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Comparative Analysis Of Stanford University Interim Model And Ccir Model For Characterising The Propagation Loss In A Musa Paradisiaca (Plantain) Plantation

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***Abstract*— In this paper, comparative analysis of Stanford University Interim (SUI) model and CCIR model for characterising the propagation loss in a Musa Paradisiaca (Plantain) plantation is presented. The study was conducted for wireless signal in the 1800 MHz frequency range. The two models are empirical models which in their original forms are not good enough for predicting the propagation loss. As such, model optimization was performed to enhance the propagation loss prediction performance of each of the two models. The results show that while optimized SUI model has Root Mean Square Error (RMSE) of 3.8 dB and prediction accuracy of 97.42 %, the optimized CCIR model has RMSE of 2.42 dB and prediction accuracy of 98.27 %. Finally, the results also show that the the CCIR model achieved 36.32 % reduction in RMSE and 0.87 % improvement in prediction accuracy over the SUI model.Essentially, the results show that the optimized CCIR model gave a better propagation loss prediction for the case study Musa Paradisiaca (Plantain) plantation area. Hence, it is recommended that the CCIR be used for characterising the propagation loss in the case study Musa Paradisiaca (Plantain) plantation area.**

Keywords*— Stanford University Interim Model, Musa Paradisiaca (Plantain) Plantation, Pathloss Loss, CCIR Model, Characterising Propagation Loss

1. Introduction

Over the years, wired and fibre optic networking have been used to provide robust networking infrastructure for various applications [1,2,3, 4,5,6, 7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19,20]. However, wireless communications have found applications in both terrestrial and satellite communication systems and also in the deep space communication [21,22,23,24,25,26,27,28,29,30,31,32,33,34]. In any case, proper design is required to achieve desired quality of service in any wireless communication system [35,36,37, 38,39, 40,41,42, 43,44,45,46, 47,48, 49]. Meanwhile, effective design of wireless communication links require accurate determination of the pathloss in the signal propagation coverage area [50,51,52,53,54,55,56,57]. Apart from the diffraction loss [58,59, 60,61, 62,63, 64,65,66, 67,68, 69,70, 71,72, 73,74, 75,76,77], there are also multipath loss, rain fading and other losses that can be experienced by the wireless signal in it propagation coverage area. Over the years, researchers have developed models and methods for estimating the various losses the wireless signal is subjected to when propagating in a given area [78,79.80]. The focus of this paper is on the pathloss estimation for wireless signal propagating within a Musa Paradisiaca (plantain) plantation [81,82,83].

Specifically, the paper seeks to determine the propagation loss prediction performance of two different models so as to determine which model can be used for characterising the propagation loss that wireless signal can experience within a given case study area. Specifically, the two] models are the The Comit´e International des Radio-Communication (CCIR) model [84,85] and Stanford University Interim (SUI) model [86,87]. The study area is Musa Paradisiaca (Plantain) plantation and the signal frequency is 1800MHz.

Notably, the two models are empirical models which in their original forms are not good enough for predicting the propagation loss. As such, model optimization is required to enhance the propagation loss prediction performance of each of the two models. The details of the models , the optimization approaches and the performance parameters used to compare the two models are presented. Finally, the study is based on the field measurement dataset published in [88]

2. Methodology

2.1 Characterization of Propagation Loss Using The Comit´e International des Radio-Communication (CCIR) Model

The CCIR propagation loss model utilizes a parameter known as degrees of urbanization (E) in characterising the propagation loss ($LP_{CCIR}(dB)$) in a given area and it the given as:

$$LP_{CCIR}(dB) = A + B * \log_{10}(d) - E \quad (1)$$

Where the parameters are defined as follows;

$$A = 69.55 + 26.16 * \log_{10}(f) - 13.82 * \log_{10}(h_b) - a(h_m) \quad (2)$$

$$a(h_m) = [1.1 * \log_{10}(f) - 0.7] * h_m - [1.56 * \log_{10}(f) - 0.8] \quad (3)$$

$$B = 44.9 - 6.55 * \log_{10}(h_b) \quad (4)$$

The CCIR model is defined for frequency (f) in the range of 150 MHz≤ f≤ 1000MHz. Also, the distance, d is in km while 30m $\le h_b \le$ 200m; 1m≤ h_m≤ 10 m and 1 km ≤ d ≤ 20km. The value of E is given with respect to the percentage of the area (PB) that is covered by buildings or other kings of obstruction, hence;

$$E = 30 - 25(\log_{10}(PB)) \quad (5)$$

Typical values of PB for different categories of area are ; for urban area PB ≥ 16%; sub-urban area PB < 16% and typically PB =8%) and for rural area PB < 16% (typically PB =3%).

