Parameters Fitting to Standard Propagation Model (SPM) for Long Term Evolution (LTE) using Nonlinear Regression Method

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***Abstract*— This paper intends to propose a model of adjustment to the Standard Propagation Model (SPM) for personal mobile communication to fourth generation networks, known as Long Term Evolution (LTE), being implemented in Brazil, whose complexity of urban and suburban environments determine a particular parameterization, in order to plan and design more efficiently and optimally these networks, as well the rational use of available resources. According to a campaign of measures carried out by a local operator, the SPM model was adjusted using a method of nonlinear exponential regression, which showed satisfactory results to evaluate the coverage area and can identify shadow areas not covered in conventional models. The results were evaluated using tools error analysis of statistics, demonstrating that the deviations of the simulations show a significant improvement in performance.**

***Keywords*— Error Analysis, LTE, Nonlinear Regression, Parameterization, SPM.**

I. INTRODUCTION

The number of mobile users in wireless communications has grown dramatically in the past two decades [1]. This growth of users will be further enhanced by the ongoing adoption of mobile broadband access technologies, mainly in developing countries like Brazil.

Following this trend, the international standardization organizations have developed their recommendations and specifications from the late 90s and beginning of the next decade, aiming to keep up with the rapid growth of data applications, especially by the appearance of current Over the Top content (OTT).

Thus the 3rd Generation Partnership Project (3GPP) Group, which unites some standards organizations in telecommunications, has been providing their members with a stable environment to define reports and specifications for LTE and LTE-Advanced technology. The project includes mobile communication network technology, which include radio access, core network transport and service capabilities such as security and quality. The group of technical specifications of 3GPP, Radio Access Network (RAN) defines, among other things, the development and deployment of global interoperability through Releases as shown in Figure 1. Since the 3GPP Release 10, LTE and LTE-Advanced has been approved jointly by the International Union of Telecommunications (ITU) [2].

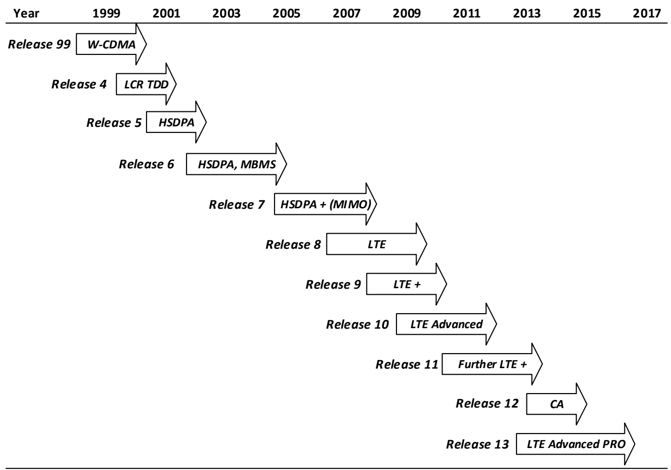

Fig. 1. 3GPP Releases evolution of radio technologies and systems.
Source: Adapted from 3GPP webpage.

According to this above scenario, the computational simulation tools of coverage and traffic are powerful coupled to evaluate the performance of mobile communication networks, especially those relying on the use of an existing infrastructure, although field measurements must be conducted to represent specific topologies. There are many advantages in computational simulations since it can evaluate the systems implementation or systems in development, including the full environmental control, such as propagation parameters, and traffic concepts repeatability [3].

This paper then presents an adjustment for the SPM model, used in radio network planning softwares, from companies like FORSK (Atoll®) and TEOCO (Asset®). To adapt the model, was used nonlinear regression method, adjusting the relevant parameters, demonstrating through error analysis, the lowering gap between measures and deviations in the simulations for urban and suburban areas, conducted in the

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metropolitan area of Curitiba, a Brazilian city located in the south region of the country.

II. Related Work

Some work has been developed applying similar adjustment methods for the empirical propagation models used in LTE networks, as can be seen in [4], [5], [6], [7], [8], [9], [10], however in this paper, it can be observed that the parameterization involves a new technique derived from a nonlinear exponential regression, provided by the methodology satisfactorily employed and the analysis of results conducted.

In this way, in the first part of this work, the SPM model will be detailed, followed by details of the data collection environment, the analysis of the regression method used, the adjustment of the model itself, the final validation and the respective conclusions.

