Performance Analysis of Standard Propagation Model For Cellular Network Along Uyo Village Road

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Abstract— In this paper, performance analysis of Standard Propagation Model (SPM) for cellular network along Uyo village road is presented. Empirical field measurement is conducted along the case study road using site survey android application installed on Samsung galaxy S4 phone. The measured path loss was used to evaluate the propagation loss prediction performance of the three versions of the SPM, namely, SPM for urban, SPM for suburban and SPM for rural area. Furthermore, the SPM models were tuned using the root mean square error RMSE)-based method. The propagation loss prediction performance of the tuned SPM models was also analyzed. In all, the tuned-SPM for rural area had the best propagation loss prediction performance for the case study site; it had the least RMSE of 3.5 dB and the highest prediction accuracy of 98. 8 %. Consequently, among the three versions of SPM that are considered, the optimized Standard Propagation Model (SPM) for the rural area is recommended for the prediction of the propagation loss along the Uyo village road.

Keywords— Standard Propagation Model, Path Loss, Path Loss Model, Model Tuning, Empirical Model, Prediction Performance.

1. INTRODUCTION

Accurate estimation of path loss is essential in cellular network design [1,2,3,4]. As such, some network designer conduct wireless network site survey (field measurement of path loss) to determine the path loss expected in a given area before the actual cellular network is deployed to the area [5,6,7,8,9]. However, apart from site survey, the expected path loss can be estimated using available path loss models [10,11,12,13,14,15]. However, in most cases, available path loss models may not give acceptable prediction performance for a given area of interest. As such, the site survey path loss data can be used to tune the path loss model.

In this paper, the path loss for a cellular network signal along Uyo village road at the outskirts of Uyo metropolis is studied. The study became necessary as the over 2.5 Km Uyo village road which was formally without any building is now populated with churches and event centers. Increasingly, more people are visiting the churches and event centers every week. As such, cellular network providers will need to ensure adequate network coverage in the area. Consequently, in this paper, the Standard propagation model (SPM) [16,17,18,19] is used to model the cellular network path loss for the Uyo village road. Empirical field measurement is conducted along the case study road and the measured path loss is used to analysis the prediction performance of the Standard propagation model. The Standard propagation model is also optimized in respect of the measured path loss. The optimized Standard propagation model for the Uyo village road is expected to serve as a model for cellular network designers to predict the expected path loss along the Uyo village road.

2. THE STANDARD PROPAGATION MODEL

Standard Propagation Model (SPM) is an empirical path loss model based on the following formula [16,17,18,19];

$$LP_{SPM(dB)} = A + B(\log_{10}(d)) + C_m \quad (1)$$

$$A = K_1 + K_3(\log_{10}(H_{TXeff})) + K_6(H_{TXeff}) + K_7(\log_{10}(H_{TXeff})) \quad (2)$$

$$B = K_2 + K_5(\log_{10}(H_{TXeff})) \quad (3)$$

$$C_m = K_4(Diffraction\ Loss) + K_{clutter}(f(clutter)) + K_{hillLOS} \quad (4)$$

Where K_1 is the frequency constant (dB); K_2 is the distance attenuation constant .;d is the distance between the receiver and transmitter (m); K_3 and K_7 are the correction coefficient of height of mobile station antenna; ,K_4 is the multiplying coefficient for diffraction loss calculation K_5 and K_6 are the correction coefficient of height of base station antenna; $K_{clutter}$ is the correction coefficient of clutter attenuation. The clutter class is used to determine the coefficient of clutter to be used as shown in Table 1. Also, hm and hb are the effective height (in meter) of antenna in mobile station and base station respectively ; H_{TXeff} is the effective mobile antenna height in meters and f(clutter) is the average of weighted losses due to clutter. Diffraction loss accounts for the loss due to diffraction over an obstructed path (dB). The values of the various coefficients listed for the Standard Propagation Model are given in Table 1.

