Journal of the Nigerian Association of Mathematical Physics
***Volume28, No. 1, (November, 2014*), pp 421 – 426**
© J. of NAMP

Prediction of Propagation Models in a Suburban and a Rural Area Using UMTS Radio Measurements at 2100MHZ

[1]Osunkwor E. O., [2]Otebele E., [3]Azi S.O., [4]Isabona O.

Physics Department, Faculty of Physical science, University of Benin.

Abstract

As a signal propagates through the air between the transmitter and the receiver, it experiences some loss, this is called path loss. In wireless mobile network, an accurate estimation of radio path loss is useful for predicting coverage areas of base stations, frequency assignments, determination of electric field strength, interference analysis, handover optimization, and power level adjustment. In this work, we studied the radio signal path loss behaviour by conducting an experimental measurement survey in a UMTS (Universal Mobile Telecommunication System) network transmitting at 2100MHz band for a suburban area and a rural area. The measured field strength data collected at various distances from the base stations was used to estimate the path loss. Firstly, the effect of distance from base stations were studied and it was observed that path loss increases with distance from the signal source due to a corresponding decrease in field strength. Secondly, the calculated path loss data was compared with data from other existing path loss prediction methods. We find that the COST 231 Hate model satisfy our measured path loss data for the rural area thus showing its suitability for path attenuation loss prediction in UMTS network in the rural area.. However, none of the considered propagation models was found suitable for the suburban area..

Keywords: Path loss, suburban, COST-231 Hata Model, Rural, UMTS, Radio Signals.

1.0 Introduction

The existence of poor signal strength and path loss due to the reduction of power density of an electromagnetic wave as it passes through multi-path propagation environment hasbeen a major challenge over the years in the use of radio mobile communications and this effect is usually higher in suburban areas[1].Radio propagation path loss model has been one of the major ways of determining the quality of mobile communication systems, derivation of network coverage area and even network optimization [2,3,4]. Moreover, path loss may be due to many effects, such as free space loss, diffraction, reflection, aperture-medium coupling loss and absorption. In some cases, congestion of buildings also does obstruct greatly signal strength across board and this has hindered effective communication in the affected areas over the years, due to the differences in building structures, local terrain profiles, weather etc., However, to ensure stable communicationwhich implies an optimum quality for the radio coverage of a wireless network the design of such network must be solely based on the best propagation model of the location of the intended network. To accurately predict such model, the model must be derived from real-time measurement data thoroughly taken from the service area in which the network design will be deployed. Although these processes of network planning and optimization has become complicated and difficult as high numbers of base stations are involved in a network with significant co-channel interference It is imperative that these be done especially before deployment of network else the network operators may face huge losses resulting from complaints from the network users due to improper link budget calculations and weak or erratic signal strength.

Usually, the calculation of path loss is called path loss prediction. An accurate estimation of path loss is specifically useful for predicting coverage areas of base stations, frequency assignments, proper determination of electric field strength, interference analysis, handover optimization, and power level adjustment [5]. Although most of the existing path loss prediction models have limitations but by comparing them with the real-time measured data and carrying out proper adjustment of such models where necessary, the most accurate path loss prediction model for any mobile propagation environment can be determined.

It is against this background that we carry out our research in view of studying the pathloss effect on two different types of environment; suburban and rural using our local vicinity Agbor park and Ekiadolor representing suburban and rural respectively as a case study. We are not ignorant of the fact that a lot of work has been done previously in this area

Corresponding author: Osunkwor E. O,E-mail: offormata.osunkwor@uniben.edu, Tel.: +2347060470621

especially in several countries[5-14], but none has been done in our chosen location. The aim here is not just to studythe extent of path loss in two locations but also to identify the best model for these locations so that necessary optimization can be carried out.

2.0 Experimental Details and Methodology Adopted

Measurement-based Prediction (MbP) is a unique radio propagation process, which increases the accuracy of conventional propagation model predictions by making use of real-time data to improve the model predictions around base station sites. The measurements were conducted from a UMTS network with WCDMA interface transmitters, located at Agbor Park and Ekiadolor, both in Edo State. The drive routes in these different locations are shown in Figures 1-2. The measured received signal strength data which is the Received Signal Code Power (RSCP) and transmitter-receiver (T-R) separation distance (d) are recorded in dB and m respectively. Every measurement points of received signal strength and T-R separation distance are recorded evenly from all the predefined routes of the two base stations. Each measurement point is represented in an average of a set of samples taken over a small area (10 square meters) in order to remove the effects of fast fading [15].

