Ericson model-based characterization of cellular network path loss for a road lined with Delonixregia trees

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***Abstract*— The propagation loss along a road that is lined with Delonixregia or flamboyant trees was studied. The study was for a cellular network located in Umuahia in Abia State and it frequency is in the 900 MHz band. The propagation loss is modeled using the urban, suburban and rural environments versions of the Ericson model. Field measurement of path loss was carried out along the case study path. The prediction performance of the three versions of the Ericson model was assessed. The models were also optimized. The rural Ericson model had the best prediction performance for both the un-tuned models and for the tuned models. Particularly, the tuned Ericson model for the rural area had the least root mean square error of 2.69 dB and the highest prediction accuracy of 97.69 %. Consequently, the tuned model was recommended for path loss prediction in the case study area.**

Keywords — Ericsson model, path loss, empirical path loss model, model optimization, prediction accuracy, path loss prediction performance

I. INTRODUCTION

Many major roads and some streets in the urban areas are lined with landscaping trees [1,2,3,4,5,6]. Apart from providing shade, some of the trees have beautiful flowers and colorful leaves that add value and beauty to the environment. In any case, these trees present additional loss to wireless signal propagating through the path where they are located [7,8,9,10,11].

In this paper, propagation loss for a cellular network in a suburban part of Umuahia in Abia State is studied. The path is a road lined with Delonixregia or flamboyant trees [12,13,13,14,15]. Delonixregia is one of the most beautiful ornamental trees that is known for flamboyant display of flowers. The study in this paper seeks to characterize the path loss along the case study road with the urban, suburban and rural environments versions of the Ericson model [16,17,18,19,2]. The study will use empirically measured path loss obtained in the case path to evaluate the Ericson models and then optimized the models for improved path loss prediction. The best model will be identified and the exact mathematical expression for the selected model will be derived.

II. ERICSSON PATH LOSS MODEL

In the Ericsson model, path loss is computed using the following mathematical expressions [16,17,18,19,2];

$$LP_E = a_0 + a_1(\log_{10}(d)) + a_2(\log_{10}(h_b)) + a_3\{\log_{10}(h_b)(\log_{10}(d))\} - 3.2\log_{10}(11.75h_m)^2 + g(f) \quad (1)$$

Where f is the frequency in MHz, h_m is the receiver antenna height in meters, h_b is the transmitter antenna height in meters and $g(f)$ is defined as follows;

$$g(f) = 44.49(\log_{10}(f)) - [4.78(\log_{10}(f))^2] \quad (2)$$

The model has provision for the path loss in different terrains, such as, the urban, the suburban and the rural environments. The values of the parameters (a_0,a_1,a_2,a_3) for the different types of terrains are given in Table 1.

Table 1: Parameter Values For Ericsson Model (Source :[16,17,18,19,2])

Environment	a_0	a_1	a_2	a_3
Rural	45.95	100.6	12	0.1
Suburban	43.20	68.63	12	0.1
Urban	36.20	30.20	12	0.1

III. THE EMPIRICAL MEASUREMENT CAMPAIGN

The empirical measurement was for a 900MHz cellular network signal. The measurement was carried out in Umuahia Abia State along a street that is lined with Delonixregia or flamboyant tree. A wireless network site survey android app, G-NetTrack Lite 8.0 was installed on a Samsung Galaxy S4 mobile phone. The mobile phone was then used to capture the received signal strength, the longitude and the latitude of the measurement point, the base station information and other relevant data for the study. The haversine formula [21] was used to calculate the distance between the base station and each of the measurement points using the data points' longitude and latitude. The haversine formula is given as follows;

$$d = 2r\left\{\sqrt[2]{\sin\left(\frac{LAT_b - LAT_m}{2}\right)^2 + \cos(LAT_m)\cos(LAT_b)\sin\left(\frac{LONG_b - LONG_m}{2}\right)^2}\right\} \quad (3)$$

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

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

Where

LAT_b and LAT_m are the latitude of the base station and the mobile unit respectively

$LONG_b$ and $LONG_m$ are the longitude of the base station and the mobile unit respectively d is the distance between the two coordinates , R is the radius of the earth = 6371 km ; R varies from 6356.752km at the poles to 6378.137 km at the equator

The field measured RSSI was used to determine the measured path loss ($PL_{m(dB)}$) as follows:

$PL_{m(dB)} = P_t + G_t + G_r - L_t - GL_r -$ RSSI (6)

where G_t and G_r are the transmitter and the receiver antenna gain respectively,P_t is the transmitter power of the base station, L_t and L_r are losses at the transmitter and the receiver and all the parameters arespecified in dB scale.

