Comparison Between Known Propagation Models Using Least Squares Tuning Algorithm on 5.8 GHz in Amazon Region Cities

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***Abstract*— This paper presents a performance comparison between known propagation Models through least squares tuning algorithm for 5.8 GHz frequency band. The studied environment is based on the 12 cities located in Amazon Region. After adjustments and simulations, SUI Model showed the smaller RMS error and standard deviation when compared with COST231-Hata and ECC-33 models.**

***Index Terms*—** 5.8 GHz band, Amazon Region, Linear Least Squares, Propagation models.

I. INTRODUCTION

Since the constant increase of the wireless networks, studies of signal propagation are needed to ensure an efficient Pre-Project Stage in coverage and quality of services. This paper presents a study of the signal propagation in 5.8 GHz on Amazon region cities.

A performance comparison between known propagation models is made for an Amazon Region environment. The least squares tuning algorithm has been used to adjust the models to the measurements. It is important to remember that the terms related to reception and transmission heights in the models equations have been left unchanged. Although the models adjustments, differences in how the models work with reception and transmission height have influence in RMS error and standard deviation which are the metrics adopted in this work.

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 collected data 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

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city is shown in *Fig.1*.

Fig. 1. Aerial view of Santarém 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 installed 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 the cities, bringing broadband access and multimedia services. It is interesting to analyze this collected data because fixed clients have different distances with respect to their Base Stations and different installation heights. 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 process for obtaining the distances between the clients and base stations is based on the coordinates that was collected during the implantation stage of these networks.

III. PROPAGATION MODELS

The propagation models used in this paper are COST231-Hata, SUI Model and ECC-33 model whose have reference in some performance comparison works [4]-[5]-[6].

A. Stanford University Interim (SUI) Model

SUI Model has had in your development the Stanford University participation. Variables involved in model prediction process are adopted for frequencies below 11 GHz. It is interesting to evaluate model performance for this case because SUI Model employs terrain properties on its equations so the base for calculating the propagation loss can be accomplished in an non-ideal way different of the free space equation method.

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The base of the propagation model and the environment characterization are represented by the following equations [7]:

$$L = A + 10\gamma \log\left(\frac{d}{d_0}\right) + X_f + X_h \quad \text{For } d > d_0 \tag{1}$$

$$A = 20\log\left(\frac{4\pi d_0}{\lambda}\right) \tag{2}$$

$$\gamma = a - bh_t + \frac{c}{h_t} \tag{3}$$

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

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

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

Where:
d - Link distance, m
d_0 - Initial distance, 100 m
λ - Wavelength, m
f - Frequency, MHz
h_t - Transmitter height, m
h_r - Receiver height, m

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 [7].

B. COST 231 - Hata

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:

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

$$a(h_{re}) = (1.1\log(f) - 0.7)h_{re} - (1.56f - 0.8) \quad \text{for small and medium cities} \tag{8}$$

$$a(h_{re}) = 3.2(\log(11.75h_{re}))^2 - 4.97 \quad \text{for large cities} \tag{9}$$

Where:
f - Frequency, MHz
d - Link distance, m
h_{te} - Transmitter height, m
h_{re} - Receiver height, m
c_m - 0 dB for soft and suburban areas and 3 dB for dense urban areas

C. ECC-33Model

ECC-33 is a model from Electronic Communication Committee based on analysis in 3.4 and 3.8 GHz band. The path loss is obtained from de following equations [4]:

$$L = A_{fs} + A_{bm} - G_b - G_r \quad (10)$$

$$A_{fs} = 92.4 + 20\log(d) + 20\log(f) \quad (11)$$

$$A_{bm} = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56(\log(f))^2 \quad (12)$$

$$G_b = \log\left(\frac{h_b}{200}\right)(13.958 + 5.8\log(d))^2 \quad (13)$$

And for medium city environments,

$$G_r = (42.57 + 13.7\log(f))(\log(h_r) - 0.585) \quad (14)$$

Where:
d - Link distance, m
f - Frequency, GHz
h_b - Transmitter height, m
h_r - Receiver height, m

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 (LS) 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:

$$E = \sum_{i=1}^{n} (Y_i - L_i)^2 \quad (15)$$

Where:

E - Error function

n - Number of total used data

$\mathbf{Y_i}$ - Measured data

$\mathbf{L_i}$ - Predicted data

The distance and frequency terms in the models equations were adjusted by the algorithm, however, the transmission and reception heights terms were not included in least squares tuning.

More details about LS algorithm applied in tuning method are described in [1]-[2].

V. Simulations and Results

Simulations have been done considering the mean and specific installation heights of the clients located at the 12 cities in study. The data obtained in the simulations are shown in Fig. 2-5.