III. Methodology Explanation

A. Standard Description of K Parameters

The SPM is a propagation model based on formulas of Hata [11] and adapted to perform signal coverage predictions in the frequencies range of 150-3500 MHz, for distances between 1-20 km. The model is best applied on mobile technologies such as LTE and LTE-Advanced, among other analogous or equivalents [12]. Equation (1) shows the complete formula with K parameters that can be changed depending on propagation conditions related to the terrain profile, the diffraction mechanisms, the morphology of clutter classes and the effective height of the transmitting and receiving antennas.

$$P_R = P_{Tx} - [K_1 + K_2 * \log(d) + K_3 * \log(H_{Tx_{eff}}) + K_4 * (DiffractionLoss) + K_5 * \log(d) * \log(H_{Tx_{eff}}) + K_6 * H_{Rx_{eff}} + K_7 * \log(H_{Rx_{eff}}) + K_{clutter} * f(clutter) + K_{hill,LOS}] \tag{1}$$

where:

P_R	received power (dBm)
P_{Tx}	transmitted power (EIRP) (dBm)
K_1	constant offset (dB)
K_2	multiplying factor for $\log(d)$
d	distance between the receiver and the transmitter (m)
K_3	multiplying factor for $\log(H_{Tx_{eff}})$
$H_{Tx_{eff}}$	effective height of the transmitter antenna (m)
K_4	multiplying factor for diffraction calculation
$DiffractionLoss$	losses due to diffraction over an obstructed path (dB)
K_5	multiplying factor for $\log(d) * \log(H_{Tx_{eff}})$
K_6	multiplying factor for $H_{Rx_{eff}}$
K_7	multiplying factor for $\log(H_{Rx_{eff}})$
$H_{Rx_{eff}}$	effective height of the receiver mobile antenna (m)
$K_{clutter}$	multiplying factor for $f(clutter)$
$f(clutter)$	average of weighted losses due to clutter
$K_{hill,LOS}$	corrective factor for hilly regions

B. Simulation Environment

The simulation was developed based on a measurement campaign, called drive test, conducted by a local operator of cellular technology, whose database has been made available for this work. It has been evaluated hundreds of the RF signal level measurements georeferenced, sampled at a rate necessary to estimate deviations, held in a large city in southern Brazil, considering the dense urban and suburban environments.

Detailed information of the sites involved, such as geographic location, types and heights of the antennas, the transmitter power and other technical data are presented in Table I. The characteristics and placement of receivers include the antenna effective height of the mobile equipment and the typical sensitivity considered in the simulation.

TABLE I
FEATURES OF INVOLVED SITES

	LTE Cell Name		
	Cell-1 Dense Urban	Cell-2 Urban	Cell-3 Suburban
Location	25,435919 S 49,325283 W	25,463472 S 49,348083 W	25,463472 S 49,348083 W
Antenna Model	RFS APXVLL13-C	HWXX6516DSVTM	HWXX6516DSVTM
Antenna Gain	18 dBi	18 dBi	18 dBi
Antenna Azimuth	270°	130°	10°
Antenna Height	34 m	42 m	40 m
Antenna Downtilt	4°	6°	6°
Frequency Band	2.600 MHz	2.600 MHz	2.600 MHz
Tx Power	43 dBm	43 dBm	43 dBm
Mobile Sensitivity	-90,0 dBm	-90,0 dBm	-90,0 dBm
Mobile Height	1,5 m	1,5 m	1,5 m

C. Regression Analysis Details

The analysis regression is a method commonly used and conceptually simple to investigate the functional relationship between variables. This relationship can be expressed as an equation or a model relating the response variable (dependent) and one or more exploratory variables (independent) [13].

In this work was used a nonlinear regression model with a mathematical form deducted from the RF signal behavior and the attenuation suffered by electromagnetic wave depending on the distance between the base station and the user's mobile station.

Due to this non-linear behavior, was chosen the model mathematically written in (2), (3) and (4), whose parameters or coefficients acquire a connotation of exponential function, where θ is the vector parameter according α and β which needs to be estimated [14].

$$y = f(x_1, x_2, \ldots, x_n; \theta) \qquad (2)$$

$$\theta = (\alpha, \beta) \qquad (3)$$

$$y \approx \alpha e^{\beta x} \qquad (4)$$

For the estimation of parameters or coefficients, the non-linear least square approximation [15] was considered using the MatLab® toolbox Curve Fitting method [16].

The Figure 2 shows the graph obtained by regression from exponential model given for the Cell_2 and the details of the parameters resulting from the application of MatLab® version R2014a software tool.

