RESEARCHERID
THOMSON REUTERS

[Chinedu, Nkwachukwu, Cosmas* *et al.*, 6(5): May, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DEVELOPMENT OF A PATHLOSS MODEL FOR 3G NETWORKS AT 1.857 GHz IN PORT HARCOURT NIGERIA

Anyanwu Chinedu*, Chukwuchekwa Nkwachukwu*, Agubor Cosmas*

Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Nigeria

DOI: 10.5281/zenodo.573555

ABSTRACT

This paper reports the development of a Path loss Model For 3G Networks using Port Harcourt City in Nigeria as a case study. Signal loss experienced by network users in and around the city has been an issue that needed to be addressed. WCDMA network operating at a frequency of 1.857GHz was monitored in some selected areas within the city namely: Rivers State University of Science and Technology (RSUST), Ikwerre road and D-line.. Drive test was used as the method for data collection. Based on the data collected and analysis done a path loss model that best describes the signal loss was developed as Lp=126.99 dB+ 27.2 log (D). It was observed that the proposed model showed significant improvement when compared to the Okumura-Hata model, COST 231 model, and LEE model.

KEYWORDS: Drive test, path loss, Okumura, WCDMA

INTRODUCTION

The era of modern wireless communication began in the 1980's and is classified into generations [1]. First Generation (1G) systems could only transmit voice calls and a limited size of data but lack roaming capability. The introduction of roaming capability into wireless communication brought about the Second Generation (2G) systems. Third Generation (3G) systems otherwise called International Mobile Telecommunication – 2000 (IMT-2000) offer better voice quality, high data rate service and global roaming. The 3G networks have the advantages of ubiquitous broadband wireless access supporting real-time and multimedia applications [2]. The Fourth Generation (4G) system is an Internet Protocol (IP) based wireless mobile network.

Erroneous path loss predictions before the establishment of most base stations cause over estimation or under assessment of coverage areas which subsequently lead to incessant problems like call drops, cross talk and network congestions. The consequence is more pronounced where there are ever increasing demand to meet the diverse service requirements of various applications. Hence, the quality of signals delivered to the mobile users are affected which renders the services offered by the mobile Operators to be below expectation.
This work focuses on developing a Path loss Model for 3G Network at 1.857GHz using Port-Harcourt Urban, in River State of Nigeria as a case study. An investigation on the level of signal loss experienced on the WCDMA (wideband code division multiple access) was undertaken. This outcome will be used to proffer solutions that will help minimize signal or path loss effects witnessed in the WCDMA network.

In designing a wireless network, radio planners and engineers make use of various propagation models. More often, they either develop their own prediction models for different areas of a wireless network or deploy the existing standard models. A work on comparison of propagation models for GSM 1800 and WCDMA systems in Kano and Abuja areas of Nigeria is presented in [3]. Drive test method was used for data collection. The result indicated that COST 231 and Hata models gave better results for Kano and Abuja environment. Also, the values of root mean squared error (RMSE) and square of correlation value was optimum for GSM 1800 but very high for WCDMA. The study concluded that Hata and COST 231 models should be modified to suit the environment.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

In [4], a work on site specific measurements and propagation models for GSM in three cities in Northern Nigeria is presented. They used Ericson Test Mobile System with all its accessories to monitor GSM signals at

900MHz and 1800MHz. The method used was TEMS drive test in verifying the actual condition of the radio frequency signals. The measured values generated were compared with Okumura – Hata and COST 231 models which showed that the classical models overestimated the path loss in the cities. Measurement and modeling for radio path and penetration losses in and around residential areas for the newly allocated U.S. National Information Infrastructure (NII) using carrier Wave (CW) transmitter placed 30 – 50m and later 150 – 210m from the house is recorded in [5]. The result obtained was used to develop measurement based path loss model for propagation prediction.

The above works covered some areas in the Northern region of Nigeria and United States. The Northern region of Nigeria has different environmental impact on the received signal strength compared to other areas of the country. This work focuses on the Southern region of Nigeria in which the level of signal loss experienced on the WCDMA network within the Port-Harcourt city was investigated. A path loss model that best describes the signal loss was developed.

MATERIALS AND METHODS

Data was obtained by conducting a drive test along selected routes using the following:
i) HP Laptop (installed with Transmission Evaluation and Monitoring System (TEMS) software)
ii) BU-353 GPS (Global positioning System)
iii) Mobile Phone (Galaxy S5 with installed TEMS software)
iv) External battery as Power supply source and
v) Car for mobility

The main routes taken for the drive test were:
i) Rivers State University Of Science and Technology (RSUST)
ii) RSUST & Ikwerre Road
iii) Ikwerre Road & D-line

These routes were chosen because of their high population density and the network challenges experienced by subscribers.

Fig 1 shows the setup of the apparatus used for data collection. The base station represents the service provider-AIRTEL 3G network operating at a frequency of 1.857 GHz and about 30m in height. A SIM card from AIRTEL was inserted into the mobile phone installed with TEMS software which was then connected to the Laptop through a USB cord. The GPS was connected to the laptop through another USB cord and then placed firmly on top of the car. An external battery source provided an extra power source to the laptop in order to ensure continuous and constant power supply throughout the drive test.