The Ericsson-model TEMS (Test Mobile Systems) cell planner tool for data collection had the antenna mounted on a moving vehicle (1.5 meter above ground level). The Global Positioning System Receiver Set (GPS system) and a piece of compass were connected to a personal computer. The personal computer serves as the communication hub for all other equipment in the system. The GPS operates with global positioning satellites to provide the location tracking for the system during data collection, on a global map which has been installed on the personal computer. The compass helps to determine the various azimuth angles of the base station transmitters. Average height of transmit antenna is about 38 – 40 meters above ground level, with the same transmit power. Sampling rate of the collected data, on the average, is about 2 – 3 samples per meter.

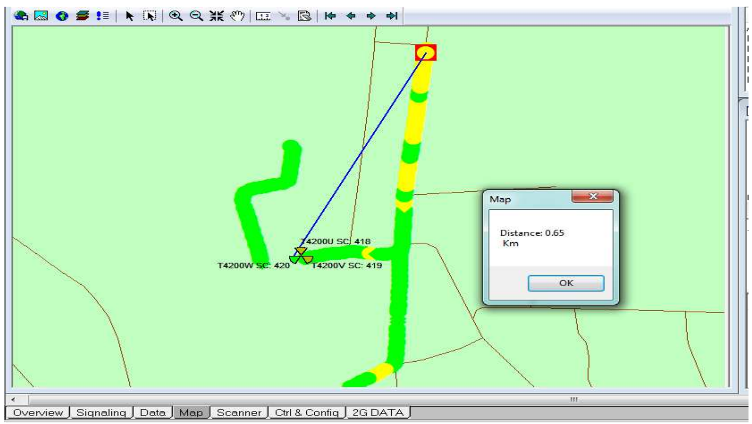

Figure 1: Measurement route for Agbor Park, in Benin city, Nigeria.

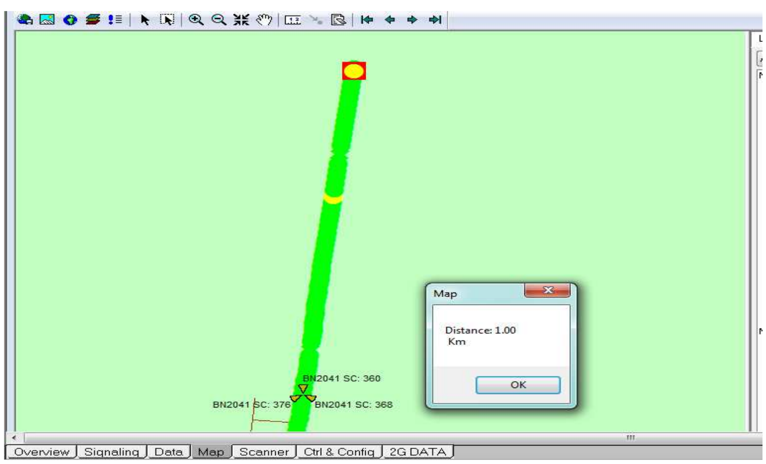

Figure 2: Measurement route for Ekiadolor in Benin City, Nigeria.

2.1 Calculation of Path Attenuation Loss Method From Measured Data

The path loss is obtained, using:

$$PL = Pt + Gt + Gr - RSCP - Losses \quad (1)$$

Where

PL = Path Loss

Pt = transmit Power
Gt = Gain of transmitter
Gr = Gain of the receiver
RSCP = Received Signal Code Power
Losses = cable loss and connection losses

The measured RSCP data is very important because we can determine the Electric Field Strength from it. We can achieve that by following the derivations given in [16].

3.0 Results and Discussion

3.1 Graphical Interpretations of Calculated Signal Path Attenuation Loss

Using the ruler in TEMS software, the RSCP data at various distances from the BS were determined. This technique enabled us to calculate the Electric Field Strength (EFS) and path loss at different distances from the BS.

