# Effective Prediction Of Path Loss In Tectona Grandis Arboretum Using Tuned Early Itu Foliage Model

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***Abstract—*** In this paper, the path loss for a 1800 GHz cellular network in a Tectona Grandis arboretum is studied using empirical measurement and the Early ITU foliage path loss model. The Tectona Grandis arboretum is located within University of Uyo annex campus. The field measurement was carried out using Netmonitor android app installed on a Samsung Galaxy S9 mobile phone. Among other things, the parameters collected during the field measurement campaign include; the received signal strength, the longitude and the latitude of the measurement point, the time of data capture as well as the cell information for the cellular network that the phone received its signal. In the study, a version of the Early ITU foliage path loss model that provided better path loss prediction performance for the case study site was derived. The improved model was derived by tuning the foliage depth with a factor that defines how the propagation loss in the site varies with the foliage depth. The results showed that the un-tuned Early ITU path loss model had a root mean square error (RMSE) value of 28.758 dB while the foliage depth factor-tuned Early ITU path loss model had a RMSE value of 4.943 dB with a foliage depth factor , $\boldsymbol{\alpha_{fd}}$ value of 37.78348. In all, the results showed that the path loss in the Tectona Grandis arboretum increases faster with respect to depth than what is specified in the Early ITU path loss model. The ideas presented in this paper are useful for network designers wishing to design network with effective coverage in the face of vegetation covered areas.

***Keywords— Path Loss, Propagation Model, Foliage Propagation Loss, Arboretum, Tectona Grandis***

## I. INTRODUCTION

Tectona Grandis arboretum is a garden consisting of Tectona Grandis trees which are grown mainly for educational purposes, scientific research and for conservation [1,2,3,4]. Tectona Grandis, generally known as teak is a tropical hardwood tree from the Lamiaceae family. It is a deciduous tree with large papery leaves. The study was conducted for a Tectona Grandis arboretum located in University of Uyo annex campus and the field measurements were conducted in August 2018 when the Tectona Grandis at the case study site was still full of its large green leaves.

Generally, wireless signal that propagates through the air or crowded paths suffers propagation loss [5,6,7]. Also, studies of propagation loss in vegetation covered areas are essential because trees and their leaves cause obstructions and additional foliage losses when wireless signals propagate through them [8,9,10,11]. The extra foliage loss can be estimated using the Early ITU foliage path loss model [12,13,14]. However, given the path loss models tend to give poor prediction performance when used in sites other than the one where they were derived, it becomes necessary to tune the Early ITU foliage path loss model for more effective path loss prediction performance for the given case study site. Hence, in this paper, the requisite mathematical expressions and field measurement procedure are presented along with the model tuning approach and the proposed tuned Early ITU foliage path loss model for the case stud site.

## II. THE EARLY ITU FOLIAGE PATH LOSS MODEL

Computation of path loss (in dB) according to the Early ITU foliage path loss model (denoted as $\text{PL}_{\textbf{EITU}}\,(dB)$) is given as [15,16]:

$$\text{PL}_{\textbf{EITU}}\,(dB) = \begin{cases} 0.2F^{0.3}\left(d_f\right)^{0.3} & for \quad 0 \le d_f \le 14\text{m} \\ 0.2F^{0.3}\left(d_f\right)^{0.6} & for \quad 14 \le d_f \le 400\text{m} \end{cases} \tag{1}$$

Where $d_f$ is the depth of foliage along the line of sight (LOS) path in meters and f is the frequency in GHz. The Early ITU path loss is an additional loss to the free-space loss. Hence, the total path loss (denoted as $\text{PL}_{\textbf{TTL}}\,(dB)$) is the sum of Early ITU foliage model's predicted path loss (denoted as $\text{PL}_{\textbf{EITU}}\,(dB)$) and the free-space path loss prediction (denoted as $\text{PL}_{\textbf{FSP}}\,(dB)$). Hence;

$$\text{PL}_{\textbf{TTL}}\,(dB) = \text{PL}_{\textbf{FSP}}\,(dB) + \text{PL}_{\textbf{EITU}}\,(dB) \tag{2}$$

The free-space path loss prediction (denoted as $\text{PL}_{\textbf{FSP}}\,(dB)$) is given as ;

$$\text{PL}_{\textbf{FSP}}\,(dB) = 32.5 + 20 * \log(\text{f}) + 20 * \log(\text{d}) \tag{3}$$

Where d is the distance in km between the transmitter and the receiver while f is the signal frequency expressed in MHz.

