The compromise with the covered area and the Bit Error Rate in a suburban environment densely arboreous

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***Abstract*— In this paper a model is used for electromagnetic propagation waves in suburban environment densely arboreous to evaluate the covered efficiency of a cellular mobile communication system. The compromise with the covered area and the Bit Error Rate (BER) is identified as the key in the propagation characteristics that have the potential to influence the performance of the system. After that, the Bit Error Probability and the covered area is studies numerically for different heights of transmitter antenna. Experimental data had been gotten in one densely arboreous environment to adjust the considered model. Simulation for a GSM system had been carried through to evaluate the covered and the BER of the system and the results obtained indicate the performance of the system for the QoS requirement.**

***Index Terms*— Mobile Communication, Propagation Model, Random variable, BER.**

I. INTRODUCTION

With the recent rapid growth in demand for personal wireless mobile communications services, it is becoming increasingly important to develop new and more efficient systems for handling greater capacity requirements. One of the *key* objectives in system development is to allow many users to coexist in a cell maintaining the efficiency, system capacity, and channel quality. The increasing number of the potential cellular users in suburban environments, made the radio systems engineer faced with a number of problems when designing such systems. The focus of this paper is to relate the covered area with the Bit Error Rate (BER) in a densely arboreous suburban area. To achieve these requirements, knowledge of how the environment affects the radio signal propagation must be obtained. Numerous studies have been developed to predict outdoor propagation characteristics with reasonable accuracy [1]- [5]. However, these approaches usually require a significant amount of detailed information about the specific environment. For this reason, this paper investigates the accuracy of system performance estimates made using a simple empirical propagation model to estimate mean signal path loss. The simple propagation model is extended to evaluate the covered area and the Bit Error Rate (BER). The Bit Error Probability and the covered area is studies numerically for different transmitter antenna heights. Experimental data had been gotten in that environment to adjust the considered model. Simulation for a GSM system had been carried through to evaluate the covered and the BER of the system. The measurement campaign is described in Section II, the details of the outdoor propagation loss model is in Section III, in Section IV is made a comparison between the measurement and predicted data, aiming to validate the proposed model, the BER is studied in Section V, the results are shown in Section VI and some conclusions are made in Section VII.

II. MEASUREMENT CAMPAIGN

The model was developed for the studding the electromagnetic waves propagation in mixed of forest and buildings environment Fig.1. This way, a measurement campaign was carried out in a suburban area of the Marituba city, distant approximately 20 km of Belém-PA. This environment presents low buildings, narrow streets and areas densely arboreous; with typical Amazonian Forest vegetation. The transmitter antenna used was an omnidirectional with a gain of 2 dBi, irradiating a CW wave in the 890.43 MHz frequency. This antenna was set in a tower of a local cellular company. Three heights (14, 44 and 70m) were used for best study the trees effect on the received signal loss. The mobile receiver antenna is an monopole with a gain of 3 dBi, it was set on a car. Some streets of the base station area, were covered using a car moving with constant speed along the streets. Received power and the geographical coordinates data were stored in a notebook computer equipped with a data acquisition and storage data program [6].

III. MODEL

To calculate the cell radius to obtain an appropriated power level, associated with a coherent bit error rate (BER), a model to predict the received power by the mobile terminal was developed. The general equation of the model is [7]:

$$P_r = K_0 - 10\gamma \log(d) - 8.686\alpha_{sp}d + \chi \qquad (1)$$

where:

K_0 = a term dependent of the environment and the height of the transmitter and receiver antennas;
γ = path loss exponent;
d = transmitter and receiver distance(m);
α_{sp} = specific attenuation(1/m);

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χ = random variable that characterizes the measurement environment.

Fig. 1. Picture of Marituba City, 44m antenna height.

Each component in this model will be described in the following subsections.

A. K_0 Term

This term is related to antenna height:

$$K_0 = a\left(\frac{h_t}{h_r}\right)^2 - b\left(\frac{h_t}{h_r}\right) + c \tag{2}$$

where h_t is the transmitter antenna height and h_r is the receiver antenna height.

The values a, b and c were obtained according to following methodology: for each transmitter antenna height, it was predicted the received power by the model without the K_0 term, this way were found three error values between the measurement and the model. A graphic was made with the error versus the relation between the transmitter and received antennas. A quadratic fitting was, then, obtained to minimize the errors. For the studied environment this coefficients are: a=0.039061, b=2.7551 and c=77.225.