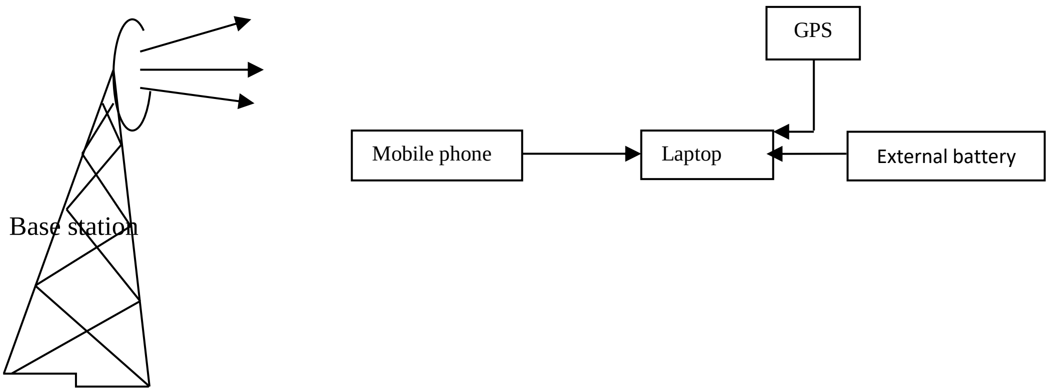

Fig. 1: Block Diagram of showing apparatus during the Drive test.

ISSN: 2277-9655
[Chinedu, Nkwachukwu, Cosmas* *et al.*, 6(5): May, 2017] Impact Factor: 4.116
IC™ Value: 3.00 CODEN: IJESS7

Fig 2 shows the drive test result for RSUST route. The log indicates various colours and each colour shows a particular range of signal strength. Dark green indicates the highest level of received signal strength, while red colour shows signal failure. The numbers such as 2252A, 2252B, and 2252C written around the fan-blade-like shapes (base stations) are the antenna identification numbers.

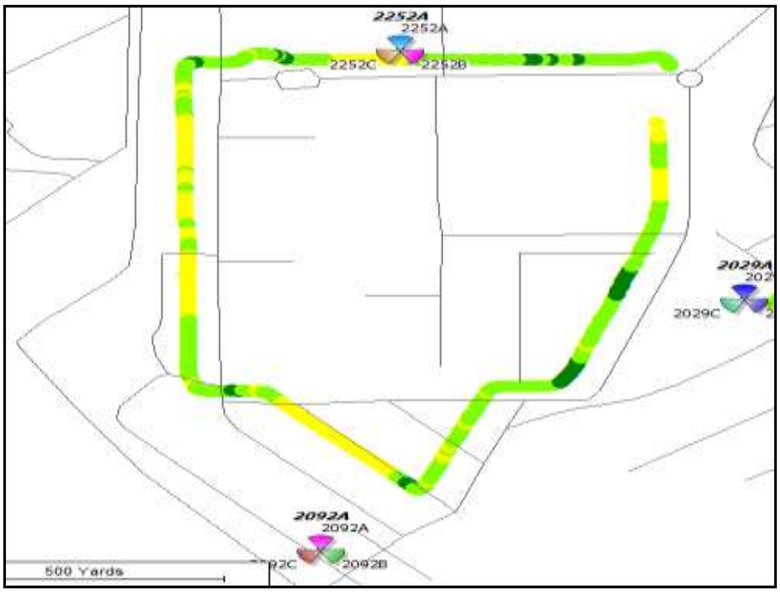

Fig.2: Drive test along RSUST route

Fig. 3 is for received signal level along RSUST & Ikwerre Road with colours depicting ranges of signal strength.

Fig.3: Log showing Received Signal Level along RSUST & Ikwerre Road

Fig. 4 indicates drive test result along Ikwerre Road & D-line area. All the drive test results were analyzed with the Actix software.

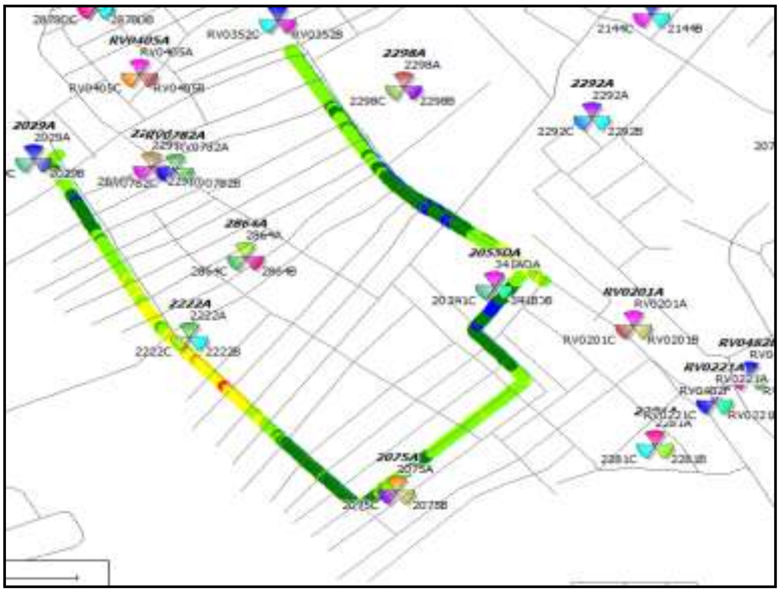

Fig.4: Log of Received Signal Level along Ikwerre Road & D-line area

Table 1 indicates the transmission parameters of the WCDMA Network monitored during the drive test.

