IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 2, Ver. VIII (Mar - Apr. 2014), PP 126-132
www.iosrjournals.org

Investigation of Path Loss of Mobile Radio Services at L-Band Frequency over Akure, South Western, Nigeria

J.S Ojo[1], A. Adekunle[2] and S.E Falodun[3]
Department of Physics, Federal University of Technology, Akure, P.M.B 704, Akure, Ondo State.

Abstract: *As the migration of wireless communication network from one generation to another continue, radio wave propagation model or path loss model plays a very significant role in achieving an optimum performance as well as suitability over different locations of interest. In this research, investigation of radio communication channel behavior based on practical measurement in the L-band frequency in Akure- one of the dense urban regions of southwestern part of Nigeria has been carried out. A total number of ten base stations of MTN GSM service located across several areas in Akure were monitored. Path loss and break point distances was deduced from the Received Signal Strength (RSS) and compared with some existing path loss models. The mean and Standard deviation (SD) of each path loss model and measured path loss were estimated and compared on environmental basis; urban and suburban. Based on the regression line (log-normal model) of the measured exponent, Erceg and Cost-231 Hata path loss models show great consistency when compared with Ericson's model with Cost-231 Hata model showing the closest fit to the measured values. The results show that either the log-normal or Cost 231 Hata models may be used to estimate the path loss in mobile micro cell coverage in this region. Path loss exponents, break point distances for each location as well as fitted parameters for the suitable models were also derived. Information from this work will be useful for channel design of micro-wave band wireless access systems in this region and environs.*
Keywords: *L-band frequency, MTN GSM service, Path loss models, Received Signal Strength, wireless signals.*

I. Introduction

A wireless communication system like the Global System for Mobile communication (GSM) has become part of us in nearly all our daily activities. The services rendered are but not limited to data transmission, internet usage, e-banking, tele-medicine, security networking, tele-education [1]. There is the need to make appropriate design, deployment and management strategies for optimum performances of the wireless network. The introduction of cellular communication systems in Nigeria using GSM and Code Division Multiple Access (CDMA) technologies brought a brighter light to mobile communication scenario in this part of tropical regions. Mobile communication was first introduced to Nigeria in 1999, it heralded in a great switch from fixed telephony to mobile telephony; today it has a joint subscriber base of over 100 million and still counting.

Reports indicated that, Africa's telecommunication market is one of the fastest growing around the globe [2]. With Nigeria's at the forefront; recent deregulation of the mobile phone market has led to the introduction of GSM operating on the 900/1800 MHz spectrum, the use of cell phones has soared to about 107 million subscribers. Nigeria hopes to be among the world's top 20 economies by the year 2020, for Nigeria to attain this height, the strengthening of the non-oil growth is essential, with the ever increasing mobile subscriber base of mobile communication and Nigeria's high rate of internet usage pegged at 43.9 million [2]. It is therefore of high importance to make accurate path loss predictions for optimum performance of wireless network services that can meet user's expectations.

In the present study, wireless radio measurements at 1.8 GHz utilizing the Mobile Telephone Network (MTN-Nigeria) cellular service (one of the cellular network operator in this region) in various dense urban areas of Akure and comparison of the observed values of the path loss deduced from the Received signal strength (RSS) with various models have been investigated. Path loss break points, the exponent and standard deviation based on the environmental categorization have also been deduced.

II. Experimental Site and Research Methodology

This research work was carried out in Akure (latitude 7°15′0″N and longitude 5°11′42″), an ancient city in the south-western region of Nigeria, it is the largest city and capital of Ondo State, with a population of approximately 387,087. Ten (10) cellular base station transmitters belonging to the MTN Nigeria GSM service were monitored based on the RSS over the study locations. Each of the location represents a different type of propagation environment relevant to macrocellular radio networks; three sites are in rural areas of different terrain and land cover types, one is located in a suburban area, and one in a medium-density urban area. These locations were selected to demonstrate progression from suburban to urban area. Fig. 1 presents the topographical view of Akure and the location of the base stations.

