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A PROPAGATION MODEL FOR MOBILE ENVIRONMENT IN CAIRO CITY

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ABSTRACT:

In this work, a propagation model is developed to predict the path loss in mobile environment for Cairo City. This model is a modification of Lee model that makes it suitable for both macrocells and microcells. The model is based on the basic propagation equations and the practical results measured in crowded area in Nasr-city, Cairo.

KEY WORDS:

Wave propagation, Propagation model, Mobile communication, and Cellular radio.

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1. INTRODUCTION:

The design of wireless communication networks requires detailed understanding of radio wave propagation mechanisms such as reflection, diffraction and scattering. Propagation prediction initially aims at the development of the models, which provide accurate estimates of the mean received power or path loss for a specific frequency band. In the system design, propagation models allow optimization of cell coverage area while minimizing cochannel interference. Considerations have to be given to the reflection from the ground and building, as well as diffraction losses due to knife-edge type obstacles or rounded obstacles [1].

The coverage requirements are coupled with the traffic-loading requirements. Therefore, the performance of the network is affected by choosing the suitable propagation model. Also the propagation models are used in other system performance aspects including handover optimization, power level adjustment and antenna placement and delay-spread minimization.

Many propagation models have been developed during the past two decades. These models may be classified into three classes: empirical, semiempirical, and deterministic [2]. Empirical models [3] consist of diagrams or equation for path loss calculation, which are obtained from statistical analysis of measurements. Two approaches are used to establish deterministic models [4]. First, a path loss equation is provided which has been derived based on idealized or obstructed environment. Second, geographical information about the investigated site supplied by means of digital maps is exploited to predict the dominant propagation paths and their loss. Semiempirical models [5] result from an empirical modification of deterministic models to improve the agreement with measurements.

The model proposed in this paper may be classified as semiempirical model. The model is based on the analysis of the measured data to modify a basic propagation model. The measurements were taken in an urban area in Nasr City, Cairo.

2. THE BASIC PATH LOSS MODEL:

The fundamental propagation situation, which is basic for all models, is illustrated in Fig.1 [6]. Here the base and mobile station antennas are suited above a flat reflecting ground (plane earth) at heights h_b and h_m respectively, so that propagation takes place via both a direct path between the antennas and a reflection from the ground. These two paths sum at the receiver with a phase difference related to the difference in length between the two paths. It is then easy to see that the received power is given by [6]:

$$P_r = P_T \frac{4\lambda}{16\pi^2 r^2} \cdot \left(k \frac{h_m h_b}{r} \right)^2 = P_T \cdot \left(\frac{h_m h_b}{r^2} \right)^2 \qquad (1)$$

Transforming eq.(1) to dB form we get the path loss as

$$\mathrm{PL} = 40 \log r - 20 \log h_b - 20 \log h_m \qquad (2)$$

where PL is the path loss in dB, r is the distance in meters, h_b is the base-station antenna height in m, and h_m is the mobile antenna height in m.
the basic model in eq.(2) will be modified according to the measured data.

3. EXPERIMENTAL WORK:

The area of measurements was chosen to be residential, consisting principally of more than five-story houses. Some taller buildings are present, together with some industrial buildings. The terrain in the area is flat. The measurements were made in Nasr City, Cairo. The base station antenna is placed on the roof of a 40 m high building. The base station antenna height is about 44 m above the ground level. The transmitted power is 43 dBm and operating frequency is 947 MHz. This cell is divided into 3 sectors with azimuthal angle 120°.
Two sets of measured data were obtained: The first set is 247 different location around the base station forming circles of constant distances from the base station and ranging from 100 to 1000m on 100 m steps. The second set consists of two different routes, a route of 532 different locations of various distances from the base station and another route of 936 different test points. These additional routes were made to add more confidence in the measurements.
The scatter diagram and three-dimensional plots of the measured data are shown in Fig.2. The conditions under which the measurements were performed is listed in table 1. The symbols dBd means that the antenna gain is given in dB referenced to the half wave dipole.

