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RESEARCH ARTICLE

MEASUREMENTSBASEDEVALUATION OF PATHLOSSEXPONENTS IN URBAN OUTDOORENVIRONMENTS

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Abstract

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In wireless networks, propagation models are used to assess the received power signal and estimate the propagation channel. These models depend on the pathloss exponent (PLE) which is one of the main parameters to characterize the propagation environment. Indeed, in the wireless channel, the path loss exponent has a strong impact on the quality of the links and must therefore be estimated with precision for an efficient design and operation of the wireless network. This paper addresses the issue of path loss exponents estimation for mobile networks in four outdoor environments. This study is based on measurements carried out in four outdoor environments at the frequency of 2600 MHz within a bandwidth of 70 MHz. It evaluates the path loss exponent, and the impact of obstacles present in the environments. The parameters of the propagation model determined from the measurements show that the average power of the received signal decreases logarithmically with the distance. We obtained path loss exponents values of 4.8, 3.53, 3.6 and 3.99 for the site 1, site 2, site 3 and site 4, respectively. Clearly the density of the obstacles has an impact on the path loss exponents and our study shows that the received signal decrease faster as the transmitter and receiver separation in the dense environments.

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Introduction:-

The propagation of radio waves depends on various factors such as reflection, refraction, and diffraction [1]. Propagation methods are important to calculate the coverage of mobile networks in outdoor environments.

These models predict the signal power at a given point by determining the path loss, that is, the difference between the transmit power and the received power, from the base station to the mobile station. They are particularly important for planning new network deployments, processing field measurements, as well as network simulation environments [2]. However, to produce accurate simulation results of a given environment, it is important to faithfully determine the parameters of these propagation models, in particular the path loss exponent.

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An over or under estimation of the path loss exponent results in large differences in the received power produced by the simulation tools. Therefore, precise estimation of path loss exponent is required.

Moreover, the path loss or received power prediction is valuable in the power control [3].

This paper presents a generic practical analysis of path loss exponents. The experiment is performed in urban outdoor environments, at a frequency of 2.6 GHz. The Received Signal Strength Indicator (RSSI) measurements were obtained over one thousand meters (1000 m) to determine path loss exponents and the standard deviation of the log-normal fading. From the simulations performed on the MATLAB platform, we have represented the point clouds of the measured powers as well as the lines of the linear regressions for four different environments called: site 1, site 2, site 3 and site 4. Then the path loss exponents were calculated from the measurement data and the path loss equations were determined and compared.

This article is organized as follows: Section II presents the theoretical concepts of radio propagation models. Section III discusses work on pathloss and path loss exponents. Section IV describes the environments and the methodology for the measurements. Section V describes the simulation scenarios, and the experimental results are shown as well. Finally, Section VI ends the paper with a conclusion, and prospects for further research.

Related Works:

Propagation models for large-scale outdoor wireless networks include free space, two-ray ground, and lognormal shadowing models [2]. Radio propagation is important for growing technologies, with appropriate design, development, and management strategies for any wireless network. It is specific to a given environment and varies considerably depending on the terrain, the frequency of use, the speed of the mobile terminal, and many other parameters [4].

Propagation models are used to characterize the losses or attenuations suffered by a signal between a base station and a mobile station. One of the most important parameters to consider is the distance, because as the distance increases, the received signal decreases [5][6][7]. This phenomenon is the large-scale fading. When obstacles are present, multiple copies of the original signal are generated from reflection, diffraction, scattering with different phases and amplitudes and the signal power is decreased. This last phenomenon is the small-scale fading. Indeed, the signal power in any wireless communication system is governed by the environment and depends on the distance, the transmission frequency and the obstacles between base station and mobile stations. Thus, the attenuation of signals at different frequencies and distances depends on the environment and is predicted by propagation models. These models give different results in different environments. In addition, one of the underlying difficulties in applying a path loss prediction model is that the environments do not have the same composition. It is therefore difficult to formulate an exact propagation model for all environments. To solve these problems, the parameters of some propagation models must be adjusted with reference to the target environment. The path loss can be calculated by the following equation [1]:

$$P_{RX} = EIRP - PL \quad (1)$$

Where P_{RX} is the Received Power (dBm), PL is the path loss (dB) gives an estimate of the loss that the transmitted signal undergoes, it indicates the quality of a radio environment. The knowledge of the path loss allows that of the received power, as indicate in (1).