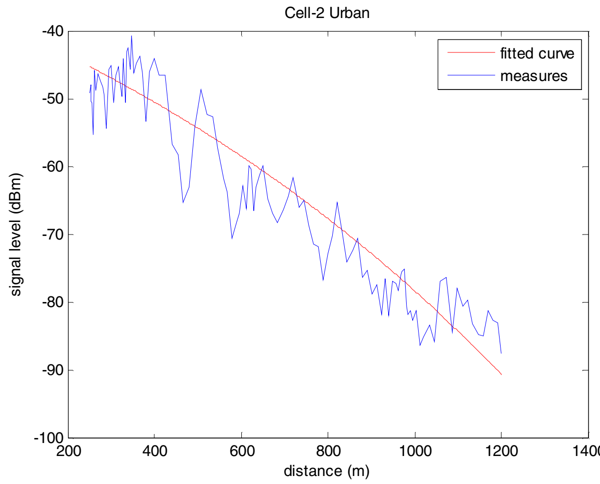

Fig. 2. Plot of measurements of Cell-2 showing the curve of variation of the signal along the route traveled in the test drive, including the respective exponential regression curve.

D. Propagation Model Tuning

The adjustment process or tuning for the SPM model was performed with aid of computational tool Atoll® version 2.8.0, which has the ability to create or modify the parameters associated with that model, based on measurement data collection [17].

The procedure adopted for tuning has compared with the curves of regression analysis including measurement and simulation data whose purpose is to minimize the error between the path loss prediction values and those actually found in the test drive process.

After comparing graphically, the plotted regression curves, with samples values, as can be seen in Figures 3, 4 and 5, it is possible to adjust the main parameters values of *K*, in accordance with the corresponding analysis of the gap, the slope of each curve and the coefficients of the model used.

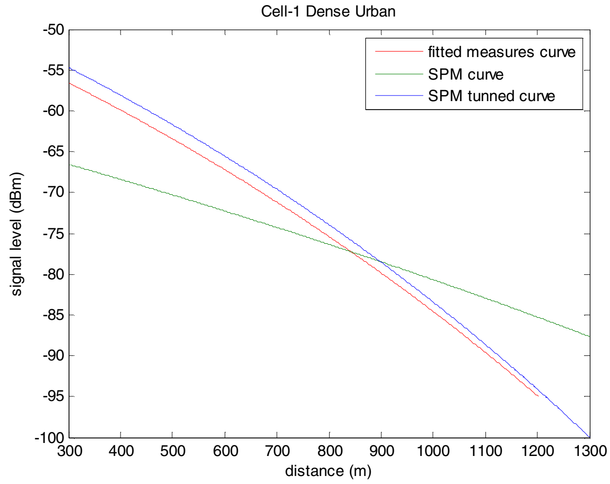

Fig. 3. Plot of regression measurements curve of Cell-1 Dense Urban, the regression SPM typical curve and the regression SPM tuned or the djusted curve.

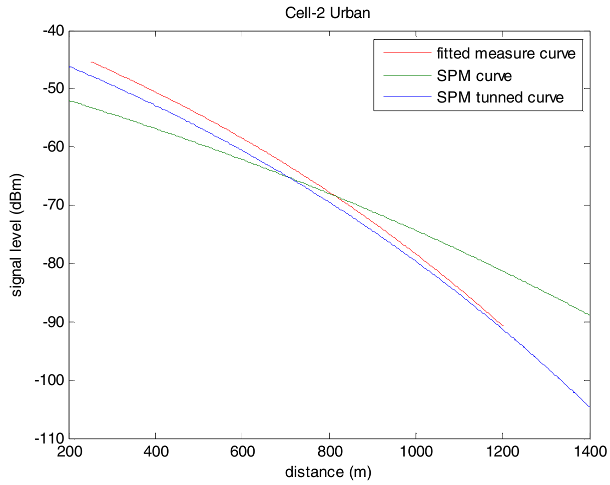

Fig. 4. Plot of regression measurements curve of Cell_2 Urban, the regression SPM typical curve and the regression SPM tuned or adjusted curve.

