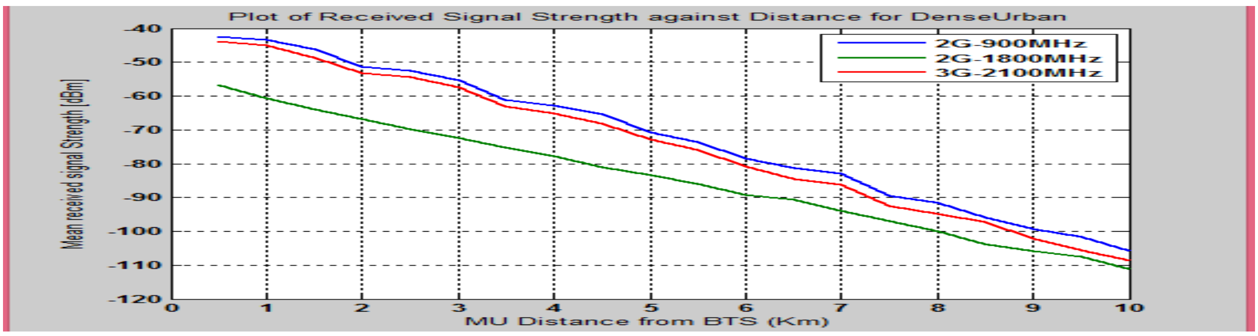

**Figure 7:** Received Signal Strength for Dense Urban

Figure 7 shows the received signal strength for dense urban for the various networks, it observed that 2G-900MHz has the highest signal strength for all distances while 3G-2100MHz has the least signal strength.

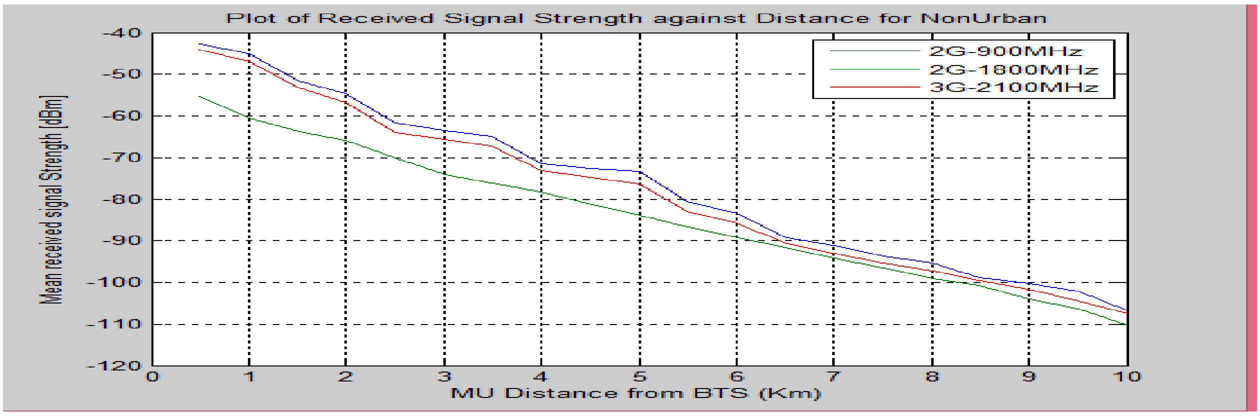


**Figure 8:** Received Signal Strength for Non- Urban

Figure 8 shows the received signal strength for non-urban for the various networks. It is observed that 2G-1800MHz has the highest signal strength for all distances while 3G-2100MHz has the least signal strength.

