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Comparison of Path Loss Prediction Performance of Egli Model and Lee Model For Cellular Network Signal Along A Dual Carriage Way In Uyo

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***Abstract*—In this paper, Egli and Lee path loss models are used to characterize the path loss expected for a cellular network signal in the 900 MHz frequency band. The study site is along a dual carriage way in Uyo and the path is sparkly lined with Polylalthialongifolia trees (masquerade trees). The empirical measured path loss from the study site was used to conduct prediction performance analysis for the two models and also to perform the model tuning. Among the un-tuned models, Egli has the best prediction performance with a RMSE of 26.6 dB and prediction accuracy of 78.5 %. The un-tuned Lee for rural area had the worst prediction performance with a RMSE of 53.3 dB and prediction accuracy of 56.7 %. On the other hand, when the tuned models are considered, the Lee model for rural area is the best model with RMSE of 2.3 and prediction accuracy of 98.2 %. The tuned Egli model is the next model with very good prediction performance of 98.1 and RMSE of 2.7 dB. In all, the Egli model is identified as the best model for the case study terrain.**

Keywords*—*Egli model, Lee model, Empirical model, Model tuning, Path loss

I. I. Introduction

Path loss models are used to determine the expected attenuation of wireless signal strength caused by factors in the signal path [1,2,3,4,5,6]. Generally, there are empirical path loss models which are developed based on field measured data [7,8,9,10,11,12]. There are deterministic models which use detailed information about the propagation environment and laws of electromagnetic wave propagation to determine the expected path loss in the given environment [13,14,15,16]. Then, the semi-empirical models combine empirical and deterministic approaches in the determination of path loss. Among these three, the empirical path loss models are the most popularly used mainly because they are simple and easy to apply and they can be readily tuned to suit any given propagation environment.

In this paper, two empirical path loss models are considered and they are the Egli path loss model [17,18,19,20,21,22,23] and the Lee path loss model [24,25,26,27,28,29,30]. The Egli path loss model is suitable for cellular network where the signal path has an irregular terrain. Also, the Lee model is particularly suitable for cellular network in the 900 MHz frequency band and it includes adjustment factors that can enable the model to be adjusted for different propagation environment. The study in this paper is for a cellular network in the 900 MHz band and the propagation environment is a dual carriage way that is sparsely lined with Polylalthialongifolia trees (masquerade trees). The prediction performance of the models is compared based on the empirically measured path loss data captured within the specified propagation environment. The models are they tuned and the tuned models are derived. The best propagation loss model for the case study propagation environment is also identified.

II. II. The Egli Path Loss Model

Path loss according to Egli model is given as follows [17,18,19,20,21,22,23]:

$$For \quad h_m \leq 10$$

$$LP_{EGLI} = 20\log_{10}(f_c) + 40\log_{10}(d) - 20\log_{10}(h_b) - 10\log_{10}(h_m) + 76.3 \qquad (1)$$

$$For \quad h_m \geq 10$$

$$LP_{EGLI} = 20\log_{10}(f_c) + 40\log_{10}(d) - 20\log_{10}(h_b) - 10\log_{10}(h_m) + 85.9 \qquad (2)$$

Where

- $h_b$is the height of the base station antenna. Unit: meter (m)
- $h_m$is the height of the mobile station antenna. Unit: meter (m)

- d is the distance from base station antenna. Unit: meter (m)
- $f_c$is the frequency of transmission. Unit: megahertz (MHz)

From the formulas, it is noted that this model predicts that

III. THE LEE PATH LOSS MODEL

Path loss according to Lee model is expressed as: [24,25,26,27,28,29,30].

$$LP_{LEE} = (10n)\log_{10}(d) - (20)\log_{10}(h_b) - (P_0) - (10)\log_{10}(h_m) + 29 \quad (3)$$

where n and Po are given in Table 1 and the other parameters are as defined for the Egli model.

Table 1 The Parameters For Lee Model (Source: [24,25])

Environment	P_o	n
Free space	80	2.0
Open area	89	4.35
North American suburban	101.7	3.85
North American suburban (Philadelphia)	110	3.68
North American suburban (Newark)	104	4.31
Japanese urban	124	3.05