A general propagation model which includes the path loss exponent and the shadow fading factor is given by the following equation:

$$PL = PL_0 + 10\gamma \log(d) + X_\sigma \quad (2)$$

where γ is the path loss exponent, representing the slope of the equation in it linear form. X_σ represents a zero-mean Gaussian random variable (dB) with standard deviation σ and PL_0 is the intercept point at the reference distance $d_0 = 1\ m$. d is the separation between the transmitter and the receiver.

The path loss can bedeterminedfrom the receivedpowersor the RSSIduringmeasurementcampaigns in a real environment.

The path loss can be determined from the received powers or the RSSI during measurement campaigns in a real environment.

The average received power decreases logarithmically with the distance between the transmitter and the receiver. A Gaussian random variable is added to this pathloss to account for environmental influences at the transmitter and receiver [8].

In most models, the path loss exponents need to be measured. The path loss exponent (PLE) is a parameter indicating how quickly the received signal strength varies with distance. Its value depends on the specific propagation environment.

Measurementcampaigns:
The measurement campaigns were carried out to determine our propagation equation. This section describes the progress of the measurement campaign.

Description of The Measurements Environnement:
Measurements were carried out in four different environments in the city of Fez Morocco, at the frequencies of 2600 MHz with a bandwidth of 80 MHz These environments are characterized by the density of obstacles, such as buildings, houses, and trees. It is also important to indicate the presence of some trees is less than buildings and houses. The difference between these environments is about the density of the obstacles, buildings to buildings distance that vary from fifteen meter (15 m) to thirty meters (30 m), the average buildings heights that can reach forty meters (40 m) and street widths that is around thirty meters. The transmitter coverage distance ranges from one (1) to two (2) kilometers (Km). We specify that the site 2 and site 3 have similar configurations in terms of obstaclescompared to the others (figure 2).

Figure 1:- General view of two environments.

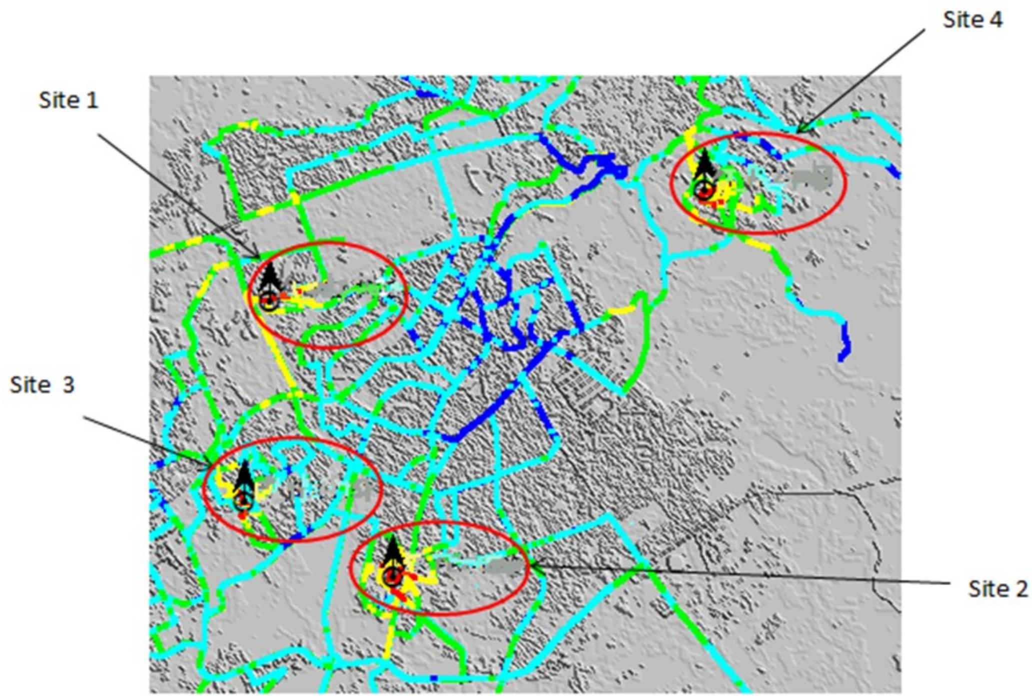

Figure 2: -Position ofdifferentsites.

