SUI Propagation Model Tuning from Collected Data in Fixed Wireless Systems at Arboreous Environments on 5.8 GHz Band

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Abstract — **This paper presents an tuning in SUI Propagation Model through the least squares algorithm. Data measurements were carried out in arboreous environments, in 12 amazon region cities containing broadband wireless networks on 5.8 GHz. The RMS error and standard deviation have been used as evaluation metrics. The results have shown a good agreement of the tuned SUI model to the measured data.**

Keywords – SUI Model; least squares tuning algorithm; 5.8 GHz; arboreous environments;

I. INTRODUCTION

Propagation models are very important tools for wireless networks planning. One can say that studies of propagation losses are needed to ensure an efficient pre-project stage in coverage and quality of services on wireless systems. This paper presents a least squares method, applied in the Stanford University Interim (SUI) model tuning, for the 5.8 GHz band in arboreous environments.

In this work, is also made a comparison between SUI model, adjusted SUI model and COST 231-Hata model. Due to the characteristics found in the amazon region environment, which are not present in the places where these models were obtained, high RMS error and standard deviation values are expected in the non-adjusted models.

The least squares algorithm has been used to get SUI model close to the measured path loss. The improvement viewed in SUI model after tuning shows an improvement in calculated propagation loss when compared with the original propagation models prediction.

This paper is organized as follows. In section II is presented explanations about the environment and the data acquisition. In section III a description of the propagation models is made. In section IV the least squares tuning algorithm is presented. In section V simulations and results are shown and finally, section VI shows the conclusions.

II. ENVIRONMENT AND DATA ACQUISITION

The path loss measurements have been carried out in 12 cities on Pará State at Amazon Region, Brazil. These cities are known by their woodland environments. The vegetation normally appears mixed with the residential and commercial constructions resulting in a single medium. An example of Amazon region city is shown in the Figure 1.

Fig. 1 Aerial view of part of Itaituba city in Pará State, Brazil

Different of the traditional measuring campaigns [1]-[2] that are made with continuous data collection in a mobile unit, this data acquisition has been carried out by taking the punctual RSSI (Received Signal Strength Indicator) in 335 fixed clients. They are located in 12 cities that have been contemplated with the Digital Inclusion Pará State Government Project named NavegaPará [3]. The project consists of WLL (Wireless Local Loop) networks installed in these cities, bringing broadband access and multimedia services. All collected data have been obtained by using a NMS (network management system) located at the PRODEPA (Pará State Data Processing Company). From the collected RSSI it can be found the path loss for each client by using values of transmission power, transmission gain and reception gain. The distances between clients and base stations were found through their coordinates, collected during the implantation stage of these networks.

III. PROPAGATION MODELS

The propagation models used in this paper are SUI Model and COST-231 Hata model whose have reference in some performance comparison works [4]-[5]-[6]-[7].

A. *Stanford University Interim (SUI) Model*

IEEE 802.16 Model, known as SUI Model, had in your development the Stanford University participation. Variables involved in model prediction process are valid for frequencies below 11 GHz.

The base of the propagation model and the environment characterization are viewed in the following equations [8]:

$$L = A + 10\gamma \log\left(\frac{d}{d0}\right) + X_f + X_h \quad \text{For } d > d0 \qquad (1)$$

$$A = 20 \log\left(\frac{4\pi d0}{\lambda}\right) \qquad (2)$$

$$\gamma = a - bh_t + \frac{c}{h_t} \qquad (3)$$

$$X_f = 6 \log\left(\frac{f}{2000}\right) \qquad (4)$$

$$X_h = -10.8 \log\left(\frac{h_r}{2}\right) \text{, terrains type A and B} \qquad (5)$$

$$X_h = -20 \log\left(\frac{h_r}{2}\right) \text{, terrain type C} \qquad (6)$$

Where:
d - Link distance, meters
$d0$ - Initial distance, 100 meters
λ - Wavelength, meters
f - Frequency, MHz
h_t - Transmitter height, meters
h_r - Receiver height, meters

Parameters a, b e c chosen according to Table I:

TABLE I
TERRAIN TYPE PARAMETERS

Model Parameter	Type A	Type B	Type C
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

Table I is based on terrain types defined in [8].