IV. THE FIELD MEASUREMENT

The field measurement was conducted along Idoro Road in Uyo which is a dual carriage way that is sparsely lined with Polylalthialongifolia trees (masquerade trees). The measurement was for a cellular network operating in the 900 MHz frequency band. The relevant data: the received signal strength intensity (RSSI), the distance of the measurement point from the base station and the base station information were obtained using CellMapper android application installed on Samsung galaxy S4 phone. Each of the measured RSSI values denoted as RSSI(measured) was converted to measured path loss ($PL_{m(dB)}$) values using the following equation:

$$PL_{m(dB)} = P_t + G_t + G_r - L_t - GL_r - \text{RSSI(measured)} \quad (4)$$

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

V. MODEL PERFORMANCE MEASURE AND OPTIMIZATION

The performance of each of the models was expressed in terms of root mean square error (RMSE) and prediction accuracy, PA which are given as follows;

$$\text{RMSE} = \sqrt[2]{\left\{\frac{1}{N}\left[\sum_{i=1}^{i=N}\left(PL_{m(i)} - PL_{p(i)}\right)\right]\right\}} \quad (5)$$

$$\mathbf{PA}(\%) = \left\{1 - \frac{1}{N}\left(\sum_{i=1}^{i=N}\left|\frac{|PL_{m(i)} - PL_{p(i)}|}{PL_{m(i)}}\right|\right)\right\} * 100\% \quad (6)$$

Where $PL_{m(i)}$is the field measured propagation loss (dB) ,$PL_{p(i)}$ is the model predicted propagation loss (dB) and N is the total number of measurement data points considered in the analysis.

Let the sum of error be denoted as SoE, where

$$\text{SoE} = \sum_{i=1}^{i=N}\left(PL_{m(i)} - PL_{p(i)}\right) \quad (7)$$

The models were optimized using the RMSE and the SoE . The optimized Egli model is denoted as $LP_{EGLIOPT}$;

$$LP_{EGLIOPT} = \begin{cases} LP_{EGLI} + \text{RMSE} & \text{for SoE} \geq 0 \\ LP_{EGLI} - \text{RMSE} & \text{for SoE} < 0 \end{cases} \quad (8)$$

The optimized Egli model is denoted as LP_{LEEOPT} ;

$$LP_{LEEOPT} = \begin{cases} LP_{LEE} + \text{RMSE} & \text{for SoE} \geq 0 \\ LP_{LEE} - \text{RMSE} & \text{for SoE} < 0 \end{cases} \quad (9)$$

Based on the measured path loss data, the two models were optimized to improve on their prediction performance. Particularly, three different terrain versions of the Lee model ware examined, namely; Lee model for urban area, Lee model for suburban area and Lee model for rural area. The best model was identified based on the prediction performance parameter values.

VI. RESULTS AND DISCUSSIONS

The measured received signal strength intensity (RSSI) versus that length is given in Figure 1. The measured path loss, the un-tuned Lee model predicted path loss and the un-tuned Egli model predicted path loss are shown in Figure 2. Similarly, the results for the measured path loss, the tuned Lee model predicted path loss and the tuned Egli model predicted path loss are shown in Figure 3. The path loss prediction performance for the un-tuned and for the tuned Egli and Lee models are shown in Figure 4.

Among the un-tuned models, Egli has the best prediction performance with a RMSE of 26.6 dB and prediction accuracy of 78.5 %. The un-tuned Lee for rural area had the worst prediction performance with a RMSE of 53.3 dB and prediction accuracy of 56.7 %. On the other hand, when the tuned models are considered, the Lee model for rural area is the best model with RMSE of 2.3 and prediction accuracy of

98.2 %. The tuned Egli model is the next model with very good prediction performance of 98.1 and RMSE of 2.7 dB. . In all, the Egli model is the best model for the terrain. The un-turned Egli model more appropriately modeled the propagation loss of the studied terrain than any of the Lee models.

The tuned models are given as follows:

$$LP_{EGLIOPT} = LP_{EGLI} + 26.6 \quad (10)$$

$$LP_{LEEOPT(RURAL)} + 53.3 \quad (11)$$

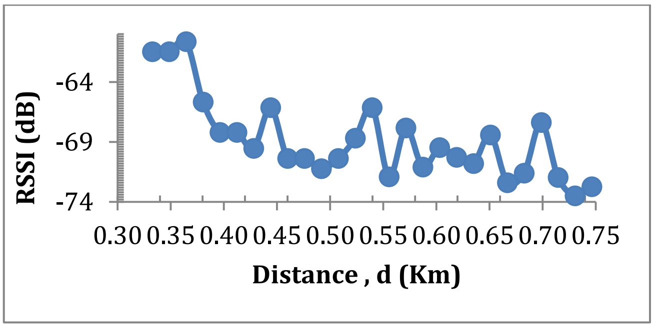


Figure 1 : The Received signal strength at the various measurement distances from the base station

