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Performance Evaluation of Hata-Davidson Pathloss Model Tuning Approaches for a Suburban Area

Wali Samuel[1], Njumoke N. Odu[2], Samuel Godwin Ajumo[2]

[1]Department of Electrical/Electronic and Computer Engineering, University of Uyo, Uyo, Nigeria
[2]Department of Electrical/Computer Engineering, Port Harcourt Polytechnic, Port Harcourt, Nigeria

Email address:
samwalliuy@yahoo.com (W. Samuel)

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Abstract: In this paper, comparative study of RMSE-base tuning and multi-parameter-based tuning of Hata-Davidson pathloss model for a suburban area is presented. The study was based on field measurement of received signal strength carried out in a suburban area for a GSM (Global System for Mobile communication) network that operates in the 1800MHz frequency band. The results show that multi-parameter-tuned Hata-Davidson model has better prediction accuracy of 98.70720432% and RMSE of 2.177522885 dB as against the RMSE-tuned Hata-Davidson model with prediction accuracy of 97.42722692% and RMSE of 4.256897001dB. However, the RMSE is quite simple and easier to implement even in embedded systems and systems with limited resource.

Keywords: Pathloss, Propagation Model, Hata-Davidson Model, Model Optimisation, Multi-Parameter-Based Tuning Method, RMSE-Base Tuning Method, Least Square Error Method

1. Introduction

Pathloss models are essential in planning wireless network. The models provide mathematical expressions that enable network designers to determine the amount of pathloss that will be experienced by the signal as it transverse the given terrain [1-5]. Basically, a propagation pathloss model predicts the difference between the transmitted power and the receiver power using empirical and deterministic methods or a combination of both. Empirical models, in general, require adjusting some parameters according to field measurements made in a particular environment. Several empirical pathloss models have been given attention for decades due to their accuracy and environmental compatibility. However, peculiarities of these models give rise to high prediction errors when deployed in a different environment other than the one they are initially built for. For instance, [6] provides the error bounds on the efficacy at predicting pathloss for eight widely used empirical pathloss models based on field strength measurements conducted in the VHF and UHF frequencies in Kwara State, Nigeria. It was concluded that no single model would provide a good fit consistently. Faruk, Adediran and Ayeni, [7] presented similar results to that of [6] and concluded that tuning of pathloss model is necessary to minimize the RMSE value within the acceptable range. For example, Dalela, Prasad and Dalela, [9] presented tuning of COST 231 Hata model based on measurements conducted in 2.3 GHz in Western India. Also. linear iterative method was used in tuning the model and it was found that the tuned model achieved better root mean square errors as compared with the conventional COST 231 Hata model. Isabona and Azi, [10] optimized Walficsh Bertoni model using least squares method. The optimized model predicts pathloss with improved accuracy of about 25-30% compared to the original model. Chen and Hsieh [11] provided a fast and precise dual least-square approach to tune the generally used propagation models, like COST231-Hata model. In this paper, two different least square optimization techniques are used for optimizing the

Hata-Davidson model [12]. The first approach is based on addition or subtraction of the RMSE value whereas the second approach is based on the adjustment of some Hata-Davidson model parameters in such a way as to minimise the sum of square error. The performance of the two tuning approaches are compared in terms of their RMSE and prediction accuracy.

2. Method

The field measurement route is identified with respect to the Cellular Network Base Station (CNBS) selected for the study. Received Signal Strength (RSS) and spatial data (longitude, latitude and altitude) dataset are then collected along the route. Samsung Galaxy S4 mobile phone with Cellmapper android application installed is used to capture and store the RSS and spatial datasets in CSV file. The RSS is converted to the measured pathloss (PL) using the formula [13-15]:

$$PL_{m(dB)} = P_{BTS} + G_{BTS} + G_{MS} - L_{FC} - L_{AB} - L_{CF} - \text{RSS (dBm)} \quad (1)$$

where

for each measurement location at a distance d (km)