2.1 Characterization of Propagation Loss Using The Stanford University Interim (SUI) Model

The SUI model characterization of propagation loss ($LP_{SUI(dB)}$ as follows;

$$LP_{SUI(dB)} = A + 10\gamma\left(\log_{10}\left(\frac{d}{d_0}\right)\right) + X_f + X_h + S \; for \; d > d_0 \quad (6)$$

Where,

d is in km, f is in MHz, d_0=100m , X_h denotes the receiving antenna height correction parameter in meters , γ denotes the path loss exponent, where typical values of γ is 2 for free space , 3 < γ < 5 for the urban and , and γ > 5 in indoor environments.

Also, X_f denotes the frequency correction parameter in MHz , S denotes the shadowing correction parameter in dB with value is in the range of 8.2 to 10.6 dB when trees and other clutters are present in the signal propagation path. The value of A is given as:

$$A = 20\left(\log_{10}\left(\frac{4\pi d_0}{\lambda}\right)\right) \quad (7)$$

Also, γ (the pathloss exponent) is defined as;

$$\gamma = a + b(h_b) + \frac{c}{h_b} \quad (8)$$

Where, h_b denotes the antenna height of the base station and 10 m≤ $h_b \le 80$. The parameters a, b and c are used to define different types of terrain, as given in Table 1.

The typical values for the terrain parameter used in SUI propagation loss model

Model Parameter	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b(m^{-1})	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

The values of X_f and X_h are defined as follows **[88];**

$$X_f = 6\left(\log_{10}\left(\frac{f}{2000}\right)\right) \quad (9)$$

$$X_h = \begin{cases} -10.8\left(\log_{10}\left(\frac{h_m}{2000}\right)\right) & \text{for terrain type A and B} \\ -20.8\left(\log_{10}\left(\frac{h_m}{2000}\right)\right) & \text{for terrain type C} \end{cases} \quad (10)$$

2.3 The Optimization Method Used for the SUI Model

The propagation predicted by SUI model was optimized to ($LP_{SUItun(dB)}$) in **[88]** by adjusting the value of the path loss exponent, γ as follows;

$$LP_{SUItun(dB)} = A + 10\left(\beta_\gamma(\gamma)\right)\left(\log_{10}\left(\frac{d}{d_0}\right)\right) + X_f + X_h + S \; for \; d > d_0 \quad (8)$$

The optimal value of β_γ was determined using Solver plugin tool in Microsoft Excel. According to the results presented in **[88]** β_γ was obtained as 1.607375.

2.4 The Optimization Method Used for the CCIR Model

Two parameters K1 and K2 were used to optimize the CCIR model propagation loss prediction as follows;

$$LP_{CCIR}(dB) = K1(A) + K2(B) * \log_{10}(d) - E \quad (12)$$

The optimal values of $K1$ and $K2$ were determined using Solver plugin tool in Microsoft Excel.

2.5 The performance parameters used to compare the SUI and CCIR Propagation Models Propagation Prediction for the Musa Paradisiaca (Plantain) plantation

The propagation prediction performance of the two models are evaluated using Root Mean Square Error (RMSE) and prediction accuracy (PA) defined as follows;

$$\text{RMSE} = \sqrt[2]{\left\{\frac{1}{n}\left[\sum_{i=1}^{i=n}\left|PL_{Meas(i)} - PL_{Pred(i)}\right|^2\right]\right\}} \quad (13)$$

$$\textbf{PA} = \left(1 - \left(\frac{1}{n}\left(\sum_{i=1}^{i=n}\left|\frac{|PL_{m(i)} - PL_{CCIR(i)}|}{PL_{m(i)}}\right|\right)\right)\right) * 100\,\% \quad (14)$$

Where $PL_{Mea(i)}$ denoes the measured propagation loss captured at data point i, while $PL_{Pred(i)}$ denotes the model predicted propagation loss for the data captured at data point i and n denotes the total number of data items considered.