The measured path loss is used to evaluate the prediction performance of the Ericsson model. The root mean square error (RMSE) and prediction accuracy, PA(%) are used as the performance measures where;

$$RMSE = \sqrt[2]{\left\{\frac{1}{N}\left[\sum_{i=1}^{i=N}\left(PL_{m(i)} - PL_{p(i)}\right)\right]\right\}} \quad (7)$$

$$\mathbf{PA}(\%) = \left\{1 - \frac{1}{N}\left(\sum_{i=1}^{i=N}\left|\frac{|PL_{m(i)} - PL_{p(i)}|}{PL_{m(i)}}\right|\right)\right\} * 100\% \quad (8)$$

Where the predicted path loss in dB is denoted as $PL_{p(i)}$, themeasured path loss in dB is denoted $PL_{m(i)}$, and the total number of measurement data points considered in the analysis is denoted as N. The RMSE optimized Ericsson model is given as;

$$LP_{EOPT} = \begin{cases} LP_E + \text{RMSE} \text{ for } \sum_{i=1}^{i=N}\left(PL_{m(i)} - PL_{p(i)}\right) \geq 0 \\ LP_E - \text{RMSE} \text{ for } \sum_{i=1}^{i=N}\left(PL_{m(i)} - PL_{p(i)}\right) < 0 \end{cases} \quad (9)$$

IV. RESULTS AND DISCUSSION

The RSSI obtained during the field measurement is shown in Figure 1. Minimum RSSI value of about -76 dB occurred at a distance of 1.44 Km from the base station. The field measure path loss and the un-tuned Ericson model predicted path loss using the urban, suburban and rural environments versions of the Ericson model are presented in Figure 2. Similar results for the tuned Ericson model are given in Figure 3 while the prediction performance is given in Figure 4. Among the three versions of the Ericson model, the rural model had the best prediction performance both for the un-tuned models and the tuned models. In all, the best model is the tuned Ericson model for the rural area which had the least RMSE of 2.69 dB and the highest prediction accuracy of 97.69 %. Essentially, the path loss along the case study path is best characterized with the tuned Ericson model for the rural area. The tuned Ericson model for the rural area is given as;

$$LP_{EOPT} = a_0 + a_1(\log_{10}(d)) + a_2(\log_{10}(h_b)) + a_3\{\log_{10}(h_b)(\log_{10}(d))\} - 3.2\log_{10}(11.75h_m)^2 + g(f) + 10.99 \quad (10)$$

wherea_0 = 45.95, a_1= 100.6, a_2 = 12 and a_3= 0.1.