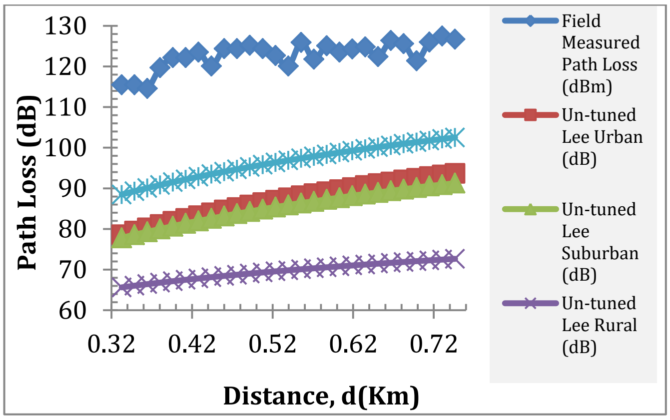


Figure 2 : The measured path loss , the un-tuned Lee model predicted path loss and the un-tuned Egli model predicted path loss

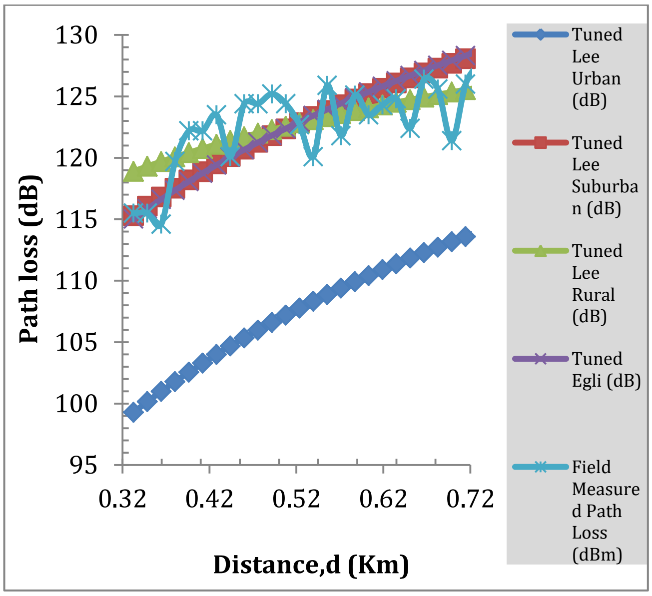
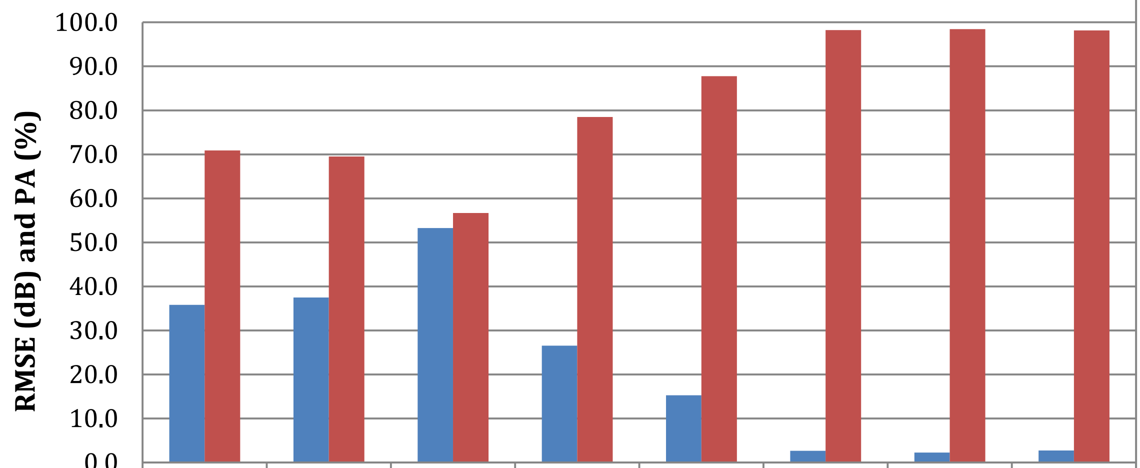


Figure 3 : The measured path loss , the tuned Lee model predicted path loss and the tuned Egli model predicted path loss



	Un-tuned Lee Urban (dB)	Un-tuned Lee Suburban (dB)	Un-tuned Lee Rural (dB)	Un-tuned Egli Urban (dB)	Tuned Lee Urban (dB)	Tuned Lee Suburban (dB)	Tuned Lee Rural (dB)	Tuned Egli Urban (dB)
RMSE (dB)	35.8	37.5	53.3	26.6	15.3	2.6	2.3	2.7
Pa (%)	70.9	69.5	56.7	78.5	87.8	98.2	98.5	98.1

Figure 4 The path loss prediction performance of Lee model and Egli model

VII. VII Conclusion

Two empirical path loss models, namely, Egli and Lee models are studied. The study is carried out for a cellular network along a dual carriage way in Uyo. The prediction performance of the models is compared and then the models are tuned using the root mean square error method. The path loss prediction performance of the tuned models is also determined and compared. The best tuned Lee model and best of Egli model are then developed. In all, the Egli model is the best model for the studied terrain.

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