3.0 Results and discussion

The data used for the analysis is the dataset presented in **[88]** which the author obtained for empirical field measurement of received signal strength intensity (RSSI) conducted in a Musa Paradisiaca (Plantain) plantation. From the measured RSSI, the measured propagation loss was computed in **[88]** and represented here in Table 1 and Figure 1.

The results of the optimized model predicted propagation loss using both the SUI and the CCIR models are shown in

Table 2 and Figure 2, as well as in Table 3, Figure 3, and Figure 4. Specifically, Table 3 shows the performance parameters used to compare the SUI and CCIR Propagation Models Propagation Prediction for the Musa Paradisiaca (Plantain) plantation. The results show that while optimized SUI model has RMSE of 3.8 dB and prediction accuracy of 97.42 %, the optimized CCIR model has RMSE of 2.42 dB and prediction accuracy of 98.27 %, as shown in Figure 3 and Figure 4. Finally, Table 3 and Figure 5 show that the the CCIR model achieved 36.32 % reduction in RMSE and 0.87 % improvement in prediction accuracy over the SUI model.

Table 1 The Field Measured Path Loss (dBm) in the case study Musa Paradisiaca (Plantain) plantation

S/N	d (km)	Field Measured Path Loss (dBm) in a Musa Paradisiaca (Plantain) plantation	S/N	d (km)	Field Measured Path Loss (dBm) in a Musa Paradisiaca (Plantain) plantation	S/N	d (km)	Field Measured Path Loss (dBm) in a Musa Paradisiaca (Plantain) plantation
1	0.453	114	10	0.459	114	19	0.488	120
2	0.453	117	11	0.462	116	20	0.492	120
3	0.454	119	12	0.463	116	21	0.503	119
4	0.454	114	13	0.465	117	22	0.525	125
5	0.454	111	14	0.468	116	23	0.536	127
6	0.455	116	15	0.474	117	24	0.56	128
7	0.456	111	16	0.477	115	25	0.568	130
8	0.456	112	17	0.481	118	26	0.577	131
9	0.457	114	18	0.485	119	27	0.602	133

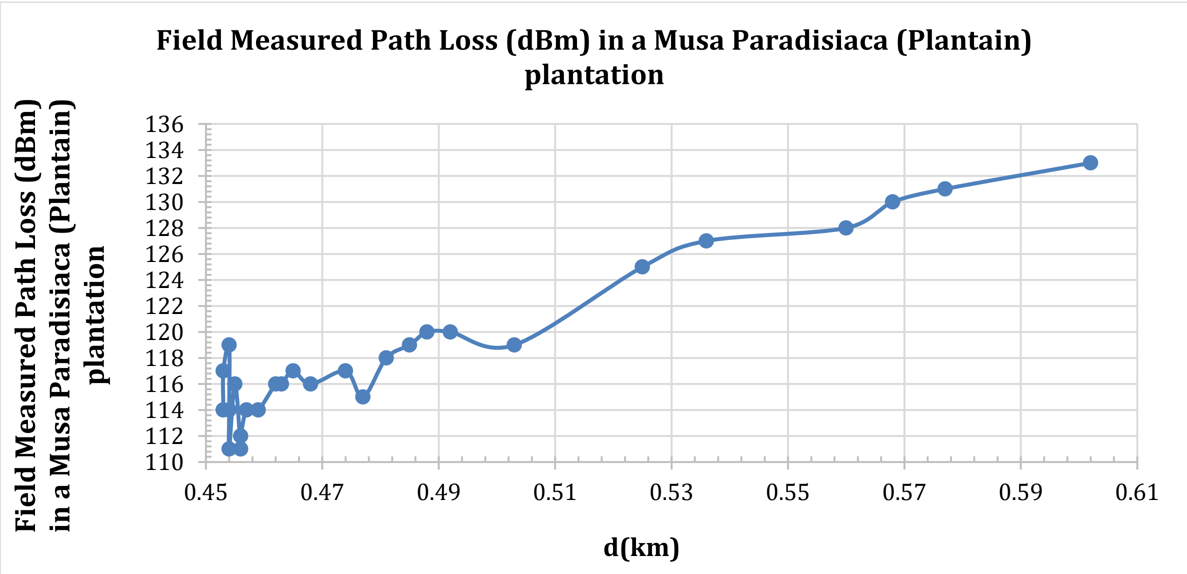

Figure 1 The Field Measured Path Loss (dBm) in the case study Musa Paradisiaca (Plantain) plantation

Table 2 The results of the optimized model predicted propagation loss using both the SUI and the CCIR models compared with the measured propagation loss.

