Journal of the Nigerian Association of Mathematical Physics
***Volume33,(January, 2016*), pp 201 – 206**
© J. of NAMP

Comparison of Path Loss and Signal Strength of GSM and CDMA In Enugu, Nigeria, Using Okumura-Hata And Cost-231 Models

J.O. Adepitan, F.O.Ogunsanwoand J.D. Ayanda

Department of Physics and Telecommunication, Tai Solarin University of Education, Ijagun, Ijebu, Nigeria.

Abstract

The main concern of any wireless network provider, is achieving a good network performance. This is measured by the strength of signal received at the mobile station. Radio propagation, which is essential for any wireless network, is heavily site specific and can vary significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor. This work is centered on comparison of path loss and signal strength of GSM and CDMA in Enugu, Nigeria, using Okumura-Hata and COST -231 models.
Geographical coordinates, determined by Global Positioning System (GPS), of antennas at ten base stations situated in Enugu; with corresponding height and transmitting frequencies of both GSM and CDMA data were extracted from site engineering parameters. With Ericsson TEMS Investigation 8.0 (data collection software) installed on personal computer, the Received Signal Strength (RSS) of each transmitting antenna at various measured distances from the antenna was recorded. Three readings were taken for each measured distance and the mean determined. The field measurementresults were compared with Okumura-Hata and COST-231 models for medium-sized city. This research thus shows that the Okumura-Hata and COST-231 models for radio wave propagation is very effective for radio wave propagation pathloss prediction in the Eastern part of Nigeria.

Keywords: Pathloss, GSM, CDMA, Model, Radio propagation.

1.0 Introduction

The recent explosion in wireless internet access has brought with it rapid erection of telecommunication masts all over the cities and the ecosystem of Nigeria. As at the end of the year 2013 for example, two major players in the telecommunication industry, namely Mobile Telecommunication Network (MTN) and Glo were having approximately 4,000 and 6,230 masts respectively erected all over Nigeria. The heights of these masts are in the range of 30m to 70m, depending on the terrain of the stations where they are erected[1].

Mobile phone base stations are radio transmitter with antennas mounted on either transmission towers or roof tops on buildings. The antennas need to be located at optimum locations and heights so they can adequately cover the area. When a person makes a cell phone call, a signal is sent from the mobile phone's antenna to the nearest base station antenna. The base station responds to this signal by assigning it an available radiofrequency channel. Radio frequency waves transfer the information to the base station. The voice/data signals are then sent to a switching center, which transfers the call to its destination. The voice signals are then relayed back and forth during the call. The possible frequency ranges at which mobile phones do operate are [2] :

(i) 869 - 890 MHz for Code Division Multiple Access (CDMA)
(ii) 935 - 960 MHz for Global System for Mobile (GSM900)
(iii) 1805 – 1880 MHz (GSM1800)
(iv) 2110 – 2170 MHz (3G)

The intensity of the receivedsignal weakens very quickly as it moves away from the transmitting antenna. The magnitude of the received signal strength is inversely proportional to the square of the distant between the transmitting antenna and the receiving antenna. Radio wave signal power attenuation depends mainly on the frequency band and terrain types between the

Corresponding author: J.O. Adepitan, E-mail:olufemiabisola@yahoo.com, Tel.: +2348028296714

transmitting and receiving antenna[3].
Radio propagation models typically focus on realization of the path loss with the auxiliary task of predicting the area of coverage for a transmitter or modeling the distribution of signals over different regions [4]. Several models have been developed to estimate the propagation path loss at various receiver distances from a transmitting base station. The received signal strength in practical wireless scenarios, especially cellular scenario was thereafter determined. Examples of such models areEgli [5] , Longley-Rice [6] , Okumura-Hata [7] , COST 231 [8], Lee [9] and Bullington [10] ; just to mention a few. From all the above models, Okumura model is one of the most widely used analytical models for signal strength predictions in urban and sub-urban areas[11]. This is valid for 150- 1920MHz.
Shoewu and Adedipe[12] investigated the effectiveness of Okumura model in SabonRijiya alongBauchi-Potiskum Road, Bauchi State, northern Nigeria ,and discovered that the Okumura-Hata model for radio wave propagation is very effective for radio wave propagation path loss prediction in suburban areas in Northern part of Nigeria. A similar work was carried out in [13] in Epe, Lagos environ, in western Nigeria and the result revealed that Okumura-Hata model for radio wave propagation is very effective for radio wave propagation pathloss prediction in sub-urban and urban areas in Western part of Nigeria.
This study is carried out at investigating the effectiveness of commonly used Okumura-Hata and COST -231 models, and comparing Received Signal Strength (RSS)-- a measure of how strong the most recent signal was when it reached its destination--measurements taken with simulation results derived from field strength model which are used for macro cells in rural and suburban areas. This investigation of radio wave signals (GSM and CDMA) covered Enugu town, in the eastern part of Nigeria.If the path loss distribution as proposed by these models are in consonance with those measured, then these models will be regarded as valid for use in cellular network planning for eastern Nigerian rural, suburban, andurban areas.