The path loss measurements can then be analysed relative to the empirical models to see whether these propagation models are accurate to be used for path loss prediction in the study area. The path loss calculation parameters include the following:

BTS Height (h_b) = 40m (Agbor Park), and 38m (Ekiadolor)
Mobile Station Height (h_m) = 1.5 m
Frequency of operation (f_c) = 2100 MHz

Tables 1-2 and Figures 3-4 below show the path loss at various distances from the BS for Agbor Park and Ekiadolor in comparison with other existing path attenuation calculation models

Table 1: Propagation Models and Measured Path Loss for Agbor Park

Distance(km)	Egli model (dB)	Free space model (dB)	Okumura Hata model (dB)	COST-231 Hata model (dB)	Lee Model (dB)	Measured path loss (dB)
0.05	56.90	72.92	87.92	91.92	6.94	131.00
0.10	68.94	78.94	98.28	102.28	18.50	137.00
0.15	75.99	82.47	104.34	108.34	25.26	131.00
0.20	80.98	84.96	108.64	112.63	30.06	141.00
0.25	84.86	86.90	111.97	115.97	33.78	137.00
0.30	88.03	88.49	114.70	118.69	36.82	142.00
0.35	90.70	89.83	117.00	121.00	39.39	147.00
0.40	93.02	90.99	119.00	122.99	41.62	151.00
0.45	95.07	92.01	120.76	124.75	43.58	146.00
0.50	96.90	92.92	122.33	126.33	45.34	148.00
0.55	98.56	93.75	123.75	127.75	46.93	145.00
0.60	100.07	94.51	125.05	129.05	48.38	152.00
0.65	101.46	95.20	126.25	130.25	49.71	157.00

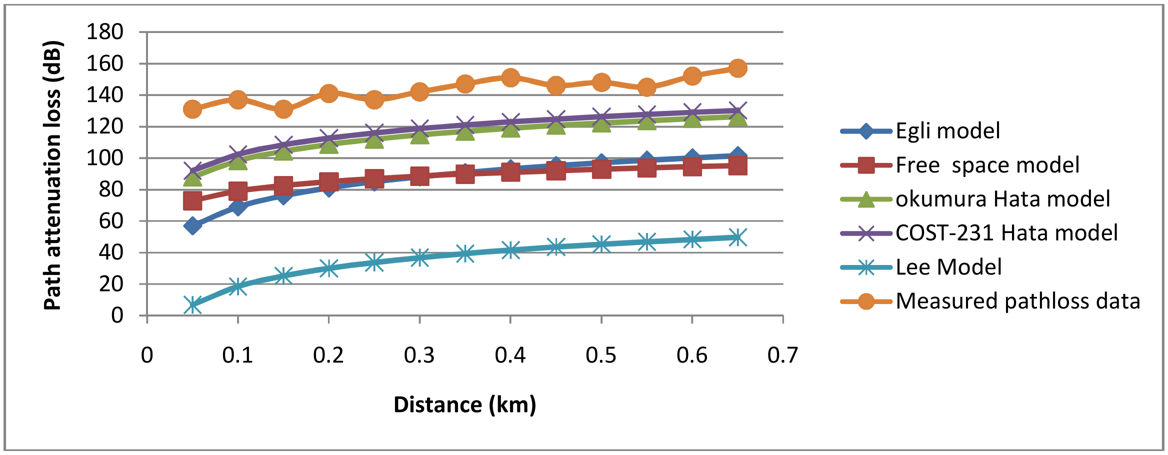

Figure 3- Path attenuation loss (dB) analysis for Agbor Park with respect to distance (km)

From the graphs in Figure 3, the following observations can be made for Agbor Park environs:

1. The Lee model highly underestimates the path loss. This can be attributed to the fact that this model takes into consideration the effective base station antenna height which is highly dependent on the exact topology of the measurement environment.

2. In fact, none of the models used was suitable for the prediction of path loss in this area. The other deviations (ups and downs) in the measured values can be attributed to Agbor Park environment having many obstructions in the path, like buildings in close proximity, as well as trees sandwiched in between houses.