RSS is the mean Received Signal Strength (RSS) in dBm

P_{BTS} = Transmitter Power (dBm), G_{BTS} = Transmitter Antenna Gain (dBi), G_{MS} = receiver antenna gain (dBi), L_{FC} = feeder cable and connector loss (dB), L_{AB} = Antenna Body Loss (dB) and L_{CF} = Combiner And Filter Loss (dB). The values of these parameters are given as [13]: P_{BTS} = 40 W = 46 dBm, G_{BTS} = 18.15 dBi, G_{MS} = 0 dBi, L_{FC} = 3 dB, L_{AB} = 3 dB, L_{CF} = 4.7 dB. Hence,

$$PL_{m(dB)} = 53.5 \text{ (dBm).} - \text{RSS (dBm)} \quad (2)$$

Again, the Haversine formula in Eq 3 is used to computer the distances (d) between each measurement point and the base station as follows;

$$d = 2r\left\{\sqrt[2]{\sin\left(\frac{LAT_2-LAT_1}{2}\right)^2 + \cos(LAT_1)\cos(LAT_2)\sin\left(\frac{LONG_2-LONG_1}{2}\right)^2}\right\} \quad (3)$$

$$\text{LAT in Radians} = \frac{(\text{LAT in Degrees} * 3.142)}{180} \quad (4)$$

$$\text{LONG in Radians} = \frac{(\text{LONG in Degrees} * 3.142)}{180} \quad (5)$$

Where

LAT1 and LAT2 are the latitude of the coordinates of point1 and point 2 respectively.

LONG1 and LONG2 are the longitude of the coordinates of point1 and point 2 respectively.

R = radius of the earth = 6371 km; R varies from 6356.752km at the poles to 6378.137 km at the equator

d = the distance between the two coordinates

Eventually, the distance (d) data is used in the Hata-Davidson model to generate the predicted pathloss. The prediction accuracy of the pathloss model is evaluated with respect to the measured pathloss. The optimised pathloss model is then develop to improve on the prediction accuracy of the Hata-Davidson model. Finally, the prediction accuracy of the optimised pathloss model is compared with the prediction accuracy of the original (un-optimised) Hata-Davidson model.

2.1. Hata-Davidson Propagation Model

Hata-Davidson model is one of the extensions or modified versions of Hata model. Particularly, Hata-Davidson is Telecommunications Industry Association (TIA) recommended model following modification to the Hata model to cover a broader range of input parameters. The modification consists of the addition of correction terms to the Hata model.

The following equations are used for the computation of the pathloss (in dB) according to the Hata-Davidson model [12]:

$$LP_{Hata\_Davidson} = LP_{HATA} + K_{Davidson} \quad (6)$$

Where

is the pathloss prediction by the Hata model and is the correction factor introduced by Davidson. The following equations are used for the computation of pathloss (in dB) according to the Hata model:

$$LP_{OK\_HATA(urban)} = A + B * \log_{10}(d) \ for\ Urban \quad (7)$$

$$LP_{OK\_HATA(suburban)} = A + B * \log_{10}(d) - C \ for\ Suburban \quad (8)$$

$$LP_{OK\_HATA(open/rural)} = A + B * \log_{10}(d) - D \ for \text{ Rural} \quad (9)$$

$$A = 69.55 + 26.16 * \log_{10}(f) - 13.82 * \log_{10}(h_b) - a(h_m) \quad (10)$$

$$B = 44.9 - 6.55 * \log_{10}(h_b) \quad (11)$$

$$C = 5.4 + 2 * \left[\log_{10}\left(\frac{f}{28}\right)\right]^2 \quad (12)$$

$$D = 40.94 + 4.78 * [\log_{10}(f)]^2 - 18.33 * \log_{10}(f) \quad (13)$$

$$a(h_m) = [1.1 * \log_{10}(f) - 0.7] * h_m - [1.56 * \log_{10}(f) - 0.8] \quad (14)$$

Eq 8 is for small city, medium city, open area, rural area and suburban area.