The carrier signals operating at L - band frequencies (1800 MHz) were monitored with Blackberry (Curve 2) GSM receiver, along with Global Positioning System (GPS) receiver to know the location's distance, coordinates as well as the elevation of the mobile receiver away from the base stations. The experimental data were taken at distances ranging from a 0.1 km interval to 1.1km along the radial routes away from each of the base stations. The transmitting powers of all the stations are +46.02 dBm while the sensitivity of the receiver is -105 dBm. Detailed base station features and the characteristics of the each of the sites are shown in Table 1

Fig 1: A topographical view of Akure showing the location of the base stations

2.1 Brief overview of wireless propagation model

The radio propagation model is made to provide empirical formulation for radio wave propagation scenarios relevant to the macro-cellular radio networks as a function of frequency, distance and some other atmospheric conditions. There are lots of prediction methods that are available for path loss estimation, but most are not valid over the range of frequencies, distances as well as other atmospheric conditions that are necessary to be considered for the analysis herein. Also, most of these models are empirically derived and cannot reflect the details of a specific environment, except in a statistical sense based on general environmental categories. Models are usually developed to predict the behavior of propagation for all similar links under similar constraints [3]. Among the existing empirical models are the Okumura-Hata model, Ericsson model, COST 231-Hata model, and Friis model [4]. The Hata model for urban areas, also known as the Okumura-Hata model for being a modified version of the Okumura model, is the most widely used radio frequency propagation models for predicting the behavior of cellular transmissions in built up areas. The model incorporates the graphical information from Okumura model and develops it further to realize the effect of diffraction, reflection and scattering in suburban areas and open areas, Hata model predicts the total path loss along a link of terrestrial microwave or other type of cellular communications [4,5]. To correlate predicted coverage capabilities with physical propagation processes, a physically-based propagation models are used for all comparisons in this study.

In the work by Famoroji and Olasoji, [6], measurement results of signal strength in UHF band were taken in the three routes of Akure and compared with the predicted results using the empirical models. However, the modified Okumura-Hata model obtained was developed based on the UHF band specifically monitored on Television broadcasting in the region.

Table 1: Details of the base stations and the characteristics of the each of the sites

Name of base station	Tx Antenna Code	Coordinate ($Lat^0N/Long^0E$)	Elevation (m)	Environmental Type/Terrain	Antenna Gain TX (dB)	Antenna Height TX (m)	Signal Strength (dBm)
FUTA Gate	OD2025	7.30787 5.14067	380.7	Suburban	-10	36	-48
Alejolowo	OD3383	7.29356 5.15757	366.0	Suburban/B	-10	36	-58
High School	OD3400	7.24791 5.22368	355.0	Urban	-10	36	-48
Shagari Estate	OD3403	7.26789 5.18987	362.6	Suburban/B	-10	36	-51
Arowosafe	OD3404	7.26913 5.18898	351.0	Suburban/C	-10	36	-48
Ilara Mokin	OD3446	7.26261 5.17025	366.9	Urban/B	-10	36	-36
Oja Oshodi	OD3449	7.25876 5.19436	335.0	Urban/C	-10	36	-54
Shagari extension	OD3454	7.27436 5.19421	408.0	Suburban/A	-10	36	-68
Ijapo area	OD3460	7.26549 5.21717	343.0	Urban/B	-10	36	-52
Rasaq oil	OD3834	7.25599 5.18437	352.0	Urban/C	-10	36	-52

In this present work, in addition to the path loss signal break point and path loss exponent obtained, a more appropriate model was suggested to be used for wireless radio communication system design in Akure and environs.

2.2. Path Loss Calculations:

The path losses for a station on any route can be deduced from the received signal strength (RSS), using the relationship:

$$PL = P_t + G_t + G_r - RSS \tag{1}$$

where PL - Path loss [dB], P_t is the transmitting antenna power,G_t Transmitting antenna gain, G_r- Mobile receiver gain (2dB) RSS-received signal strength.

The free space path loss is losses in strength of the signal in free air (where there no object obstructing the propagation from transmitter to receiver). Free Space Path Loss is a function of frequency and distance and can be represented by:

$$PL = 32.45 + 20\log10\,(d) + 20\log10\,(f) \tag{2}$$

where, f = frequency of operation [MHz] , d = transmitter and receiver separation [m]

For a physically propagation models, the path loss *L*, could be expressed as:

$$L = L_0 + 10\gamma \log\left(\frac{d}{d_0}\right) + S \tag{3}$$

where; L_0- Path loss at 100 m, γ- Path loss exponent, d- Distance (m), d_o- Reference distance (100m) and s - Shadow fading.