4. DATA ANALYSIS:

We are interested in a general propagation path-loss formula in radio environment. From the measured data the average 100-m intercept level is found to be -49.5 dBm and the 1000-m intercept level is -89.3 dBm. By connecting these two points we obtain a straight line, representing the path loss, with slope n = 4.4222, as shown in Fig.3. The basic prediction model of eq.(1) may now be modified using the measured conditions listed in table 1 to give the form [7]:

$$P_r = (P_t - 43) - 49.5 - 10n\log\frac{r}{100} + 20\log\frac{h_b}{44} + 10\log\frac{h_m}{1.7} + g_t + g_m \qquad (3)$$

Or can be simplified for urban areas to have the final form

$$PL = 10n\log r - 20\log h_b - 10\log h_m + K \qquad (4)$$

where K=39.216, and n = 4.4222
Each urban environment (City) is different and has its own human-made structures. Therefore, · the values of n and K will be different accordingly. The proposed model is plotted versus distance in Fig.4.

5. COMPARISON WITH THE MODELS:

5.1 Comparison With The Hata And Atefi Models:

Comparison of this model with Hata model [8] and Atefi model [9] using the same propagation conditions for urban environment with measured data obtained by the route1 and rout2 is illustrated in Fig.5.
The comparison shows good agreement with the measurements both in terms of the absolute level of the predictions and the slope of the prediction curve. While the Hata and Atefi models tend to underestimate the path loss especially for large distances. Another criterion for comparison is the mean prediction error and standard deviation error [10]. Fig.6 summarizes the results of comparison of the proposed model and Okumura-Hata model and Atefi model with the measured data. For both routes the proposed model is better than the Hata model and Atefi model in terms of mean and standard deviation. The Hata model and Atefi model consistently underestimate the loss, confirming that they are not applicable to this area.

5.2 Comparison With Lee Model:

To lend credence to the expression obtained in the eq.(4), we compare it with Lee model. The received signal strength P is therefore calculated under the same set of transmission conditions used in [7], namely; base station transmit power P_t = 10 W (40dBm), base station antenna gain g_b = 6 dBd (8.2 dBi), and mobile station antenna gain g_m = 0 dBd (2.15 dBi), where dBi is the antenna gain with respect to an isotropic antenna. Using eq.(4), the received signal strength P between two isotropic antennas is obtained as

$$P = P_t + g_b + g_m - PL = 50.4 - PL \quad \text{dBm} \qquad (5)$$

By substituting the path loss in eq.(5) into the eq.(6), the received signal strength P becomes

$$P = -10n\log r + 20\log h_b + 10\log h_m + 21.184 \ \text{dBm} \qquad (6)$$

For the 1-km distance the received signal strength using eq.(6) is P = -76.06 dBm. Fig.7 shows our proposed model together with Lee model for various types of environments.
From the Fig.7 we notice that the predicted path loss for Cairo City is above the path loss for New York City and Tokyo city, which is expected since both cities have higher building than those in Cairo.

6. CONCLUSION

The model presented in this paper provides a self-consistent method to predict path loss in urban and crowded suburban of Cairo City and other cities where the human-made structures are similar.
The model will be suitable for the design of modern cellular mobile systems that employ cells of radius ranging from 100 to 1500m.

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Table 1. Conditions of the experiment.

Transmitted power in dBm	43
Base-station antenna height in m	44
Mobile antenna height in m	1.7
Base-station antenna gain in dBd	14
Mobile antenna height gain in dBd	0