Table 1: Transmission Parameters for the Network

S/N	**Transmission parameters**	**Values**
1	Frequency of operation	1.857 GHz
2	Transmitter power	30W
3	Transmitter height	35m
4	Mobile Station height	1.5m
5	Gain of transmitter	18dBi
6	Gain of receiver	1.76dB

The resultant pathloss model for the field measurement is expressed as [6]

$$L_p(dB) = L(d_o) + 10 * np * log\frac{d}{d_o} + \sigma \quad (1)$$

Where L_p =path loss in dB
$L(d_o)$= reference path loss; np = pathloss exponent
d=distance in meters
d_0= close-in distance in meters
σ = Standard Deviation

The linear regression method is shown in Table 2.

Table 2: Estimated path loss for urban area

Distance(d)	Xi=10*log10(d/do)	Yi(Pli(dB))	Xi^2	XiYi	Yi^2
0.10	0.0000	112	0.0000	0	12,544
0.20	3.0103	119	9.0619	358.2257	14,161
0.30	4.7712	134	22.7645	639.3408	17956
0.40	6.0206	135	36.2476	812.781	18225
0.50	6.9897	121	48.8559	845.7537	14641
0.60	7.7815	158	60.5519	1229.477	24964
0.70	8.4510	114	71.4191	963.414	12996
0.80	9.0309	101	81.5572	1065.646	10201
0.90	9.5424	104	91.0579	992.4096	10816
1.00	10.0000	158	100.0000	1580	24964
SUM	65.5976	1256	521.5159	8,487.048	161,468

$$np_{urban} = \frac{(N\sum_{i=1}^{n}(XiYi) - (\sum_{i=1}^{n} Xi)(\sum_{i}^{n} Yi))}{N(\sum_{i}^{n} Xi^{2}) - (\sum_{i=1}^{n} Xi)^{2}} \quad (2)$$

Where; $Xi = 10 * log10\frac{d}{d_o}$; $Yi =$ measured path loss
N= number of data points

Pathloss exponent, $\text{npurban} = \frac{(10*8487.0478)-(65.5976)*(1256)}{10*(521.5159)-(65.5976)^{2}} = 2.72$

The reference path loss is given by

$$L(d) = \frac{(\sum_{i=1}^{n} Y_i - np\sum_{i=1}^{n} X_i)}{N} \quad (3)$$

That is, $L(d) = \frac{1256-2.72*65.5976}{10} = 107.76\ dB$ (4)

The sum of mean squared error $e(np)$, was obtained from

$$e(np) = \sum_{i=1}^{k}[L_m(d) - L_p(d)]^2 \quad (5)$$

Where L_m is measured path loss and L_p the predicted path loss.

Table 3 is a tabulation of the Mean Squared Errors (MSE) of the network obtained by substituting values of measured and predicted path losses into equation 5.

Table 3: The Mean Squared Error computation

Distance(km)	**Measured Path loss (dB)**	**Predictedpath loss(dBm)**	$[L_m(d) - L_p(d)]^2$
0.10	112	107.7600	17.98
0.20	136	115.9480	402.08
0.30	135	120.7376	203.42
0.40	158	124.1359	1146.78
0.50	121	126.7719	33.31
0.60	158	128.9256	845.32
0.70	114	130.7465	280.45
0.80	118	132.3239	205.17
0.90	128	133.7152	32.66
1.00	158	134.9598	530.85

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The sum of the MSE is $e(np)$=3,698
The standard deviation, is given as [7]

$$\sigma = \sqrt{\sum \frac{[(L_m)-(L_p)]^2}{N}} \quad (6)$$

Where σ = Standard deviation
L_m = measured path loss
L_{pred} = predicted path loss
N=Number of data points (10)

$$\sigma = \left[\frac{3{,}698}{10}\right]^{\frac{1}{2}} = 19.23 \text{ dB} \quad (7)$$

The resultant path loss model for the WCDMA network in of Port-Harcourt is given as;

$$Lp = 107.76 + 10 * 2.72 * \log_{10}\left(\frac{d_i}{d_0}\right) + 19.23\, dB, \quad \text{or}$$

$$Lp = 126.99\, dB + 27.2 \log(D) \quad (8)$$

Where, $D = \frac{d_i}{d_0}$.

This shows that an increase in distance, the signal loss will be increased by a factor of 27.2 *log* (D)

Applying Hata equation with f (frequency in MHz), h_m (mobile antenna height in meters) and h_b (base station antenna height in meters) the path loss for Port Harcourt was obtained using the transmission parameters in Table 1 and given as

$$PL = 69.55 + 26.16\log_{10}(f) - 13.82\log_{10}(h_b) + \left(44.9 - 6.55\log_{10}(h_b)\right)\log_{10}(d) - a(h_m) \quad \text{or}$$

$$PL = 125.2273 + 34.7864\log_{10}(d) \quad (9)$$

The path loss for Port Harcourt Urban using COST 231 model was obtained from

$$PL(dB) = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m) + \left(44.9 - 6.55\log(h_b)\right)\log_{10}(d) + c_M \quad \text{or}$$

$$PL\ (urban) = 138.7737 + 34.7864\log_{10}(d) \quad (10)$$

With n and α_o as path loss exponent and the correction factor respectively, the path loss for Port Harcourt urban using the LEE path loss model was obtained by

$$LEE = 123.77 + 30.5\log_{10}(d) + 10n\log_{10}(f/900) - \alpha_o \quad \text{or}$$

$$LEE_{urban} = 95.8289 + 30.5\log_{10}(d) \quad (11)$$

RESULTS AND DISCUSSION

Fig.5 shows the relationship between the signal path losses and distance within RSUST. It is seen from the plot that at a distance of 0.1 Km and 0.45Km, the path losses are 103dB and 108dB respectively.