III. Results and Discussion

Each of the observed values of path loss for all the base stations considered have been deduced for distances ranging from 100 m interval to 1.1 km. Path loss exponents from the data have been deduced from the (3) using the observed path losses for various distances and L_0 depicting the path loss at 100 m distance as reported by.

From equation (3)

If parameter d/d_0 is represented by *m*, then:

$$L = L_0 + 10\gamma \log m + S \tag{4}$$

Based on the approach used in the work of Erceg et al., [7] and the application of Friis model for two isotropic antennae in free space, $L_0 = 20 \log (4\pi d_0/\lambda)$, where λ is the wavelength corresponding to 1.8 GHz and d_0 is the line of sight distance taken as one hundred meter. s is the shadow fading variation and varies from one location to another within given macrocell. It has been reported that the parameter S takes Gaussian approximation in a given macrocell and denoting a lognormal shape. Using the expression we have deduced the path loss exponent γ, for each of the base station because the so called path loss exponent is the known to be critical in establishing the coverage of any cellular system. It is assumed to be equal to 2 in free space and when there is obstruction, it is always with larger values [3].

Each of the base stations follows the same trend of the Gaussian shape with log normal patterns, for example Fig, 2 is a typical average exponent values variation for a base station in Ijapo Estate (urban environment), with the code OD3460 and antenna height of 36 m over the two routes (1 and 2), we observed an exponents of the order of 9 at the distances closer to the transmitter and this order steeply falls to a value of about 6 around 450 m and then maintain steady steps for the remaining distance. Higher path loss exponent may be as a result of the high density of obstructions (built-up areas) in the signal path and the mountainous terrain of the region. Prasad and Ratnamala, [8] had earlier observed same trend in Delhi, India with an exponent peak value of the order of 7 and steady step at 400 m.

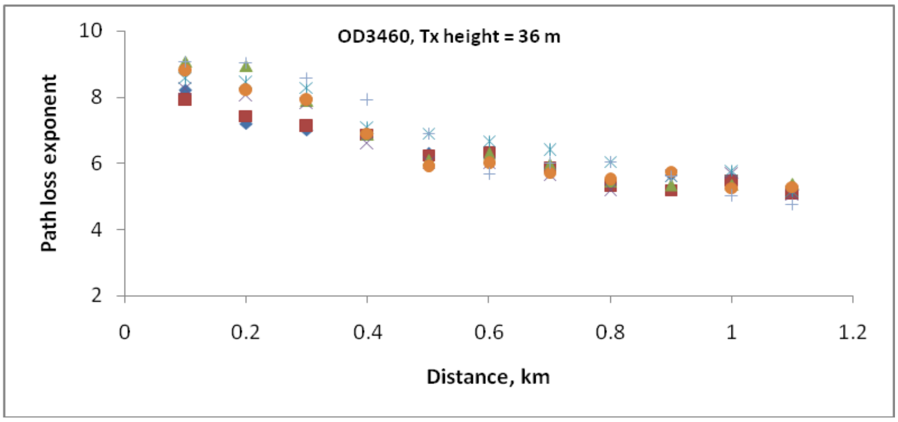

Fig. 2: A typical variation of path loss exponent with distance for Ijapo (OD3460) base station

Fig. 3 also presents an average exponent value variation for a base station in a typical suburban environment – FUTA Gate (OD2025) antenna height of 35 m over the two routes (1 and 2) considered in this work. We observed the same trend, but with variation in the exponents. In this case, it is of the order of 8 at the distances closer to the transmitter and this order steeply falls to a value of about 6 around 420 am and then maintain steady steps for the remaining distance. The reduction in the order of the path loss exponent may be due to the fact that path loss is high in the dense urban areas when compared with the rural and suburban areas. The same trend could be observed in other situations, although with different variations in the path loss exponent. The results are presented in Table 2.