In order to improve on the prediction performance of the Early ITU path loss model, the foliage depth if tuned using a parameter called foliage depth factor, $\alpha_{fd}$ follows;

$$\text{PL}_{\textbf{EITU}}\,(dB) = \begin{cases} 0.2F^{0.3}\left(\left(d_f\right)\alpha_{fd}\right)^{0.3} & for \quad 0 \le d_f \le 14\text{m} \\ 0.2F^{0.3}\left(\left(d_f\right)\alpha_{fd}\right)^{0.6} & for \quad 14 \le d_f \le 400\text{m} \end{cases} \tag{4}$$

## III. THE FIELD MEASUREMENT CAMPAIGN

The field measurement was carried out in a Tectona Grandis arboretum located inside University of Uyo annex campus. The Tectona Grandis trees (Figure 1) are about 20 meters tall and with a space of 6 meters apart.

The field measurement of the received signal strength and collection of the 3G network cell information within the Tectona Grandis arboretum was carried out using Netmonitor android app installed on a Samsung Galaxy S9 mobile phone.

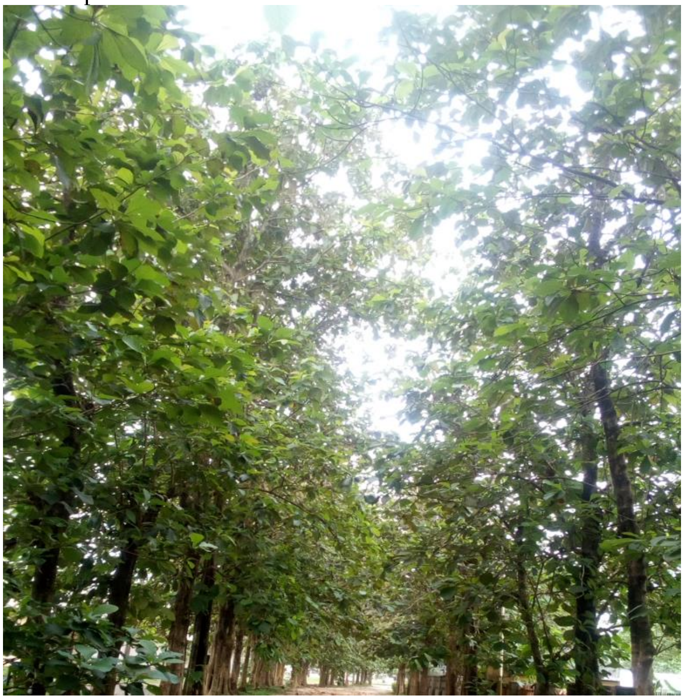

Figure 1 The Tectona Grandis Arboretum

As the Samsung Galaxy S9 mobile phone was carried while walking slowly through the Tectona Grandis arboretum, the Netmonitor android app running in the phone captured and logged the relevant field measurement parameters and store the data in a text file which was loaded into the computer for further processing . Among other things, the parameters collected during the field measurement campaign include; the received signal strength, the longitude and the latitude of the measurement point, the time of data capture as well as the cell information for the cellular network that the phone received its signal. Based on the cell information captured during the field measurement campaign, the base station for the cellular network was identified and its location was collected by physically going to the base station location and using a GPS android app on the Samsung Galaxy S9 mobile phone to read the longitude and the latitude of the base station location.