B. *COST-231 Hata Model*

This one is an extension of Okumura-Hata Model. It was made to embrace a frequency range from 1500 MHz to 2000 MHz. The propagation loss obtained can be calculated through the following equation:

$$L = 46.3 + 39.9\, log(f) - 13.82\, log(h_{te}) - a(h_{re}) + (44.9 - 6.55\, log(h_{te}))\, log(d) + C_m \qquad (7)$$

Where:
f - Frequency, MHz
d - Link distance, meters
h_{te} - Transmitter height, meters
h_{re} - Receiver height, meters
C_m - $\begin{cases} 0 \text{ dB for soft and suburban areas} \\ 3 \text{ dB for dense urban areas} \end{cases}$

IV. LEAST SQUARES ALGORITHM

Due to the different characteristics of the environment where the models have been made, a tuning proceeding is needed to adjust model parameters to the measured data.

Least Squares criterion is useful for linear adjustment cases. In this situation, the algorithm is represented by the idea of minimizing the sum of the squares of the differences between measured data and predicted data. These differences become an error function expressed as follows:

$$E = \sum_{i=1}^{n} (Y_i - L_i)^2 \qquad (8)$$

Where:
E - Error function
n - Number of total used data
Y_i - Measured data
L_i - Predicted data

The terms of SUI model main equation, used in tuning process, are $10\gamma \log\left(\frac{d}{d0}\right)$, from equation (1), and X_f, from equation (4). In the algorithm these terms were expressed in a general form, as follows:

$$K_1 \gamma \log\left(\frac{d}{d0}\right) \qquad (9)$$

$$X_f = K_2 \log\left(\frac{f}{2000}\right) \qquad (10)$$

More details about least squares algorithm applied in tuning process are described in [1]-[2]-[9]. For avoiding problems in least squares convergence, data outliers were removed according to the method presented in [9]. After outliers filtering, the maintained data were around 90 percent.

V. SIMULATIONS AND RESULTS

Simulations have been done considering the mean installation heights of the clients located at the 12 cities in study. After least squares tuning algorithm the obtained values for K_1 and K_2 are showing in the Table II.

TABLE II
SUI MODEL PARAMETERS

Model Parameters	Before Least Squares Tuning	After Least Squares Tuning
K_1	10	4.74
K_2	6	20.35

Results of models performance obtained in the simulations are shown in Figures 2-3.

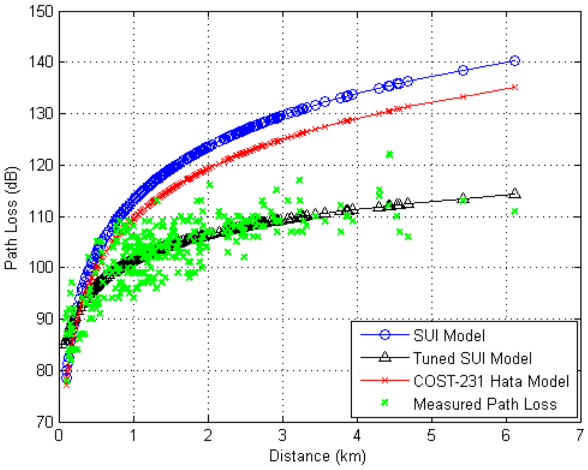

Fig. 2 Propagation models behavior in linear scale

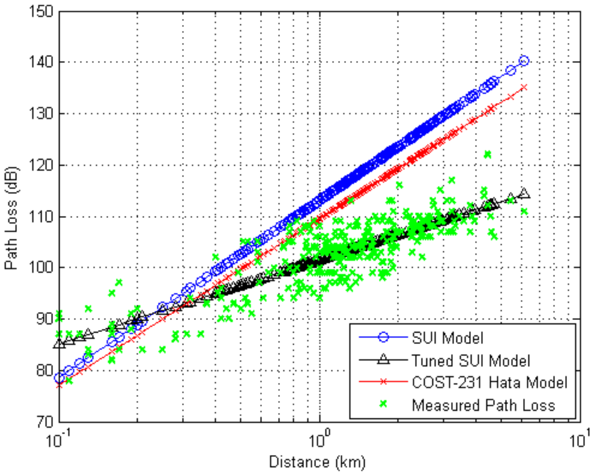

Fig. 3 Tuned propagation models behavior in logarithmic scale

After simulations, the obtained values of RMS error and standard deviation for all three models are shown in the Table III.