Now, for large city

$$a(h_m) = 8.28 * [\log_{10}(1.54 * h_m)]^2 - 1.1 \text{ f} \leq 200\text{MHz} \quad (15)$$

$$a(h_m) = 3.2 * [\log_{10}(11.75 * h_m)]^2 - 4.97 \text{ f} \geq 400\text{MHz} \quad (16)$$

Where

- f is the centre frequency f in MHz
- d is the link distance in km
- is an antenna height-gain correction factor that depends upon the environment
- C and D are used to correct the small city formula for suburban and open areas
- 150 MHz≤ f≤ 1000MHz
- 30m ≤ ≤ 200m
- 1m≤ ≤ 10 m
- 1 km ≤ d ≤ 20km

The following equations are used for the correction factor, introduced by Davidson:

$$K_{Davidson} = \text{A}(h_b, d) - S_1(d) - S_2\ (h_b, d) - S_3\ (f) - S_4\ (f, d) \quad (17)$$

Where

A (, and (are distance correction factors, (, is base station antenna height correction factor, (and (, are frequency correction factors.

A (, and (are distance correction factors, with d in km, in m;

(, is base station antenna height correction factor with d in km, in m;

(and (, are frequency correction factors with f in MHz and d in km.

$$K_{Davidson} = \text{A}(h_b, d) - S_1(d) - S_2\ (h_b, d) - S_3\ (f) - S_4\ (f, d) \quad (17)$$

Where

A (h_b, d) and $S_1(d)$ are distance correction factors, S_2 (h_b, d) is base station antenna height correction factor, S_3 (f) and S_4 (f, d) are frequency correction factors.

A (h_b, d) and $S_1(d)$ are distance correction factors, with d in km, h_b in m;

S_2 (h_b, d) is base station antenna height correction factor with d in km, h_b in m;

S_3 (f) and S_4 (f, d) are frequency correction factors with f in MHz and d in km.

$$\text{A}(h_b, d) = \begin{cases} 0 & d < 20km \\ 0.62317\ (d - 20)\left[0.5 + 0.15\log\left(\frac{h_b}{121.92}\right)\right] & 20 < d < 64.38km \\ 0.62317\ (d - 20)\left[0.5 + 0.15\log\left(\frac{h_b}{121.92}\right)\right] & 20 < d < 300km \end{cases} \quad (18)$$

$$\text{S}_1(\text{d}) = \begin{cases} 0 & \text{d} < 20\text{km} \\ 0 & 20 < \text{d} < 64.38\text{km} \\ 0.174(\text{d} - 64.38) & 20 < \text{d} < 300\text{km} \end{cases} \quad (19)$$

$$S_2\ (h_b, d) = 0.00784\ \left|\log\left(\frac{9.98}{d}\right)\right| (h_b - 300)\ \text{ for } h_b < 300 \quad (20)$$

$$S_3\ (f) = \frac{f}{250\left(log\left(\frac{1500}{f}\right)\right)} \quad (21)$$

$$S_4\ (f, d) = \left[0.112\left(log\left(\frac{1500}{f}\right)\right)\right](d - 64.38)\ \text{ for } d > 64.38km \quad (22)$$

2.2. Performance Analysis of the Models

The statistical performance measures or goodness of fit measures for the Hata-Davidson model are defined as follows:

i) The Root Mean Square Error (RMSE) is calculated as follows:

$$\text{MSE} = \sqrt[2]{\left\{\frac{1}{n}\left[\sum_{i=1}^{i=n}\left|PL_{(measured)(i)} - PL_{(predicted)(i)}\right|^2\right]\right\}} \quad (23)$$

ii) Then, the Prediction Accuracy (PA, %) based on mean absolute percentage deviation (MAPD) or Mean Absolute Percentage Error (MAPE) is calculated as follows:

$$\text{PA} = \left\{1 - \frac{1}{n}\left(\sum_{i=1}^{i=n}\left|\frac{\left|PL_{(measured)(i)} - PL_{(predicted)(i)}\right|}{PL_{(measured)(i)}}\right|\right)\right\} * 100\% \quad (24)$$

2.3. Model Optimization Process

The parameters of the Hata-Davidson pathloss model were adjusted (optimized) using least square algorithm to fit to measured data using the following process.

