



## Comparative Study of Path Loss Models for Mobile Communication Networks

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### ABSTRACT

*This study presents a comparative study of path loss models for mobile communication networks in Ubiaja, Edo State, Nigeria. Data were obtained for one year and the mobile equipment deployed was Infinix X650B, with software "RF signal tracker" used to determine, distance, Receive Signal Strength (RSS), latitude, and longitude. Also, the "cellular pro" software was used to determine the network operating frequency. Three recommended path loss models were used in the analysis and four mobile network providers were considered in this study. It was observed that the path loss values obtained varied with an increase in distance. Also, the obtained mobile communication RSS values were not linear; but have a logarithmic distribution pattern. The results obtained from the comparison showed that the variation between the Hata model and COST 231 Hata model is 2.07dB, while that of the Hata model and the free space propagation model is 34.11dB. The result obtained from this work will enhance mobile communication network planning and overall Quality of Service (QoS) for the area under investigation.*

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Distance; operating frequency; Receive Signal Strength and Quality of Service.

### INTRODUCTION

Mobile communication networks have to be one of the major technological advancements that have revolutionized mankind's existence on earth, such as e-banking, video conference, e-learning, etc. With the ongoing upgrade of mobile communication networks from 4G to 5G which will be associated with the Internet of Things (IoT), smart cities application, etc.; subscribers are worried about the Quality of Service (QoS), especially the level of Received Signal Strength (RSS) and path loss that will be experienced from these mobile networks. Presently, the existing mobile communication networks in Nigeria are short of adequate RSS, thereby giving rooms to pockets of the dead zone [1, 12]. The mobile communication system signal is usually transmitted through a path and is affected by propagation factors such as atmospheric

particles, diffraction, reflection, scattering, and absorption. This phenomenon can seriously limit signal strength during transmission which results in attenuation [3]. Also, most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and where the presence of high-rise buildings causes severe diffraction loss.

Received Signal Strength can be determined based on Path loss or path attenuation. Path loss is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a mobile communication system [1]. Propagation models are useful for predicting signal attenuation or path loss which may be used as a controlling factor for system performance or coverage to achieve perfect



reception [2]. Propagation models are of two types:

Free space propagation and Plane earth propagation. The wave is not reflected or absorbed in the free space propagation model. The ideal propagation radiates in all directions from transmitting source and propagating to an infinite distance with no degradation. Attenuation occurs due to the spreading of power over greater areas. Power flux is calculated by Eq. (1),

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

Where  $P_t$  is transmitted power,  $P_d$  is power at distance "d" from the antenna. The amount of power captured by the antenna at the required distance "d", depends on the effective aperture of the antenna and the power flux density at the receiving element. There are mainly three factors by which the actual power received depends upon by the antenna such are; the aperture of receiving antenna, the power flux density, and the wavelength of the received signal [4].

#### RELATED STUDIES

Research works on path loss evaluation and analysis in Nigeria are not new as seen in [5] which determined a suitable model for Global System for Mobile Communication (GSM) network deployment in Makurdi. The performance of Okumura – Hata Model, COST 231 – Hata Model, Standard Propagation Model, and Stanford University Interim Model were evaluated. A driving test was conducted to obtain the field measured data with which the models were appraised. The analysis of the results showed that Hata Model would be more suitable for GSM 900 and GSM 1800 network planning and deployment respectively in Makurdi City, Nigeria. According to [6], a study on path loss measurement and modelling for Lagos state was conducted for twelve (12) different sites location for 52 weeks. Data collection was carried out through drive testing using TEMS software and relative parameters like RSSI, Path loss was measured under 2G and 3G frequencies of operation. COST 231-Hata model was used as a reference model for path loss calculation of field data. This was further adjusted to develop optimized models (tagged OMODEEN models)

for path loss prediction in all environments of study, which showed results within 6dB acceptable range.

