Optimized Walficsh-Bertoni Path Loss Model For 1800GHZ Cellular Network Signal In Imo International Market Umusasa, Orlu

Nwokonko, Chisom S.[2]
Department of Electrical/Electronic Engineering, Imo State University , Owerri, Nigeria

Ezenugu, Isaac A.[2]
Department of Electrical/Electronic Engineering, Imo State University , Owerri, Nigeria
isaac.ezenugu@yahoo.com

Abstract— In this paper, Walficsh-Bertoni path loss model is evaluated and optimized for estimating the path loss for a 3G cellular network in a market area. Particularly, the case study site is Imo international market UmuezealaOrlu located at latitude and longitude of 5.785584 and 7.040083 respectively. Empirical measurement of the received signal strength was conducted for the 1800 MHz cellular network within the market area. The field data collection was conducted with G-NetTrackLite 8.0 Android app installed on Infinix Zero 5. Also, relevant dimensional parameters of the buildings and their spacing were collected and used in the Walficsh-Bertoni model path loss prediction. Two methods were used to optimize the Walficsh-Bertoni path loss model; one method is based on the root mean square error (RMSE) while the other method is based on an error function derived as a function of the distance between the transmitter and the receiver. According to the result, the un-tuned Walficsh-Bertoni model had a RMSE of 14.41 dB and prediction accuracy of 89.56 %. The RMSE-tuned Walficsh-Bertoni model had a RMSE of 3.85dB and prediction accuracy of 97.48 % and the function–tuned Walficsh-Bertoni model had RMSE of 1.52 dB and prediction accuracy of 99.01%. Finally, the error function-tuned Walficsh-Bertoni path loss model for the market was derived. The idea presented in this paper showed that better path loss prediction model can be derived by employing more effective model optimization methods.

Keywords— Path Loss, Propagation Loss Model , Optimisation, Walficsh-Bertoni Model, 3G Network, Cellular Network

I. INTRODUCTION

Path loss is a drop in signal strength due to factors that emanates from the path [1,2,3]. Apart from the signal spreading loss , otherwise called free space path loss, some of the other path losses that are caused by obstructions in the signal path depend on the nature of the obstructions, their location and separation distance [4,5,6,7,8,9,10,11]. Some of these factors are captured in the semi-empirical path loss model like the Walficsh-Bertoni path loss model [12,13,14]. In this model, the building height and separation distance are accounted for in the path loss prediction. Consequently, such model is particularly suitable for estimating the path loss in a market with rows of building that are separated with a small distance.

In this paper, the Walficsh-Bertoni path loss model is used to model the path loss that is expected to be encountered by a 1800 MHz cellular network signal as it propagates through a market. The Walficsh-Bertoni model is optimized based on empirical received signal strength intensity measurement conducted within the market. Two different model optimization approaches were used and the model with the best path loss prediction performance for the market was adopted as the effective path loss model for the market.

II. THE WALFICSH-BERTONI PATH LOSS MODEL

The Walficsh-Bertoni path loss model is a semi-empirical model that is applicable to propagation through buildings in built-up environments. The path loss by Walfisch-Bertonimodel , denoted as $LP_{WB}(dB)$ is given as follows [15,16]:

$$LP_{WB}(dB) = 89.5 - 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B-h_m)^2}\right)\right) + 21\log_{10}(f_m) - 18\log_{10}(h_b - H_B) + 38\log_{10}(d_k) \quad (1)$$

Where;

$$\rho_1 = \sqrt{\left(\left(\frac{R}{2}\right)^2 + (H_B - h_m)^2\right)} \quad (2)$$

f_m is the frequency in MHz; h_b is the base station antenna height in meters ; H_B is the building height in meters, h_m is the mobile height in meters; R: Space between buildings in meters and d: is the distance between base station transmitter and mobile station in Km.

III. OPTIMISATION OF THE WALFICSH-BERTONI MODEL

Two methods were used to optimise the Walficsh-Bertoni path loss model. In the model optimization method 1, the sum of errors (SE) and the root mean square error (RMSE) were computed for all the data points (i = 1,2,3,…n). Then, for each data point, i the optimisedWalficsh-Bertoni model predicted path loss denoted as $LP_{WBOPT(i)}(dB)$ is given as follows;

$$LP_{WBOPT(i)}(dB) = \begin{cases} LP_{WB(i)}(dB) + RMSE & for \;\; SE \geq 0 \\ LP_{WB(i)}(dB) + RMSE & for \;\; SE < 0 \end{cases} \quad (3)$$