After the fierld data had been loaded into the computer, then a web-based Haversine distance calculator was used to compute the distance between the base station and each of the data capture point's longitude and latitude. Afterwards, the measured path loss, $Pl(dBm)$ was computed from the filed measured RSSI value in dBm as follows;

$$Pl(dBm) = P_{BT}(dBm) + G_T(dBi) + G_R(dBi) - \text{RSSI(dBm)} \quad (5)$$

Where the transmitter power (dBm) , $P_{BT}(dBm)$ = 22 dBm; the transmitter antenna gain (dBi), $G_T(dBi)$ = 12 dBm and $G_R(dBi)$is the receiver antenna gain (dBi) = 12 dBi.

## IV. Results and Discussion

The field measured RSSI (dB) and the field measured path loss (dBm) for the 1800 GHz cellular network signal within the case study Tectona Grandis arboretum are given in Table 1 and Figure 2. The Tectona Grandis arboretum is about 80 meters long. The results for the path loss prediction by the un-tuned Early ITU path loss model and by the foliage depth factor-tuned Early ITU path loss model are shown in Figure 3. The un-tuned Early ITU path loss model had a root mean square error (RMSE) value of 28.758 dB while the foliage depth factor-tuned Early ITU path loss model had a RMSE value of 4.943 dB with a foliage depth factor , $\alpha_{fd}$value of 37.78348. Essentially, the improved Early ITU path loss model for the given case study Tectona Grandis arboretum is given as;

$$\text{PL}_{\textbf{EITU}}(dB) = \begin{cases} 0.2F^{0.3}\left(37.78348(d_f)\right)^{0.3} & for \quad 0 \leq d_f \leq 14\text{m} \\ 0.2F^{0.3}\left(37.78348(d_f)\right)^{0.6} & for \quad 14 \leq d_f \leq 400\text{m} \end{cases} \quad (6)$$

Furthermore, the results showed that the path loss in the given arboretum increases faster with respect to depth than what is specified in the Early ITU path loss model.

**Table 1 The field measured RSSI (dBm) and the field measured path loss (dBm)**

| d (km) | Field Measured RSSI (dBm) | Field Measured Path Loss (dBm) |
|---|---|---|
| 0.6729 | -73 | 119.0 |
| 0.6775 | -75 | 121.0 |
| 0.6821 | -74 | 120.0 |
| 0.6871 | -75 | 121.0 |
| 0.6884 | -73 | 119.0 |
| 0.6912 | -74 | 120.0 |
| 0.6948 | -76 | 122.0 |
| 0.6976 | -78 | 124.0 |
| 0.7034 | -79 | 125.0 |
| 0.7089 | -77 | 123.0 |
| 0.7135 | -77 | 123.0 |

| | | |
|---|---|---|
| 0.7229 | -75 | 121.0 |
| 0.7317 | -79 | 125.0 |
| 0.7340 | -79 | 125.0 |
| 0.7382 | -80 | 126.0 |
| 0.7412 | -80 | 126.0 |
| 0.7459 | -83 | 129.0 |
| 0.7487 | -84 | 130.0 |
| 0.7477 | -83 | 129.0 |
| 0.7471 | -86 | 132.0 |
| 0.7470 | -88 | 134.0 |
| 0.7481 | -88 | 134.0 |
| 0.7485 | -89 | 135.0 |
| 0.7472 | -88 | 134.0 |
| 0.7462 | -87 | 133.0 |
| 0.7479 | -87 | 133.0 |
| 0.7506 | -91 | 137.0 |

