ERROR ANALYSIS FOR EMPIRICAL PATH LOSS MODELS IN GSM AND WCDMA BANDS IN KANO METROPOLIS OF NIGERIA

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Abstract
Empirical path loss models are of interest due to global increase in demand of wireless data service. They are used extensively in coverage planning and optimization, signal prediction, and is found very useful for interference analysis. These models are built based on the unique characteristics of a given environment in which the technology is to be deployed.This paper presents an evaluation and assessments of five widely used empirical path loss models in predicting signal in the GSM and WCDMA bands in Kano City, Nigeria. In the work, five error analysis methods are used and a large scale field strength measurement was conducted within Kano State metropolis using specially configured dual band handset, GPS and GENEX® Probe software, data samples were collected along a predefined route. The routes covered were: Hotoro-NNDC Quarters, Hotoro-Kaduna-Zaria highway along the eastern bypass road and Bayero University, Kano old site, Hotoro GRA, Badawa Layout to Enugu RD Sabon Gari along Murtala Mohd way and Bayero University permanent site. For the GSM network, a total of sixteen (16) BTSsand seventeen (17) WCDMA NodeBs were visited. Overall, in GSM, it is found that HATA model provides the best results in terms of minimum mean error, RMSE and SC-RMSE. Also in terms of Skewness, Kurtosis and Normalized Probability Density FunctionError for GSM, HATA model has the best fit which falls within the acceptable range of ±10dB. In WCDMA, COST 231 model provides the best results in terms of minimum mean error, RMSE and SC-RMSE.

Keywords: Empirical model, GSM, Hata, Path loss, WCDMA

Introduction
Despite the extensive research in the area of wireless propagation in general and path loss models specifically, network providers in developing countries still find so much room for the conventional method for coverage analysis. This may be due to the cost of employing

professionals for the initial pilot coverage in the use of path loss models. However, this tends to affect the quality of service of the network. The conventional approach is based on BTS/NodeB placement whereby, a drive test is conducted to map out the cell boundaries.This process causes challenges such as cost and extended project completion time. The network providers might end up incurring additional cost after they might have put up a BTS site without first predicting pathloss.Path loss models are used extensively in coverage planning, optimization and signal prediction, and are found very useful for interference analysis. Most cellular network operators employ propagation modelssuch as the Hata, COST 231 and Walfisch Ikegami models for predicting signal losseswhen planning GSM, WCDMA and other wireless systems in a given environment. However, it is not clear which of the widely used models give a better fit. Most of the models applied today were built based on measurements conducted in regions that are different from Nigeria and, therefore suitability in terms of usage may raise question due to environmental peculiarities. In addition, peculiarities of these models give rise to high prediction errors when deployed in a different environment other than the one for which they were initially built for. Hence the need for the error analysis to determine the extent of variability from the established model and its actual implementation outside the areas they were built for.It istherefore necessary to have accurate assessment of the propagation models in the GSM and WCMDA bands in order to modify a model or choose a model that gives better fits so as to achieve high accuracy in the planning, design and even implementation processes. This paper presents an evaluation and assessments of five widely used empirical path loss models in predicting signal in the GSM and WCDMA bands in Kano City, Nigeria.