In the model optimization method 2, the error (e_i) were computed for all the data points (i = 1,2,3,…n) with a transmitter-receiver distance, d_i. Then, an error function, $f(e_i, d_i)$ is derived to determine the error, e_i as a function of distance, d_i. Then, for each data point, i the optimized Walficsh-Bertoni model predicted path loss denoted as $LP_{WBOPT(i)}(dB)$ is given as follows;

$$LP_{WBOPT(i)}(dB) = LP_{WB(i)}(dB) + f(e_i, d_i) \quad (4)$$

IV. THE FIELD MEASUREMENT

The case study site is Imo International Market UmuezealaOrlu located at latitude and longitude of 5.785584 and 7.040083 respectively. The section of the market considered is lined with one-story buildings that are 3 meters apart. It is a daily market and the study was conducted during the market busy hours on a Saturday in the month of October 2018. The field data collection was conducted with G-NetTrack Lite 8.0 Android app installed on Infinix Zero 5. During the field measurement campaign in the case study market, the following essential data items were logged by the G-NetTrack Lite 8.0 app and stored in a text file on the phone; the received signal strength intensity in dB (RSSI), the time of data collection, the longitude and the latitude and the base station information. The base station longitude and the latitude were also collected by a physical visit to the base station site based on the captured base station information. Haversine formula was used to determine the distance between the base station and each of the measurement points. The link budget equation (5) was used to determine the measured path loss, $PL_{m(dB)}$) from the measured RSSI.

$$PL_{m(dB)} = PTX + GTX + GMX - RSSI(dBm) \quad (5)$$

Where PTX is the transmitter power (dBm) = 25 dBm; GTX is the transmitter antenna gain (dBi) = 12 dBm and GTX is the receiver antenna gain (dBi) = 12 dBm.

V. RESULTS AND DISCUSSION

The measured received signal intensity, RSSI (dB) and the measured path loss for the case study site are shown in Figure 1. The resulted for the un-tuned Walficsh-Bertoni model predicted path loss, the RMSE-tuned Walficsh-Bertoni model predicted path loss, and the error function – tuned Walficsh-Bertoni model predicted path loss are given in Table 1 and Figure 2.

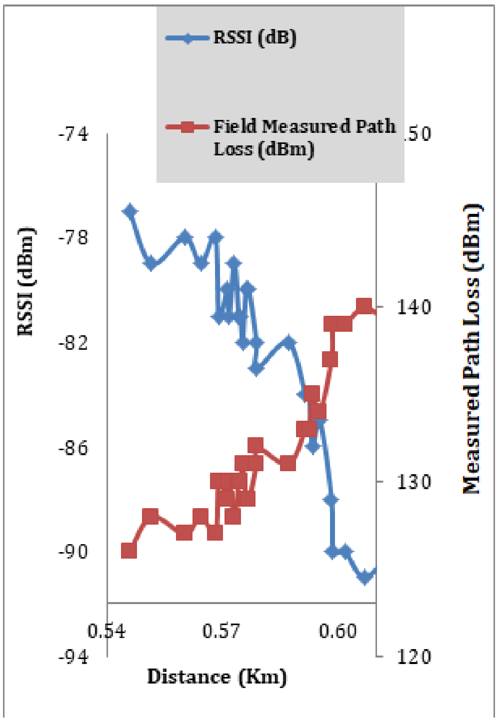

Figure 1 The measured path loss and the measured received signal strength intensity

According to the result, the un-tuned Walficsh-Bertoni model had a RMSE of 14.41 dB and prediction accuracy of 89.56 %. The RMSE-tuned Walficsh-Bertoni model had a RMSE of 3.85dB and prediction accuracy of 97.48 % and the function–tuned Walficsh-Bertoni model had RMSE of 1.52 dB and prediction accuracy of 99.01%. As such, the function–tuned Walficsh-Bertonimodel is the best Walficsh-Bertoni model for estimating the path loss in the case study market. Meanwhile, the error function is derived using online Xuru nonlinear regression tool and the error function obtained is given as;

$$f(e_i, d_i) = e_i = 290.0037896(d_i) - 129.5565119 \quad (6)$$

Hence, the most effective Walficsh-Bertoni model estimating the path loss in the market is given as;

$$LP_{WBOPT(i)}(dB) = LP_{WB(i)}(dB) + 290.0037896(d_i) - 129.5565119 \quad (7)$$

Where $LP_{WB(i)}(dB)$ is given by equation 1.