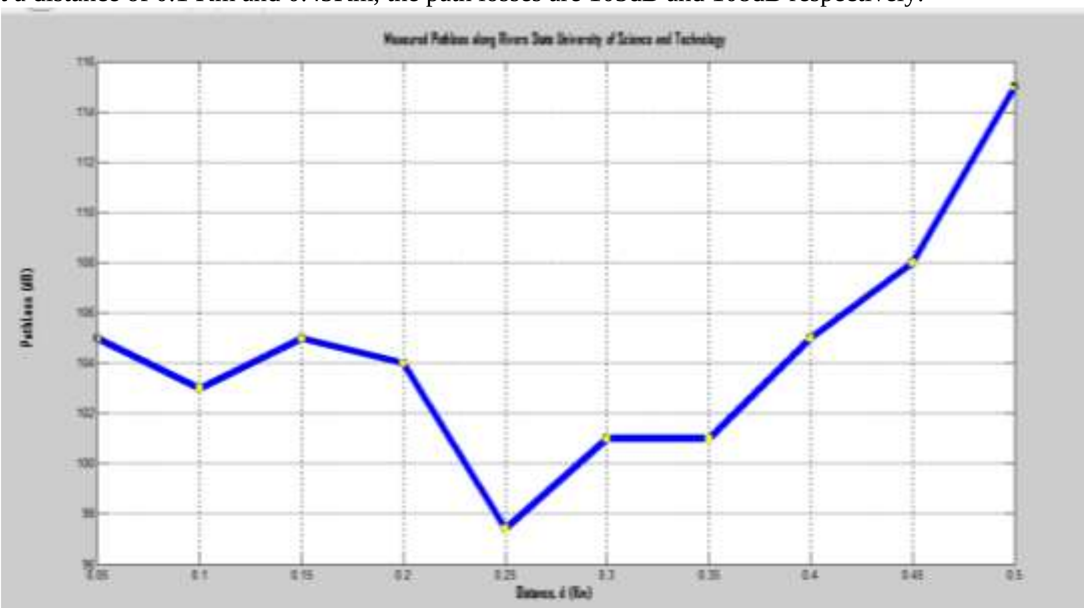

Fig.5: The MatLab plot of the Signal Path loss across RSUST

Fig. 6 is plot of the signal path losses and distance within RSUST and Ikwerre Road. From the plot a distance of 0.2 Km and 1.0 Km, the path losses are 101dB and 158dB respectively.

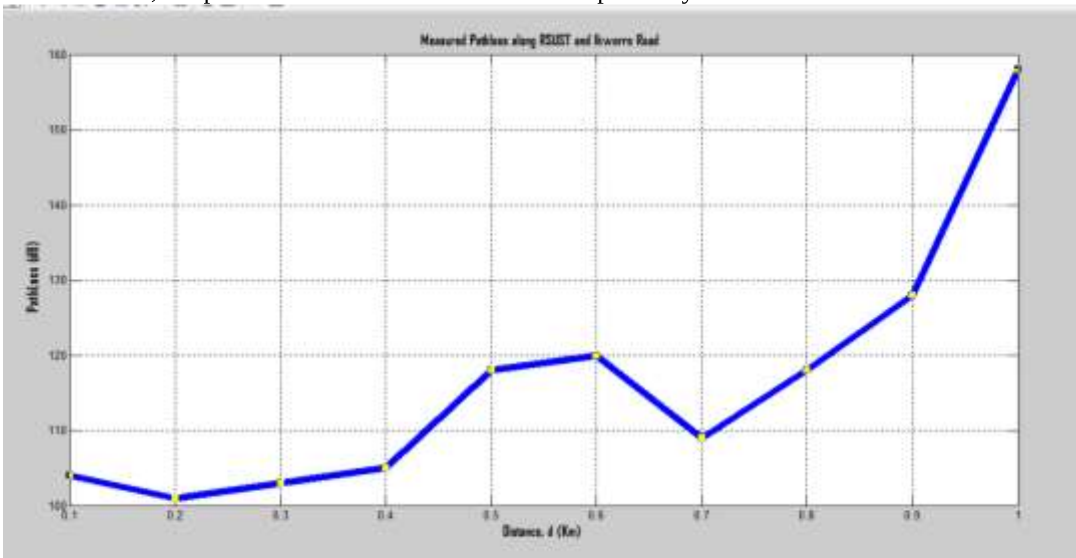

Fig.6: The MatLab plot of the Signal Path loss across RSUST & Ikwerre Road

A plot showing the relationship between the signal path losses and distance along Ikwerre Road and D-line is shown in Fig.7 At a distance of 0.2 Km and 1.0 Km, the path losses on the proposed model are about 104.6 dB and 128dB respectively.