2.0 The Okumura–Hata Model [7]

The pathloss of the common form of Okumura-Hata model is written as :

$$PL = A + B\log(d) + C \tag{1}$$

whereA,B, and C are factors that depend on frequency and antenna height.

$$A = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) - a(h_m) \tag{2}$$

$$B = 44.9 - 6.55\log(h_b) \tag{3}$$

wheref_c is given in MHz , h_m is mobile station height in m , and d in km.

The function $a(h_m)$ and the factor C depend on the environment:

In case of small and medium-size cities:

$$a(h_m) = (1.1\log(f_c) - 0.7)h_m - (1.56\log(f_c) - 0.8) \tag{4}$$

$$C = 0\ . \tag{5}$$

For metropolitan areas

$$a(h_m) = 8.29(\log(1.54h_m)^2 - 1.1 \qquad for \quad f_c \le 200MHz$$

$$3.2(\log(11.75h_m)^2 - 4.97 \qquad for \quad f_c \le 400MHz \tag{6}$$

$$C = 0 \tag{7}$$

ForSuburban environments

$$C = -2[\log(f_c/28)]^2 - 5.4 \tag{8}$$

For rural area

$$C = -4.78[\log(f_c)]^2 + 18.33\log(f_c) - 40.98 \tag{9}$$

The function $a(h_m)$ in suburban and rural areas is the same as for urban (small and medium-sized cities) areas.
The Okumura-Hata model also assumes that there are no dominant obstacles between the base station and the mobile station, and that the terrain profile changes only slowly
Okumura model is valid for the following range:

(i) Carrier frequency $f_c : 150 - 1500MHz$

(ii) Effective base station antenna height, $h_b : 30 - 200m$

(iii) Distance d : 1-20km

3.0 COST-231 Model [8]

The COST 231 model is a pathloss model for the case of small distances between mobile station and base station,and/or small height of the mobile station. The COST 231-Hata model extends the validity of the frequency range of Okumura-Hata model to 1500 to 2000MHz, thus taking care of the second generation (2G) and third generation (3G) cellular systems. Replacing some of the constants in equation (2) gives equation (10).

$$A = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m) \quad (10)$$

where $a(h_m)$ is defined in equation (4). C is 0 in small and medium-sized cities, and 3 in metropolitan areas.

The field strength, E measured in dB (μV/m)

$$E = 69.82 - 6.16\log(f_c) + 13.82\log(h_b) + a(h_m) - (44.9 - 6.55\log(h_b))\log(d)^b \quad (11)$$

where $a(h_m)$ is same as Eq. (4).

$$b = 1 \qquad for \quad d < 20\,km \quad (12)$$

$$b = 1 + (0.14 + 0.000187\ f_c + 0.00107\,h_1)(\log(0.05d))^{0.8} \qquad for \quad d > 20km \quad (13)$$

$$h_1 = h_b \Big/ \sqrt{((1 + 0.000007\ (h_b)^2))} \quad (14)$$

4.0 Methodology

Data in relation to ten base stations located in Enugu town (a medium-size city), eastern region of Nigeria, were collected. With the aid of the Global Positioning System (GPS), geographical coordinates of the antennas were determined. Antenna height and transmitting frequencies of both GSM and CDMA data were extracted from site engineering parameters. Making use of Ericsson TEMS Investigation 8.0 (data collection software) installed on personal computer, the Received Signal Strength (RSS) of each transmitting antenna at various measured distances from the antenna was recorded. Three readings were taken for each measured distance and the mean determined.