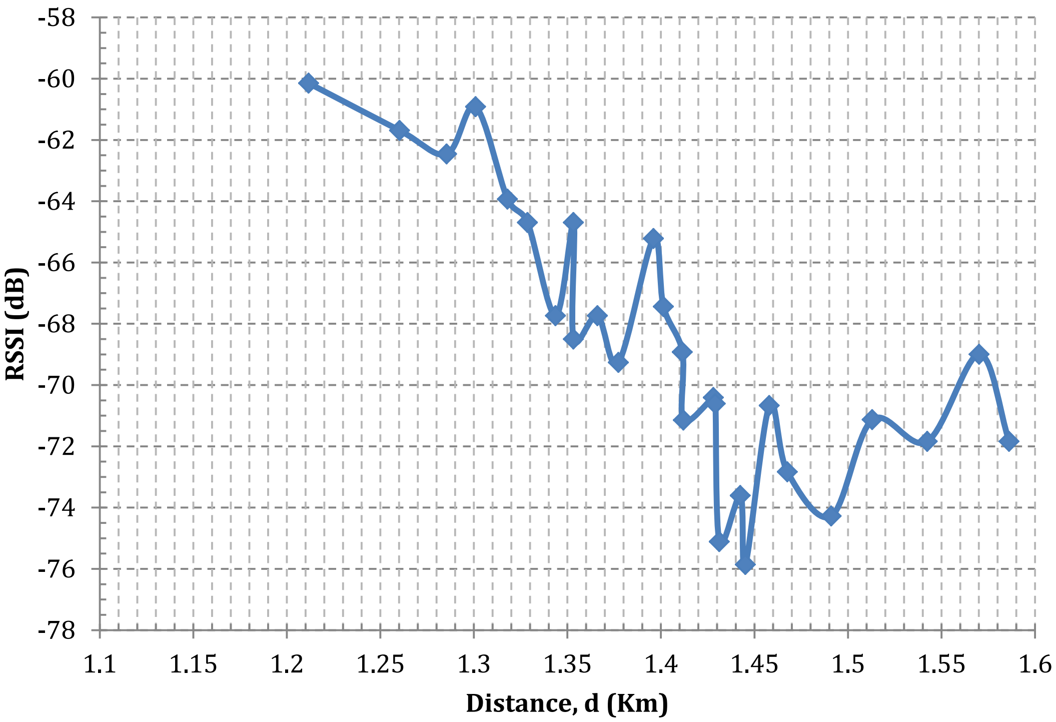


Figure1 The field measure RSSI (dB)

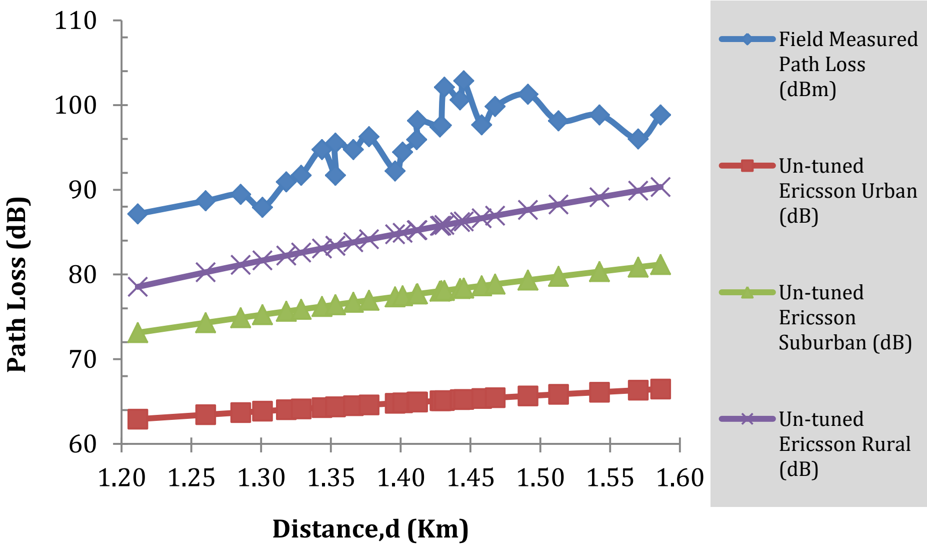


Figure 2 Field measure path loss and the un-tuned Ericson model predicted path loss for the urban, suburban and rural environments