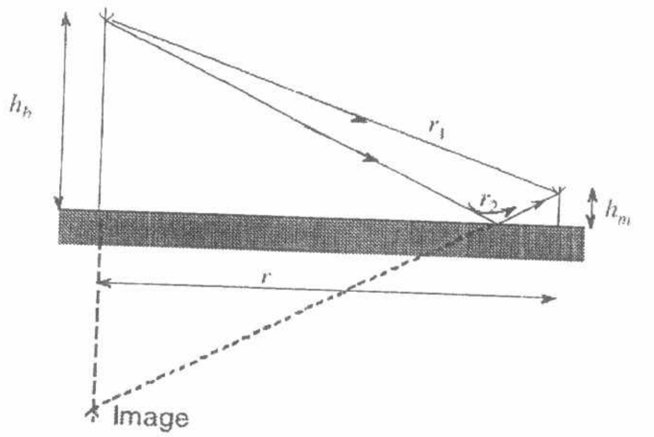

Fig.1. Physical situation of the flat earth propagation model

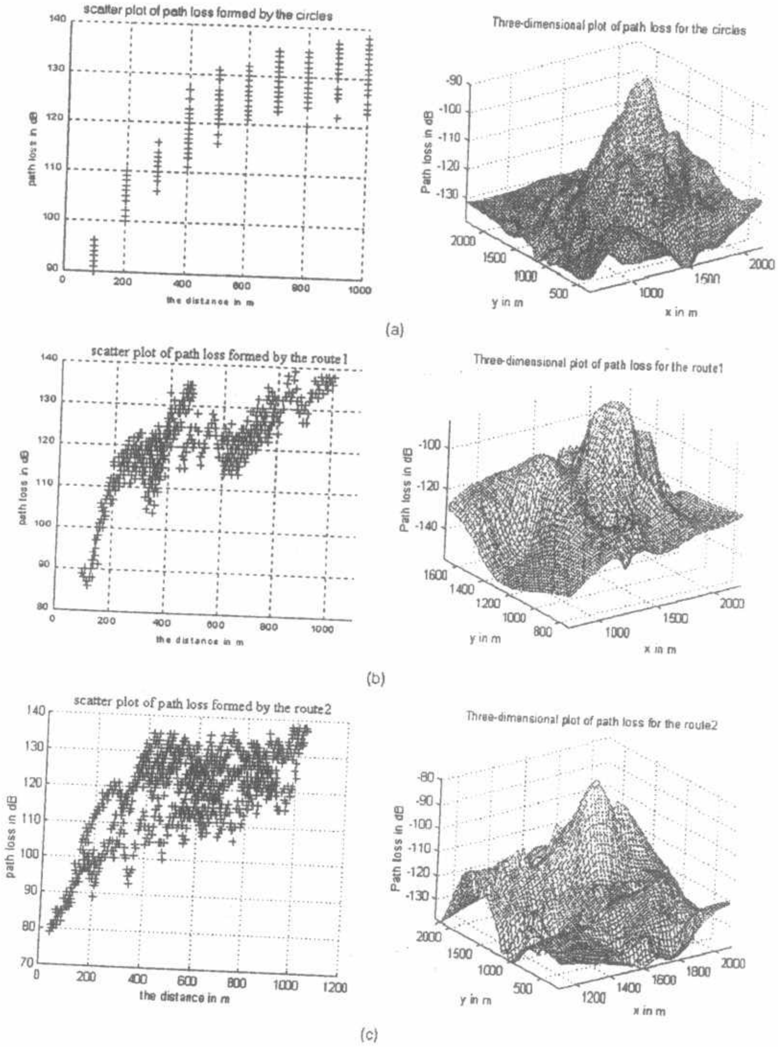

Fig.2. The scatter plot and surface plot of the path-loss measurement for various routes