Related Work

Several research works onthe analyses of the efficacy of path loss models were reported (Ayeni et. al, 2012; COST 231, 1991; Surajudeen-Bakinde *et al*., 2012; Faruk et. al., 2013; Faruk *et al*., 2013B; Ogundapo *et al*., 2011; Abhayawardhana *et al*., 2005; Prajesh & Singh 2012; Phillips 2012 and Phillips, 2011). In Ayeni *et al*., (2012), measurements were conducted in GSM band in Kano city, the results were compared with widely used path loss models. It was found that COST 231 is more suitable for use in the Kano environment. The work was further extended by Surajudeen-Bakinde *et al*., (2012) where anadvance service such as the WCDMA was included. In the extension, Abuja of Nigeria which is a denser city was considered in the work. It was found that COST 231 and Hata give fairer results for Kano and Abuja environments. It was further noticed that, the suitability in terms of predicting signal level swings between Hata and COST 231 for varying sites and frequency. Though the work provides error bound in terms of Root Mean Square Error (RMSE) and Mean Error, however, important metrics such as the Spread Corrected Root Mean Square Error (SC-RMSE), Skewness, Kurtosis and Normalized Probability Density Function (PDF) of the Error were not considered. Ogundapo, *et al*. (2011), determined the path loss prediction error statistics of an urban environment using the COST-231 Hata, Lee and COST-231 Walfisch-Ikegami. The work was conducted in the semi urban environment of Kano, Nigeria for nine base stations. The work concluded that COST-231 Hata Model gives a better prediction of the environment in the GSM. However, the work did not provide results for WCDMA systems. Measurements taken in Cambridge, UK were compared against predictions made by three empirical propagation models, SUI, COST231Hata and ECC-33 models in a research carried out by Abhayawardhana *et al*. (2005). The work concluded that the SUI model showed quite large mean path loss prediction errors. Prajesh and Singh (2012), present the analysis of a significant number of propagation measurement performed at 900 MHz. The measurement was conducted in Gujarat, India. The field measured data were compared with different models (HATA, SUI, ECC-33, Okumura-Hata and etc) for rural, suburban and urban areas. This work concludes that HATA Model is better in suburban areas and the ECC-33 Model in urban areas (Prajesh & Singh, 2012). In our work, five empirical path loss models i.e. LEE, COST 231, HATA, Walfish-Ikegami and Egli models were considered and, also thirty three (33) base stations were visited, sixteen (16) operating in the GSM band and seventeen (17) in the WCDMA band.

Measurements Campaign

A drive test was conducted in Kano State. Kano State is located at the north west of Nigeria with average building height of 15 m. The Kano Urban area covers 137 sq. km with a population of 2,828,861 at the 2006 Nigerian census (Ngex, 2013; NPC, 2006). The metropolitan area covers 499 sq. km. Using specially configured dual band handset, GPS and GENEX® Probe software, received signal strength were collected along predefined routes. All the drive tests were conducted inside the metropolis. The routes coveredwere: Hotoro-NNDC Quarters, Hotoro-Kaduna-Zaria highway along the eastern bypass road and Bayero University, Kano as shown in Figure 1. For the GSM network, a total of sixteen (16) BTSs wasanalyzed, while, a total ofseventeen (17) NodeBs were analyzed for cluster 1, 2 and 3.The clusters routes span from Hotoro GRA, Badawa Layout to Enugu RD Sabon Gari along Murtala Mohd way and Bayero University permanent site. The routes covered the whole metropolitan area. The handset was configured to automatically make calls to a fixed destination number. Each call lasted for 30 seconds hold time, after which the call was dropped. The phone remained idle for some period after which another call was initiated. This experiment was repeated for GSM and WCDMA bands. The measurements results were converted to path loss and compared with model's predictions.