5.0 Results and Discussion

Table 1: Stations Parameters

	Longitude/deg.	Latitude/deg.	Antenna Height/m
Station 1	7.50951	6.46046	26.0
Station 2	7.49402	6.43078	28.0
Station 3	7.53016	6.46707	29.0
Station 4	7.51536	6.48089	26.0
Station 5	7.48468	6.4783	23.0
Station 6	7.52806	6.43072	32.0
Station 7	7.49407	6.40919	29.0
Station 8	7.49383	6.45648	24.0
Station 9	7.48107	6.43618	29.0
Station 10	7.70736	6.43717	45.0

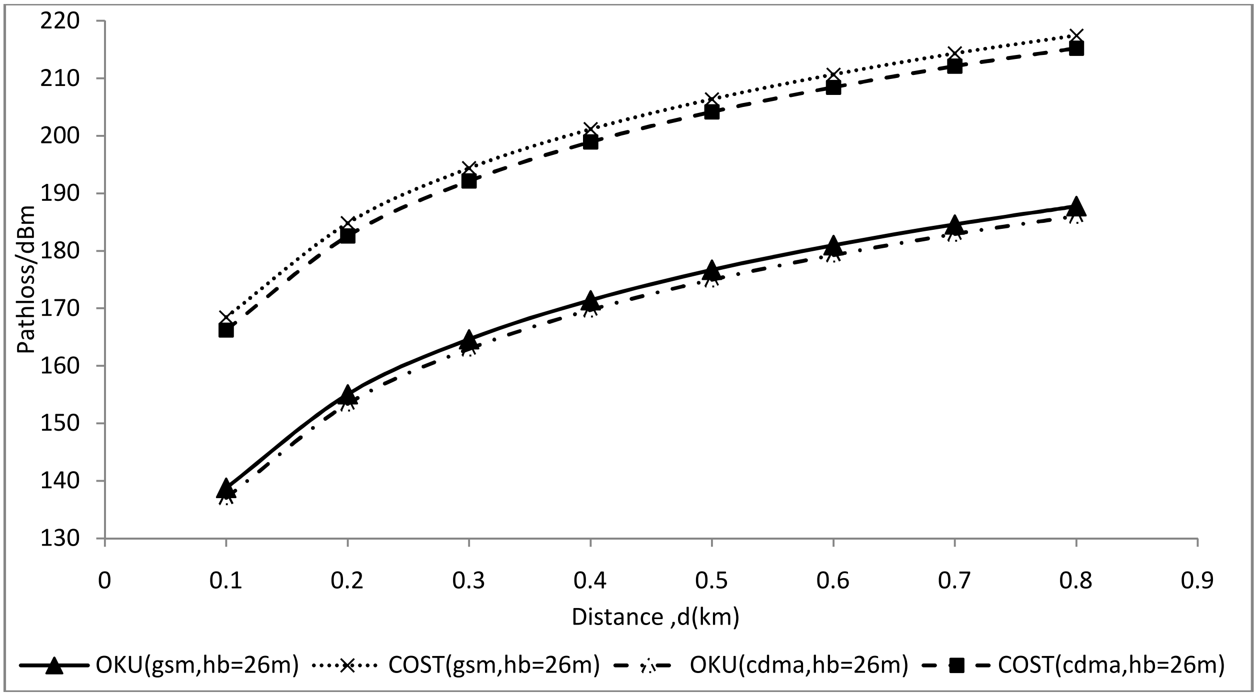

Figure 1: Pathloss profiles for Station 1 for both Okumura and COST 231 models

Table 2: Field Strength/Received Signal Strength for Station 1 (Measured and Modeled)

Station 1 Parameters: hb=26m, long.=7.50951 deg., lat.=6.46046 deg.										
	RSS/dB for GSM(940MHz)					RSS/dB for CDMA(876.87MHz)				
	Measured					Measured				
d/km	1	2	3	Mean	Modeled	1	2	3	Mean	Modeled
0.1	-50	-49	-48	-49.0	137.5358	-48	-46	-48	-47.3	137.964
0.2	-52	-53	-55	-53.3	121.2056	-50	-51	-53	-51.3	121.6339
0.3	-56	-55	-56	-55.7	111.6531	-55	-53	-56	-54.7	112.0813
0.4	-60	-65	-67	-64.0	104.8754	-58	-60	-63	-60.3	105.3037
0.5	-70	-72	-74	-72.0	99.6183	-68	-69	-70	-69.0	100.0465
0.6	-73	-75	-77	-75.0	95.3229	-71	-73	-75	-73.0	95.7511
0.7	-80	-84	-85	-83.0	91.6912	-77	-79	-83	-79.7	92.1194
0.8	-97	-95	-93	-95.0	88.5452	-88	-90	-91	-89.7	88.9735