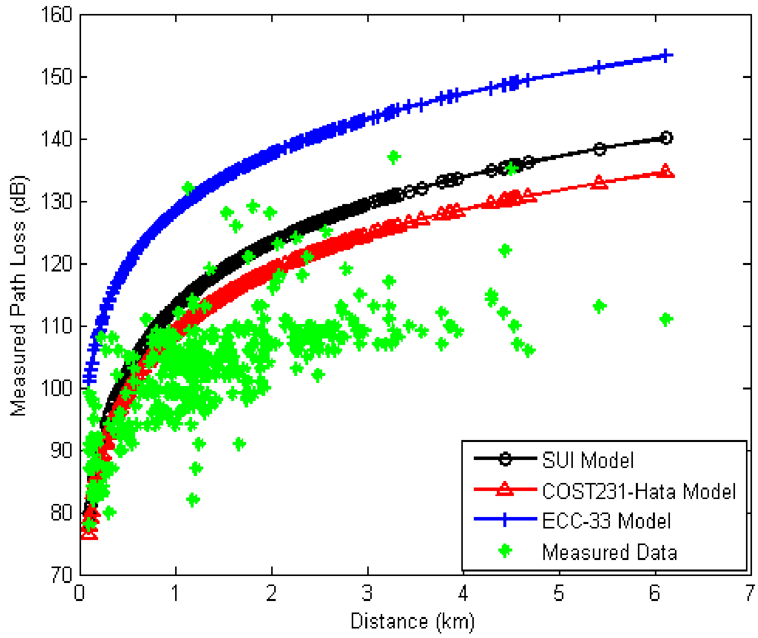

Fig. 2. Propagation models performance using mean reception heights of the clients

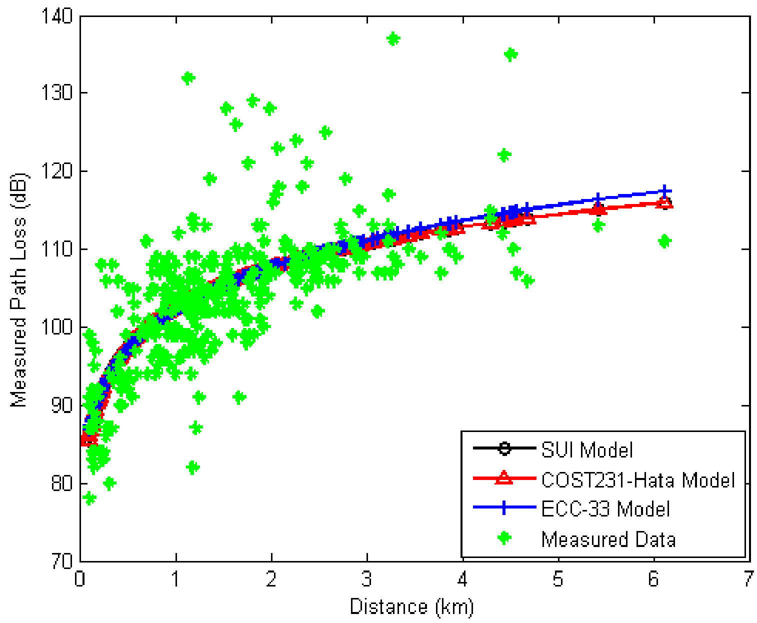

Fig. 3. Tuned propagation models performance using mean reception heights of the clients

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After simulations, the obtained values of RMS error (dB) and standard deviation (dB) for all three models are shown in the Table II, before and after tuning.

TABLE II. RESULTS FOR MEAN INSTALLATION HEIGHT

Models	**RMS Error Before**	**Standard Deviation Before**	**RMS Error After**	**Standard Deviation After**
SUI	14.66	6.60	6.25	4.47
COST231-Hata	11.29	5.54	6.25	4.47
ECC-33	28.03	7.64	6.24	4.43

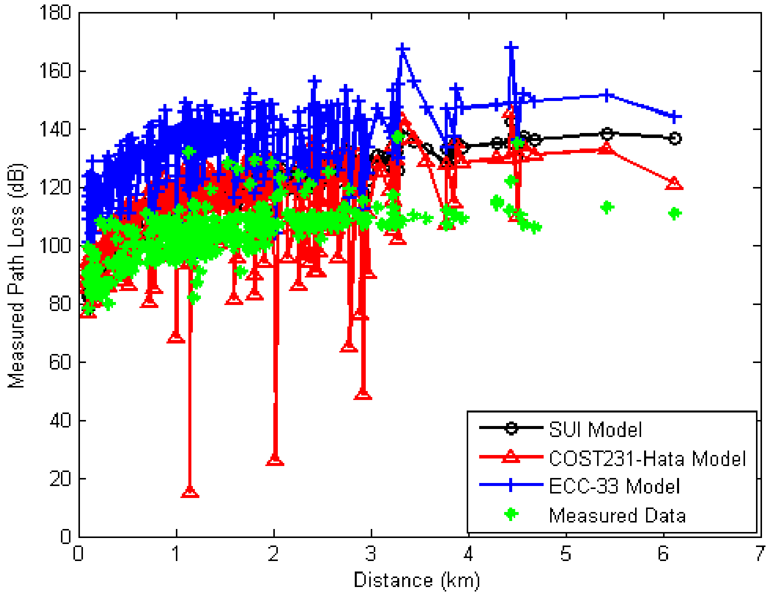

Fig. 4. Propagation models performance using specific reception heights of the clients