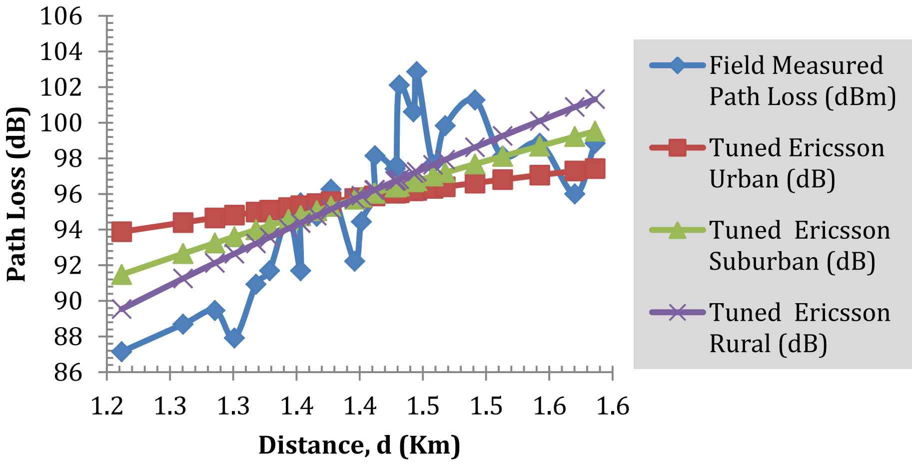
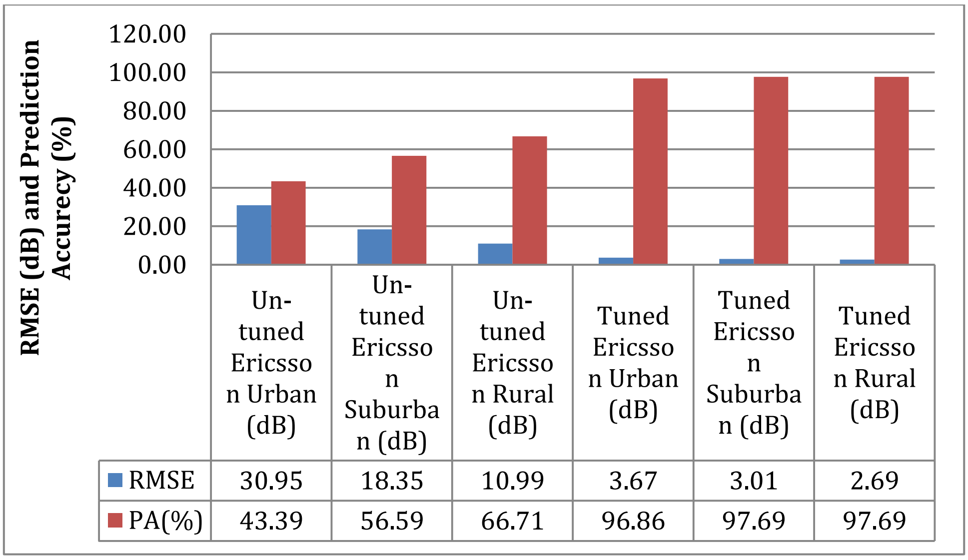


Figure 3 Field measure path loss and the tuned Ericson model predicted path loss for the urban, suburban and rural environments



	Un-tuned Ericsson Urban (dB)	Un-tuned Ericsson Suburban (dB)	Un-tuned Ericsson Rural (dB)	Tuned Ericsson Urban (dB)	Tuned Ericsson Suburban (dB)	Tuned Ericsson Rural (dB)
RMSE	30.95	18.35	10.99	3.67	3.01	2.69
PA(%)	43.39	56.59	66.71	96.86	97.69	97.69

Figure 4 Path Loss Prediction Performance for the models

V. CONCLUSION

The path loss for a cellular network is modeled using the urban, suburban and rural environments versions of the Ericson model. Field measurement of path loss was carried out and the measured path loss was used to assess the prediction performance of the three versions of the Ericson model. Among the un-tuned models, the Ericson model for rural area gave the best prediction. The models were also optimized using the root mean square error method. Again, the tuned Ericson model for rural area gave the best prediction. The tuned model was then recommended for path loss prediction in the case study area.