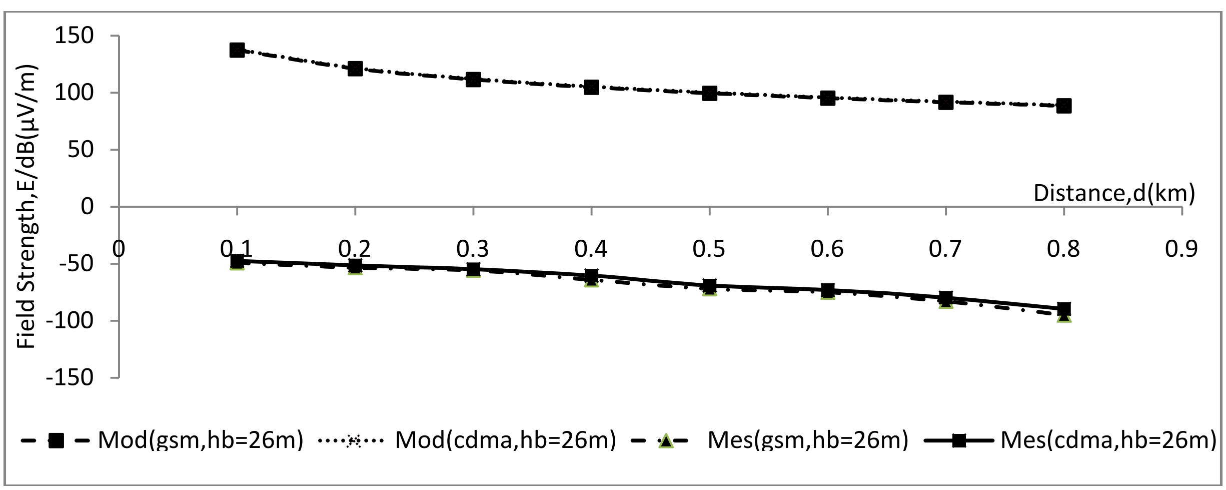

Figure 2: Graphs of Modeled RSS versus distance compared with measured RSS for Station 1

