International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2019.33136

Volume 5, Issue 4
April - 2019

Optimization of Hata Model for 2.1 GHz Communication Networks in Owerri Metropolis Nigeria

Nkwachukwu Chukwuchekwa[1], Amaka Nwokoro[2] and Ekeocha Akujobi[3]

[1-2]Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Imo State Nigeria

[3]Department of Computer Science, University of Port Harcourt, Rivers State, Nigeria

---

ABSTRACT

It is often frustrating to experience call drops and poor signal reception, especially when it is motivated by an environmental factor. This reiterates the need for adequate planning of communication signal facilities. Integrating the use of tuned models is of great importance since it enhances the propagation of signals and improves the Quality of Service (QoS). In this work, signal reception was enhanced through model optimization using the least square method. Drive test approach for the 3G network at 2.1 GHz in Owerri metropolis Nigeria was used to capture data from the environment. Predictions using Hata and COST 231 models were done. Hata model was chosen for optimization. Validated results show the Mean Square Error (MSE) of 31.39, 43.51 and 25.95; the Mean Absolute Percentage Error (MAPE) of 23.98%, 34.84% and 20.25% for Hata, COST 231 and optimized models respectively. The result showed minimal error prediction for the optimized model, which implies that it can be used for signal prediction for the environment under study.

Key Words: Hata, COST 231, Least Square, Mean Square Error, Mean Absolute Percentage Error.

---

1. INTRODUCTION

The continual drops in the level of received signal as experienced within Owerri metroplolis prompted the need to carry out an evaluation on the strength of signal received from a live 3G network in Owerri, Nigeria. The resultant drop has incurred losses to the service providers and some sort of undesired drops in Quality of Service (QoS) as experienced by network users within the area. Environmental factors have been attributed to influence the integrity of transmitted signals during propagation. These factors include buildings, trees, rain, dust, fog, vapor, and mist among others [1]. They degrade the transmitted signals by reflecting back some of the radiated signal into the initial medium, diffracting some of the signal, scattering some and causing the medium to absorb some signal [2]. This has raised the question of how and what model suites the environment.

In modeling signal transmission, the use of Propagation models have found great application as a mathematical tool used by engineers to design and optimize wireless network systems [3]. These models capture environment related parameters to adequately suite the environment. This follows series of processes; measurement data collection from the live network, tuning of model which optimizes parameters of the propagation model to achieve minimal error between predicted and measured data [4]. This leads to the realization of more accurate and reliable empirical model [5].

This paper aims to develop an optimized model for the study area which was realized through the model tuning. To realize this the following were done; drive test carried out to capture measurement data, predictions based on empirical models, comparison between measured predicted models (Hata and COST231), optimization using Least Square method and validation of the models.

The remainder of this paper is structured as follows: Section 2 gives a review on Hata propagation model, Section 3 presents the Methodology adopted, Section 4 presents the model optimization approach, Section 5 presents the results and discussion; Section 6 is conclusion.

2. HATA PROPAGATION MODEL

The Hata model is an equation which was obtained through measurements and extrapolations taken from curves that are derived by Okumura [6]. It is an empirical formula for graphical path loss [7]. Hata presented the prediction area into three divisions:

Open, suburban and urban areas. This model is appropriate for frequency range of 150-1500 MHz (UHF) and for distance of 1km-20km. However, Hata model does not consider terrain profile like hills that are found between transmitter and receiver [7]. In the words of [8], Hata model for calculation of path loss are used in three situations namely:

Situation1: Urban Hata pathloss

The urban Hata pathloss (PL) is expressed as

$$PL = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(h_b) + \left(44.9 - 6.55log_{10}(h_b)\right)log_{10}(d) - a(h_m) + c_{\ M} \quad (1)$$

Where,

f is the frequency in MHZ

h_m is the height of the mobile antenna in meters

h_b is the height of the base station antenna in meters [6], [8] and [9].