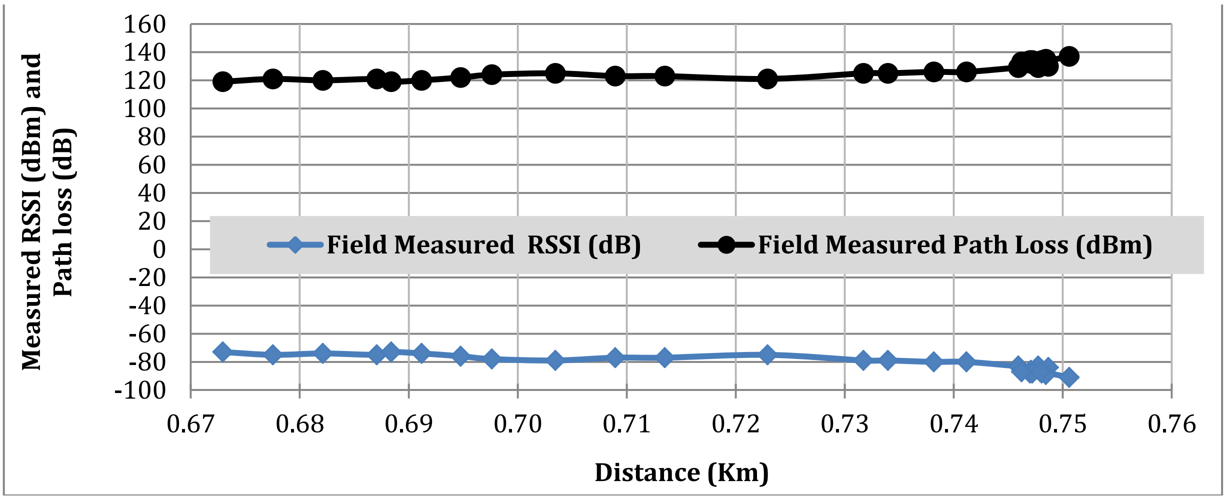


**Figure 2 Graph of the measured field measured RSSI (dB) and the field measured path loss (dBm)**

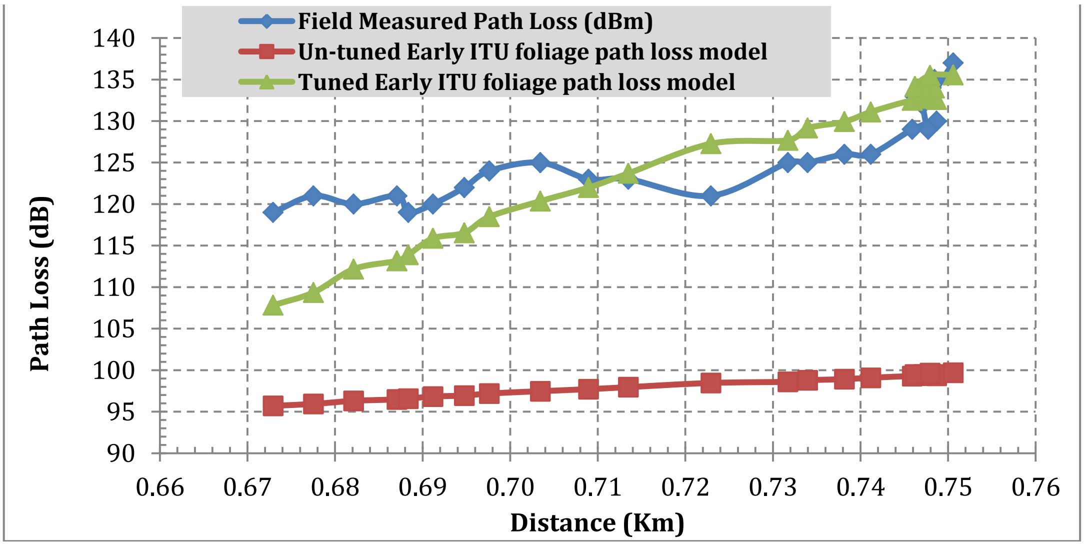


Figure 3 The results for the path loss **prediction** by the un-tuned Early ITU path loss model and by the foliage depth factor-tuned Early ITU path loss model are shown in Figure 3

## V. Conclusion

Early ITU foliage path loss model was presented for a Tectona Grandis arboretum case study site and for a 3G cellular network . The study derived a version of the Early ITU foliage path loss model that provided better path loss prediction performance for the case study site than the original Early ITU foliage path loss model. The improved model was derived by tuning the foliage depth with a factor that defines how the propagation loss in the site varies with the foliage depth. The results showed that the path loss in the Tectona Grandis arboretum increases faster with respect to depth than what is specified in the Early ITU path loss model.

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