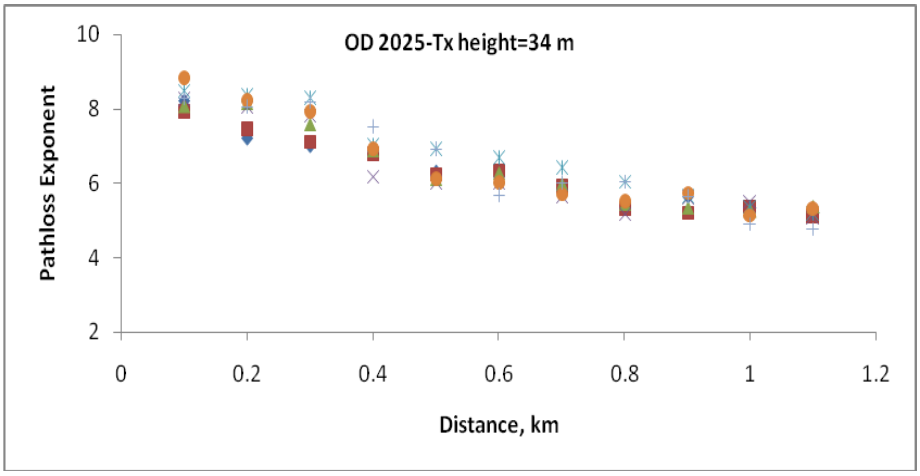

Fig. 3: A typical variation of path loss exponent with distance at FUTA Gate (OD2025) base station

Table 2: Break point of signals along the propagation paths

Base station code	Environment	Antenna height (m)	Observed signals break point (m)
OD3400	Urban	36	445
OD3446	Urban	36	450
OD3449	Urban	35	440
OD3460	Urban	36	450
OD3834	Urban	36	450
OD2025	Suburban	35	420
OD3383	Suburban	34	400
OD3403	Suburban	34	400
OD3404	Suburban	35	415
OD3454	Suburban	36	420

The comparison was also made for the losses with those predicted models from Erceg model, Ericsson model and COST 231-Hata model. At some distances close to the transmitter, we observed high path losses up to about 120 dB in an urban environment (OD2025) with an estimated measurement error of about 1.4 dB as presented in Fig. 2. Considering the effective isotropic radiated power of the transmitter of +46.02 dBm with the sensitivity of the receiver of -105 dBm, the mean measured value of the path loss is about 139 dB. The mean path losses range between 165 and 115 dB from Erceg to Ericsson model. Both Ericsson and Cost 231-Hata models overestimated the measured values by about 40 and 3 dB respectively. While Erceg model underestimates by about 2 dB. Both the Cost 231-Hata and Ericsson models increases with a constant increase in predicted path loss with respect to increasing path length based on constant path loss adjustments (depending on the category of the environment). A regression line with coefficients estimated by the log-normal model is also plotted along with the comparison.

Similarly, a typical variation of observed path losses in a sub-urban environment with Ericsson, Erceg and COST 231-Hata models for OD3460 is presented in Fig. 3. For a station with signal strength of about -48dBm with a receiver sensitivity of – 105 dBm, the mean measured value of the path loss is about 125 dB. At distances close to the transmitter, high path losses up to about 115 dB in a sub-urban environment (OD3460) with an estimated measurement error of about 1.25 dB could be observed. The highest path losses of about 145, 135 and 140 dB could be observed for Ericsson, Cost 231-Hata and Erceg model respectively. In general, the higher mean path loss difference observed for urban terrain could be explained by the fact that the overall propagation loss in this type of environment is dominated by diffraction attenuation due to terrain obstacles, which is well-known to be more severe at higher frequency band [5]. This is more noticeable in Ericsson model when compared with the other two models.

Similar results could be observed for all the remaining eight base stations, the deduction of path loss exponents as a function of distance and comparison of observed values with predicted values has been carried out. The figures of these base stations are not presented in this report due to space reduction and repetitions of results.