S/N	d (km)	Field Measured Path Loss (dBm)	Path-Loss Exponent Tuned SUI Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation	Tuned CCIR Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation	S/N	d (km)	Field Measured Path Loss (dBm)	Path-Loss Exponent Tuned SUI Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation	Tuned CCIR Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation
1	0.453	114	115.5	111.2	14	0.473	114	116.4	113.9
2	0.454	108	115.6	111.3	15	0.476	112	116.5	114.4
3	0.454	113	115.6	111.3	16	0.479	112	116.6	114.7
4	0.454	115	115.6	111.3	17	0.485	117	116.9	115.5
5	0.455	116	115.6	111.4	18	0.486	114	116.9	115.6
6	0.455	109	115.6	111.5	19	0.491	119	117.1	116.3
7	0.456	109	115.7	111.7	20	0.492	114	117.2	116.5
8	0.457	106	115.7	111.7	21	0.524	118	118.4	120.5
9	0.458	116	115.7	111.9	22	0.526	125	118.5	120.6
10	0.462	110	115.9	112.5	23	0.558	123	119.7	124.4
11	0.462	112	115.9	112.5	24	0.565	127	119.9	125.2
12	0.464	114	116.0	112.7	25	0.573	126	120.3	126.2
13	0.466	113	116.1	113.0	26	0.585	129	120.6	127.4
14	0.473	114	116.4	113.9	27	0.636	130	122.3	132.7

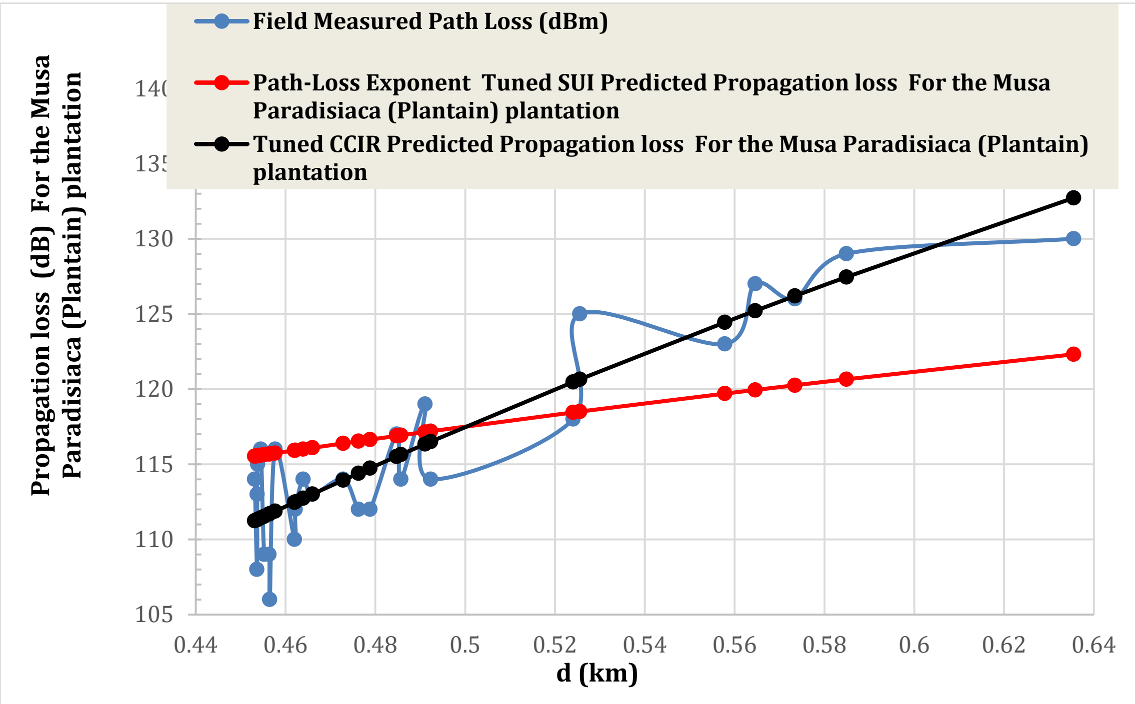

Figure 2 The scatter plot of the optimized model predicted propagation loss using both the SUI and the CCIR models compared with the measured propagation loss.