Table 2: Propagation Models and Measured Path Loss for Ekiadolor

Distance (km)	Egli model (dB)	Free space model (dB)	Okumura Hata model (dB)	COST Hata model (dB)	Lee Model (dB)	Measured path loss (dB)
0.05	57.35	72.92	138.75	92.04	7.38	127
0.10	69.39	78.94	149.15	102.44	18.94	121
0.15	76.43	82.47	155.24	108.52	25.71	124
0.20	81.43	84.96	159.55	112.84	30.50	130
0.25	85.31	86.90	162.90	116.19	34.22	139
0.30	88.47	88.49	165.64	118.93	37.26	135
0.35	91.15	89.83	167.95	121.24	39.84	136
0.40	93.47	90.99	169.96	123.24	42.06	140
0.45	95.52	92.01	171.72	125.01	44.03	139
0.50	97.35	92.92	173.30	126.59	45.78	140
0.55	99.00	93.75	174.73	128.02	47.37	137
0.60	100.51	94.51	176.04	129.33	48.82	147
0.65	101.90	95.20	177.24	130.53	50.16	143
0.70	103.19	95.85	178.35	131.64	51.40	141
0.75	104.39	96.45	179.39	132.67	52.55	135
0.80	105.51	97.01	180.36	133.64	53.62	137
0.85	106.56	97.53	181.27	134.55	54.63	135
0.90	107.56	98.03	182.12	135.41	55.59	135
0.95	108.50	98.50	182.94	136.22	56.49	141
1.00	109.39	98.94	183.71	136.99	57.34	147

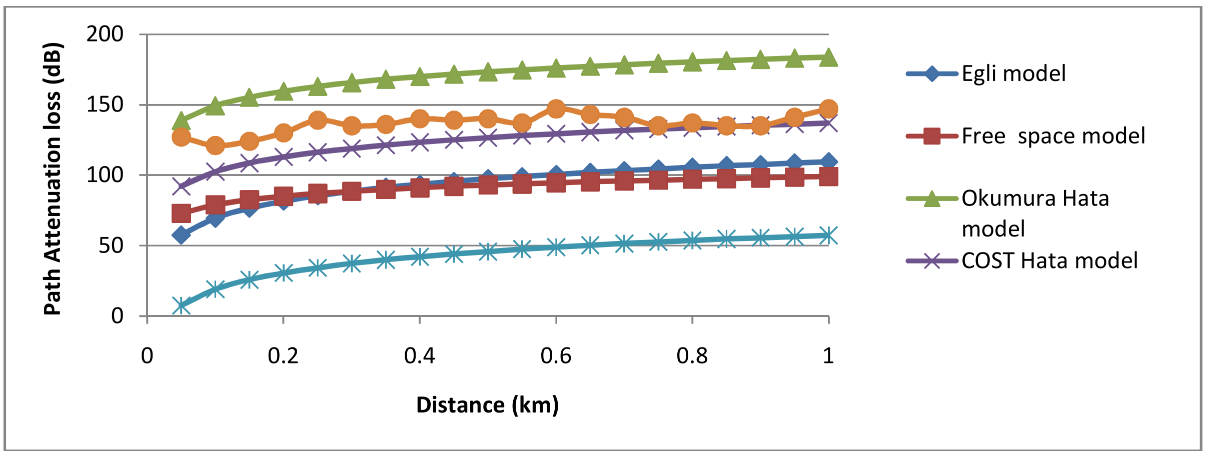

Figure 4- Path Attenuation loss (dB) analysis for Ekiadolor with respect to distance (km)

The following can be deduced from the graph for Figure 4:

1. It is observed that the measured value experienced some stability with zero fluctuation from distance 0.25km to about 0.55km. This may be attributed to an almost clear Line of Sight (LoS) between the transmitter antenna and the receiver antenna.
2. The Lee model again highly underestimates the path loss. This can be attributed to the fact that this model takes into consideration the effective base station antenna height which is highly dependent on the exact topology of the measurement environment. While the Okumura Hata overestimates the path loss. The COST 231 Hata model can be used as an estimate for path loss for the Ekiadolor rural region.

Furthermore, by taking readings at various distances, it is possible to understand the performance of the base station transmitter in terms of electric field strength. This can be seen by studying the variation of electric field strength and pathloss.

