Path Loss Model for Densely Arboreous Cities in Amazon Region

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Abstract — **This work proposes a propagation loss model for densely arboreous environment at 900 and 1800 MHz bands. In this model, the environment non-homogeneities and the base station antenna height effects are incorporated in the total loss. A measurement campaign was accomplished in three cities of the State of Pará, Brazil, for validate the model.**

Index Terms — **Distribution functions, mobile communication, modeling, propagation, loss measurement.**

I. INTRODUCTION

The losses propagation modeling presented by a signal in the path between the transmitter and the receiver is something classical and already quite studied. There are, basically, three forms of modeling these losses: deterministic, statistics and empiric forms. The deterministic models are very accurate and use the Maxwell equations, besides of it, the transmission, reflection and diffraction laws [1]. Prediction technique, such as FDTD (Finite Difference Time Domain) [2] and the ray tracing [3] the most used, needs accurate information concerning the environment measurement and a great computation effort. The statistical models present a probability loss in each traveled distance. The latter, models are not very accurate [1]. The empiric models are the most used in cellular planning. They use equations obtained from results of several measurement campaigns. These models don't need great computational effort, they are not, however, very accurate because they are an ordinary representation of the mean values of the signal [1]-[4].

The proposed model in this work computes the propagation loss in densely arboreous environments at 900 and 1800 MHz bands. In this model, the environment non-homogeneities and the Base Station antenna height effects are incorporated in the total loss. A measurement campaign in the Abaetetuba, Barcarena and Marituba cities (State of Pará) was accomplished for validation of the model.

II. THE MODEL

The propose model incorporates to the free space model the loss due to diffraction in buildings, trees, etc., and a factor namely gain-height, and two more factors that characterize the variability of the signal. This variability is represented by a probability density function (pdf) and by a sinusoidal function that is associated to the non-homogeneities present in the tiers which the measured area is divided (model point-area). The general equation of the model is given by:

$$L = L_{\mathbf{0}} + \mathbf{10}\gamma \log\left(\frac{d}{d_{\mathbf{0}}}\right) + L_{DIF} + G_{HEIGHT} + L_{TIER} + X + K \quad (1)$$

Where K is an empirical constant, depending on the measurement environment. The others factors will be described in the next sections.

A. Free Space Loss (L_0)

In (1) L_0 is the free space loss, given by (2), f is the transmission frequency in MHz, d_0 (km) is a reference distance and G_T, G_R, is the transmitter and receiver antennas gain, respectively.

$$L_0 = 32.44 + 20\log f + 20\log(d_0) - G_T - G_R \quad (2)$$

B. Diffraction Loss (L_{DIF})

L_{DIF} is the loss due to obstacles as buildings, trees, etc. L_{DIF} results from the knife-edge model [4]. For obstacles with heights lower than transmitter antenna, the parameter ν_0 is given by, see [5]:

$$\nu_{\mathbf{0}} = \sqrt{\mathbf{2}}\left[(h_F - \mathbf{2}h_R) - \frac{w(h_T - h_R)}{(d+w)}\right]\sqrt{\frac{d\cos^{\mathbf{2}}\theta}{\lambda(d\cos\theta - w)w}} \quad (3)$$

In (3), h_F is the medium height of the obstacles, h_R is the receiver antenna height, h_T is the transmitter antenna height, d is the radio distance between the transmitter and receiver, w is the half- width of street, finally, θ is the angle between the measured data and the azimuth of the transmitter antenna.

For ν_0 lower than -2.4 (verified to every cities considered in this work), the diffraction loss is given by [5]:

$$L_{DIF} = 20\log\left(\frac{0.225}{\nu_0}\right) \quad (4)$$

C. Gain-Height (G_{HEIGHT})

G_{HEIGHT}, in (1), is the gain-height. This term proposed represents the influence of the Base Station antenna height in the total loss; its equation is given by:

$$G_{HEIGHT} = 20\log\left[\frac{(h_F - h_R)h_R}{h_T}\right] \quad (5)$$

D. Tier Loss (L_{TIER})

The environment non-homogeneities are incorporated in the term L_{TIER}, which represents the losses in each tier, each one, with width D. Fig. 1, illustrates the measurement path in the environment of the antenna coverage area.