B. Specific Attenuation - α_{sp}

The electromagnetic properties of the attenuation in the forest don't depend only of it density and others physics characteristics, for example, quantity of trees and its distribution in the forest. They depend too of the kind of the trees existent in the forest. The vegetation quantitative effect in the radio wave attenuation is considered along of the wave path: the same path with a environment with vegetation has larger attenuation than an environment with absence of the vegetation, for the same system setup and the same communication parameters. The loss in excess, in this case, will consider the foliage presence[7]. The specific attenuation is obtained through the transmission loss by distance unit and it is expressed in dBm. The specific attenuation shows two different characteristics, one for the vegetation and other for the wave propagation mode. In the vegetation case, the specific attenuation measured is independent of the distance of the wave path and the mode propagation if the environment considered is homogeneous. If the forest is not homogeneous, the specific attenuation varies point-to-point and, consequently, influence significantly in the transmission loss and the respective mode propagation (direct wave, reflected or lateral wave).

The specific attenuation is defined in the asymptotic limit like:

$$\alpha = \lim_{d\to\infty}\{ln'[L(d)]\} \tag{3}$$

where:

$L(d)$ = the propagation loss with the distance d;
ln' = the derivative of the natural logarithm [7].

The attenuation can be expressed in terms of the received power in function of distance:

$$\alpha_{nep/m} = -0.5\lim_{d\to\infty}\{ln'[P_r(d)]\} \tag{4}$$

That definition is in agreement with the theoretical studies [7] showing that in a homogeneous propagation environments, the variation of the power received with the distance assumes the following form:

$$P_r = Kd^{-\gamma}e^{-2\alpha d} \tag{5}$$

where:

K e γ = parameters that depends of the environment;
α = specific attenuation (1/m);
d = radio distance between the transmitter and receiver(m).

The power received [7], in dB is:

$$P_r = K_0 - 10\gamma\log(d) - 0.8686\alpha d \tag{6}$$

By definition the transmission loss or path loss is given for:

$$L = 10log\left(\frac{P_t}{P_r}\right) \tag{7}$$

where:

P_t = the power transmitted by the transmitter antenna;
P_r = the maximum power that can be extracted of the receiver antenna (received power).

Usually, in forest environments the transmitter can be inside or out of the forest. So, the signal arrives to the receiver for a path direct and/or, reflected, diffracted or through lateral waves. In this work, the antenna transmitter height will be put in three situations: a lot above the of treetop; a little above and; in the top of the trees. The receiver antenna will be fixed above a car and will be moved in the streets enclosed by trees and houses. It is noticed then that the reflection and diffraction phenomena are, clearly, presents in this scenery. Equation (6 describes the power received in homogeneous environments. For propagation in non homogeneous environments this formulation can be used since makes modifications, mainly in the specific attenuation, α, for the effects of the path not homogeneity to be compensated. For example, S.S. Seker and A. Schneider [7] have been showing that forests with predominance of trunks has the specific attenuation directly proportional to the density of the number of trees's trunks. It is considered that, the chosen scenery for the proposition of the radio propagation model is typical of small cities in the State of Pará, prevailing forests, houses and streets. For this case, the specific attenuation will be given for:

$$\alpha = \alpha_0 \rho \tag{8}$$

Here, α_0 is a constant that depends of the path loss exponent of the environment (γ) and ρ are factors that correlate the antenna transmitter height and forest effects.

$$\alpha_0 = \left(\frac{1}{20\gamma}\right); \tag{9}$$

$$\rho = \frac{h_f}{h_t\left(h_t + h_f\right)}, [\frac{1}{m}]; \tag{10}$$

where:

h_t = transmitter height;
h_f = forest mean height.

C. Random Variable - χ

The signal randomness of the measured environment was described better for Rayleigh probability distribution function (PDF).

IV. MODEL VALIDATION

The received power in the measurement campaign was separated in the short and long terms using the moving average method [8]. The long term component of the power received by model and by measurement was compared. The Fig. 2 shows this comparison for the transmitter antenna at 14m only. For the other transmitters height (44 and 70m) is present just the error while compared with experimental data (see Table I).

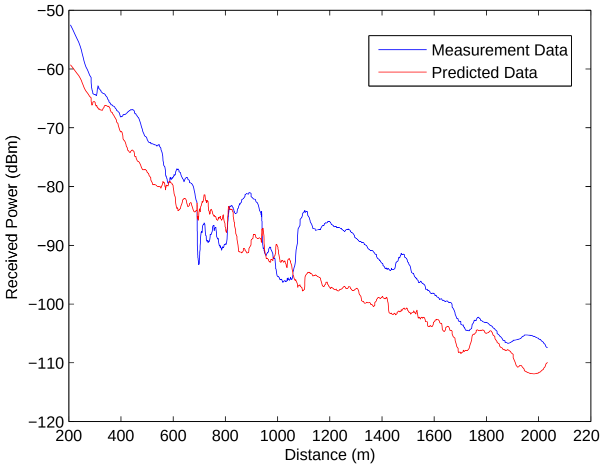

Fig. 2. Comparation between the predicted and measured power for the transmitter antenna at 14m.