Table 3 The performance parameters used to compare the SUI and CCIR Propagation Models Propagation Prediction for the Musa Paradisiaca (Plantain) plantation

	Root Mean Square Error (RMSE) in dB	Prediction Accuracy (%)
Path-Loss Exponent Tuned SUI Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation	3.8	97.42
Tuned CCIR Predicted Propagation loss For the Musa Paradisiaca (Plantain) plantation	2.42	98.27
Difference between the performance of CCIR and SIU model	-1.38	0.85
Percentage improvement (%) achieved	-36.32	0.87

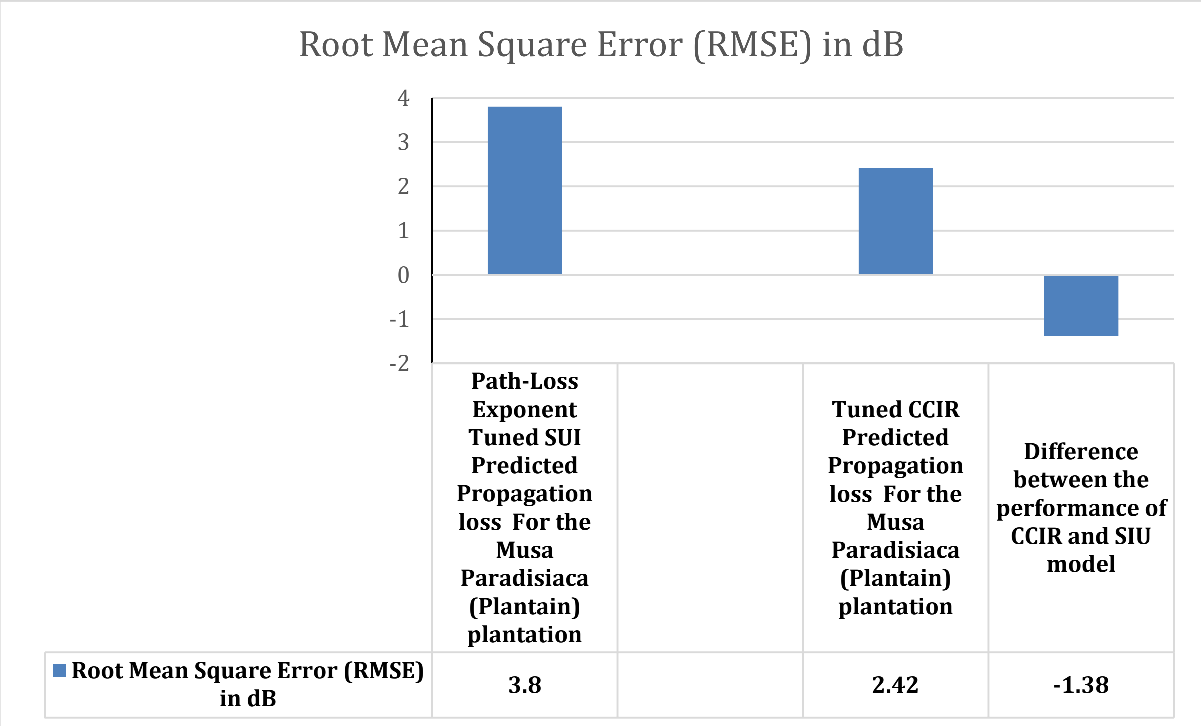

Figure 3 The results of the comparison of the Root Mean Square Error (RMSE) of optimized CCIR and SUI models