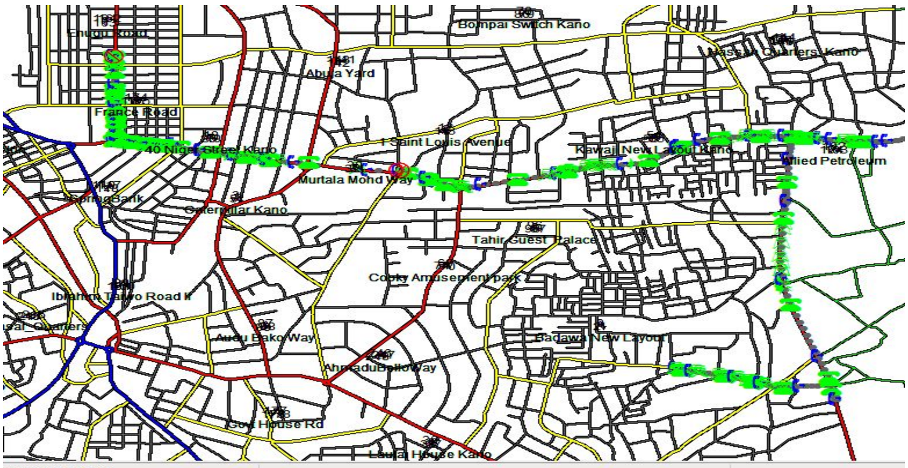


Figure 1: Sample Measurement Route

Results and Discussion

Figure 2 illustrates measured and predicted path losses. Figure 2a shows the comparison of the measured path loss with the predicted path loss as a function of distance for BTS 666. It shows that HATA and COST 231 models are the closest in agreement to the measured path loss. Walfisch-Ikegami, Egli and LEE models overestimate the path loss throughout the range of interest. HATA and COST 231 model give better results. Figure 3a shows the comparison of the measured path loss with the predicted path loss as a function of distance for cell with primary scrambling code (P-SC) 104. It shows that HATA and COST 231 models are the closest in agreement to the measured path loss. Walfisch-Ikegami, Egli and LEE models overestimate the path loss throughout the range of interest.

Table 1 shows the statistical results for GSM band in terms of mean error and RMSE respectively. COST 231 model provides RMSE value of 14.79 dB while Hata model turns out to give RMSE value of 13.295 dB and mean error value of about -11.13dB. However, Walfisch-Ikegami, Egli and LEE perform poorly with higher RMSE values. However, HATA model achieved the best result with RMSE and mean error value of 12.73 dB and 5.95 dB respectively for WCDMA band (*See Table 3*). The mean error was found to be about 50% lower as compared with that of GSM band.

Table 1: Measurement equipments and configurations

QUANTITY	WCDMA					GSM			
Area Type					High density Urban				
Node Type	Node	BTS1	BTS2	BTS3	BTS4	BTS5	BTS6	BTS7	BTS8
Frequency (MHz)	2112.40	905.2	1742.2	1742.4	1742.6	1743.2	1743.8	1740.6	1741.6
Average Antenna height (m)					30.00				
Mobile Station height (m)					1.50				
Transmitter's Power (W)	430					80.00			
Transmitter's power (dBm)	56.33					49.03			
Cable Loss (dB)	1.65					1.65			
Antenna gain (dB)	18					18.00			
EIRP (dBm)	72.68					65.38			