TABLE I
ERROR BETWEEN THE PREDICTED AND MEASURED RECEIVED POWER

Transmitter Height(m)	Error(dB)
14	3.03
44	2.51
70	2.33

Through the analysis of the obtained errors is possible to verify that the proposed model presented a good prediction of the measured data. Besides the power level received, however, there are several other parameters that should be analyzed to determine the quality of the channel communication between the transmitter and the receiver.

V. CHARACTERIZATION AND EVALUATION OF THE MOBILE RADIO CHANNEL

The information (voice or data) sent of the transmitter to the receiver is contaminated and distorted by five destructive influences: the modulator, the transmission medium, noise sources, fading phenomena and the demodulator. Everything that corrupts a signal originating in the way between the transmitter and the receiver is called of channel [9]. The Fig. 3 show a schematic mobile radio system, where it is has the transmitter, the receiver and the channel. Depending on the communication sense, if uplink or downlink, the base station (BS) can be the transmitter or the receiver, the same happening with the mobile station (MS). In this paper, the mobile channel radio is characterized by the model described in the previous section and that it have some parameters that characterize the environment and the system studied: K_0 is dependent of the transmitter and receiver heights, χ is a random variable, α_{sp} characterizes the non homogeneities.

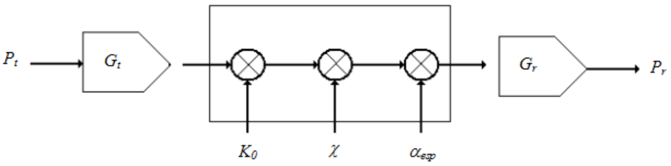

Fig. 3. Schematic diagram of the Mobile Radio System.

In this paper the received power level is predicted through the proposed model, however, as already mentioned previously, the communication link quality between the transmitter and the receiver is not only measured through of this parameter. The quality of Sevice (QoS) depend of the others factors [10]. Among that several parameters, it will be analyzed in this paper what is called as bit error rate (BER), that it is defined as the probability of the rebuilt bit in the receiver to differ of the transmitted bit [11]. To evaluate the system was analyzed the worst transmission situation that is in the uplink, because, in this situation the power transmitted is smaller and, therefore, it more subjects to errors of transmission. The BER for systems with modulation GMSK (Gaussian Minimum Shift Keying), in channels with Rayleigh fading [12] is given by:

$$BER = \frac{1}{2}\left(1 - \sqrt{\frac{\overline{\gamma}_b}{1+\overline{\gamma}_b}}\right) \tag{11}$$

Where $\overline{\gamma}_b$ = mean signal-to-noise ratio for bit, that for this paper is estimated as following [12]-[13]:

$$\overline{\gamma}_b = \frac{2\gamma_{GSM} T_b E(\chi^2) 10^{\left(\frac{P_t - P_t^d + \overline{P}_r(d)}{10}\right)}}{G_r k T_n} \tag{12}$$

where:

γ_{GSM} = characteristic factor;
T_b = transmitter time for each bit;
$E\left(\chi^2\right)$ = mean value of random variable χ^2 for the considered model;
P_t = transmitted power;
P_t^d = transmitted power at downlink;
$\overline{P}_r(d)$ = mean received power in each distance;
G_r = received antenna gain;
k = Boltzman constant;
T_n = noise temperature.

VI. RESULTS

This section gives a plot of the average BER for a GSM system as a function of the transmitter-receiver distance . The expression given by (11) was used to simulate the BER and the parameters values were assumed as: γ_{GSM} is 0.7 [13], T_b is 3.7μs for a transmission rate of 270Kbps, T_n is 300K, $E\left(\chi^2\right)$ is 5.86×10^3 for 14m antenna height, 4×10^3 for 44m antenna height, 4.44×10^3 for 70m antenna height, P_t is -60dBm and P_t^d is 22dBm. The compromise with the covered area and the Bit Error Rate (BER) was performed considering for each antenna height the radius of the cell, according a threshold received power, W_0, and a probability of received signal in the border of the cell, β. In this simulation it is assumed: W_0= -85; β = 90%. The Table II shows the values of radius of the cell and the corresponding antennas heights. The Figs. 4-6 show the bit error rate (BER) versus covered distance for 14, 44 and 70m of antenna height, respectively. The BER of 10^{-3} was used as reference for the system performance analysis. In Figs.4-6 the gray area corresponding the distances where the signal presents a power received level above of the threshold power, and a BER below of the fixed value. Therefore, in this area the system present a good performance for received power level and QoS (in this case, bit error rate).