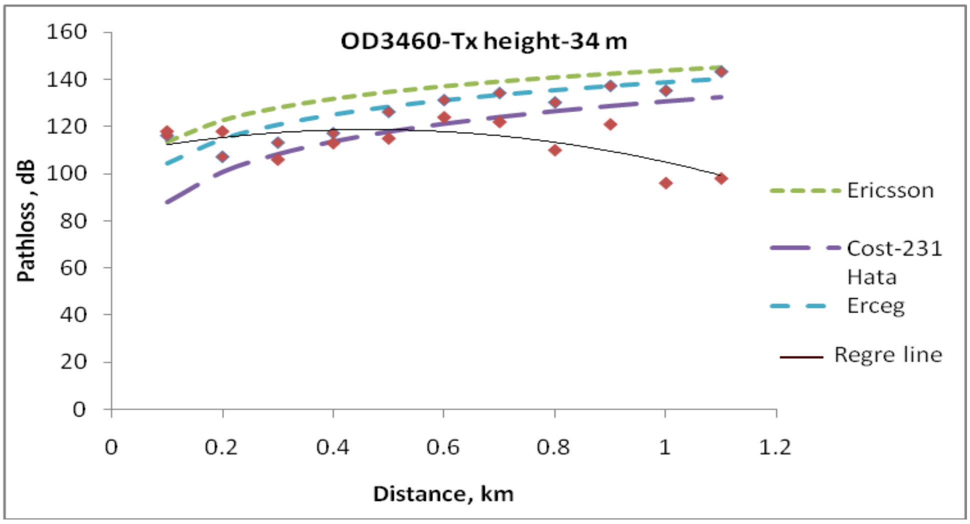

Fig. 2: Comparison of observed path losses in an urban environment with Ericsson, Erceg and COST 231- Hata models for OD 3460

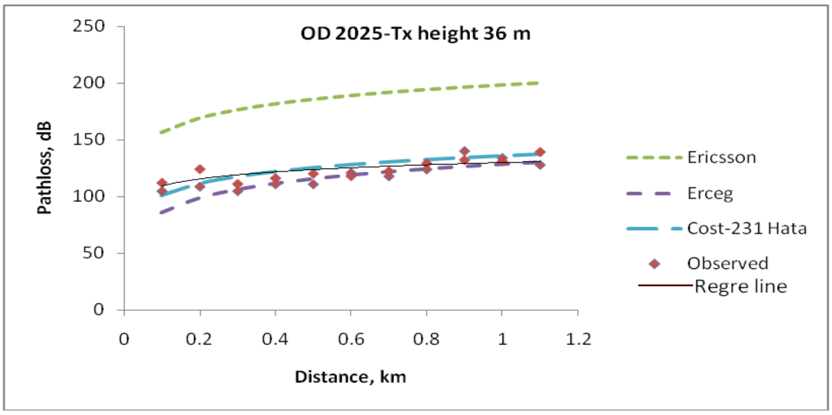

Fig. 3: Comparison of observed path losses in a sub-urban environment with Ericsson, Erceg and COST 231-Hata models for OD2025

Table 3 presents mean error and standard deviations of COST 231 Hata, Erceg, Ericsson models and measured regression line based on the observed values. The statistical estimations have been obtained as a function of distance for all the ten base stations. The standard deviations exhibited by measured regression line are low, ranging from 6 to 12 dB compared with Cost 231 Hata, Erceg and Ericsson models. Cost 231 Hata shows high values ranging from 8 to 18 dB, while a higher value up to about 22 dB is exhibited by Ericsson model. For a typical sub-urban base station like FUTA gate with base station code OD 2025, all the three models of Cost 231 Hata, Erceg, and Ericsson exhibited more or less same value. In the case of Ijapo area base station code OD3460, Erceg model exhibited a standard deviation of 9.95 which is much less than that of Cost 231 Hata and Ericsson models but closer to the regression model. The trend continued for other base stations with Cost 231-Hata model exhibiting less standard deviation than Erceg and Ericsson models. Although each of the base stations exhibited different average deviation for all the three models considered, however, it was observed from the results, that there is a strong positive correlation and consistency between Erceg model, Cost231-Hata model and the measured path losses on the two radial routes.