[7] Presented research which was aimed at predicting the propagation path loss model which can help plan the best Global System for Mobile Communication (GSM). The methodology employed was the measurement and instrumentation method. Digital wheel meter and handheld Spectrum analyzer (AARONIA AG HF 2025E spectra) were used to measure signal path loss at four sites in Dutse town at 900MHz frequency range. Results showed that the empirical model developed from the Log-Normal shadowing concept can work for GSM network service providers for planning and optimization of their services in Dutse, Nigeria. In [2], an extension of path loss analysis in Urban, Rural, and Semi-Urban environments in Oman was performed. A new software package that incorporates modified propagation models and the proposition of Radio Frequency (RF) network design output for proper and efficient planning to be used by RF engineers for path loss studies was developed. The Root-Mean Square Error (RMSE) was calculated between measured and predicted values according to the Okumura-Hata propagation model. PCHIP analysis technique has been used for the prediction of unknown data which gave a good result. Authors in [8] presented a measurement-based path loss model, from experimental data collected in Aba, South-East Nigeria. Received Signal Strength (RSS) measurements were gathered in Aba from GlobalCom Limited (GLO) Network operating at 900MHz. The results of the measurements were used to develop the path loss model for the urban environment and the result showed that the path loss for the measurement environment increases by 3.10dB per decade.

In [9], a study on measurement and modelling of path loss propagation for three GSM operators in Mubi town was presented. COST 231-Hata model was adopted as a reference model and a modified model based on the experimental data measured was developed. Autoregressive neural network (ARNN) predicted that the average path loss for each GSM operator is 16.96dB, 16.077dB, and 24.5dB with their corresponding Mean Square Error (MSE) as

1.76329dB, 1.2958dB, and 2.37112 for AIRTEL, MTN, and GLO respectively. GLO operator experienced more path loss followed by the AIRTEL and MTN is the least. According to [10], a comparative Study of free space and Okumura-Hata Models in GSM Signal Path Loss Prediction in Ughelli, a suburban terrain of Delta state was conducted. A new monitor software installed in a smartphone, and a Garmin Nuvi Global Positioning System (GPS) device were used to measure the Received Signal Strength (RSS) and distances between Base Transceiver Stations (BTS), and Mobile Station (MS) respectively. The analysis of the result showed that the Okumura-Hata model is more accurate in path loss prediction. [11, 12] presented a study on comparative analysis of three empirical path loss models with measured data for urban, suburban, and rural areas in Rivers State. The results showed that the COST 231 Hata model gives better predictions and is therefore

recommended for path loss predictions in River State.

This study is on a comparative study of path loss models for Mobile Communication Networks at Ubiaja, aimed at determining the path loss using three recommended path loss models based on the four mobile communication networks provider in Ubiaja, Edo State, Nigeria.

### RESEARCH METHODOLOGY

This study presents a comparative study of path loss models for mobile communication networks using Ubiaja as a case study. Ubiaja is a semi-urban City in Esan South East Local Government Area, Edo State, in the rainforest region of Nigeria. It is at an altitude of 221 m with 1,800 millimetres (71 in) to 2,000 millimetres (79 in) of rainfall each year. The map of Ubiaja is shown in Fig 1, with geographical coordinates of (lat.): 6° 39' 18" N (6.655), (long.): 6° 23' 13" E (6.3869).



Fig.1: Ubiaja Map

The mobile equipment deployed to determine the path loss in the area under investigation is Infinix X650B, with software is known as "RF Signal Tracker" used to determine, distance, Receive Signal Strength (RSS), latitude, and longitude. Also, the "Cellular Pro" software was used to determine the network operating frequency. The survey, using "RF Signal Tracker" software was carried for four different mobile communication network providers in Nigeria for a period of one year, from

September 2019 to August 2020). The average data from the "RF signal tracker" software are analyzed with assumed parameters presented in Table 1.

Three path loss models considered are;

- 1) Free Space Propagation Model;
- 2) Hata model and;
- 3) COST 231 Hata model.

Table1: Parameters for Pathloss

S/N	Define Parameters	Corresponding parameters values
1	MTN Network Type	GPRS
2	Globacom Network Type	EDGE
3	9mobile Network Type	EDGE
4	Airtel Network Type	EDGE
5	MTN Frequency (f)	1842.5 MHZ
6	Globacom Frequency (f) DL/UL	1829.9/1734.9 MHZ
7	9mobile Frequency (f) DL/UL	1857.3/1762.3 MHZ
8	Airtel Frequency (f) DL/UL	1857.3/1762.3MHZ
9	BTS Distance (d), MTN	8969.345 KM
10	BTS Distance (d), GLO	5573.241 KM
11	BTS Distance (d), 9mobile	5523.19KM
12	BTS Distance (d), Airtel	1149.7KM
13	High of the antenna mask (h <sub>t</sub> )	30m
14	Clutter correction factor (C)	0dB suburban and 3dB urban