1) First, the residual (or error, e) between measured pathloss, and the Hata-Davidson model predicted pathloss is calculated for each location point, i.

$$e_{(i)} = PL_{m(dB)(i)} - Pr_{m(dB)(i)} \quad (25)$$

2) Second, the RMSE is calculated based along with sum of errors, that is .

3) Thirdly, if < 0 then the optimised model is obtained by subtracting RMSE from each otherwise, if ≥ 0 the optimised model is obtained by adding RMSE to each .

3. Results and Discussions

Table 1 gives the measured Received Signal Strength (RSSI), the measured pathloss and the distance of the measurement point from the GSM (Global System for Mobile communication) base station in a suburban area of Uyo, Akwa Ibom state, Nigeria. The GSM network operates in the 1800MHz frequency band.

Table 2 and figure 1 show the measure pathloss, the predicted pathloss by untuned Hata-Davidson model, the predicted pathloss by the RMSE-tuned Hata-Davidson model and the predicted pathloss by the multi-parameter-tuned Hata-Davidson model. The results in table 2 show that the multi-parameter-tuned Hata-Davidson model has the better prediction accuracy of 98.70720432% and RMSE of 2.177522885 dB as against the RMSE-tuned Hata-Davidson model with prediction accuracy of 97.42722692% and RMSE of 4.256897001dB. According to experts, pathloss model with RMSE of less than 6dB is acceptable. In any case, the result shows that the multi-parameter tuning approach may be preferred when more accurate prediction result is required. However, the RMSE is quite simple and easier to implement even in embedded systems and systems with limited resource.

Table 1. *The Measured Received Signal Strength (RSSI) and Measured Pathloss and Distance.*

S/N	d (km)	RSSI (dB)	Field Measured Path Loss (dBm)	S/N	d (km)	RSSI (dB)	Field Measured Path Loss (dBm)
1	0.7726	-79	132.45	14	0.900146	-89	142.45
2	0.8038	-83	136.45	15	0.900379	-95	148.45
3	0.8199	-83	136.45	16	0.91072	-95	148.45
4	0.8297	-83	136.45	17	0.911539	-95	148.45
5	0.8404	-83	136.45	18	0.912705	-95	148.45
6	0.8475	-83	136.45	19	0.920038	-95	148.45
7	0.8568	-89	142.45	20	0.921517	-95	148.45
8	0.8630	-89	142.45	21	0.92993	-95	148.45
9	0.8632	-89	142.45	22	0.935997	-95	148.45
10	0.8713	-89	142.45	23	0.950936	-95	148.45
11	0.8784	-89	142.45	24	0.96501	-95	148.45
12	0.8903	-89	142.45	25	0.983726	-95	148.45
13	0.8936	-89	142.45	26	1.001317	-95	148.45
14	0.9001	-89	142.45	27	1.011593	-97	150.45

Table 2. *Measure Pathloss, Predicted Pathloss By Untuned and Tuned Hata-Davidson Models.*

S/N	d (km)	Field Measured Path Loss (dBm)	Pathloss Predicted By Untuned Hata-Davidson	Pathloss Predicted By RMSE-Tuned Hata-Davidson	Pathloss Predicted By Multi-parameter-Tuned Hata-Davidson
1	0.772603	132.45	194.5315667	141.4519063	133.3167896
2	0.803794	136.45	195.1579865	142.0783261	136.196652
3	0.819946	136.45	195.4728802	142.3932198	137.6443243
4	0.829696	136.45	195.6599952	142.5803347	138.5045546
5	0.840393	136.45	195.8627504	142.78309	139.4366887
6	0.847533	136.45	195.9966457	142.9169853	140.0522505
7	0.856774	142.45	196.1682945	143.088634	140.8413774
8	0.862983	142.45	196.2825869	143.2029265	141.3668182
9	0.863182	142.45	196.286228	143.2065675	141.3835574
10	0.871291	142.45	196.4342326	143.3545722	142.0639844
11	0.878356	142.45	196.5620523	143.4823919	142.6516147
12	0.890336	142.45	196.776467	143.6968066	143.6373511
13	0.893609	142.45	196.8345553	143.7548948	143.9044023
14	0.900146	142.45	196.9499155	143.870255	144.4347519
15	0.900379	148.45	196.954018	143.8743576	144.4536126
16	0.91072	148.45	197.1347703	144.0551099	145.2845916
17	0.911539	148.45	197.1489902	144.0693297	145.3499651
18	0.912705	148.45	197.1692174	144.0895569	145.4429565
19	0.920038	148.45	197.2958754	144.216215	146.0252462
20	0.921517	148.45	197.3213044	144.241644	146.1421518
21	0.92993	148.45	197.4651553	144.3854949	146.8034826
22	0.935997	148.45	197.5680686	144.4884081	147.2766095
23	0.950936	148.45	197.8187074	144.739047	148.4288805
24	0.96501	148.45	198.0512414	144.971581	149.4979174