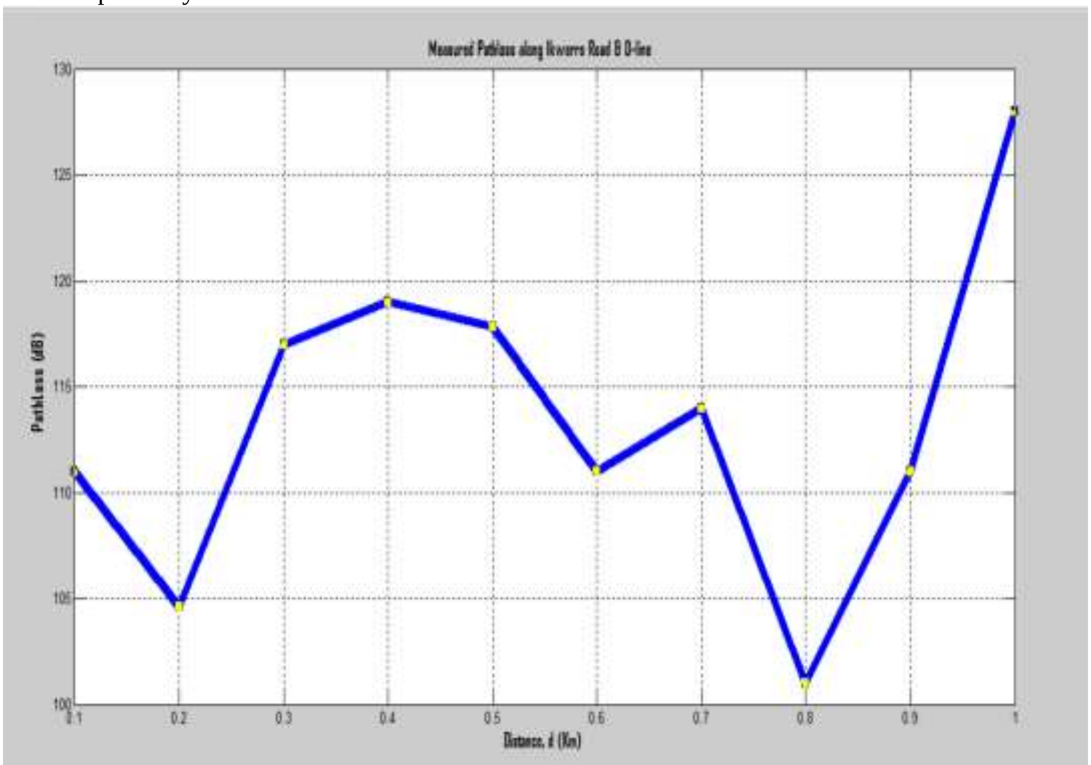

Fig.7: plot of the Signal Path loss along Ikwerre Road & D-line

In Fig. 8, the path loss of WCDMA network in Port Harcourt city are shown. The model revealed an exponential increase of path loss with distance. At a distance of 0.1Km and 1.0Km the path losses are126.9900 dB and 154.1898dB respectively.

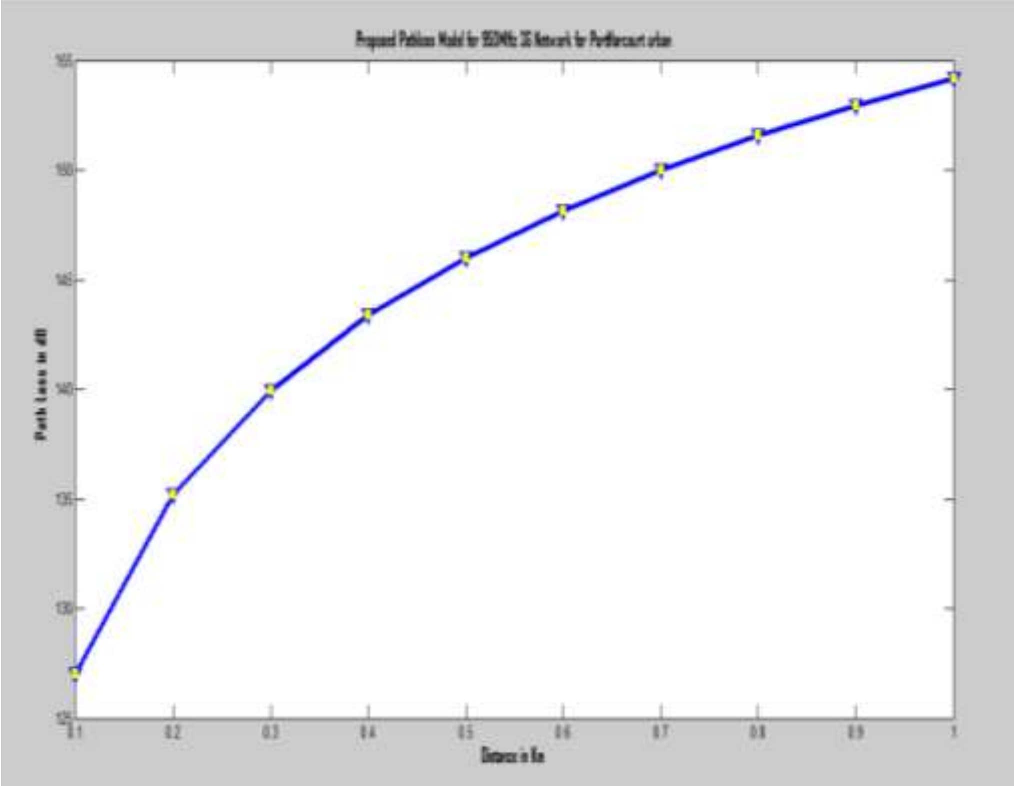

Fig.8: Plot of WCDMA network Model for Port-Harcourt urban at 1.857 GHz.