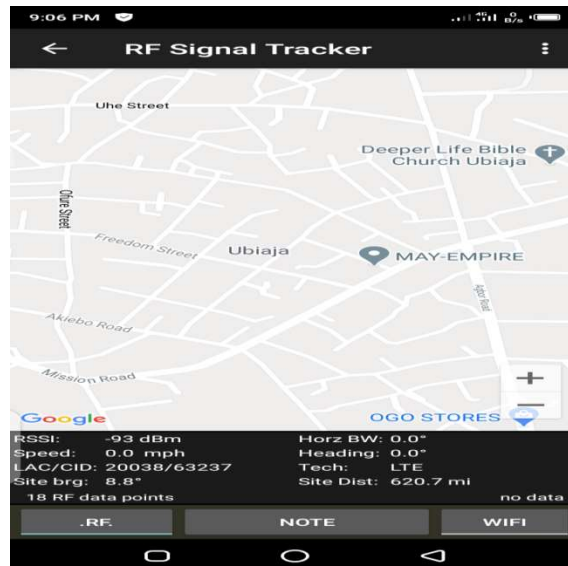


Fig. 2: The screenshot of Ubiaja Environment using “RF signal tracker” software

Table 2: Average RSS parameters

Mobile network operators	RSS
Airtel	-43.13
GLO	-48.67
9MOBILE	-36.80
MTN	-39.20

### The Pathloss Analysis on Ubiaja Environment

Three pathloss models were deployed to determine the pathloss from four mobile communication networks in Nigeria. The mobile networks are MTN Nigeria, Globacom, 9mobile,

and Airtel network in Nigeria. The analysis makes use of the assumed parameters in Table1, alongside the three pathloss models.



### MTN Pathloss Analysis

The basic assumed parameters for pathloss analysis for MTN mobile network at Ubiaja. Frequency is 1842.5 MHz and distance 345 KM

$C = 0$  dB, for suburban areas or open environments and 3dB for Urban environment  
 $(h_r)$  = mobile station antenna height correction factor is defined as

$$a(h_r) = (1.11 \log_{10}^f - 0.7)h_r - (1.5 \log_{10}^f - 0.8) \quad (2)$$

For suburban or rural areas

$$a(h_r) = 3.20 \left[ \log_{10}^{(11.75 \times h_r)} \right] - 4.97 \quad (3)$$

For  $f > 400$  MHz for Urban environment

### Free-space Propagation Model

Recall, Free space propagation model ( $p_l$ ), using the assumed parameters of the MTN mobile network in Table 1.

$$p_l = 32.5 + 20 \log_{10}^d + 20 \log_{10}^f \quad (4)$$

$$p_l = 32.5 + 20 \log_{10}^{8969.345} + 20 \log_{10}^{1842.5}$$

$$p_l = 32.5 + 50.76 + 65.308 = 148.56 \text{ dB}$$

### Hata Model

Recall the path loss Hata Model Equation, using the assumed parameters of MTN mobile network in Table 3.

$$p_h = 69.55 + 26.16 \log_{10}^f - 13.82 \log_{10}^{h_t} - a(h_r) + (44.9 - 6.55 \log_{10}^{h_t}) \log_{10}^d \quad (5)$$

Note:

For rural or suburban like Ubiaja

$$a(h_r) = (1.11 \log_{10}^f - 0.7)h_r - (1.5 \log_{10}^f - 0.8)$$

$$a(h_r) = 87.74 - 4.098 = 83.64$$

$$p_h = 154.97 - 20.41 - 83.64 + 35.225 \log_{10}^d$$

$$p_h = 50.92 + 35.225 \log_{10}^{345} = 50.92 + 89.39$$

$$p_h = 140.31 \text{ dB}$$

### Cost 231 Hata Model

The cost 231 Hata Model ( $L_{cost}$ )

$$L_{cost} = 46.3 + 33.9 \log_{10}^f - 13.82 \log_{10}^{h_t} - a(h_r) + [44.9 - 6.55 \log_{10}^{h_t}] \log_{10}^d + c \quad (6)$$

$$a(h_r) = (1.11 \log_{10}^f - 0.7)h_r - (1.5 \log_{10}^f - 0.8)$$

$$a(h_r) = 87.74 - 4.098 = 83.64$$

$$L_{cost} = 156.997 - 20.41 - 83.64 + 35.23 \log_{10}^d$$

$$L_{cost} = 52.95 + 35.23 \log_{10}^{345} = 142.36 \text{ dB}$$

**Table 2:** The Comparison Obtained from Various Pathloss Models and Different Mobile Communication Network

S/N	Various models	Pathloss	MTN Network Pathloss(dB)	GLO Network Pathloss(dB)	Airtel Network Pathloss (dB)	9mobile Network Pathloss(dB)
1	Free space model		148.56	145.39	114.78	123.45
2	Hata Model		140.31	134.92	80.67	95.94
3	Cost 231 Hata Model		142.36	136.86	82.73	98.01