REFERENCES

1. Ely, M. E. (2010). *Integrating trees into the design of the city: expert opinions on developing more sustainable practices for planting street trees in Australian cities* (Doctoral dissertation).
2. Kadir, M. A. A., & Othman, N. (2012). Towards a better tomorrow: street trees and their values in urban areas. *Procedia-Social and Behavioral Sciences*, *35*, 267-274.
3. Wolf, K. L. (2007). Benefits and Risks of Urban Roadside Landscape: Finding a Livable, Balanced Response. In *Proceedings on the 3rd Urban Street Symposium p1-17. Transportation Research Board of the National Academies of Science,(June 24-27*.
4. Kadir, M. A. A., & Othman, N. (2012). Towards a better tomorrow: street trees and their values in urban areas. *Procedia-Social and Behavioral Sciences*, *35*, 267-274.
5. Endress, A. G. (1990). The importance of diversity in selecting trees for urban areas. *Journal of Arboriculture*, *16*(6), 143-147.
6. Zhao, S., Liu, S., & Zhou, D. (2016). Prevalent vegetation growth enhancement in urban environment. *Proceedings of the National Academy of Sciences*, *113*(22), 6313-6318.
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. Meng, Y. S., Lee, Y. H., & Ng, B. C. (2009). Study of propagation loss prediction in forest environment. *Progress In Electromagnetics Research*, *17*, 117-133.
9. Meng, Y. S., & Lee, Y. H. (2010). Investigations of foliage effect on modern wireless communication systems: A review. *Progress In Electromagnetics Research*, *105*, 313-332.
10. Anastassiu, H. T., Vougioukas, S., Fronimos, T., Regen, C., Petrou, L., Zude, M., & Käthner, J. (2014). A computational model for path loss in wireless sensor networks in orchard environments. *Sensors*, *14*(3), 5118-5135.
11. Pélet, E. R., Salt, E. J., & Wells, G. (2004, May). Signal distortion caused by tree foliage in a 2.5 GHz channel. In *Canadian Conference on Electrical and Computer Engineering 2004 (IEEE Cat. No. 04CH37513)* (Vol. 3, pp. 1449-1452). IEEE.
12. Abulude, F. O., & Adejayan, A. W. (2017). *Nutritional values of flamboyant (Delonixregia) seeds obtained in Akure, Nigeria*(No. e2764v1). PeerJ Preprints.
13. Oyedeji, O. A., Azeez, L. A., & Osifade, B. G. (2017). Chemical and nutritional compositions of flame of forest (Delonixregia) seeds and seed oil. *South African Journal of Chemistry*, *70*, 16-20.
14. Singh, S., & Kumar, S. N. (2014). A review: introduction to genus Delonix. *World J Pharm PharmSci*, *3*(6), 2042-55.
15. Goldson Barnaby, A., Reid, R., Rattray, V., Williams, R., & Denny, M. (2016). Characterization of Jamaican Delonixregia and Cassia fistula seed extracts. *Biochemistry research international*, *2016*.
16. Alam, D., & Khan, R. H. (2013). Comparative study of path loss models of WiMAX at 2.5 GHz frequency band. *International Journal of Future Generation Communication and Networking*, *6*(2), 11-24.
17. Chebil, J., Lwas, A. K., Islam, M. R., &Zyoud, A. H. (2011, May). Comparison of empirical propagation path loss models for mobile communications in the suburban area of Kuala Lumpur. In *Mechatronics (ICOM), 2011 4th International Conference On* (pp. 1-5). IEEE.
18. Mawjoud, S. A. (2013). Path loss propagation model prediction for GSM network planning. *International Journal of Computer Applications*, *84*(7).
19. Mawjoud, S. A. (2013). Path loss propagation model prediction for GSM network planning. *International Journal of Computer Applications*, *84*(7).

20. Temaneh-Nyah, C., &Nepembe, J. (2014, January). Determination of a suitable correction factor to a radio propagation model for cellular wireless network analysis. In *2014 5th International Conference on Intelligent Systems, Modelling and Simulation* (pp. 175-182). IEEE.

21. WorguS., AjumoS.G. and N. N. Odu (2017) Comparative Evaluation of the Pathloss Prediction Performance Hata-Okumura Pathloss Model for Urban, Suburban and Rural Areas . *International Journal of Systems Science and Applied Mathematics* 2017; 2(1): 42-50