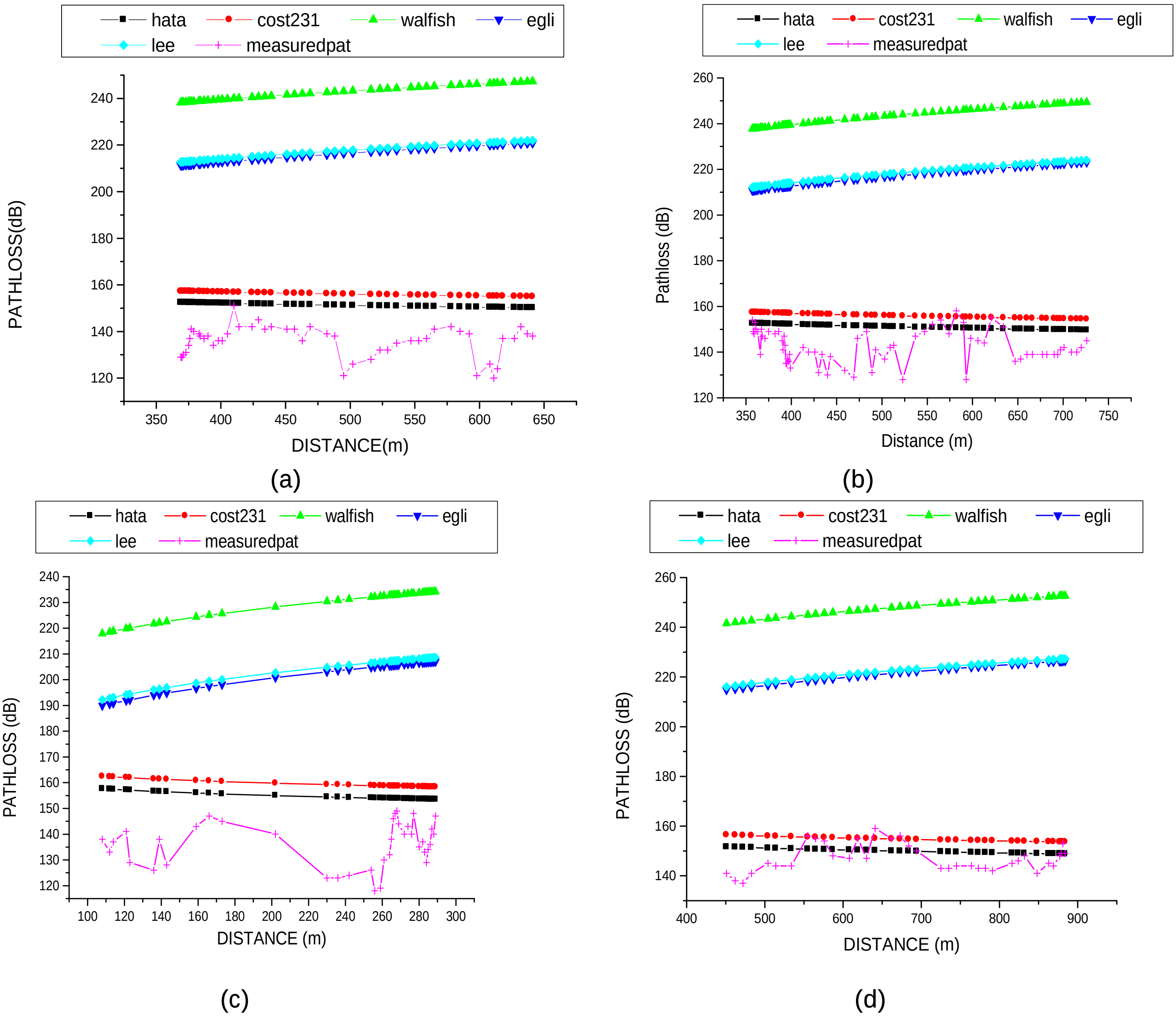
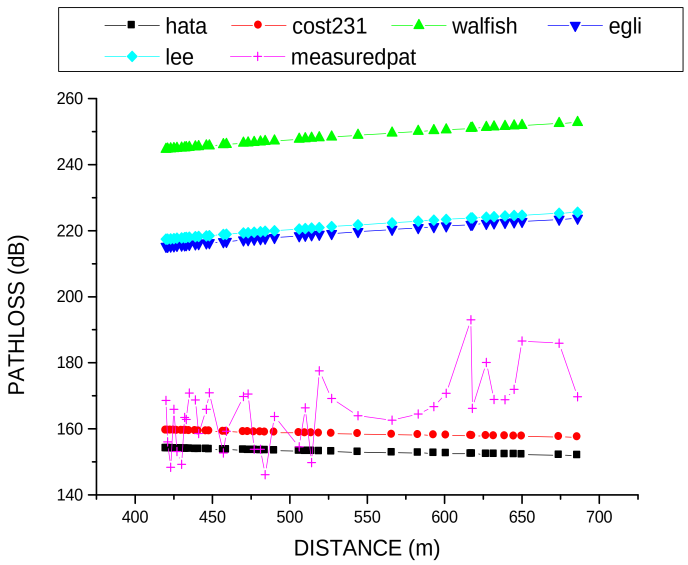