The comparison path loss models with varying distance using MTN parameters

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Table 3: Pathloss obtained from various Distance

Distance (km)	Free space propagation model (dB)	Hata Model (dB)	cost 231 Hata Model (dB)
1000	157.81	156.60	158.64
2000	163.81	167.20	169.25
3000	167.35	173.40	175.45
4000	169.85	177.80	179.82
5000	171.79	181.22	183.26

### RESULT, ANALYSIS, AND DISCUSSION

The measurement using “RF Signal Tracker” and “Cellular Pro” software, the corresponding data were obtained and analyzed using three path loss models to determine the path loss values of Ubiaja town considering four mobile communication networks. The Received Signal Strength (RSS) and the path loss values

from different mobile communication networks are presented in the Figures below.

#### Received Signal Strength (RSS)

The Received Signal Strength (RSS), obtained from various locations, corresponding distances, and various mobile communication networks are presented from Fig. 3. to Fig. 6.

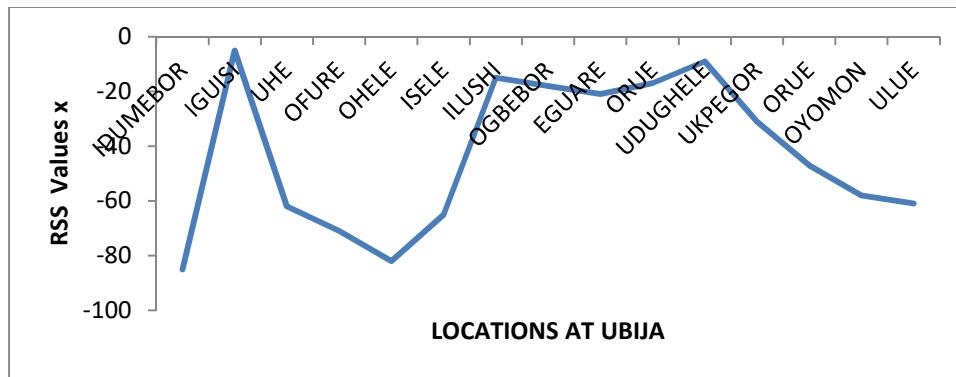


Fig.3: Airtel RSS Location at Ubiaja

Fig.3, presents the measured Received Signal Strength (RSS) obtained from 15 various locations from Airtel mobile network at Ubiaja. It was observed that the received signal strength

transmitted is not constant or the same from the various BTS located at Ubiaja. This implies that various geographical locations witnessed a different level of RSS on the mobile station.

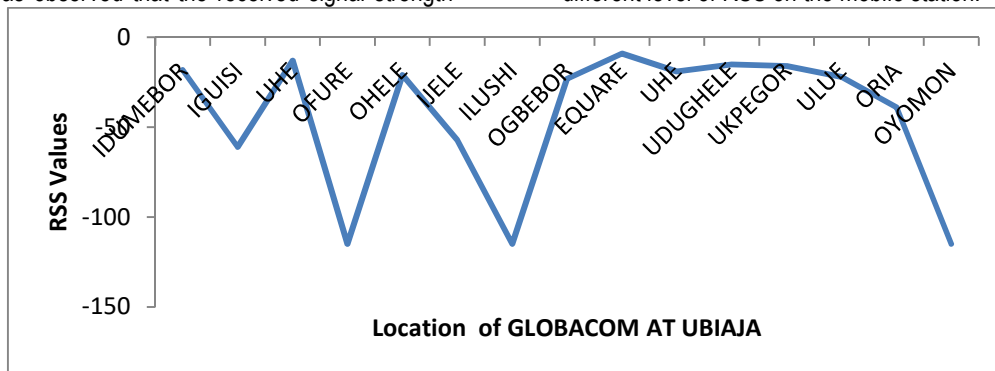


Fig. 4: Globacom (GLO) RSS Location at Ubiaja

In Fig. 4 the measured Received Signal Strength (RSS) obtained from 15 various locations from Globacom mobile network at Ubiaja is presented. It was observed that received signal strength has a similar distribution pattern to other investigated mobile networks. However, the random drop-in RSS distribution is

probably due to the presence of tall trees in suburban areas. This implies that the undulating of RSS that was witnessed is also duplicated at various geographical locations and by another mobile communication network.