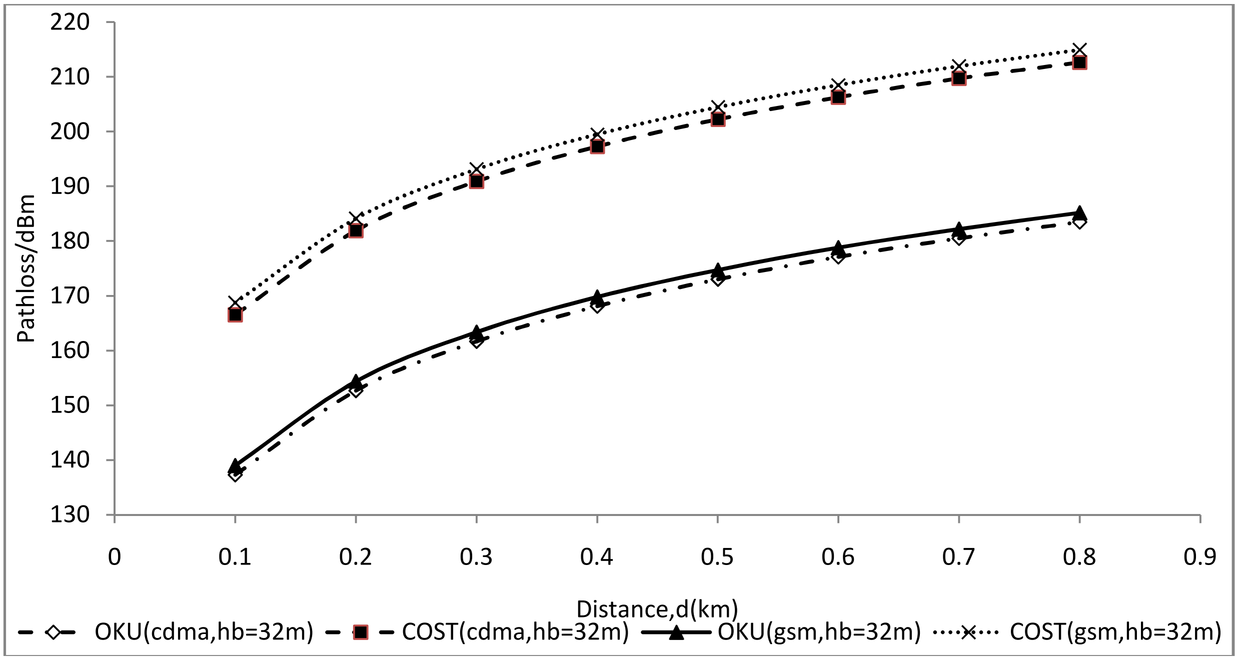

Figure 3: Path loss profiles for Station 6 for both Okumura and COST 231 models

Table 3: Field Strength/Received Signal Strength for Station 6 (Measured and Modeled)

Station 6 Parameters: hb=32m, long.=7.52806deg., lat.=6.43072deg.										
	RSS/dB for GSM(940MHz)					RSS/dB for CDMA(876.87MHz)				
	Measured					Measured				
d/km	1	2	3	Mean	Modeled	1	2	3	Mean	Modeled
0.1	-49	-47	-50	-48.7	137.2738	-46	-44	-47	-45.7	137.581
0.2	-54	-52	-55	-53.7	121.8863	-51	-49	-52	-50.7	122.1936
0.3	-54	-59	-69	-60.7	112.8852	-54	-56	-66	-58.7	113.1925
0.4	-71	-76	-79	-75.3	106.4988	-68	-70	-71	-69.7	106.8061
0.5	-81	-82	-84	-82.3	101.5452	-73	-76	-78	-75.7	101.8524
0.6	-87	-88	-89	-88.0	97.4977	-81	-83	-87	-83.7	97.805
0.7	-90	-91	-93	-91.3	94.0757	-90	-88	-91	-89.7	94.3829
0.8	-94	-95	-96	-95.0	91.1113	-92	-93	-94	-93.0	91.4186

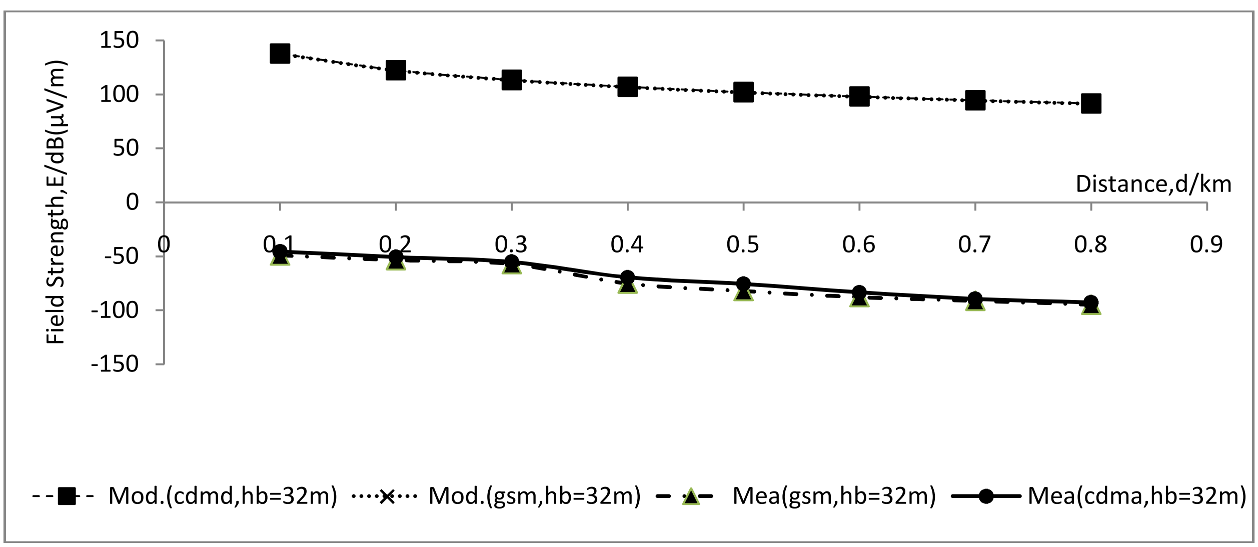

Figure 4: Graphs of Modeled RSS versus distance compared with measured RSS for Station 6