Table 1 The un-tuned Walficsh-Bertoni model predicted path loss, the RMSE-tuned Walficsh-Bertoni model predicted path loss, and the error function – tuned Walficsh-Bertoni model predicted path loss

d (km)	Measured Path Loss (dBm)	Un-tuned Walficsh-Bertoni path loss model (dB)	RMSE-tuned Walficsh-Bertoni path loss model (dB)	Error function-tuned Walficsh-Bertoni path loss model (dB)
0.5456	126.00	117.0963663	131.5028	123.8367
0.5514	128.00	117.2703926	131.6769	125.1565
0.5600	127.00	117.5263887	131.9329	127.1201
0.5642	128.00	117.6488183	132.0553	128.0685
0.5680	127.00	117.7603547	132.1668	128.938
0.5689	130.00	117.7872657	132.1937	129.1485
0.5712	129.00	117.8535864	132.26	129.6687
0.5716	130.00	117.8638682	132.2703	129.7495
0.5730	128.00	117.9048448	132.3113	130.072
0.5741	130.00	117.9356615	132.3421	130.3149
0.5745	130.00	117.9473861	132.3538	130.4075
0.5751	131.00	117.9658756	132.3723	130.5535
0.5760	129.00	117.9909354	132.3974	130.7517
0.5768	129.00	118.0133824	132.4198	130.9295
0.5787	131.00	118.0683115	132.4748	131.3653
0.5788	132.00	118.0717047	132.4782	131.3923
0.5870	131.00	118.3036853	132.7101	133.2475
0.5916	133.00	118.4302413	132.8367	134.2692
0.5924	133.00	118.4548571	132.8613	134.4688
0.5933	135.00	118.4788521	132.8853	134.6635
0.5953	134.00	118.5335591	132.94	135.1085
0.5983	137.00	118.6176535	133.0241	135.795
0.5987	139.00	118.6294549	133.0359	135.8915
0.6018	139.00	118.7124051	133.1189	136.5721
0.6070	140.00	118.8546214	133.2611	137.746
0.6148	139.00	119.0666941	133.4732	139.5132
0.6181	140.00	119.1543443	133.5608	140.2494

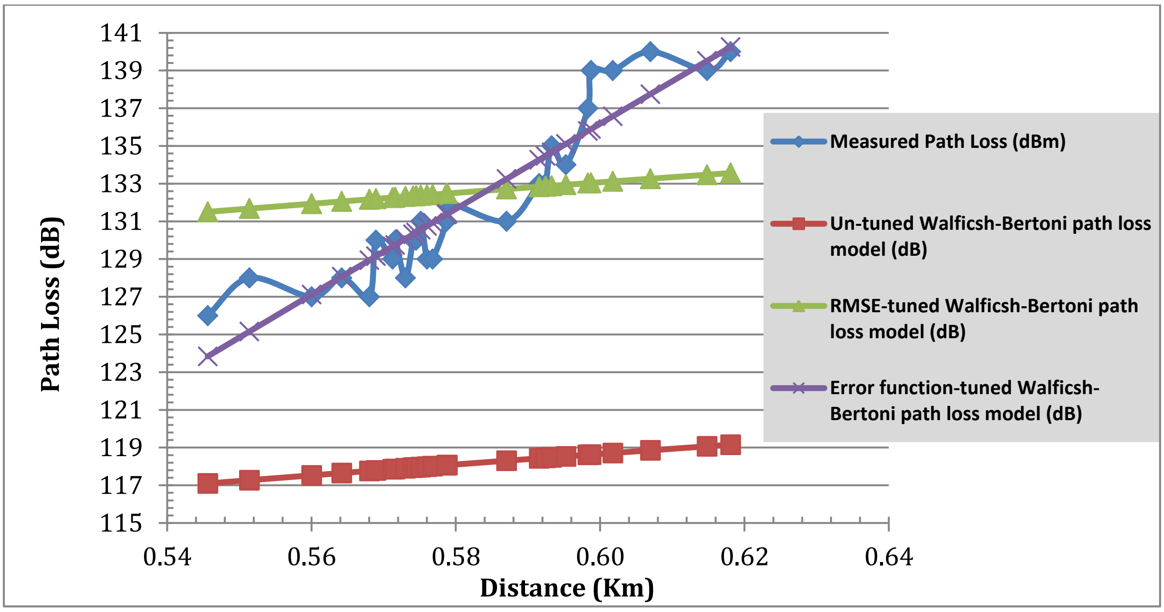

Figure 2 The un-tuned Walficsh-Bertoni model predicted path loss, the RMSE-tuned Walficsh-Bertoni model predicted path loss, and the error function –tuned Walficsh-Bertoni model predicted path loss

VI. Conclusion

Walficsh-Bertoni model is presented. The model is used to model the path loss in a market with mainly one-story buildings. Two methods are used to optimize the model; one method is based on the root mean square error while the other method is based on an error function derived as a function of the distance between the transmitter and the receiver. In all, the optimized model based on the error function gave the best path loss prediction performance for the market . In all, it can be concluded that different path loss optimization approach can be explored to determine the best model for a given case study site. Most often the root mean square error based method is used but this study has shown that significant improvement in the prediction performance can be achieved with other methods , as has been demonstrated in this study.