C_M is a constant (which is 0 for urban region and 3 suburban region)

$a(\ h_m)$ is the mobile station antenna correction factor expressed as

$$a(\ h_m) = (1.11log_{10}\ (f) - 0.7)h_m - (1.56log_{10}(f) - 0.8) \text{ in dB} \quad (2)$$

Situation 2: Suburban Hata pathloss

The Suburban Hata pathloss (PL) is expressed as

$$\text{PL} = P_L Urban - 2\left[\log_{10}\left(\frac{f}{28}\right)\right]^2 - 5.4 \quad (3)$$

Situation 3: Rural Hata pathloss

The Rural Hata pathloss (PL) is expressed as:

$$\text{PL} = \text{PL (Urban)} - 4.78(log_{\ 10}(f)^{\ 2}) + 18.33log_{\ 10}(f) - 40.98 \quad (4)$$

3. METHODOLOGY

Experimental data was gathered from some areas within Owerri which include Akanchawa (Concord Hotel area), Imo state government house road, Wetheral road, Royce road, Bank road, Tetlow road, Obinze- Owerri express way, FUTO and Ihiagwa road, through a drive test campaign. The signal strength data of the mobile operator within the study area was recorded as the vehicle moved through the environment. The key materials used for the drive test are: a laptop, Ericsson Transmission Evaluation and Monitoring System (TEMS 11) software installed on a laptop, a global positioning system (BU353 GPS) to determine positions (Longtitude and Latitude), power supply unit and a vehicle. The picture for the Setup of the field experiment is shown in Fig.1 [10]. The TEMS handset was set to initiate calls that will last for 10 seconds each before the calls got terminated and then the calls commenced again. This call process continued all through the routes under the study. The test phone sends the measured data to the computing device which stores data as recorded log files. The recorded log files were then preprocessed and analyzed using the Actix analyzer tool.

DOI: 10.31695/IJASRE.2019.33136

Fig. 1: The picture for the Setup of the field experiment

The investigation was carried out in six (6) phases which covered the major routes under consideration. The log of measurements along these various drive test routes has been shown in the authors' previous work [11].

The network parameters are displayed in Table1. These are parameters from the transmitting device. Table 2 shows measured data obtained from the drive test campaign and data obtained from the empirical models using network parameters at various distances.

Table1. Network Transmission Parameters

S/N	Transmission parameters	Values
1	Transmitter Power	30 W
2	Transmitter Height	35 m
3	Mobile Station Height	1.5 m
4	Gain of Transmitter	18 dB
5	Gain of Receiver	1.76 dB
6	Frequency of Operation	2.1 GHz

Table 2. Empirical model and Measured data

Distance (km)	Measured data (dB)	Hata (dB)	COST 231 (dB)
0.1	115	126.46	140.5
0.2	107	136.93	151.05
0.3	100	143.05	157.17
0.4	115	147.40	161.52
0.5	127	150.77	164.89
0.6	158	153.53	167.65
0.7	112	155.86	169.98
0.8	107	157.87	171.99
0.9	158	159.65	173.77
1.0	136	161.24	175.36

4. OPTIMIZATION OF HATA MODEL

Model optimization in some literatures is achieved by adjusting the coefficients of one or more parameters contained in the model [12]. In this paper, the least square approach was adopted to determine the slope and intercept which was introduced to the k-factor model.

The Okumura Hata model used in this work is presented as thus;

$$L_p = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) + (44.9 - 13.82\log(h_b)) * log(d) - E \quad (5)$$

DOI: 10.31695/IJASRE.2019.33136

With $E = 32(\log(11.75h_m))^2 - 4.97$,

for h_m=1.5 ; $E = 3.2(log(11.75 * 1.5))^2 - 4.97$ for f ≥ 400MHz

$= -9.190 \times 10^{-4}$ (negligible).

Considering the following standard form given by equation (5):

$$L_p = k_1 + k_2 * \log(d) + k_3 * (H_m) + k_4 * \log(H_m) + k_5 * \log(H_b) + K_6 * \log(H_b) * \log(d) \quad (6)$$

With (6) it is possible to determine the Okumura Hata model Coefficients, K as shown in Table 3.

Equation (6) can also be rewritten as

$$L_p = [k_1 + k_3 * H_m + k_4 * \log(H_m) + k_5 * \log(H_b)] + [k_2 + k_6 * \log(H_b)] * \log(d) \quad (7)$$

Assuming,

$$A = k_1 + k_3 * (H_m) + k_4 * \log(H_m) + k_5 * \log(H_b)$$

$$B = k_2 + k_6 * \log(H_b)$$

Then,

$$L_p = [1 \quad \log(d)] * \begin{bmatrix} A \\ B \end{bmatrix} \quad (8)$$

Once we get the measured propagation loss L_1 for N points at different distances d_1, (8) can be written in matrix form as :

$$\begin{bmatrix} L_1 \\ \vdots \\ L_N \end{bmatrix} = \begin{bmatrix} 1 & \log(d_1) \\ \vdots & \vdots \\ 1 & \log(d_N) \end{bmatrix} * \begin{bmatrix} A \\ B \end{bmatrix} \quad (9)$$