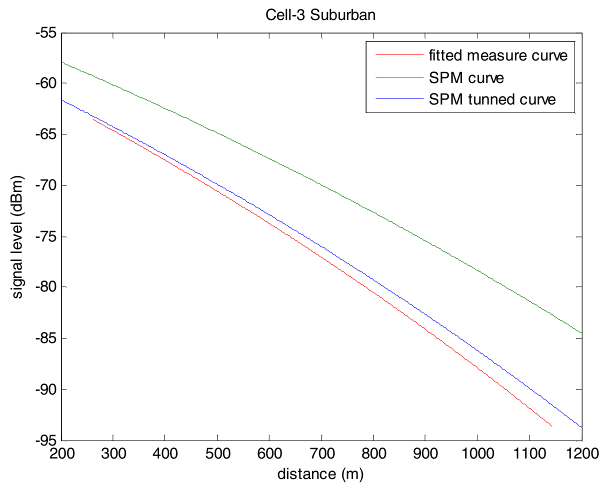

Fig. 5. Plot of regression measurements curve of Cell_3 Suburban, the regression SPM typical curve and the regression SPM tuned or adjusted curve.

The tables II and III for the urban and suburban cells, shows the values of *K*, typical and adjusted, applied to the SPM model formula (1) in this paper.

TABEL II

TYPICAL AND ADJUSTED PARAMETERS FOR SPM APLLIED TO CELL-1 DENSE URBAN AND CELL-2 URBAN

Model	Typical	Adjusted	
Distance	> 0 m	850 m	> 850 m
k1	17,40	17,40	26,10
k2	44,90	43,50	44,90
k3	5,83	5,83	5,83
k4	1,00	1,00	1,00
k5	-6,55	-6,55	-6,55
k6	0	0	0
k7	0	0	0

TABEL III

TYPICAL AND ADJUSTED PARAMETERS FOR SPM APLLIED TO CELL-3 SUBURBAN

Model	Typical	Adjusted	
Distance	> 0 m	850 m	> 850 m
k1	17,40	26,10	26,10
k2	44,90	43,50	44,90
k3	5,83	5,83	5,83
k4	1,00	1,00	1,00
k5	-6,55	-6,55	-6,55
k6	0	0	0
k7	0	0	0

IV. RESULTS AND DISCUSSION

In order to evaluate the results, several methods of checking and hundreds of research papers have been published, comparing the adjusted model with the measurement data collected in the field, as more recent work in [18]. In these cases, and in this paper, were applied statistical methods to determine the deviation of standard errors between measured and simulated values.

In this study were considered two statistical methods for validation of the predictions: an absolute evaluation mechanism, known as Mean Absolute Error – MAE, the Mean Square Error – MSE and the Root Mean Square Error – RMSE [19]. These absolute and quadratic calculation mechanisms are based on the error value obtained by expression (5).

$$e_i = (y_i - f_i) \tag{5}$$

where:

y_i measured value

f_i predicted value

The Mean Absolute Error – MAE, is given by (6):

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|e_i| = mean_{i=1,n}|e_i| \tag{6}$$

where:

n number of samples or measured values

$mean$ a mean operation

The Mean Square Error – MSE, is given by (7):

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(e_i^2) = mean_{i=1,n}(e_i^2) \tag{7}$$

The Root Mean Square Error – RMSE, is given by (8):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(e_i^2)} = \sqrt{mean_{i=1,n}(e_i^2)} \tag{8}$$

Finally, Table IV shows the results obtained by calculating statistical parameters, by application of Neural Network toolbox from MatLab® version R2014a software [20].

TABLE IV

STATISTICAL PARAMETERS

	SPM Typical		SPM Adjusted	
	MAE (%)	RMSE (dB)	MAE (%)	RMSE (dB)
Cell-1 Dense Urban	5,37	6,12	1,43	1,47
Cell-2 Urban	5,12	5,75	1,83	1,92
Cell-3 Suburban	7,18	7,46	1,07	1,20

V. CONCLUSION

In this paper were presented and discussed the method of fitting parameters to standard propagation model SPM for the LTE technology using a non-linear regression method.

Measures of different level of power of the main LTE standard systems, with tests made in the urban and suburban environment, it were presented in order to verify the reliability and availability of this fixed and mobile system in normal conditions.

The main objective of this paper is to contribute to evaluate the LTE cells coverage area and identify shadow areas not covered in predictions by conventional propagation models. The results were validated using tools statistics error analysis, demonstrating that the deviations of the simulations show a significant improvement in performance for the adjusted model. It is hope to provide an additional guideline for choosing the planning and development of LTE system to be deployed in one big city.

The analytical and statistical methods employed has been concluded that the performance of tuned SPM model was significantly improved in accordance with small errors found in the final simulation, with values next 1dB of average margin.

Thereby with the prediction simulation using the collection of data obtained from the environment of interest, the tuned SPM model is recommended to be used, to provide the best analysis applicable for planning, implementation and expansion of the LTE networks in regional peculiar own characteristics of Brazilian cities, in dense urban, urban and suburban environments.

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