Table 3: Calculated Path Loss, RSCP and EFS For Ekiadolor

Distance of MS from BS(km)	RSCP(dBm)	EFS(dBµVm)	Path loss(dB)
0.05	-67	31.644386	127
0.10	-61	37.644386	121
0.15	-64	34.644386	124
0.20	-70	28.644386	130
0.25	-79	19.644386	139
0.30	-75	23.644386	135
0.35	-76	22.644386	136
0.40	-80	18.644386	140
0.45	-79	19.644386	139
0.50	-80	18.644386	140
0.55	-77	21.644386	137
0.60	-87	11.644386	147
0.65	-83	15.644386	143
0.70	-81	17.644386	141
0.75	-75	23.644386	135
0.80	-77	21.644386	137
0.85	-75	23.644386	135
0.90	-75	23.644386	135
0.95	-81	17.644386	141
1.00	-87	11.644386	147

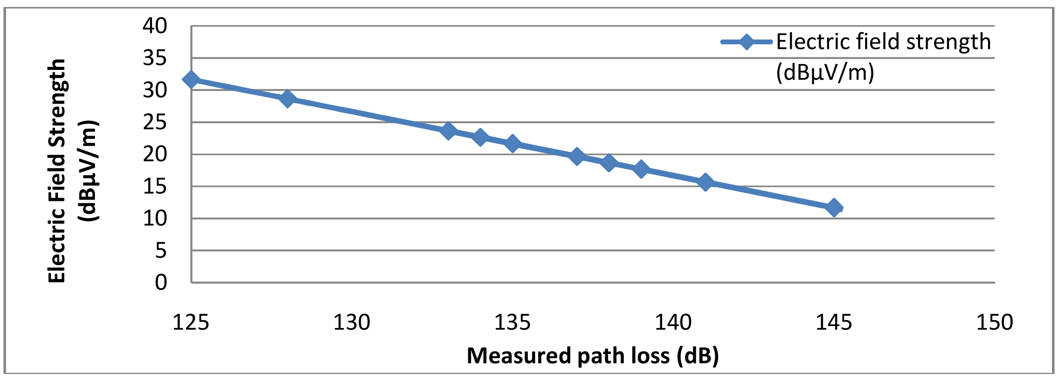

Figure 5: Variation of Electric Field Strength and Path loss for Ekiadolor Area.

Table 4: Calculated Path Loss, RSCP And EFS for Agbor Park

Distance of MS from BS(km)	RSCP(dBm)	EFS(dBµVm)	Path loss(dB)
0.05	-73	27.64439	131
0.10	-79	21.64439	137
0.15	-73	27.64439	131
0.20	-83	17.64439	141
0.25	-79	21.64439	137
0.30	-84	16.64439	142
0.35	-89	11.64439	147
0.40	-93	7.644386	151
0.45	-88	12.64439	146
0.50	-90	10.64439	148
0.55	-87	13.64439	145
0.60	-94	6.644386	152
0.65	-99	1.644386	157

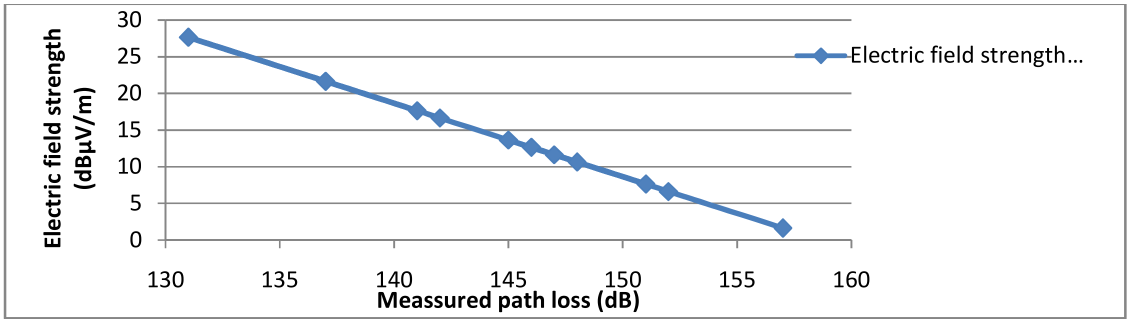

Figure 6: Variation of Electric Field Strength and Path loss for Agbor Park Area.

It can be seen from Figures 5 and 6 that the path loss increases as the Electric field strength decreases and this implies a decrease in quality of service especially for people far from the base stations.