References

1. TSAI, M. (2011). Path-loss and shadowing (large-scale fading). *National Taiwan University October*, *20*, 2011.
2. Nnanyerem, Umesi Cosmos, Ozuomba Simeon, and Afolayan J. Jimoh. "Near Ground Path Loss Prediction for UMTS 2100 MHz Frequency Band Over Propagating Over a Smooth-Earth Terrain." International Journal of Theoretical and Applied Mathematics 3.2 (2017): 70.
3. Aloziem, Njoku Chukwudi, Ozuomba Simeon, and Afolayan J. Jimoh. "Tuning and Cross Validation of Blomquist-Ladell Model for Pathloss Prediction in the GSM 900 Mhz Frequency Band." International Journal of Theoretical and Applied Mathematics 3.2 (2017): 94.
4. Sun, S., Thomas, T. A., Rappaport, T. S., Nguyen, H., Kovacs, I. Z., & Rodriguez, I. (2015, December). Path loss, shadow fading, and line-of-sight probability models for 5G urban macro-cellular scenarios. In *Globecom Workshops (GC Wkshps), 2015 IEEE* (pp. 1-7). IEEE.
5. Akaninyene B. Obot , Ozuomba Simeon and Kingsley M. Udofia (2011); *"Determination Of Mobile Radio Link Parameters Using The Path Loss Models"* NSE Technical Transactions , A Technical Journal of The Nigerian Society Of Engineers, Vol. 46, No. 2 , April - June 2011 , PP 56 – 66.
6. TSAI, M. (2011). Path-loss and shadowing (large-scale fading). *National Taiwan University October*, *20*, 2011.
7. Nwawelu, U. N., Nzeako, A. N., &Ahaneku, M. A. (2012). The limitations of campus wireless networks: A case study of University of Nigeria, Nsukka [Lionet]. *International Journal of Networks and Communications*, *2*(5), 112-122.
8. Ozuomba, Simeon, Johnson Enyenihi, and Ngwu Chinyere Rosemary. "Characterisation of Propagation Loss for a 3G Cellular Network in a Crowded Market Area Using CCIR Model." Review of Computer Engineering Research 5.2 (2018): 49-56.
9. Rappaport, T. S., Sun, S., Mayzus, R., Zhao, H., Azar, Y., Wang, K., ...& Gutierrez Jr, F. (2013). Millimeter wave mobile communications for 5G cellular: It will work!.*IEEE access*, *1*(1), 335-349.
10. Ozuomba, Simeon, Enyenihi Henry Johnson, and Emmanuel Nsese Udoiwod. "Application of Weissberger Model for Characterizing the Propagation Loss in a Gliricidia sepium Arboretum." (2018).
11. Akaninyene B. Obot , Ozuomba Simeon and Afolanya J. Jimoh (2011); *"Comparative Analysis Of Pathloss Prediction Models For Urban Macrocellular" Nigerian Journal of Technology (NIJOTECH)* Vol. 30, No. 3 , October 2011 , PP 50 – 59
12. Ebhota, V. C., Isabona, J., &Srivastava, V. M. (2018). Improved Adaptive Signal Power Loss Prediction Using Combined Vector Statistics Based Smoothing and Neural Network Approach. *Progress In Electromagnetics Research*, *82*, 155-169.
13. Chen, J., Shen, D. Y., Yao, N., & Zhang, R. (2013). 3-D Research about Walfisch-Bertoni Model. In *Applied Mechanics and Materials* (Vol. 385, pp. 1527-1530). Trans Tech Publications.
14. Akinyemi, P., Azi, S. O., Ojo, J. S., &Abiodun, C. I. (2015). Evaluation for suitable propagation model to mobile communications in South-South Nigeria Urban Terrain. *Am. J. Eng. Res*, *4*, 01-05.
15. of Propagation Models in Three Built-Up Cities of South-South, Nigeria. *American Journal of Engineering Research (AJER)*, *2*(05), 96-106.
16. Joseph, I., & Michael, B. (2013) Statistical tuning of walfisch-bertonipathloss prediction model based on building and street geometry sensitivity parameters in built-up terrains. *American Journal of Physics and Applications;* 1(1): 10-17