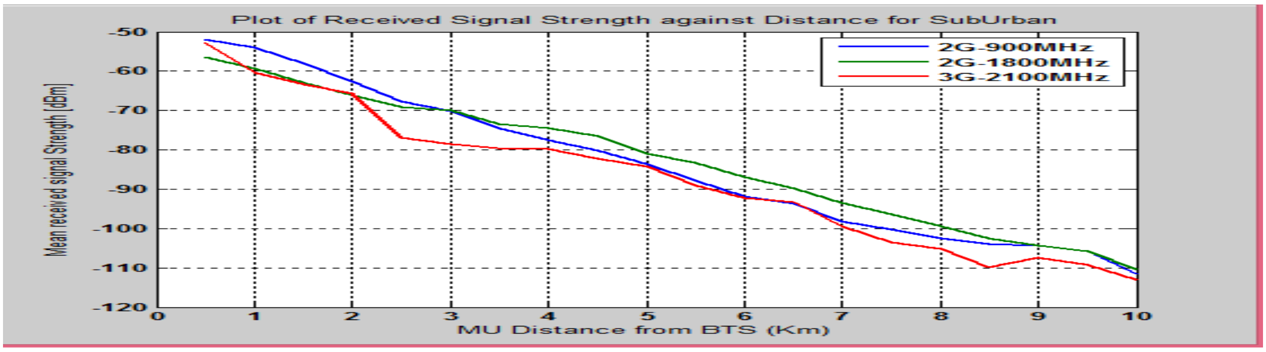


**Figure 9:** Received Signal Strength for Sub – Urban

Figure 9 shows the received signal strength for sub urban for the various networks. It observed that 2G-900MHz has the highest signal strength for all distances while 3G-2100MHz has the least signal strength.

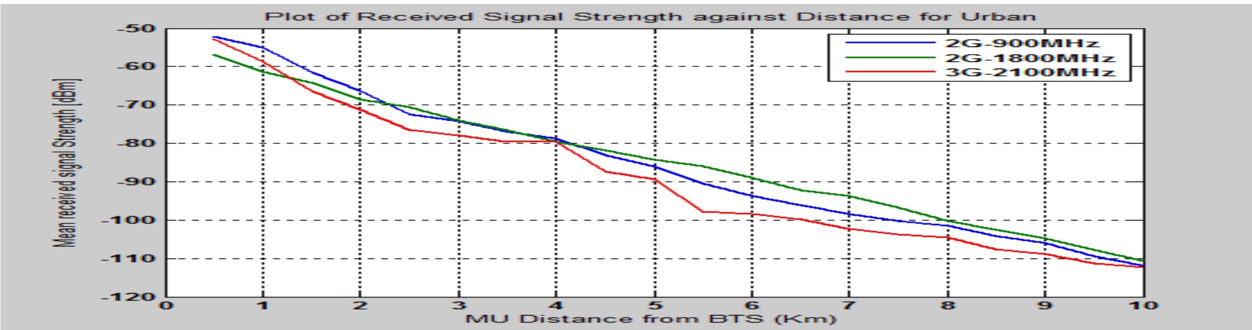


**Figure 10:** Received Signal Strength for Urban

Figure 10 shows the received signal strength for urban for the various networks. It is observed that 2G-900MHz has the highest signal strength at some distances while 2G-1800MHz has the least signal strength.

## 4. Conclusion

In this research work, the measured path losses in the four different GSM environments using COST231 Hata model was adjusted to obtain optimized model for the prediction of path loss experienced by GSM Signals in the 900/1800/2100 MHz band in Non-urban, Sub-Urban, Urban and Dense-Urban environments of Akwa Ibom State. Regular and more intensive Drive Test for optimization purpose should be carried out by the service providers for Quality of Service (QoS) on their own part and quality of Experience (QoE) from the perceptive of the consumers.

Based on the results our findings from this research work, revealed the adoption of our models for path loss prediction purpose in these environments and any other environments with similar characteristics.Planning and optimization is very vital in mobile radio communication systems because imprecise planning leads to power wastages.

Accurate path loss models should be employed in a particular environment in order to predict a good signal strength in a network coverage areas, since most of the models have limitations and these could lead to poor predicting coverage areas of base stations, improper determination of electric field strength, interference analysis and hand over optimization.

## References

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