TABLE II
MAXIMUM RADIUS FOR EACH TRANSMITTER ANTENNA HEIGHT

Transmitter Antenna Height(m)	Maximum Radius (m)
14	485
44	985
70	1285

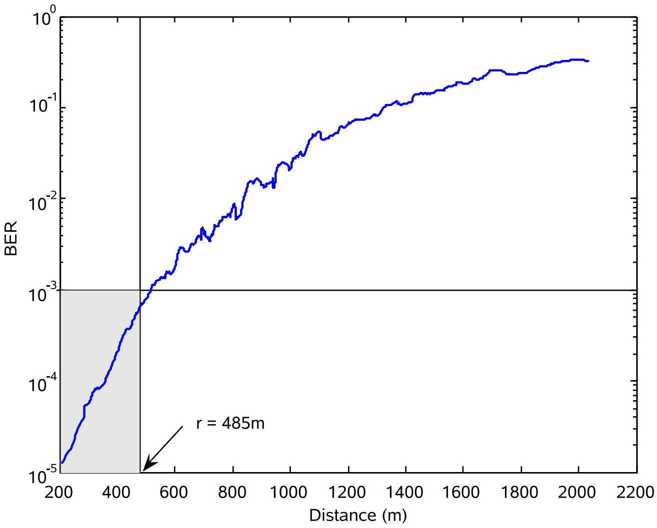

Fig. 4. BER versus Distance for 14m antenna transmitter height

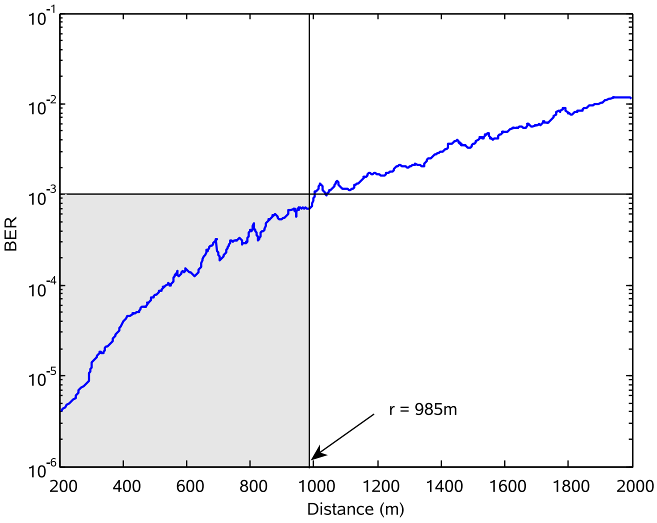

Fig. 5. BER versus Distance for 44m antenna transmitter height

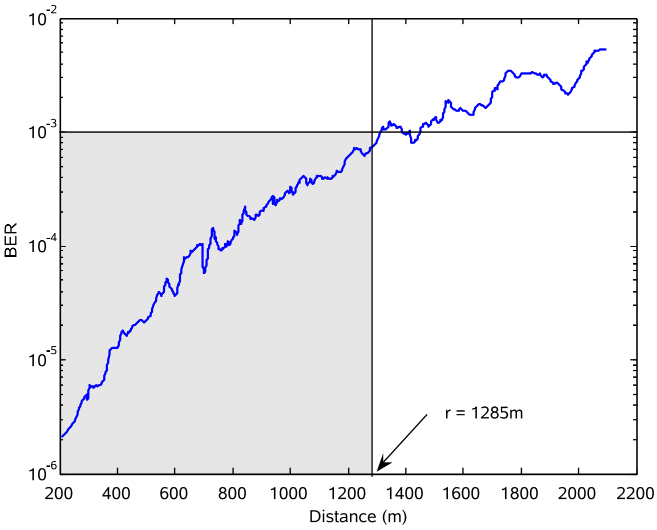

Fig. 6. BER versus Distance for 70m antenna transmitter height

VII. CONCLUSIONS

In this paper a model for electromagnetic propagation waves in suburban environment densely arboreous was used to evaluate the covered area and the Bit Error Rate (BER) in a cellular mobile communication system. The compromise with the covered area and the bit error probability was identified as the *key* in the propagation characteristics that has influence in the performance of the system. The simulations results obtained by the BER for a GSM system as a function of the transmitter-receiver distance, associated with the probability of a signal to be received in the border of cell given a good indicative about the system performance in this environment.

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