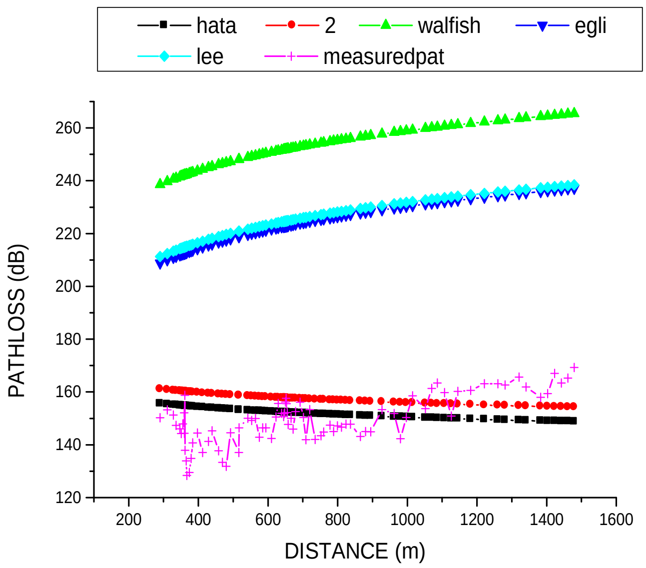
Figure2: Comparison of empirical models with Measured Path loss for (a) BTS 666 (b) BTS 677 (c)BTS 680 and (d) BTS679

Table 2: Mean Error and Root Mean Square Error (RMSE) Forgsm

	MEAN ERROR (GSM)					ROOT MEAN SQUARE ERROR (RMSE)				
BTS	HATA (dB)	COST 231 (dB)	WALFISCH IKEGAMI (dB)	EGLI (dB)	LEE (dB)	HATA (dB)	COST 231 (dB)	WALFISCH IKEGAMI (dB)	EGLI (dB)	LEE (dB)
EASTERN BYE 1	-15.412	-20.231	-106.387	-79.6493	-80.9751	16.65396	21.19241	106.662	80.0249	81.33739
EASTERN BYE 4	9.796003	14.61926	91.78914	64.65824	66.29133	12.45063	16.51603	92.98598	66.43131	67.95525
HOTORO 1	7.300358	12.12169	88.7817	61.63665	63.28424	10.39201	14.19979	88.98827	61.93883	63.57461
HOTORO 3	5.268417	10.08859	92.39288	65.489	66.94555	9.435501	12.76918	93.30979	66.87008	68.22342
HOTORO 5	5.467395	10.28563	99.14424	72.52251	73.75652	7.324366	11.38192	99.26236	72.68407	73.91525
HOTORO 7	2.7457	7.567413	89.86176	62.95162	64.41065	9.578775	11.89453	90.02217	63.19268	64.63647
MOBILE 1	13.90846	18.73172	100.0673	73.11119	74.60448	15.52451	19.96102	100.3103	73.44381	74.93016
MOBILE 4	18.60273	23.42483	93.48927	66.06463	67.93462	20.51398	24.96967	93.99617	66.80154	68.63463
AVERAGE	5.959637	9.576018	68.64237	48.34806	49.53154	12.73422	16.61057	95.69213	68.9234	70.4009



(a)