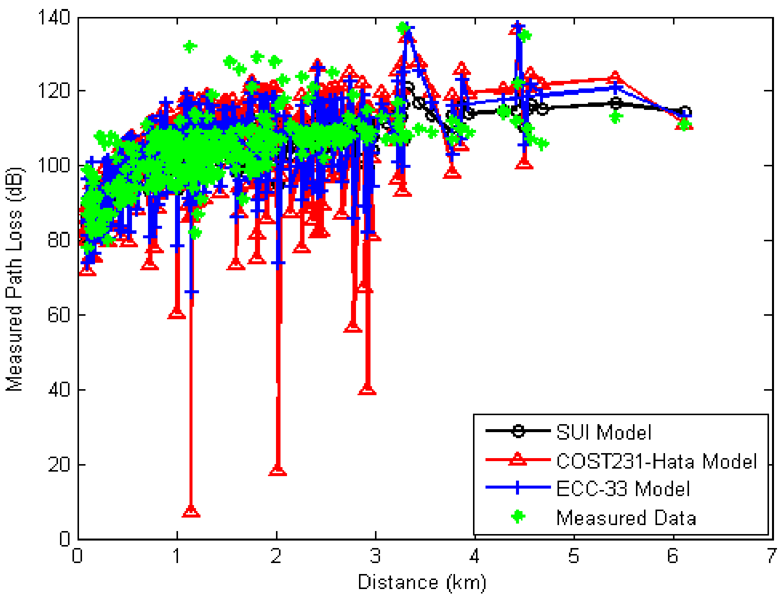

Fig. 5. Tuned Propagation models performance using specific reception heights of the clients

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For the specific client heights, the obtained results are shown in the Table III, for the RMS error and standard deviation as well.

TABLE III. RESULTS FOR SPECIFIC INSTALLATION HEIGHT

Models	RMS Error (Before)	Standard Deviation (Before)	RMS Error After	Standard Deviation After
SUI	15.26	6.88	7.22	4.84
COST231-Hata	17.27	9.88	15.51	10.97
ECC-33	31.32	10.67	11.12	6.99

From the results in Table II, it is seem that SUI, COST231-Hata and ECC-33 models, reach the same RMS error (6.2 dB) when mean reception height is used in least squares tuning.

In the other hand, when specific client installation height was used for tuning process, SUI Model obtained the best improvement with a RMS error of 7.22 dB and COST 231-Hata had the worst one equal to 15.51 dB. RMS errors have obtained a maximum improvement about 20 dB (ECC-33 Model) and a minimum improvement around 2 dB (COST231-Hata Model). The minor standard deviation value belongs to SUI Model.

Results are relevant because RSSI collecting process has been performed in peculiar site-specific clients. Variations in models predictions, from Fig. 4 and Fig. 5, are justified because each client has a specific CPE (customer premises equipment) installation height.

RMS error (RE) and standard deviation (SD) values for all 12 cities in study are shown in Table IV.

TABLE IV. RESULTS FOR SPECIFIC INSTALLATION HEIGHT

Cities	SUI Model		COST231-Hata Model		ECC-33 Model	
	RE	SD	RE	SD	RE	SD
Abaetetuba	7.05	4.24	27.14	10.31	10.95	6.45
Altamira	5.81	3.93	20.26	9.64	10.61	7.61
Barcarena	10.64	6.71	33.48	14.63	11.91	6.86
Itaituba	7.34	4.89	30.26	10.14	10.24	6.42
Jacundá	5.21	3.04	35.27	10.30	7.11	4.02
Marabá	7.14	4.80	26.25	17.77	14.67	9.04
Pacajá	5.25	2.69	33.95	7.62	9.11	5.02
Rurópolis	4.50	2.78	30.45	8.59	7.44	4.70
Santarém	8.86	6.21	22.88	13.18	13.37	7.80
Tailândia	8.08	4.96	37.05	11.22	10.36	6.51
Tucurí	7.87	6.33	24.65	10.70	11.42	7.62
Uruará	4.46	2.43	31.75	5.34	6.77	3.78

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VI. CONCLUSION

In this paper, a performance comparison between COST231-Hata, Stanford University Interim (SUI) and ECC-33 models is made for an Amazon Region environment. At the final performance evaluation, SUI Model has shown a better behavior than COST231-Hata and ECC-33 Models. Based on the obtained results, 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, measurement campaigns will be carried out.

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