Table 1 K-Parameters for the Standard Propagation Model (SPM) (source: [16,17,18,19])

K Values	Dense Urban	Urban	Suburban	Rural	Highways
K_1	16.375	17.575	17.675	5.275	26.625
K_2	48	45.9	45.9	48	40.1
K_3	5.83	5.83	5.83	5.83	5.83
K_4	0.8	0.8	0.8	0.8	0.8
K_5	-0.655	-0.655	-0.655	-0.655	-0.655
K_6	0	0	0	0	0
K_7	0.8	0.8	0.8	0.8	0.8
$K_{clutter}$	1	1	1	1	1

The prediction performance of the model is evaluated using the root means square error (RMSE) and the prediction accuracy, PA (%). The RMSE is computed as follows;

$$RMSE = \sqrt[2]{\left\{\frac{1}{n}\left[\sum_{i=1}^{i=n}\left(PL_{(measured)(i)} - PL_{(predicted)(i)}\right)\right]\right\}} \quad (5)$$

The prediction accuracy, PA (%) is calculated as follows:

$$PA(\%) = \left\{1 - \frac{1}{n}\left(\sum_{i=1}^{i=n}\left|\frac{|PL_{(measured)(i)} - PL_{(predicted)(i)}|}{PL_{(measured)(i)}}\right|\right)\right\} * 100\% \quad (6)$$

Where $PL_{(measured)(i)}$ is the measured path loss (dB) ,$PL_{(predicted)(i)}$ is the predicted path loss (dB) and n is the number of measured data points.

The model is optimized using the RMSE as follows;

$$LP_{SPMTUN(dB)} = \begin{cases} LP_{SPM(dB)} + RMSE for \sum_{i=1}^{i=n}\left(PL_{(measured)(i)} - PL_{(predicted)(i)}\right) \geq 0 \\ LP_{SPM(dB)} - RMSE for \sum_{i=1}^{i=n}\left(PL_{(measured)(i)} - PL_{(predicted)(i)}\right) < 0 \end{cases} \quad (7)$$

Where $LP_{SPMTUN(dB)}$is the tuned SPM path loss model and $LP_{SPM(dB)}$ is the un-tuned SPM path loss model at measurement point i.

The analysis is conducted for the SPM for the urban, the suburban and the rural environments. The prediction performances of the three versions of the model will be compared.

3. FIELD MEASUREMENT CAMPAIGN

The received signal strength, the distance between the measurement point and the network base station, as well as the relevant base station information were captured using Netmonitor 1.5.84 android application installed on a Samsung Galxy S4 mobile phone. The measurement was carried out along Uyo village road (Figure 1) which is on the outskirt of Uyo metropolis in AkwaIbom State, Nigeria.

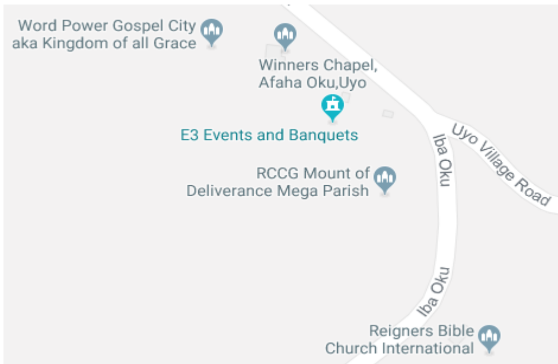


Figure 1: The cut section of the screenshot of the Google Map for Uyo village road

The cellular network signal was in the 900MHz frequency band. The link budget equation [20] was used to determine the measured path loss from the measured signal strength (RSSI). The measured path loss was then used to evaluate and hence optimize three different terrain versions of the Standard Propagation Model (SPM), namely; SPM for urban area, SPM for suburban area and SPM for rural area.

4. RESULTS AND DISCUSSION

The results of the measured path loss and the un-tuned Standard propagation model (SPM) predicted path loss using the urban, suburban and rural areas version of the SPM is shown in Figure 2. In Figure 3, the result of the tuned SPM predicted path loss is presented. The prediction performance of the un-tuned SPM and the tuned SPM models are presented in Figure 4. Among the un-tuned SPM models, the SPM for rural area had the best prediction performance with RMSE of 12.6 dB and prediction accuracy of 89.7 %. When the tuned SPM models are considered, the best model is the tuned-SPM for rural area which has the least RMSE of 3.5 dB and prediction accuracy of 98. 8 %. The SPM for suburban area gave the worst prediction performance both for the un-tuned SPM models and also for the tuned SPM models. The optimized Standard Propagation Model (SPM) for the rural area is recommended for the prediction of the path loss along Uyo village road. The model is given as follows;

$$LP_{SPMTUN\_rural(dB)} = LP_{SPM(dB)} + RMSE = LP_E + 12.6 = A + B(\log_{10}(d)) + C_m + 12.6 \quad (8)$$