Fig. 9 is the Hata model chosen to compare the proposed model. From the figure it is observed that at a distance of 0.100km, the path loss is 125.2273 dB. Also at a distance of 0.50km and 1.0 km, the path losses are 149.5418 dB and 160.0135dB respectively

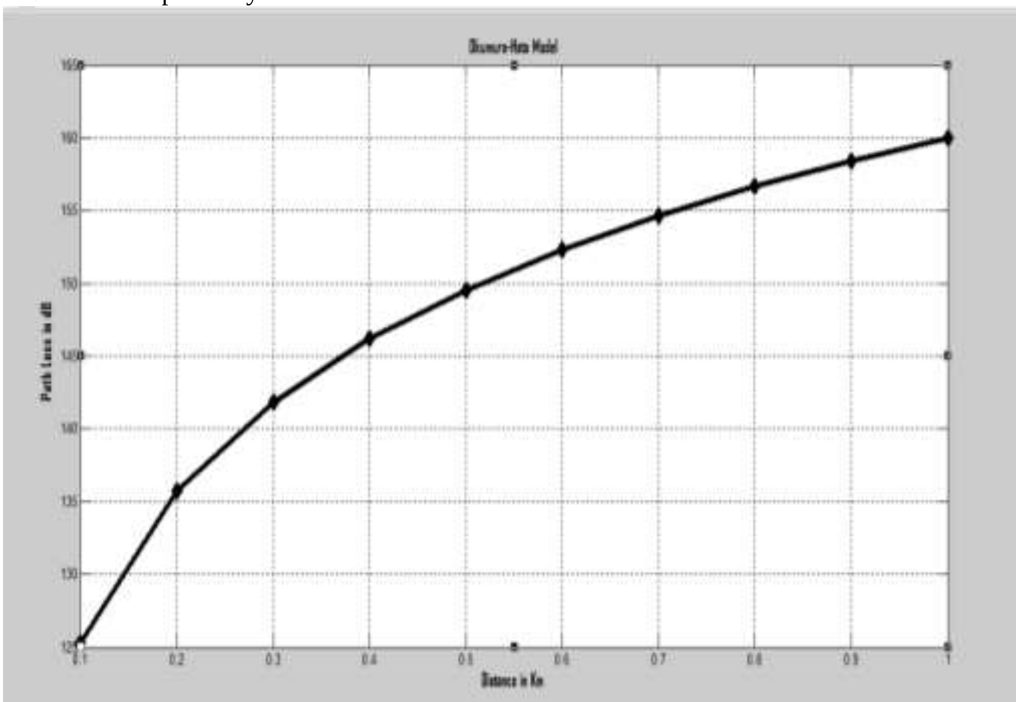

Fig. 9: A plot showing relationship between distance and path loss of Hata model

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Fig. 10 is a plot of COST 231 model chosen to compare the proposed model. From the plot, at a distance of 0.100km, the path loss is 138.7737 dB. At a distance of 0.5 km and 1.0 km, the path losses are 163.0907 dB and 173.5635dB respectively.

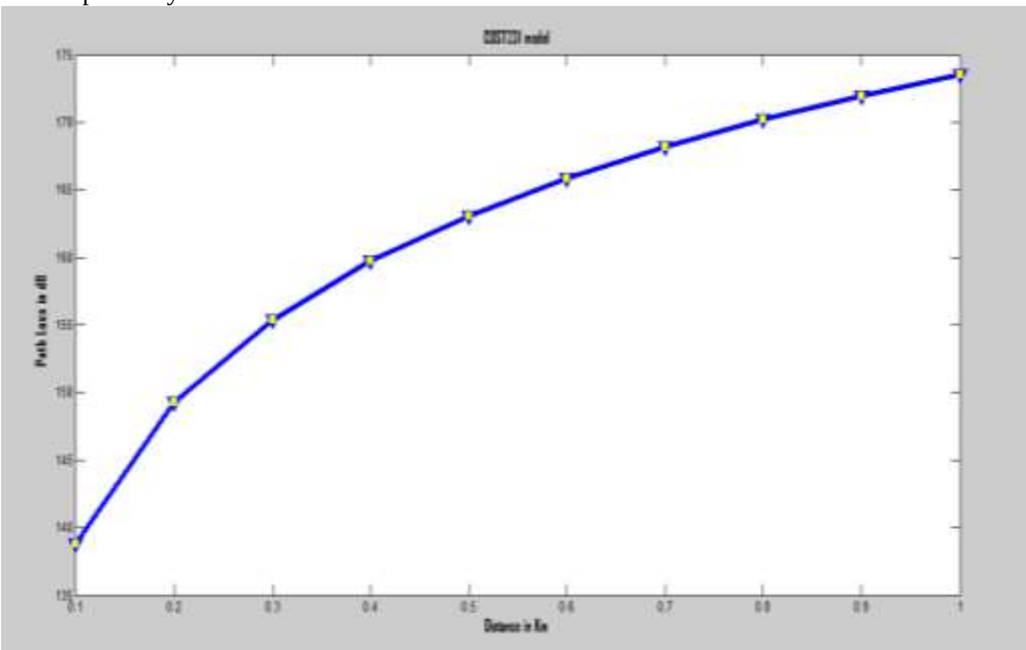

Fig.10: A plot showing relationship between distance and path loss of COST231 model

The plot of LEE model chosen to compare the proposed model also is shown in Fig.11. From the plot, at a distance of 0.10 km, the path loss is 95.8289 dB. With increased distance from 0.5 km to 1.0 km, the path loss increased from 117.1473 dB to126.3287dB.