The figure 2 shows the map of the different environments where the radio measurements were performed. The geographical coordinates of the measurement environments and the heights of the transmitters are presented in Table 1.

Base station	Latitudes	Longitudes	Height(m)
Site1	34,0397	-5,0314	26
Site2	34,00245	-5,01357	23
Site3	34,013	-5,03674	21
Site4	34,05214	-4,96199	26

Table1: - Base station characteristics.

Measurementsequipments and methods: -

Measurementsequipments:

To ensure that a good model reflecting the reality of predictions with the maximum fidelity is obtained, an analogue measurement chain is used to collect the measurements during the drive test campaigns. The used received antennas are magnetic antennas located on the roof of the car. A geo localization software was used to trace the route and analyze the power of the acquired measurements. The transmission chain is composed of the following equipment shown in Figure 3:

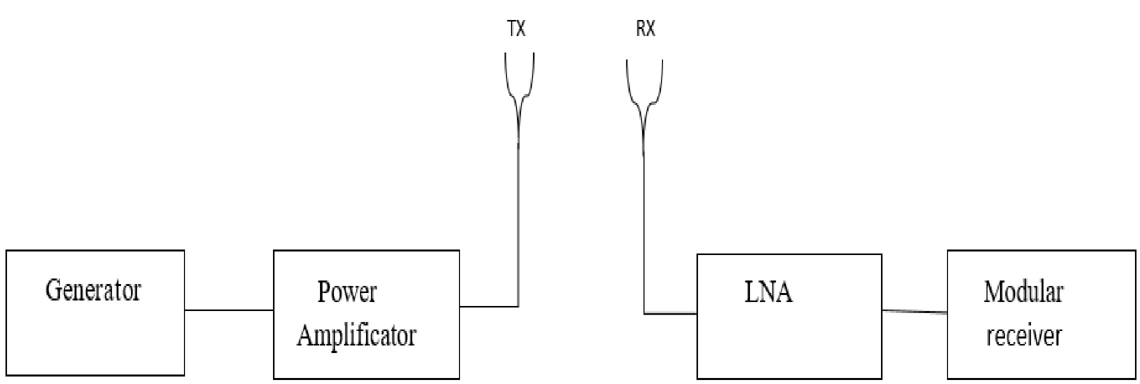

Figure 3:- Simplified transmission chain.

The transmission chain is composed with an analog signal generator, an amplifier, and a wideband omnidirectional antenna. The generator is of type Agilent N9310A with a maximum power of 13 dBm and a frequency range of 0.9 - 3 GHz. The amplifier is an Amplifier Research 25S1G4A and has a 16 dBi gain within a frequency range of 0.8 - 4.2 GHz.

The reception chain is composed of a multi-band receiver, GPS, and magnetic antennas. The receiver is Coyote Modular Receiver and can support several bands by changing the appropriate modules. It is a Berkeley Varitronics Systems Coyote Modular Receive type with a sensitivity range of -118 dBm / -30 dBm to +/- 1 dB, adjacent channel rejection greater than 45 dB. The GPS is a modular receiver composed of 12-channels with active antenna. The magnetic antennas have cable gains and losses which are compensated by the reception modules.

Measurementmethodology:

The measurements were performed using Continuous Wave (CW) analog signals with sample rates that respects the criterion of Lee to eliminate the problems related to fast fading. The number of samples can be configured at the receiver side. We used approximately 256 samples per second for all bands. For each frequency, the number of samples, the averaging and the exact frequency of reception have been fixed. As already mentioned, the number of samples per second is between 128 and 256.