The results of all the ten stations follow the same pattern. Hence, results of two stations (1 and 6) are hereby examined into details. The pathloss distribution graph in Figures 1 and 3 show the relationship that exists between the Okumura and COST-231 propagation models in terms of pathloss. It can be seen that there are variations between the models. Between the communication models, Okumura model shows the lesser path loss than COST-231 model. The signal strength trends are opposite to that of path loss as signal strength with respect to distance between transmitter and receiver. The path loss shows increasing trend with respect to increasing transmission distance, while the received signal strength shows decreasing trend with respect to increasing distance between transmitter and receiver antennas. Figures 2 and 4, being representations of the ten stations, revealed that the modeled signal strength is larger in all the ten stations than the measured ones.The results revealed that path losses experienced at GSM (940 MHz) are about 2.24 dB larger than those experienced at CDMA(876.87MHz) in case of Okumura model; while that of COST-231 are 1.70dB larger. For a given base station height, the modeled received signal strength values are almost the same for both GSM and CDMA. Same applied to the measured signal strength values. Though there is a significant difference between the modeled and measured values of the field strength of the received signal, the degree of correlation of these values are very high. Thus regression was used to couple the modeled and measured values together.

6.0 Conclusion

This research thus shows that the Okumura-Hata and COST-231 models for radio wave propagation is very effective for radio wave propagation path loss prediction,thereby these models will be regarded as valid for use in cellular network planning for eastern Nigerian rural, suburban, andurban areas.

7.0 References

[1] Longley, A. G., andHufford, G. A. (1975).“Sensor path loss measurements analysis andcomparison with propagation models”, OT Report 75-74. Available from NTIS, Access. No.PB-247-638/AS.

[2] McQuate, P. L., Harman,J. M.,McClanahan, M. E. and Barsis, A. P. (1970). Tabulationspropagation data over irregular terrain in the 230 to 9300 MHz frequency range; Part III,North Table Mountain--Golden, ESSA Tech. Report ERL 65-ITS 58-3. Available from NTIS, Access. No. AD-7l5-753.

[3] Emagbetere, J.O. and Edeko, F.O. (2007). An Evaluation of Outgoing Calls Quality of GSM Network Services in Oghara, Delta State. *Research Journal of Applied Sciences,Vol.2 ,No. 10, pp.1016 – 1018.*

[4] Schmitz , A. and Wenig, M.,(2008). “The Effect of the Radio Wave Propagation Model in Mobile Ad Hoc Networks” *Proceedings of World Academy of Science, Engineeringand Technology, Vol 36, 2070-3740*

[5] Egli, J. J. (1957), Radio propagation above 40 Mc over irregular terrain, Proc. IRE Vol. 45, pp. 1383-1391.

[6] Longley, A. G., and Rice ,P. L. (1968). “Prediction of tropospheric radio trans-mission loss over irregular terrain--a computer method”. 1968, ESSA Tech. Report ERL 79-ITS 67. Available from NTIS, Access. No. AD-676-874.

[7] Okumura Y., Ohmori E., Kawano,T. , Fukuda,K. "Field strength and its variability in VHF and UHF landmobileservice," *Review of the ElectricalCommunication Laboratory*, vol. 16,no. 9-10, 1968, pp. 825-873.

[8] COST 231, "Urban transmission loss models for mobile radio in the 900- and 1,800 MHz bands (Revision 2),"*COST*

[9] Lee, W. C. Y.(1993). *Mobile Communications System Design*. New York: Wiley.

[10] Bullington, K. (1950), Radio propagation variations at VHF and UHF, Proc. IRE 38, pp. 27-32.

[11] Abhayawardhana, V.S, Wassell, I.J. , Crosby, D, Sellars, M.P. and Brown, M.G, (2005).“Comparison of empirical propagation path loss models for fixed wireless access systems”,*Proceedings of IEEE Conference on Vehicular Technology , Stockholm, Sweden, Vol. 1,pp 73-77.*

[12] Shoewu, O. and Adedipe, A. (2010) . “Investigation of radio waves propagation modelsinNigerian rural and sub-urban areas.”*American Journal of Science and IndustrialResearch, 1(2): 227-232* **.**

[13] Shoewu, O. and Edeko, F.O. (2011). “Analysis of radio wave propagation in Lagosenvirons”. *American Journal of Science and Industrial Research, 2(3): 438-455*