$$L_{TIER} = \sqrt{2}\sigma \sin\left(C\frac{d}{\lambda}\theta\right) \quad (6)$$

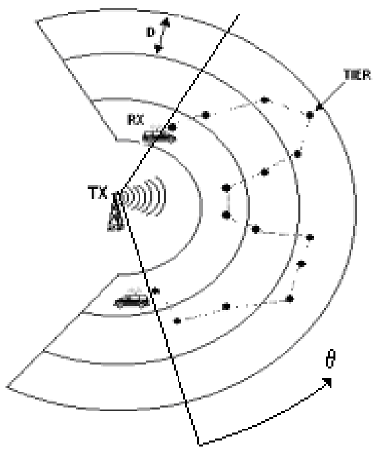

Fig. 1. The mobile path divided in tiers.

In (6), σ is the standard deviation of the measured data, C = 0.001 is an empiric constant and λ is the transmitted signal wavelength. The function sine in (6) is justified by the jitter behavior of the loss propagation in each tier. Fig. 2 presents the losses propagation for the tiers 2, 5 and 11 in the measured environment.

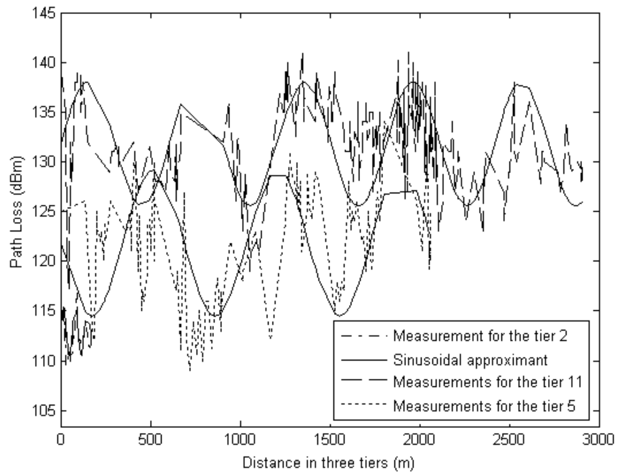

Fig. 2. Loss propagation in the tiers and the fitted sine function.

E. Rayleigh Random Variable (X)

The signal randomness in every tier measured is represented by a Rayleigh probability distribution function. This distribution was selected among several others, i.e. Weibull, Log-normal, Log-logistics, Rice and Nakagami-m [6]-[7], using the chi-square criterion.

III. ENVIRONMENT MEASURED

To validate the proposed model some measurement campaigns were accomplished: the first campaign was accomplished 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, Fig. 3. In this campaign, the transmitter antenna height was set in 14, 44 and 70 m and the transmitted frequency was 890.43 MHz.

Two other measurement campaigns were accomplished in country cities of the Pará State. These cities have as characteristic also low buildings and high densely arboreous. In Barcarena city, Fig. 4, the transmitter height is 60m and in Abaetetuba city is 80 m. In both cities, the transmitted frequency was in the 1800 MHz band.

Fig. 3. View, at base station antenna height 70 m, of the measurement campaign.

Fig. 4. View of Barcarena city.

IV. MEASUREMENT SETUP

The transmitter antenna used in the Marituba city measurement 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 were used for best study the trees effect on the received signal loss.

The mobile receiver antenna is an omnidirectional with a gain of 3 dBi, it was set on a car. Some streets of the base station area, were covered using this car, receiving the power and the geographical coordinates data, that were stored in a notebook computer equipped with a data acquisition and storage data program.

In the Barcarena and Abaetetuba cities the transmitter antenna was a panel antenna with a gain of 17.5 dBi and the receiving antenna was an omnidirectional with a gain of 0 dBd. The receiver system is similar those used in Marituba.

V. RESULTS

The Figs. 5-7 present the results obtained for the Marituba, Abaetetuba and Barcarena cities, respectively. In these figures, the dashed line represents the measured data and the continuous line represents the model prediction. A good agreement is observed in the predicted and measured values. The Table I presents some numeric results of the proposed model performance. The empiric constant K is obtained by optimization minimizing the difference between the measured and predicted values, using the Nelder-Mead simplex method [8]. It is also presented the propagation loss coefficient (γ) for each city, as well as the mean error (dB) between the measured and predicted losses.