During this measurement campaign, the minimum duration of drives test was three hours, and the radius was at least 1 km in all the sites. Measurements started when all the conditions were met and with the aim of obtaining regular measurements, the following conditions were met:

1. Stay in the samesoil class as much as possible.
2. Avoidcoming back several times on the same route
3. Driving at low speed (max 50 km/h)
4. Stop when the fieldweakens (< -115 dBm)

Simulation's interpretations of results and validation:

Simulation and interpretation:

In mobile radio propagation channels, the received signal strength varies with time, space, and frequency. During the measurement campaigns, the mobile receiver powers were collected. Concerning the processing of these data, we represent the path loss point clouds as well as the linear regression lines for four (4) environments from equation (1). This method allows us to characterize our study environment by determining the path loss exponents (γ) for each environment.

The figure 4, figure 5, figure 6, and figure 7 show the path loss at 2600 MHz for the site 1, site 2, site 3 and site 4, respectively. The path loss is calculated from (1).

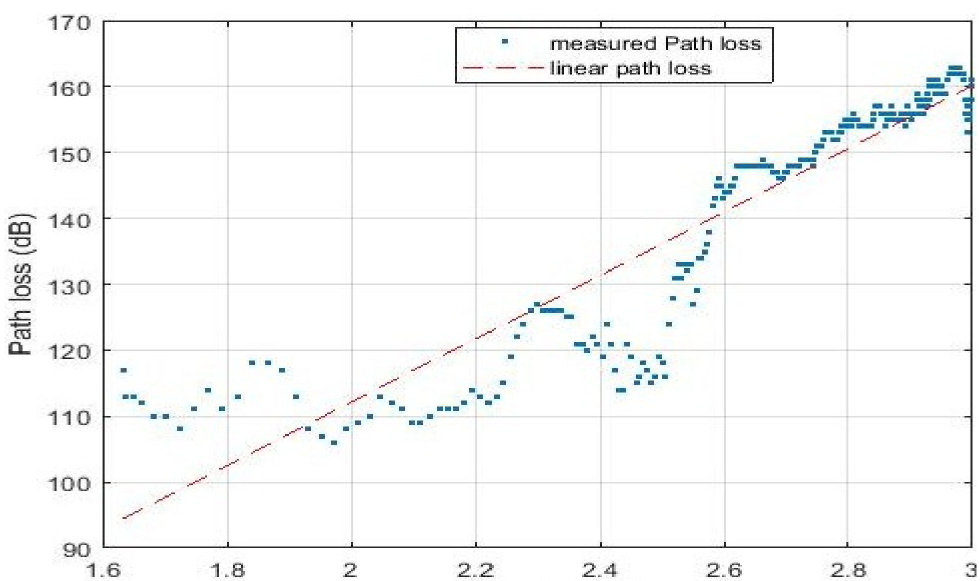

Figure 4:- Pathloss for site 1.