Therefore for K3, K4, K5 and K6 constants, we get:

$$K_1 = A^*(K_3 * h_m + K_4 * \log(h_m) + K_5 * \log(h_b))$$

$$K_2 = B^* - K_6 * \log(h_b)$$

Table 3: Tuned Parameters for k values in 2.1 GHz environment

Model	K1	K2	K3	K4	K5	K6
Okumura Hata	173.57	37.64	0	0	-13.82	-6.55

To validate the optimized Hata model, Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) were determined based on Okumura Hata model, COST 231 and Measured (Actual) data.

$$\textbf{MSE} = \frac{1}{n}\sum_{i=1}^{n}(y - \dot{y}_i)^2 \quad \textbf{(10)}$$

Where

n = number of points

y = Represents observed values

$y^{\cdot}_i$ = Represents predicted values

$$\textbf{MAPE} = \frac{1}{n}\sum\frac{|Actual - forcast|}{|Actual|} \quad \textbf{(11)}$$

Table 4 shows the MSE and the MAPE evaluated for the Hata, COST 231 and the optimized models.

Table 4 Performance Evaluation of different models

	Hata model (dB)	COST 231 (dB)	Optimized (dB)
Mean Square Error (MSE)	31.39	43.51	25.95
Mean Absolute Percentage Error (MAPE)	23.98	34.84	20.25

5. RESULTS AND DISCUSSION

The measured data collected from the environment as displayed in Table 2 showed some level of fluctuations when compared to the empirical models as shown in Fig. 2. The measured data had its maximum peak at 158db and minimum 100dB. The empirical model predictions showed that COST 231 had higher pathloss than Hata model with maximum values range predicted at 175.36 dB and 159.65 dB respectively, and minimum at 140.5 dB and 126.46 dB respectively. Both models showed less fluctuation as compared to measured data.

The optimized Hata model prediction performed better than the COST 231, Hata models and measured data as shown in Fig 3. This is also depicted in Table 4 where the performance evaluation was achieved using metrics such as MSE and MAPE. The performance evaluation was achieved using metrics such as MSE and MAPE. The metrics showed that the optimized Hata model had the lowest MSE of 25.95 compared to 45.51 and 31.39 for COST 231 and Hata models respectively. The MAPE also showed

DOI: 10.31695/IJASRE.2019.33136

lowest percentage error of 20.25% as compared to 34.84% and 23.98% for COST 231 and Hata models respectively. This implies that the proposed model can be deployed for use in this environment for better reception.