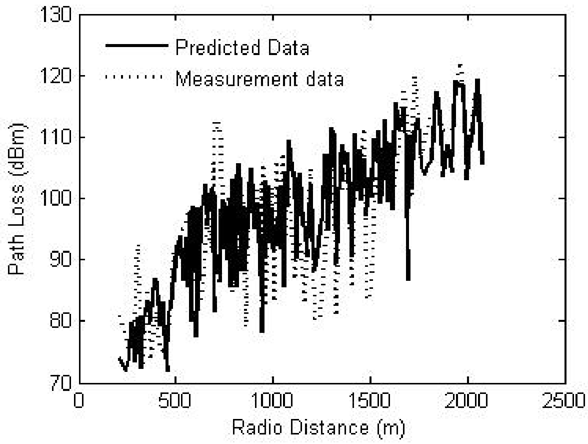

Fig. 5. Measured and predicted loss propagation in Marituba city. Transmitter antenna height 70 m.

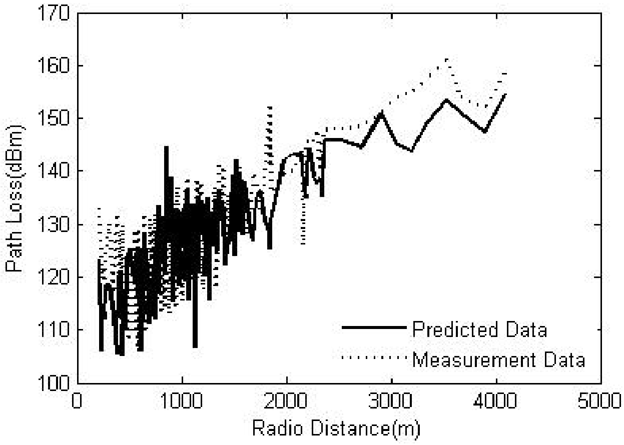

Fig. 6. Measured and predicted loss propagation to Abaetetuba city.

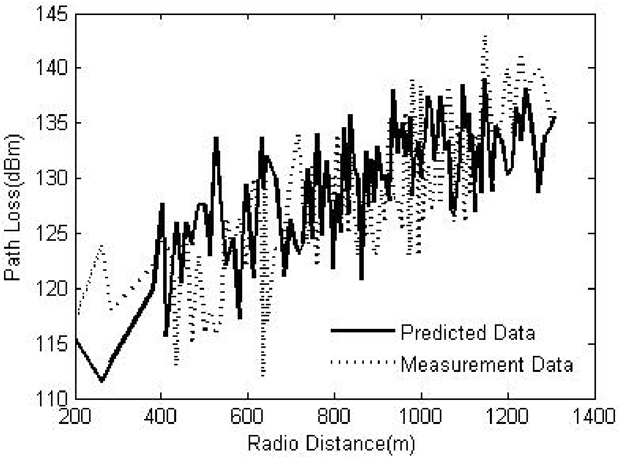

Fig. 7. Measured and predicted loss propagation to Barcarena city.

TABLE I
SOME NUMERICAL DATAS TO THE STUDIED CITIES.

City	Empirical Constant (K) (dB)	Loss Propagation Coefficient (γ)	Mean Error (dB)
Abaetetuba	72	3.2	8.62
Barcarena	83	2.8	6.29
Marituba	24	4.8* 3.5**	6.90

* Transmitter antenna at 14m; **Transmitter antenna at 44 e 70m.

VI. CONCLUSION

The model proposed in this work joins the great qualities of the empiric models, which are: mathematical and computing simplicity. The introduction of the random variable and the sine function, that describes the signal variations in the tiers, allows a better environment representation. The gain-height factor, provides a relationship with the total loss, in this way, it will allow a better definition for the establishment of a great height ERB. The obtained results are quite encouraging for new systems design in cities densely arboreous, very common in the Amazonian Region.

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