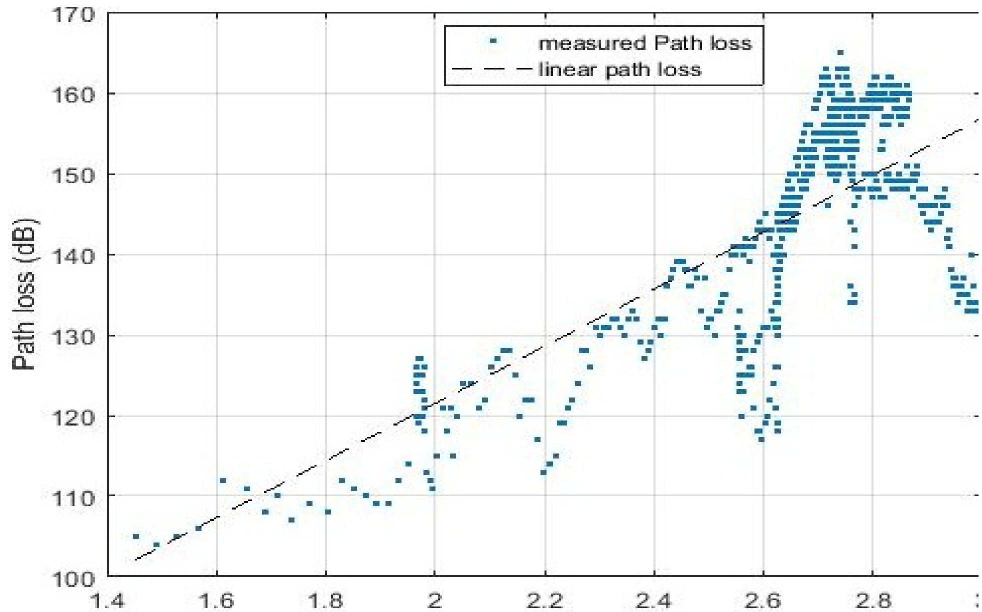

Figure 5:- Pathloss forsite 2.

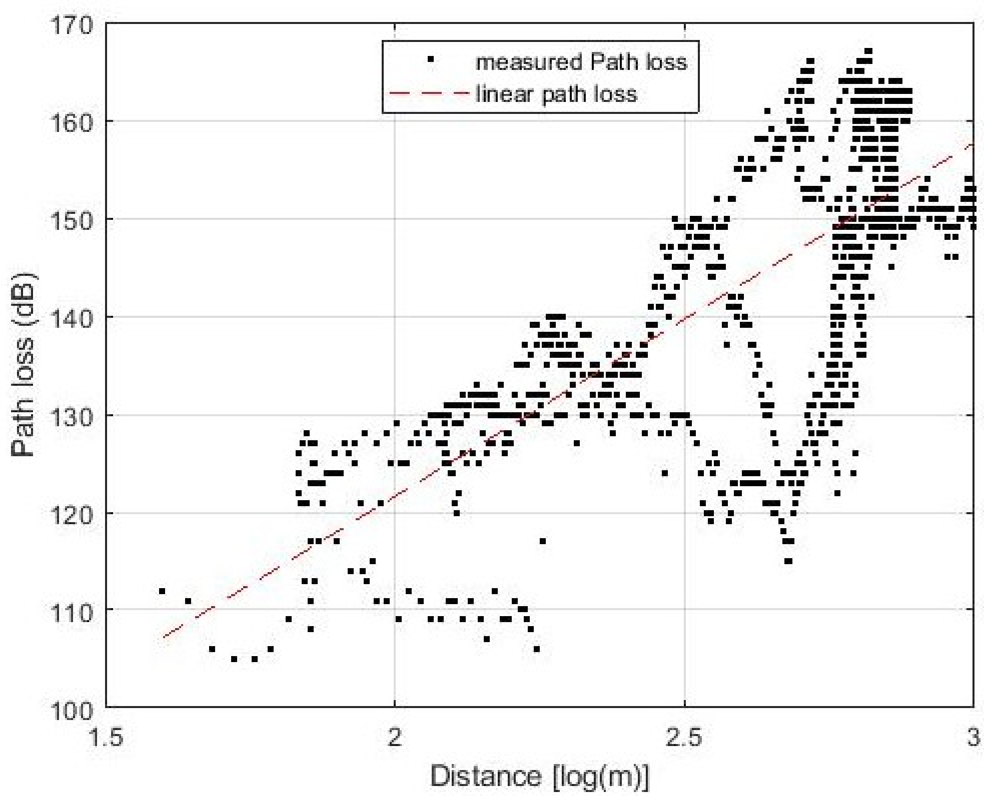

Figure 6:- Pathloss forsite 3.