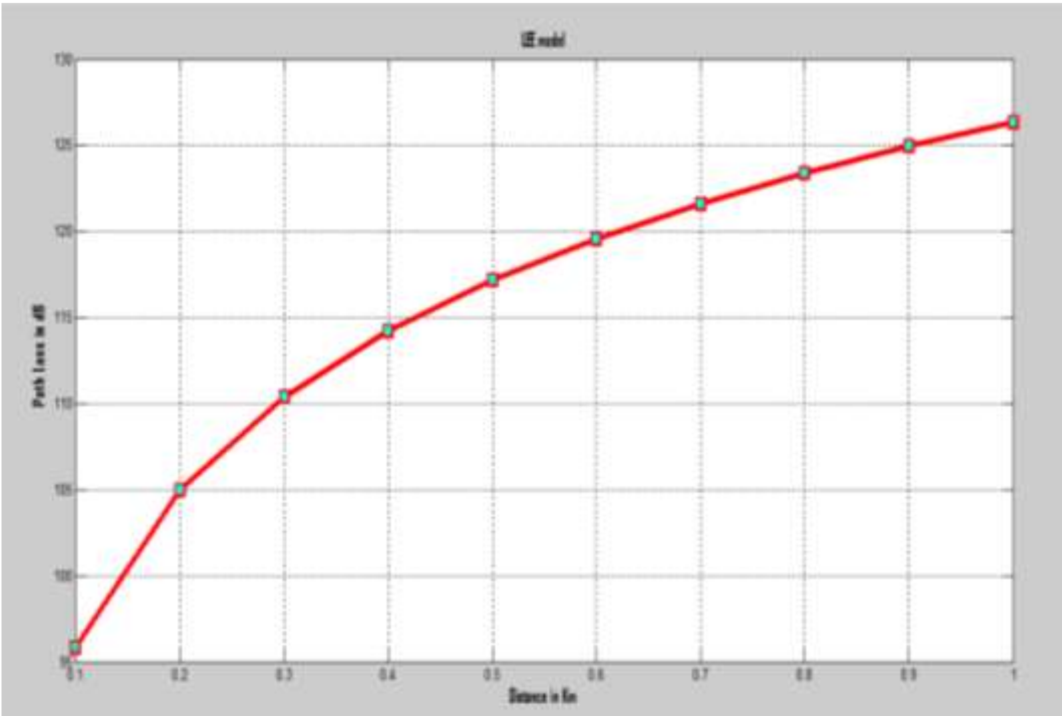

Fig.11: Plot showing relationship between distance and path loss of LEE model

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Fig.12 is a plot for the comparison of the entire models. It is shown that at a distance of 0.10 km, the path losses are 125.2273 dB, 138.7737 dB, and 95.8289 dB for Okumura-Hata, COST 231, and LEE models respectively. Also, at a distance of 1.0 km, the path losses are 160.0135dB, 173.5635dB, and 126.3287dB for Hata, COST 231, and LEE models respectively.

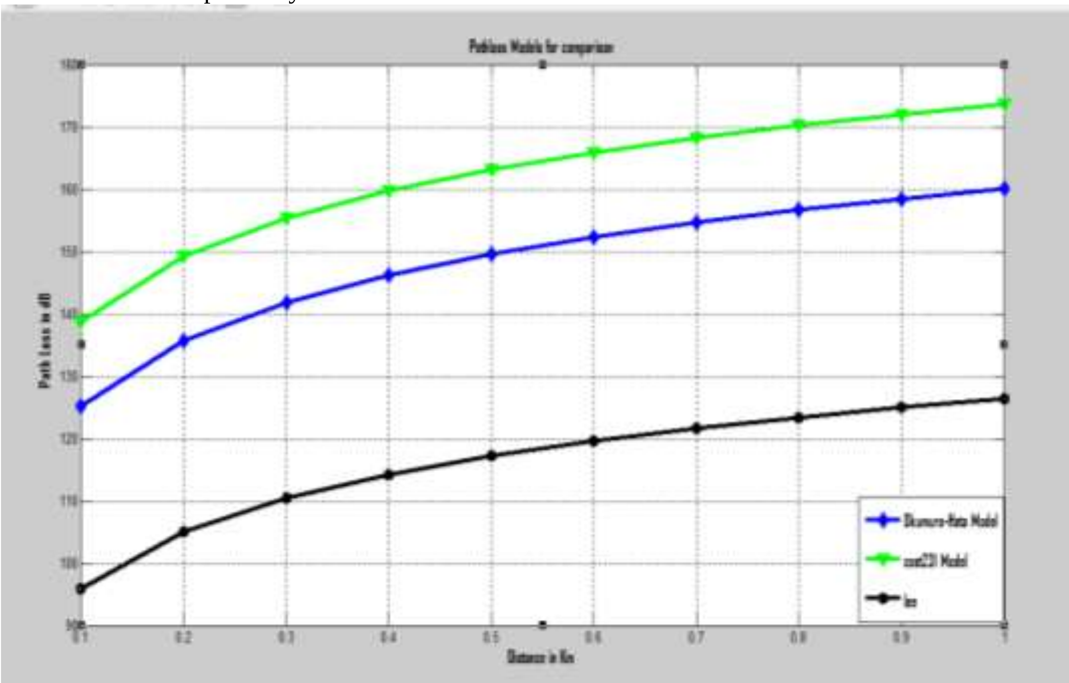

Fig.12: A graph showing relationship between distance and path loss of Hata, COST 231 and LEE models

Fig. 13 compares the path loss of the proposed 1.857 GHz WCDMA network model with the measured path loss, Hata, Cost 231 and LEE models. From the plot, at a distance of 0.10 km, the path losses experienced in the measured path loss, proposed model path loss, Hata, COST 231 and LEE models are 112 dB, 126.99 dB, 125.2273 dB, 138.7737 dB and 95.8289 dB respectively. When the distance covered was 1.0 km, the path losses were 158 dB, 154.1898dB, 160.0135dB, 173.5635dB, and 126.3287dB for the measured path loss, proposed model path loss, Hata, COST 231 and LEE models respectively.