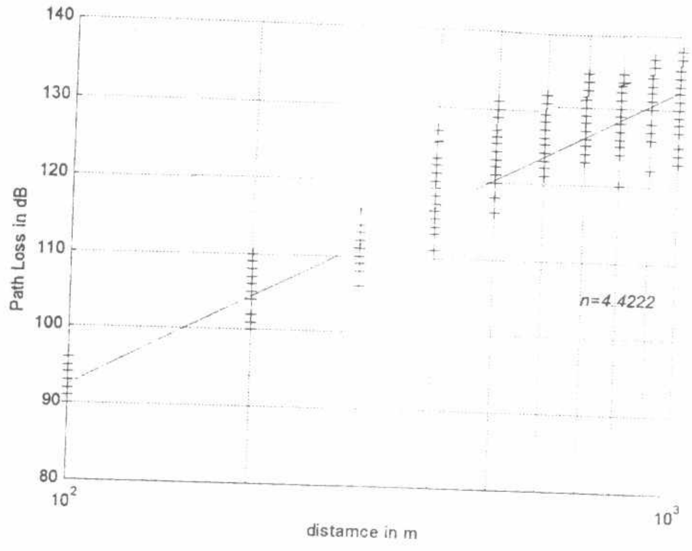

Fig.3. Calculation of the path loss slope for Cairo city

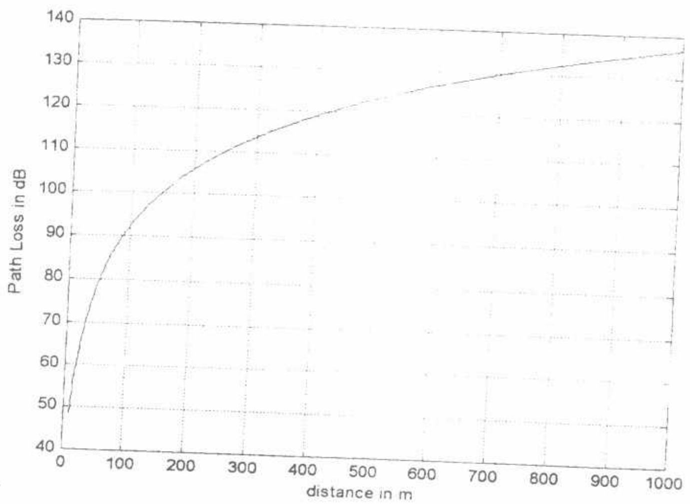

Fig.4. Propagation model of the Cairo city

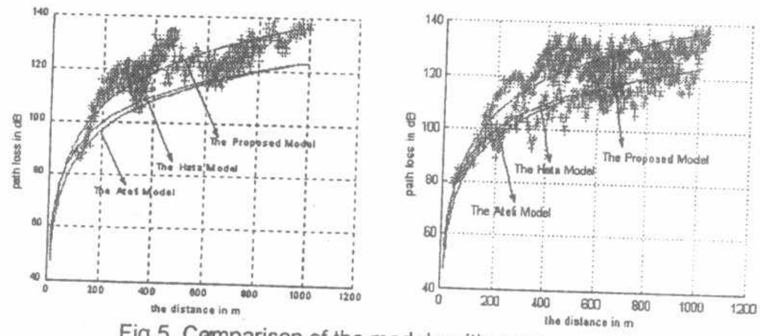

Fig.5. Comparison of the models with measurements.

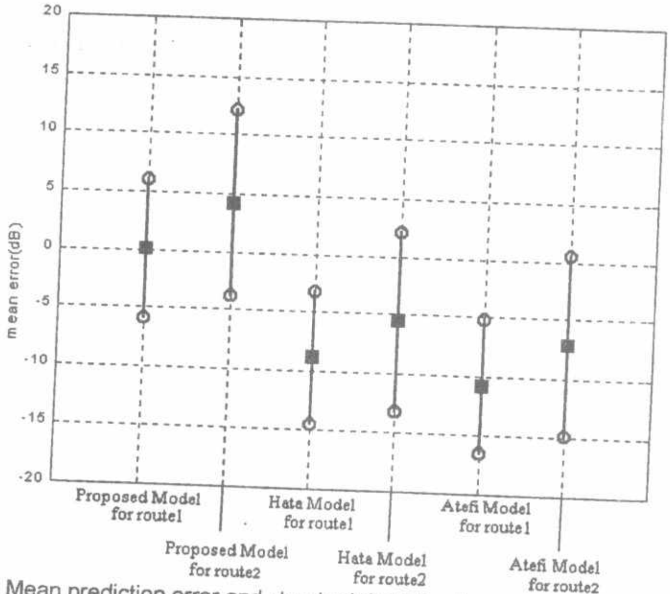

Fig.6. Mean prediction error and standard deviation for propagation models

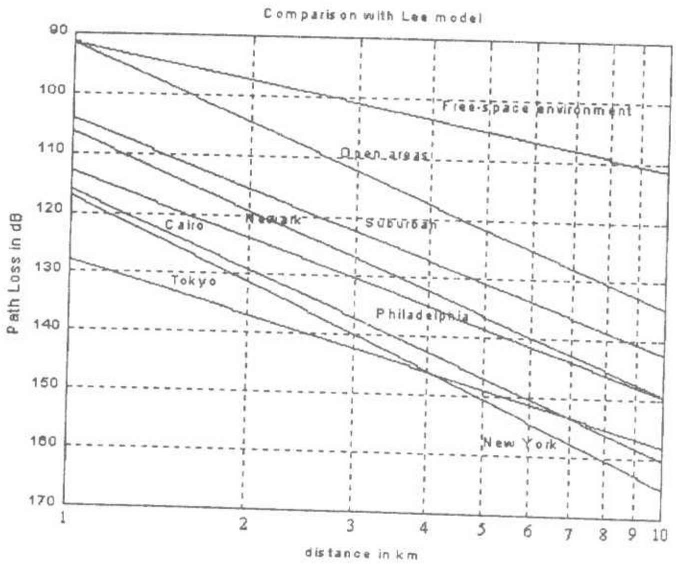

Fig.7. Lee model and the proposed model as function of distance large than 1 Km