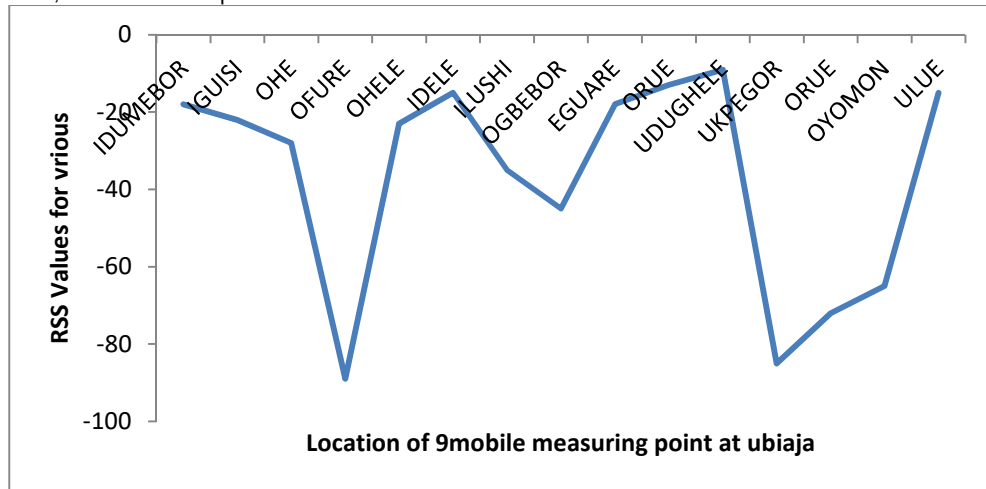


Fig.5: 9mobile Network RSS Location at Ubiaja

The Received Signal Strength (RSS) obtained from 15 various locations from the 9mobile network and MTN network at Ubiaja is shown in Fig. 5 and Fig. 6 respectively. It was observed that the received signal strength

witnessed from the BTS is not linear, therefore giving room to loss of network signal and dead zone resulting in low quality of service in the environs.