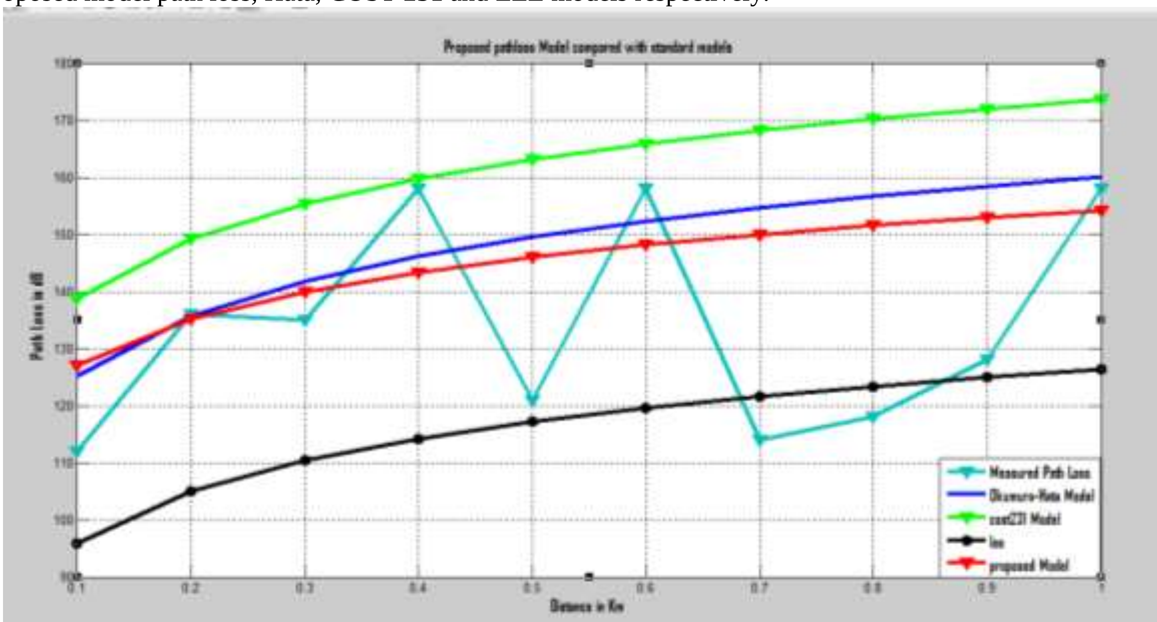

Fig.13: Plot of measured path loss, proposed model path loss, Hata, COST 231 and LEE models

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

It was observed from the graph that Hata model and COST 231 model are good for analyzing the signal losses in 1.857 GHz Port-Harcourt urban WCDMA network as their values had insignificant variation from the proposed model. The third model (LEE model) indicated much divergence from the proposed model.
The causes of poor signal coverage and improper signal handover along the routes could be traced to multipath propagation and Doppler spread. It is suggested that WCDMA network Operators operating in the monitored area should substitute their directional BTS antennas with a bi-sector high gain antenna in order to ensure wider and Omni-directional signal coverage within Port-Harcourt urban.

CONCLUSION

A drive test was carried out at a vehicular speed within the Port-Harcourt area in this work using TEMS 11 installed with a Phone, Global Positioning System (BU-353 GPS) and HP laptop with installed TEMS software. From the data collected and analysis done, a path loss model that best describes the signal loss was developed, a path loss exponent for the Port-Harcourt urban WCDMA network at 1.857 GHz was deduced as 2.72; the proposed model with the COST 231 and Hata standard models were compared; the standard deviation between the measured path and the predicted path losses in the Port-Harcourt WCDMA network was computed, and solutions on how to minimize the service degradation in the network was offered.

REFERENCES

[1] A Sing, A Review of Different Generations of Mobile Technology. *International Journal of Advanced Research in Computer Engineering & Technology 4(8)*, 2015.
[2] C. Dalele, Propagation path loss Modeling for Deployed WiMAX Network, .*International Journal of Emerging Technology and Advanced Engineering*,.2(8), 2012
[3] N.T.S. Bakinde, N. Faruk, A.A. Ayeni, M.Y. Muhammad and M.I. Gumel, (2012). Comparison of Propagation Models for GSM 1800 and WCDMA Systems in Selected Urban Areas of Nigeria. *International Journal of Applied Information Systems, 2(7),* 2012, 6 – 13.
[4] J.C. Ogbulezie, M.U. Onuu,, D.E. Bassey and S. Etienam- Umoh, S., Site specific measurements and propagation models for GSM in three cities in northern Nigeria, *American Journal of scientific and industrial Research*, 2013.
[5] G. Durgin, T.S. Rappaport, and H. XU, (1998), Measurement and models for Radio Pathloss and Penetration loss in and Around Homes and Trees at 5.85GHz". *IEEE Transaction on communications, 46(11)*,1998.
[6] G.C. Nwalozie, (2014). Pathloss predicition for GSM mobile networks for Urban Region of Aba, South-East Nigeria. *International journal of computer science and mobile company. 3(2),* 2014, 267-287.
[7] V.N. Okorogu, (2013), Empirical Characterization of Propagation Path Loss and Performance Evaluation for Co-Site Urban Environment, *International Journal of Computer Applications: 70(10),* 2013.

CITE AN ARTICLE

Chinedu, A., Nkwachukwu, C., & Cosmas, A. (2017). DEVELOPMENT OF A PATHLOSS MODEL FOR 3G NETWORKS AT 1.857 GHz IN PORT HARCOURT NIGERIA. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(5), 423-433. doi:10.5281/zenodo.573555