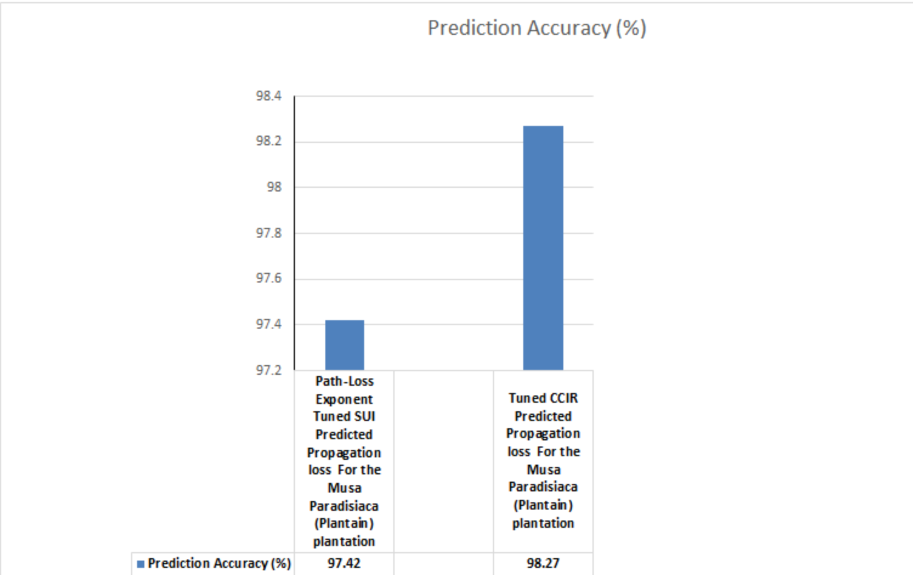

Figure 4 The results of the comparison of the propagation loss prediction accuracy (%) of CCIR and SUI models

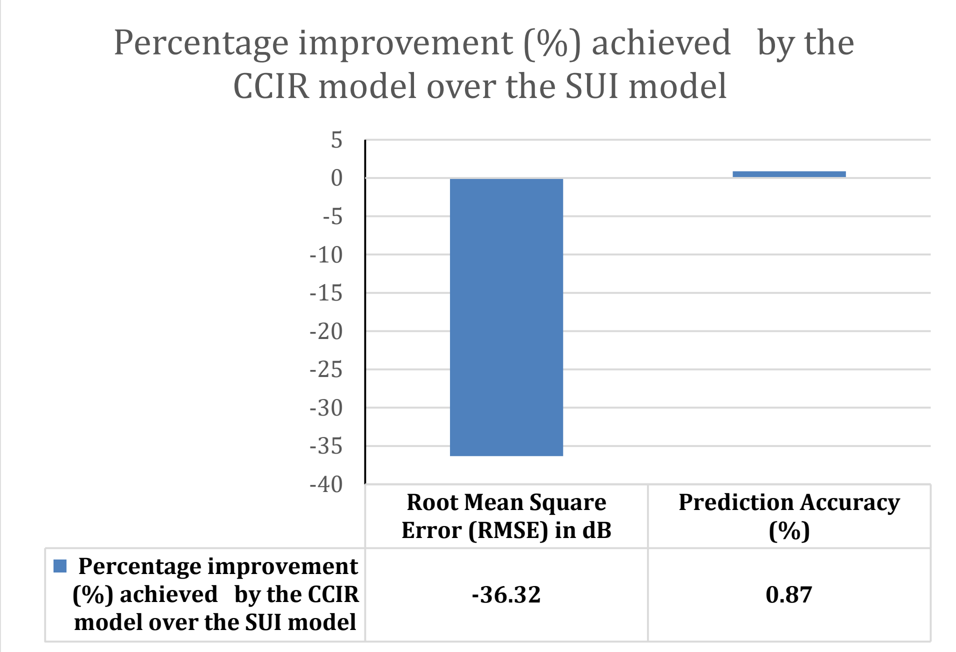

Figure 5 Percentage improvement (%) achieved by the CCIR model over the SUI model

4. Conclusion

Two different models, namely CCIR and SUI models are used to characterise the propagation loss that can be experienced by 1800 MHz wireless signal in propagating in a Musa Paradisiaca (Plantain) plantation area. The two models were optimized, the SUI was optimised by adjusting the pathloss exponent parameter whereas the CCIR model was optimized by adjusting the constants that are associated with the path length. The study was based on the field measurement dataset published in **[88].** The results show that the optimized CCIR model gave a better propagation loss prediction for the case study Musa Paradisiaca (Plantain) plantation area. Hence, it is recommended that the CCIR be used for characterising the propagation loss in the case study Musa Paradisiaca (Plantain) plantation area.

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