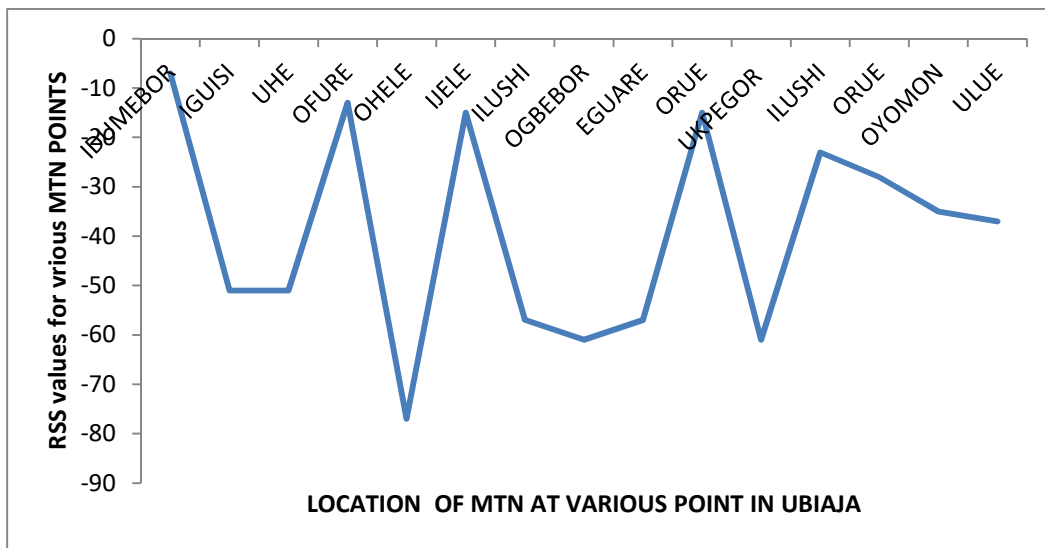


Fig. 6: MTN Network RSS Location at Ubiaja

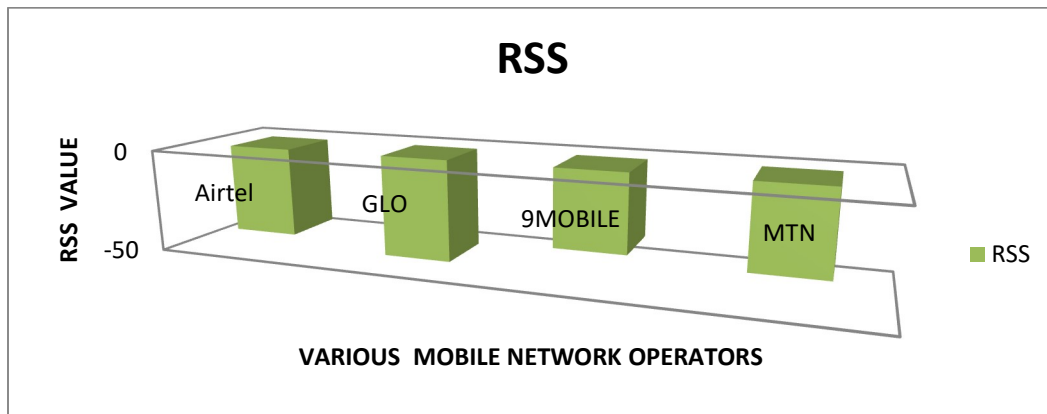


Fig.6: Comparison of Various Network Operators Average RSS at different Location in Ubiaja

In the comparison of measured Received Signal Strength (RSS) from four different mobile communication networks, it is observed that total Received Signal Strength (RSS) witnessed less than 50dB recommended

by ITU. From Table 1, it was observed that Globacom has the highest average RSS value of -48.67dB while Airtel mobile communication witnessed the lowest RSS value of -36.80dB.

#### Pathloss Analysis Output

The mobile communication pathloss values obtained from selected pathloss models from the four different mobile communication networks in Ubiaja town are presented in Fig. 7 to Fig. 9.

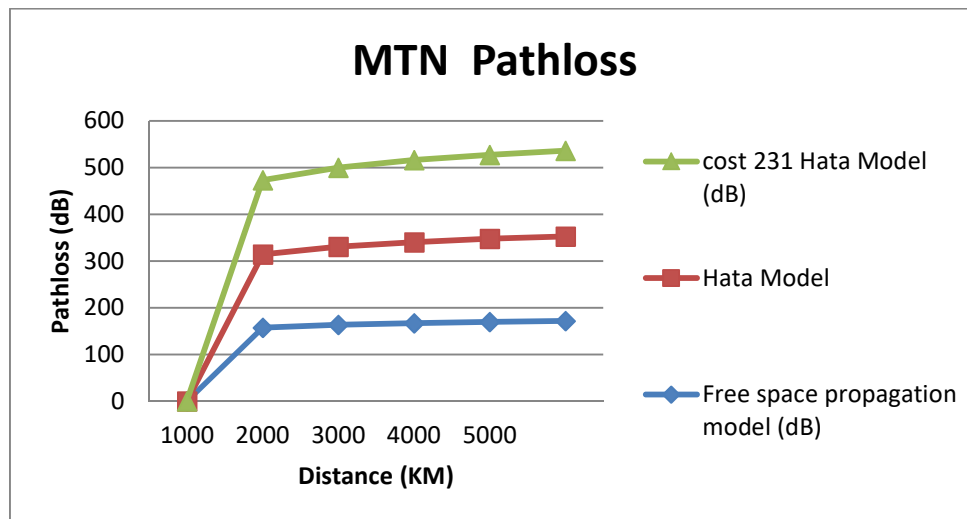
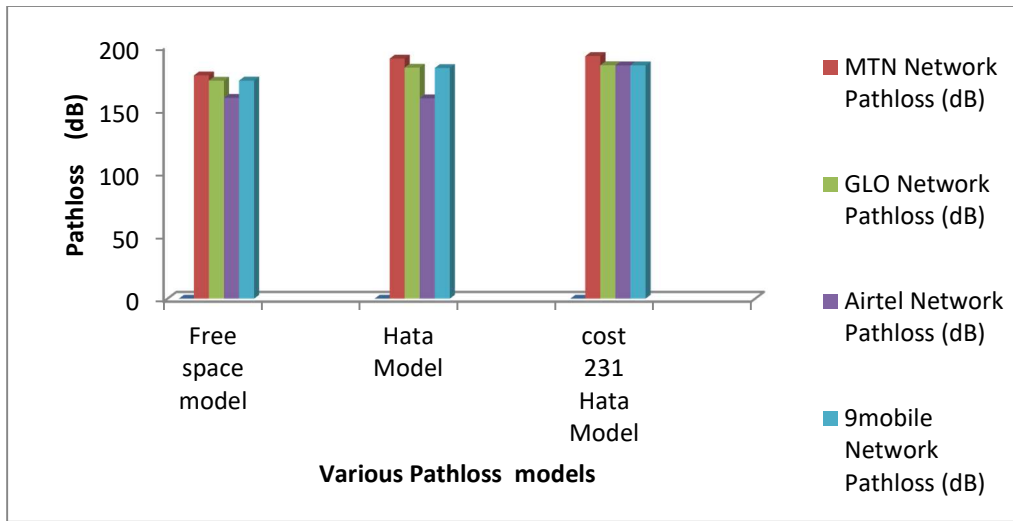