S/N	d (km)	Field Measured Path Loss (dBm)	Pathloss Predicted By Untuned Hata-Davidson	Pathloss Predicted By RMSE-Tuned Hata-Davidson	Pathloss Predicted By Multi-parameter-Tuned Hata-Davidson
25	0.983726	148.45	198.3552694	145.275609	150.8956364
26	1.001317	148.45	198.6358081	145.5561477	152.1853672
27	1.011593	150.45	198.7974058	145.7177454	152.928286
RMSE			53.07966043	4.256897001	2.177522885
Prediction Accuracy (%)			63.0840512	97.42722692	98.70720432

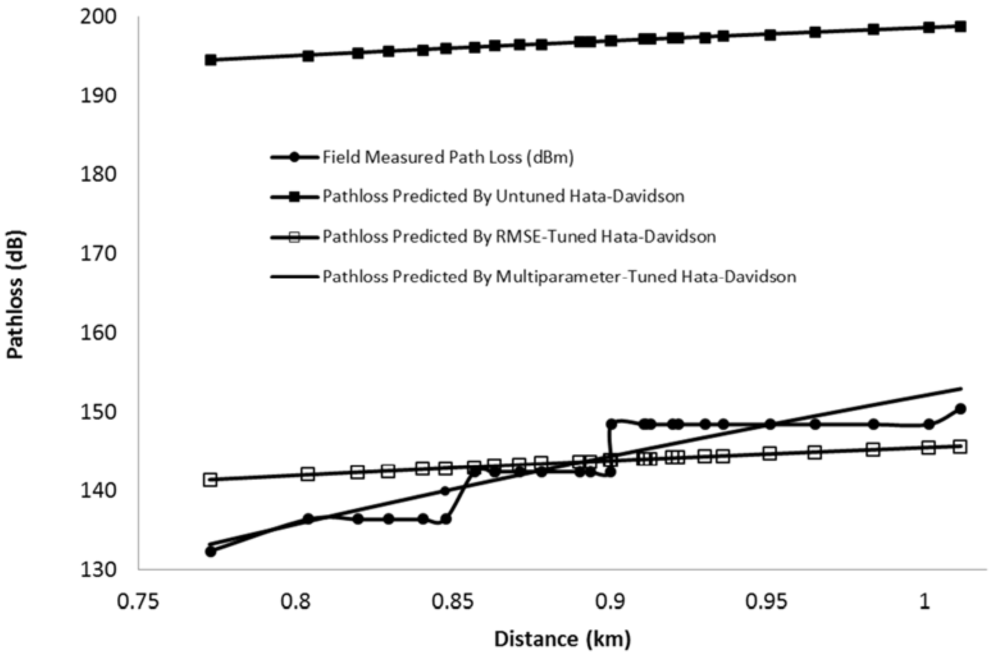

Figure 1. *Measure Pathloss, Predicted Pathloss By Untuned, Pathloss Predicted By The RMSE-Tuned Hata-Davidson Model and Pathloss Predicted By The Multi-parameter-Tuned Hata-Davidson Model.*

For the multi-parameter tuning, the parameters tuned are:

(i) The constant 69.55 the expression for A, hence, A for the tuned Hata-Davidson model is

$$A = 25.33162938 + 26.16 * \log_{10}(f) - 13.82 * \log_{10}(h_b) - a(h_m) \quad (26)$$

(ii) The constant 69.55 the expression for B, hence, B for the tuned Hata-Davidson model is

$$B = 175.6953369 - 6.55 * \log_{10}(h_b) \quad (27)$$

(iii) The constant 0.00784 the expression for S_2, hence, S_2 for the tuned Hata-Davidson model is;

$$S_2\ (h_b, d) = 0.009022299 \left|\log\left(\frac{9.98}{d}\right)\right| (h_b - 300)\ \text{for}\ h_b < 300 \quad (28)$$

4. Conclusion

In this paper, comparative study of RMSE-base tuning and multi-parameter-based tuning of Hata-Davidson pathloss model for a suburban area is presented. The study was based on field measurement of received signal strength for a GSM network that operates in the 1800MHz frequency band. The results show that the multi-parameter-based tuning performs better than the RMSE-base tuning. However, the RMSE-base tuning is simpler and easier to implement in resource limited systems.

References

[1] Liechty, L. C. (2007). Path loss measurements and model analysis of a 2.4 GHz wireless network in an outdoor environment (Doctoral dissertation, Georgia Institute of Technology).

[2] Bola, G. S., & Saini, G. S. (2013). Path Loss Measurement and Estimation Using Different Empirical Models For WiMax In Urban Area. International Journal of Scientific & Engineering Research, 4 (5).

[3] Obot, A., Simeon, O., & Afolayan, J. (2011). Comparative analysis of path loss prediction models for urban macrocellular environments. Nigerian journal of technology, 30 (3), 50-59.

[4] Ogundapo, E. O., Oborkhale, L. I., & Ogunleye, S. B. (2011).

[5] Comparative Study of Path Loss Models for Wireless Mobile Network Planning. International Journal of Engineering and Mathematical Intelligence, 2 (1-3), 19-22.

[6] Faruk, N., Adediran, Y. A., & Ayeni, A. A. (2013, July). error bounds of empirical path loss models at vhf/uhf bands in kwara state, Nigeria. InEUROCON, 2013 IEEE (pp. 602-607). IEEE.

[7] Faruk, N., Ayeni, A. A., & Adediran, Y. A. (2013). Impact of Empirical Path loss models on Spatial TV white space Utilization. European scientific journal.

[8] Faruk, N., Ayeni, A., & Adediran, Y. A. (2013). On the study of empirical path loss models for accurate prediction of TV signal for secondary users. Progress In Electromagnetics Research B, 49, 155-176.

[9] Dalela, C., Prasad, M. V. S. N., & Dalela, P. K. (2012). Tuning of COST-231 Hata model for radio wave propagation predictions. Computer Science and Information Technology (CS & IT), DOI, 10, 255-267.

[10] Isabona, J., & Azi, S. (2012). Optimized Walficsh-Bertoni Model for Pathloss Prediction in Urban Propagation Environment. International Journal of Engineering and Innovative Technology (IJEIT) Volume, 2, 14-20.

[11] Chen, Y. H., & Hsieh, K. L. (2006, May). A dual least-square approach of tuning optimal propagation model for existing 3G radio network. In 2006 IEEE 63rd Vehicular Technology Conference (Vol. 6, pp. 2942-2946). IEEE.

[12] Faruk, N., Adediran, Y. A., & Ayeni, A. A. (2013, May). Optimization of Davidson Model based on RF measurement conducted in UHF/VHF bands. In Proceedings of 6th IEEE Conference on Information Technology.

[13] Ajose, S. O., and Imoize, A. L. (2013). Propagation measurements and modelling at 1800 MHz in Lagos Nigeria. International Journal of Wireless and Mobile Computing, 6 (2), 165-174.

[14] Seybold, J. S. (2005) Introduction to RF Propagation, John Wiley and Sons Inc., New Jersey.

[15] Rappaport, T. S. (2002) Wireless Communication: Principles and Practice, 2nd ed., Prentice Hall, Upper Saddle River, NJ, USA.