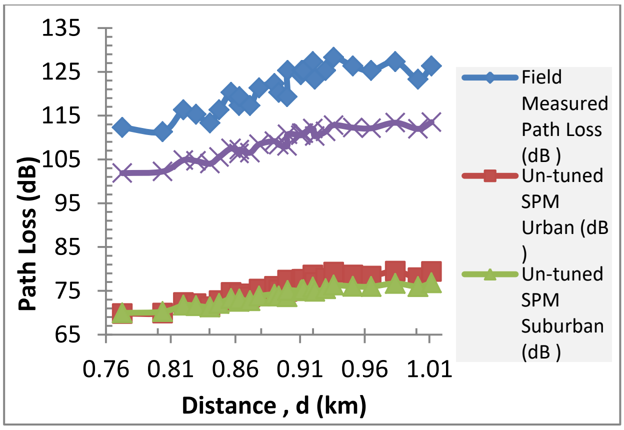


Figure 2: The measured path loss and the un-tuned SPM predicted path loss

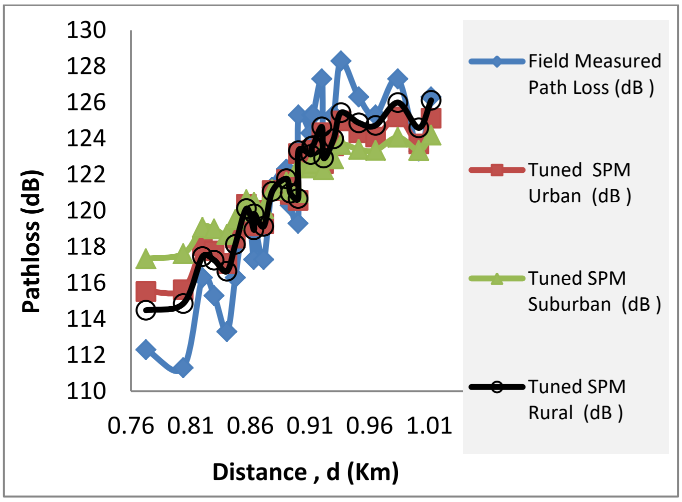
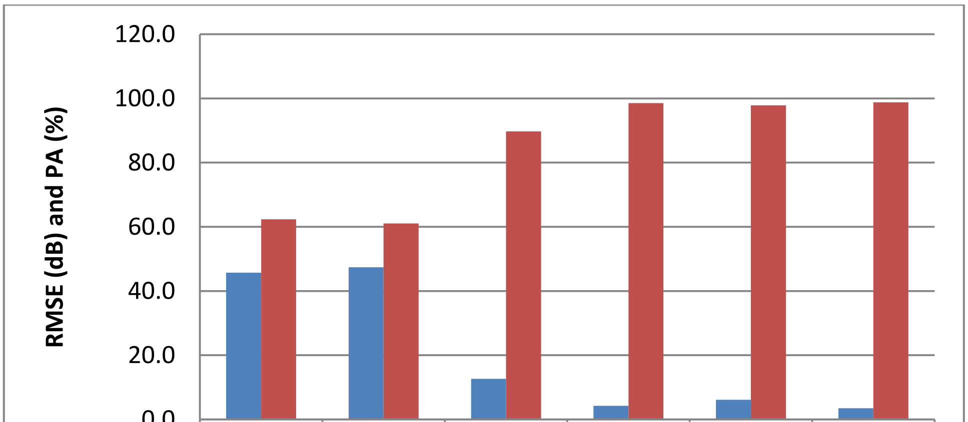


Figure 3: The measured path loss and the tuned SPM predicted path loss



	Un-tuned SPM Urban (dB)	Un-tuned SPM Suburban (dB)	Un-tuned SPM Rural (dB)	Tuned SPM Urban (dB)	Tuned SPM Suburban (dB)	Tuned SPM Rural (dB)
RMSE (dB)	45.7	47.4	12.6	4.2	6.1	3.5
PA(%)	62.3	61.0	89.7	98.5	97.9	98.8

Figure 4 : The Propagation Loss Prediction Performance

5 CONCLUSION

The standard propagation model for estimating the path loss along a road in the outskirts of Uyo metropolis is presented. The study used empirically measured path loss obtained along the case study road to evaluate the prediction performance and also optimize the standard propagation model. The root mean square-based optimization method is used and the optimized standard propagation model for rural area gave the best prediction performance for the study site.

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