Fig 7: Pathloss variation with distance

The three pathloss models result were considered against distance in Fig.7, using the data analysis obtained from the MTN network at Ubiaja town, which was considered a suburban

environment. It was observed that pathloss values in decibel witnessed an exponential increase against distance.

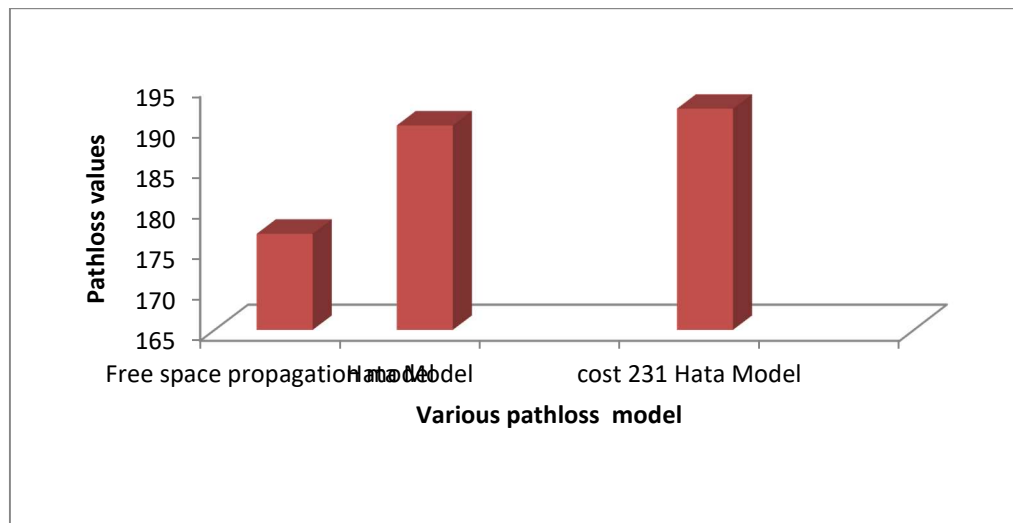




**Fig. 8:** The Comparative of Path loss Models from the Four Mobile Networks at Ubiaja Town

Fig. 8, has shown the comparative study of three pathloss models under the area of investigation, using the four mobile communications available at Ubiaja town. It was

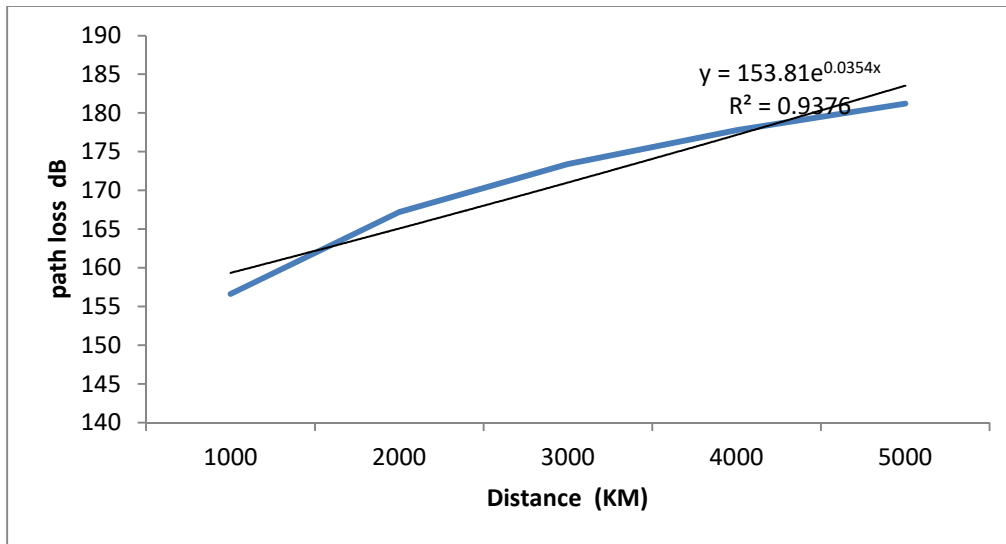
observed from the three pathloss models considered, that it has a close correlation of pathloss result area investigated.