Table 1.8: Path loss standard deviation for urban environment

		Mean Error				**Standard Deviation**			
Base station code	Environment	Ericsson	Erceg	COST 231-Hata	Regre	Ericsson	Erceg	Cost 231-Hata	Regre
OD3400	Urban	19.34	12.23	11.23	9.64	22.23	17.24	15.45	12.16
OD3446	Urban	18.33	10.54	9.22	7.08	21.45	11.45	11.10	10.22
OD3449	Urban	14.21	9.45	10.23	5.27	19.23	15.83	13.45	10.23
OD3460	Urban	18.25	9.23	8.25	7.09	17.23	9.95	11.22	9.45
OD3834	Urban	17.23	7.56	7.12	5.27	20.54	11.00	10.98	10.75
OD2025	Suburban	10.25	7.45	6.45	5.09	12.01	11.93	11.58	10.10
OD3383	Suburban	11.22	8.93	7.22	5.19	13.23	9.99	10.10	9.22
OD3403	Suburban	13.23	8.34	9.23	6.09	20.23	18.23	15.23	11.89
OD3404	Suburban	11.24	8.73	8.21	5.27	16.34	9.34	8.23	6.25
OD3454	Suburban	12.23	9.45	10.23	9.44	19.12	14.45	13.23	12.24

*Regre means regression lines

The overall result of this research work points to the fact that, Erceg model and Cost231-Hata model will have a larger coverage area and least hand-offs. Both log-normal and Cost 231-Hata models are most suitable for path loss calculation in the observed region.

IV. Conclusion

In this work, investigation of radio communication channel behavior based on the path loss measurement in the L-band frequency over Akure southwestern part of Nigeria have been considered. The measured path loss has been compared with three propagation models for wireless access environment, namely the Erceg model, COST231-Hata model and Ericsson model.

The result shows a strong positive correlation and consistency between Erceg model, Cost231-Hata model and the measured path losses on the two radial routes. All the stations exhibited high values of deviations at a close distance to the transmitter and fell steeply from 450 m onwards. Measured regression line exhibits a log normal shape with lowest standard deviations followed by Cost 231-Hata propagation model when compared with other two prediction models. Both log-normal and Cost 231-Hata models are most suitable for path loss calculation in this region. Path loss exponents of around 9 at the distances closer to the transmitter and this order steeply fall to a value of about 6 at a break point value of 450 were observed at the urban environment while an order of 8 at a break point value of about 415 m were observed in a suburban environment. Higher path loss exponent may be as a result of the high density of obstructions (built-up areas) in the signal path and the mountainous terrain of the urban region considered. Information from this research will be useful in the planning of the migration into new generation wireless propagation in the area.

References

[1] Ojo, J.S., Ajewole, M.O. and Sarkar, S.K. "Rain Rate and Rain Attenuation Prediction for Satellite Communication in Ku and Ka Bands Over Nigeria", Progress in Electromagnetics Research B, Vol. 5, 2008, pp 207–223.

[2] http://www.phyorg/news/2012

[3] Rappapot S.T., Wireless Communications Principle and Practice, Prentice-Hall Communications Engineering and Emerging Technologies Series, U.S.,New Jersey, 324-325 (2002).

[4] Erceg V, Hari KVS, SmithMS, Baum DS, Sheikh KP, Tappenden C, Costa JM, Bushue C, Sarajedini A, Schwartz R, Branlund D, Kaitz T, Trinkwon D. Channel models for fixed wireless applications. Contribution IEEE P 802.16 3C-01/29r4, IEEE 802.16.

[5] Sarkar, Z.K.; Ji, Z.;Kim,K.; Medouri,A.; Salazar-Palma . A Survey of Various Propagation Models for Mobile Communication (2003). IEEE Antennas and Propagation Magazine, 45, 3, 2003, 51-82

[6] Famoriji J.O. and Olasoji Y.O : UHF Radio Frequency Propagation Model for Akure Metropolis. Research Journal of Engineering Sciences, 2 (5), 2013, 6-10.

[7] Erceg V, Tjandra SY, Parkoff SR, Gupta A, Kulic B, Julius AA, Bianchi R (1999) An empirically based path loss model for wireless channels in suburban environments. IEEE J Sel Areas Commun 17(7), 1999, 1205–1211.

[8] Prasad M. V. S. N. & K. Ratnamala (2010): Experimental investigation of mobile radio propagation at 1.8 GHz over macrocellular dense urban regions of Delhi, Ann. Telecommun. (2010) 65:385–389 DOI 10.1007/s12243-010-0161-7.