5.0 Conclusion

Although propagation models are available to predict the losses, they are not very accurate in determining the coverage area of a system. This is due to the fact that these models have been designed based on measurements elsewhere. Therefore, real-time measurements must support the path loss prediction models for better and accurate results. The measured field strength data collected over different distances from the base stations was used to estimate the path loss. Firstly, in our methodology, the effect of different parameters, such as distance from base stations was studied and it is observed that path loss increases with distance due to a corresponding decrease in field strength. Secondly, the observed results have been compared with various prediction methods. We find that the COST 231Hata model path loss values were closest of all the outdoor propagation models considered in classifying the environment into consideration (see Figure 4). Thus, the performance of COST 231 Hata model shows its suitability for path attenuation prediction in UMTS network in Ekiadolor area (rural). We also found out that none of the various prediction methods used (see Figure 3) was suitable for Agbor Park (suburban). The result of this studyis also recommended to telecommunication providers to improve their services for better signal coverage and capacity for mobile user satisfaction in the studied areas.

References

[1] Emagbetere, J. O. and Edeko, F. O. (2009). "Measurement of Validation of Hatalike Models for Radio Path Loss in Rural Environment at 1.8GHz", Journal ofMobile Communications pp 17-20

[2] Anderson R.H. (2006). Coverage Prediction for Digital Mobile Systems. PrismBusiness media Inc.., Overland Park, KS. USA

[3] Bachir B. & Saunder, S., (2004). Accurate coverage prediction and optimization for digital broadcasting. EBU Technical Review, Cellular Design ServicesSpectrum Planning. Pp 84-89.

[4] Neskovic, A. Neskovic N. And Paunovi, D. Macrocell. Electric Field StrengthPrediction Model Based Upon Artificial Neural Networks, IEEE Journal onselected areas in Communications, Vol. 20, Number 6, 2002, Pp. 1-10.

[5] Obot, A., Simeon, O., and Afolayan J. (2011). "Comparative Analysis of Pathloss Prediction Models for Urban Microcellular, Nigerian Journal ofTechnology" Vol. 30, No. 3, pp 50-59.

[6] Sharma, D. and Singh, R.K. (2010). The Effect of Path Loss on QoS at NPL,International Journal of Engineering Science and Technology, Vol. 2(7),pp.3018-3023.

[7] Rappaport T.S. (1996) Wireless Communications: Principles and Practice,Prentice Hall PTR, New Jersey

[8] Abhayawardhana,V.S., Wassel, I.J., Crosby, D., Sellers, M.P. and Brown, M.G.(2005). "Comparison of Empirical Propagation Path Loss Models for FixedWireless Access Systems". 61th IEEE Technology Conference, Stockholm.Vol.1, Pp.73-77

[9] Seybold, John S. (2005). Introduction to RF Propagation. John Wiley and Sons.

[10] Sahajahan, M. and Abdulla, A.Q. (2009). "Analysis of Propagation Modelsfor WiMAX at 3.5 GHz". Master Thesis, Blekinge Institute of Technology,Karlskrona, Sweden.

[11] Mardeni, R. and Priya, T.S. (2010). "Optimized COST 231 Hata Models forWiMAX Path Loss Prediction in Suburban and Open Urban Environments"Canadian centre of science and education, vol. 4, no. 9, pp. 75-89.

[12] Goldsmith, A. (2005). "Wireless Communication." Cambridge UniversityPress, New York.

[13] Isabona, J. and Isaiah G. P. (2013). CDMA2000 Radio Measurements at1.9GHz and Comparison of Propagation Models in Three Built-Up Cities ofSouth-South, Nigeria, American Journal of Engineering Research, Vol. 02, Issue-05, pp 96-106.

[14] Isabona, J., Konyeha, C.C., Chinule, C.B., and Isaiah, G.P. (2013). " Radio FieldStrength Propagation Data and Path Loss Calculation Methods in UMTSNetwork"ISSN 2224-719X(Paper) ISSN 2225-0638 (Online), Vol.21.pp. 54-68.

[15] Takahashi, S., Kato, A., Sato, K., and Fujise, M. (2004). "Distance Dependenceof Path Loss for Millimeter Wave Inter-Vehicle Communication" IEEEVehicular Technology. vol.1. pp. 26-30

[16] SEMTECH, (2007). Calculating Radiated Power and Field Strength forConducted Power Measurements. www.semtech.com as at 10/04/2014