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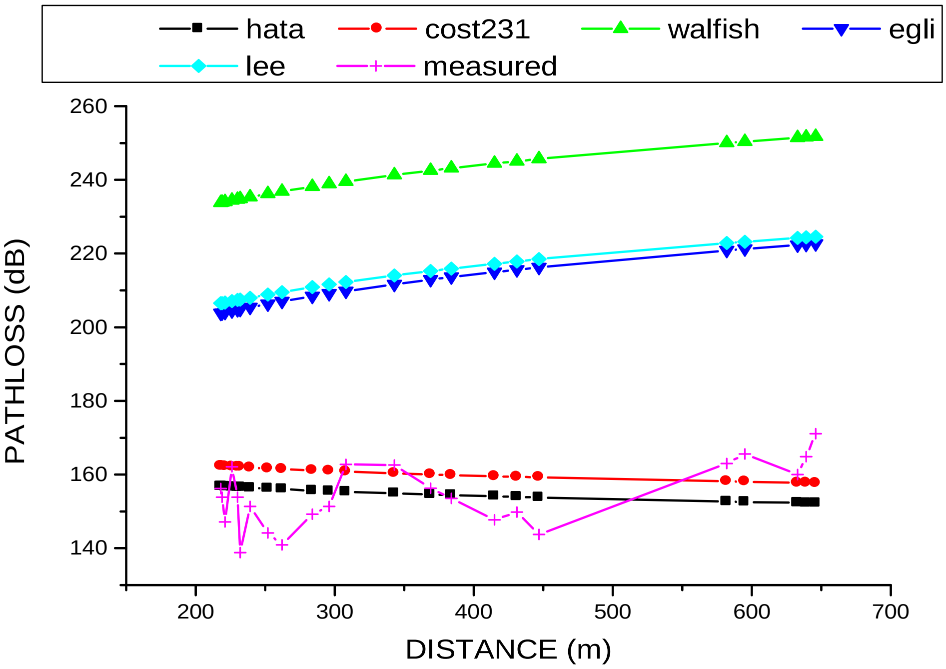

(c)

Figure 3: Comparison of empirical models with Measured Path loss for (a) PSC 104 (b) PSC 46 and (c) PSC 60

Table 3: Mean error and Root Mean Square Error (RMSE) for WCDMA

BTS	MEAN ERROR (WCDMA) HATA (dB)	COST 231 (dB)	WALFISCH IKEGAMI (dB)	EGLI (dB)	LEE (dB)	ROOT MEAN SQUARE ERROR (RMSE) HATA (dB)	COST 231 (dB)	WALFISCH IKEGAMI (dB)	EGLI (dB)	LEE (dB)
3G_CLUSTER 1_1	-19.6619	-14.1929	91.24505	62.63538	64.20432	20.27085	15.02517	91.45372	62.95122	480.7124
3G_CLUSTER 1_2	0.981923	6.450919	102.5709	73.57032	75.45198	12.01771	13.60425	102.7799	73.8678	75.73694
3G_CLUSTER 2_2	-31.9655	-26.4965	98.81867	71.04286	71.94472	32.52627	27.17039	99.16469	71.54511	72.42348
3G_CLUSTER 2_3	-27.2512	-21.7822	84.09158	55.5002	57.05451	27.60615	22.22467	84.3813	55.96818	57.48638
3G_CLUSTER 2_6	0.043217	5.512213	101.7072	72.70977	74.58891	6.811639	8.76248	102.0456	73.20202	75.05343
3G_CLUSTER 3_2	-3.71983	1.749166	93.34382	64.15341	66.18695	8.572806	7.919308	93.70372	64.69891	66.69788
3G_CLUSTER 3_4	4.808023	10.27702	94.55249	65.05505	67.33421	11.47877	14.6377	94.85079	65.47615	67.75016
3G_CLUSTER 3_6	-12.3444	-6.87544	104.5386	76.17968	77.54806	13.67521	9.049745	104.6685	76.35622	77.72275
AVERAGE	-11.1387	-5.66971	96.35854	67.60583	69.28921	16.6199	14.79921	96.63103	68.0082	121.6979

Conclusion

Comparative Error Analysis of the measured path loss with the predicted path loss using HATA, COST 231, Walfisch Ikegami, Egli and Lee models was carried out. For GSM band, HATA model provides least mean error and RMSE of 5.9 dB and 12.7 dB respectively. However, for WCDMA band, Hata and COST 231 models give RMSE values of 16.6 dB and 14.7 dB respectively. COST 231 model achieves good results in the WCDMA band and this is expected as the model's frequency validity extends up to 2 GHz while Hata is limited to 1500 MHz. However, the acceptable RMSE values for urban area is 10 dB and up to 15 dB in the suburban and rural areas. In order to achieve optimal coverage prediction, modification of Hata or COST 231 models is necessary to decrease the RMSE values within the acceptable range.

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