TABLE III
RESULTS FOR ALL THREE MODELS

Model	RMS Error (dB)	Standard Deviation (dB)
SUI	14.9	6.2
Tuned SUI	3.8	2.3
COST231-Hata	11.4	5.2

From the results in Table III, it is seen that SUI and COST231-Hata have a high RMS error of 14.9 dB and 11.4 dB and a standard deviation of 6.2 dB and 5.2 dB respectively. The tuned SUI model has obtained a RMS error of 3.8 dB and standard deviation of 2.3 dB. The least squares tuning process has reached an improvement around 11 dB when compared to non-tuned SUI model.

VI. CONCLUSION

In this paper, an improvement in SUI model prediction for an Amazon Region environment is made. The adjustment has used as reference measurements carried out in 5.8 GHz band. The tuning process is performed through least squares algorithm, then, performance comparison between COST231-Hata, Stanford University Interim (SUI) and Tuned SUI models are made. At the final performance evaluation, Tuned SUI Model has shown a good improvement by using least squares tuning algorithm. A proposal for future works can consider an adjustment of SUI Model by changing some parameters or adding a term which is related to some new environment feature. It is also foreseen an adjustment in SUI model for path loss prediction in mobility conditions. For such a purpose, extensive measurement campaigns will be carried out.

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REFERENCES

[1] M. Yang, W. Shi, *"Linear Least Square Method of Propagation Model Tuning for 3G Radio Network Planning"*, Fourth International Conference on Natural Computation *ICNC*, Jinan, 18-20 October 2008, pp. 150-154.

[2] G. R. Pallardó, *"On DVB-H Radio Frequency Planning: Adjustment of a Propagation Model Through Measurement Campaign Results"*, Master's Thesis, Department of technology and Built Enviroment, University of Gävle, Sweden, 2008.

[3] NavegaPará Project. Available in: http://www.navegapara.pa.gov.br/

[4] V. S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars and M.G. Brown, *"Comparison of Empirical Propagation Path Loss Models for Fixed Wireless Access Systems"*, *IEEE* 61st Vehicular Technology Conference VTC, Stockholm, 30 May-1 June 2005, pp. 73-77.

[5] J. Milanovic, S. Rimac-Drje, K. Bejuk, *"Comparison of Propagation Models Accuracy for Wimax on 3.5 GHz"*, 14th IEEE International Conference on Circuits and Systems *ICECS*, Marrakech, 11-14 December 2007, pp. 111-114.

[6] T. Schwengler, M. Gilbert, *"Propagation Models at 5.8 GHz - Path Loss & Building Penetration"*, IEEE Radio and Wireless Conference *RAWCON*, Denver, 10-13 December 2000, pp. 119-124.

[7] B.S.L. Castro, I.R. Gomes, F.C.J. Ribeiro, G.P.S. Cavalcante, *"COST231-Hata and SUI Models Performance Using a LMS Tuning Algorithm on 5.8 GHz in Amazon Region Cities"*, European Conference on Antennas and Propagation EUCAP, Barcelona, 12-16 April 2010.

[8] V. Erceg, *"Channel Models for Broadband Fixed Wireless Systems"*, *IEEE* 802.16 Broadband Wireless Access Working Group, California, 2000.

[9] B.S.L. Castro, *"Propagation Model for Fixed Wireless Networks in the 5.8 GHz Band in Typical Amazon Region Cities"*, Master's Thesis, Technology Institute – Federal University of Pará, Brazil, May 2010, pp. 18.