**Fig. 9.** Comparison of various Path loss Models using Ubiaja MTN network

From the comparative study of various path loss model results using data obtained from Ubiaja town, it was observed that there is a correlation between these path loss models deployed, with the highest variation between the Hata model and COST 231 Hata model is 2.07dB. While 34.11dB is the variation between

the Hata models and the free space propagation model. This high variation is due to not considering the effect of tall trees by the free-space propagation model which probably affects the electromagnetic signal leading to a large path loss value in the mobile communication system.

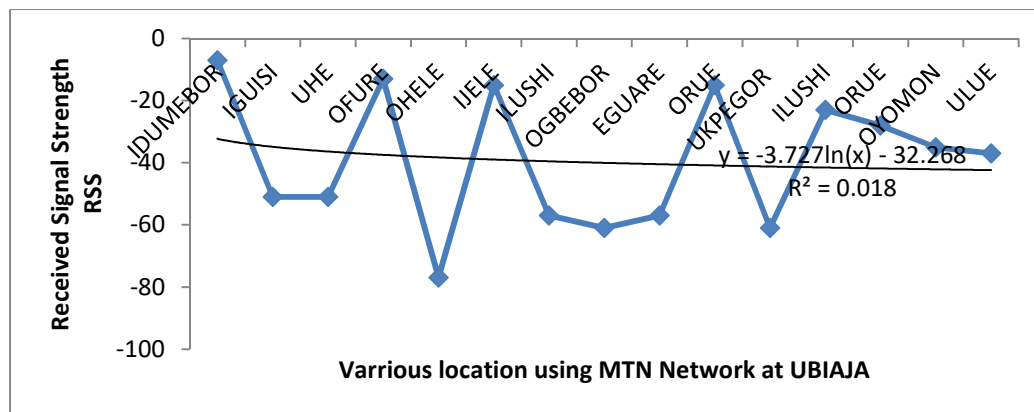


**Fig 10:** Empirical Modeling of Path loss against Distance

The variation of pathloss against distance is developed into empirical modelling shown in Fig. 10. Therefore,

$$y = 153.8 e^{0.035x} \quad (7)$$

Y represents the pathloss while X represents the corresponding distance which major parameters outside in Table 1. The R-Square value is given as 0.937, with an exponential distribution pattern. Therefore the pathloss against distance is exponentially distributed.



**Fig. 11:** The Logarithmic Distribution Pattern of Received Signal Strength RSS

It is observed that received signal strength from MTN network has Logarithmic Distribution Pattern, which is supposed to be linearly distributed.

The findings and contribution of this study are as follows; Mobile communication pathloss and the received signal strength were

determined for the area under investigation (Ubiaja). It was observed that path loss values obtained vary with an increase in distance and the obtained mobile communication RSS values are not linear. The result obtained from this work will enhance mobile communication network planning and overall Quality of Service (QoS).



## CONCLUSION

This research work has unveiled various mobile communication path loss values for Ubiaja in Edo State using three recommended path loss models. The mobile equipment deployed was Infinix X650B, with software "RF signal tracker" to determine, distance, Receive Signal Strength (RSS), latitude, and longitude. Also, the "cellular pro" software was used to determine the network operating frequency. The survey was carried out from four different mobile communication network providers in Nigeria for a period of one year, from September 2019 to August 2020. It was observed that the pathloss values obtained varied with an increase in distance. In addition, the obtained mobile communication RSS values were not linear. The result obtained from this work will enhance mobile communication network planning and overall Quality of Service (QoS).

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