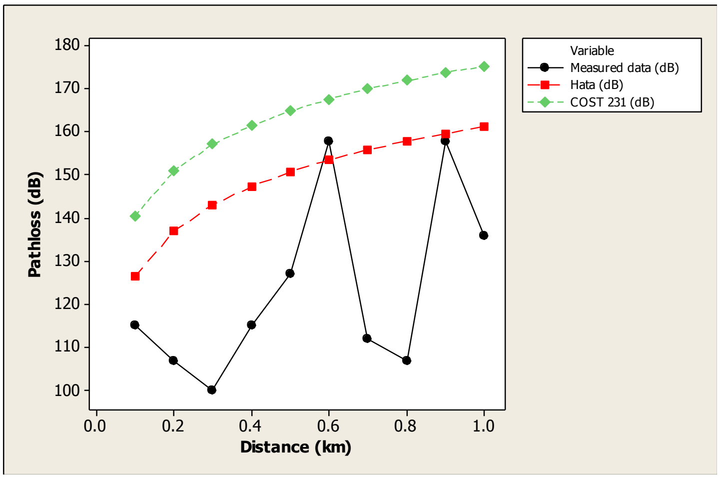

Fig. 2: Pathloss for predicted models and measured data

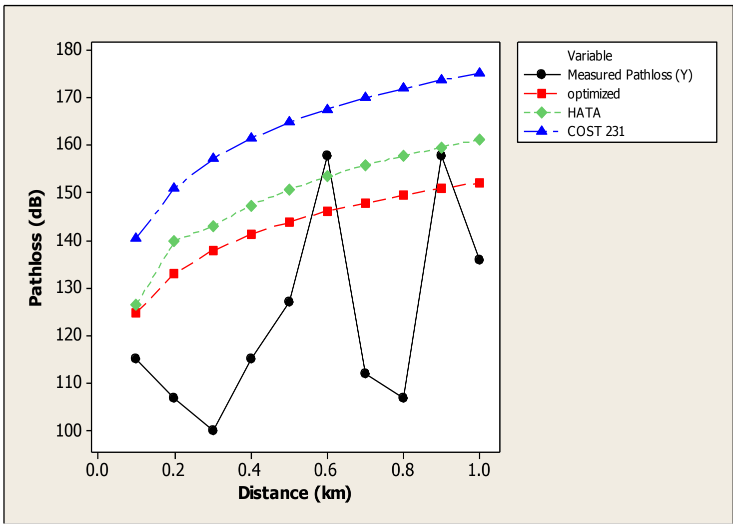

Fig. 3 Graph showing Pathloss predicted from existing models, measured Data and optimized at 2.1 GHz

6. CONCLUSION

Optimization of Hata model was carried out using the Least Square method on large number of measured data. Measurements were taken in Owerri metropolis, Nigeria. The optimized model was compared with the existing Pathloss models and measured data. The results presented led to the conclusion that the performance of the optimized Hata model was the best among the tested empirical models. The result further shows the capability of the optimizing technique to yield acceptable results when used in this environment. The model has shown a potential improvement on its application to the environment compared to the empirical models and measured data. This improvement when adopted will alleviate the drop in QoS experienced in the area, and also aid in proper planning which in turn will maximize profit for the service providers.

REFERENCES

1. A. Folaponmile and M. S. Sani, Emperical model for the prediction of mobile radio cellular signal attenuation in harmattan weather. *Information Technology Research Journal*, Vol 1(1), Pg 13 – 20, 2011.
2. U. N. Nwawelu and M. A. Ahaneku, M.A., The Limitations of campus wireless Networks: A case study of university of Nigeria Nsukka (Lionet). *International Journal of Networks and communication*, 2(5), pp. 112-122, 2012.

DOI: 10.31695/IJASRE.2019.33136

3. I. A. Gbenga-Ilori and O. Obiyemi, Optimization of Hata Path Loss Model For Broadcast Communication Systems In Lagos State, Proceedings of *International Conference on Innovations in Engineering and Technology (IET 2011*), August 8th – 10th, 2011.
4. A.N. Jadhav and Sachin S. Kale, Suburban Area Path loss Propagation Prediction and Optimisation Using Hata Model at 2375MHz, *International Journal of Advanced Research in Computer and Communication Engineering* Vol. 3, Issue 1, January 2014
5. A. Mousa, Y. Dama, M. Najjar and B. Alsayeh, Optimizing Outdoor Propagation Model based on Measurements for Multiple RF Cell" *International Journal of Computer Applications* (0975 – 8887) Volume 60– No.5, December 2012
6. E. A. Ubom, V. E. Idigo, A. C. O. Azubogu, C. O. Ohaneme and T. I. Alumona, T.L "Pathloss Characterization of Wireless Propagation for South – South Region of Nigeria". *International Journal of computer theory and Engineering*, vol.3, N03, Pg 360 – 364, 2011.
7. Ayyappan, k. and Dananyayan, p., *Propagation Model for Highway in Mobile Communications Jounal*, VOL. 3, N0 4, Pg 61 – 66, 2014.
8. M. A. Alsami, T. Arslan, J. Thompson,and A. T. Erdogan, "Frequency Analysis of path loss models on WiMAX". *Computer science and Electronic Engineering conference (CEEC,), 2011.*
9. N. Rakesh and S. K. Srivatsa,. A Study on Path Loss Analysis For GSM Mobile Networks For Urban, Rural and Suburban Regions Of Karnataka State. *International Journal of Distributed and parallel systems (IJDPS)*, vol.4, N01, pp. 53 – 66, 2013.
10 A. Nwaokoro, Signal Strength Evaluation of a 3G Network in Owerri Metropolis using Pathloss Propagation Model at 2.1GHz, Master of Engineering thesis, Federal University of Technology, Owerri, Nigeria
11 A. A. Nwaokoro., N. Chukwuchekwa and O. C. Nosiri, Signal Strength Evaluation of a 3G Network in Owerri Metropolis Using Path Loss Propagation Model at 2.1GHz, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE),Volume 11, Issue 6, Ver. IV, PP 44-53. Nov.-Dec .2016.
12 K. M. Udofia, N. Friday and A. J. Jimoh, Okumura-Hata Propagation Model Tuning Through Composite Function of Prediction Residual. *Mathematical and Software Engineering*, Vol. 2, No. 2, 93-104, 2016.

DOI: 10.31695/IJASRE.2019.33136