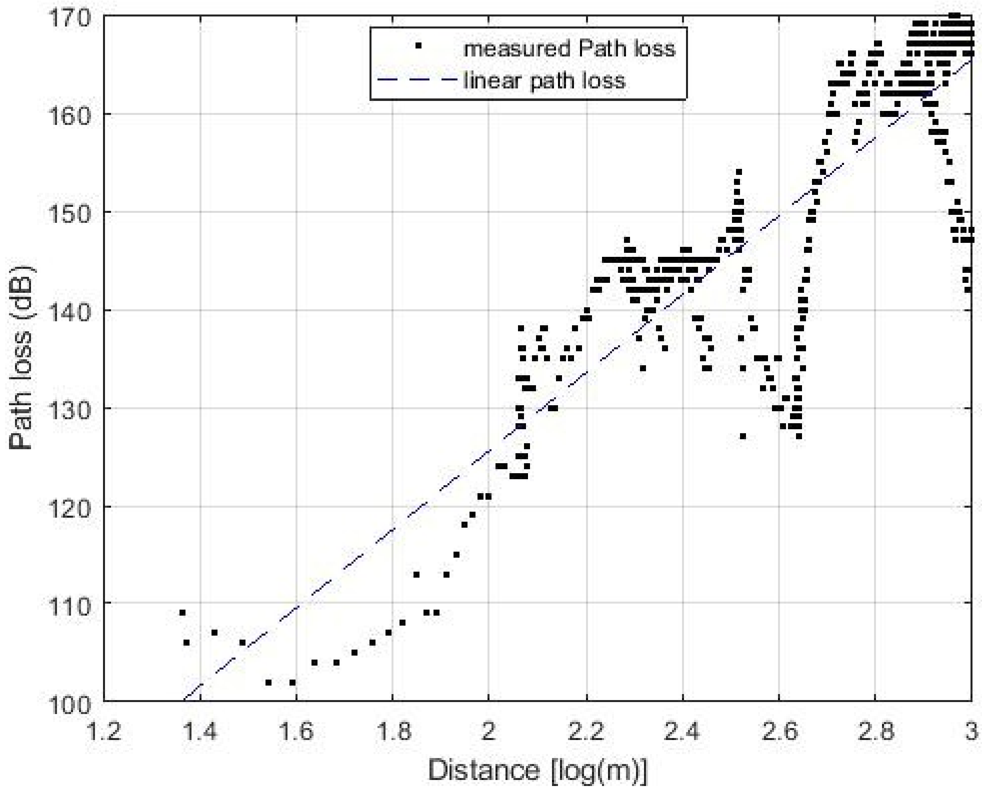

Figure 7:- Pathloss forsite 4.

Figures 4 to figure 7 show that the path loss values increase with increasing distance. The colored points represent the measured propagation losses, and the lines their linear regression. For the site 1, site 2, site 3, and site 4, we have determined the path loss in 256, 740, 1214, and 660 measurement points, respectively. We determine the parameters expressed in (2) i.e., γ, PL_0 et X_σ, from the measurements. Among these parameters, the path loss exponent is the most important as it represents the slope of the linear regression line.

Tables 2:- summarizes the different parameters of the model.

Sites	Site 1	Site 2	Site 3	Site 4
γ	4,8	3,53	3,6	3,98
PL_0	15,90	50,71	49,46	45,68
mean (X_σ)	-5.1181e-14	-3.3568e-14	-1.6374e-13	6.7609e-15
Standard Deviation(σ)	6.81	9.78	10.19	7.90

Table 2:- Parameters of the model.

We note that the average path loss exponents range from 3.53 to 4.8. The largest of these values is very close to 5, and corresponds to site 1, which proves that we are in an outdoor environment with a high density of obstacles around the transmitter. The lowest path loss exponent corresponds to the site 2. The obtained values of path loss exponents then justify the strong presence of obstacles in the measurement environments.

We notice that the path loss exponent values and intercept points PL_0 for sites 2 and 3 are very close. This is explained by the fact that these sites are adjacent and have practically the same environmental configuration. The difference in path loss exponent values is due to the non-uniformity of obstacle density in the propagation zones.

We observed that the mean values of the parameter X_σ is zero (0) for all the sites. The distribution of the shadowing values is the same for all the sites. Therefore, we can say that the parameter X_σ is a Gaussian random variable with a zero mean value and with standard deviation σ and it characterizes the shadowing effect.

Results validation:

To validate our study, we compare the obtained results with the literature. In [9], the measurement results show that the path loss exponents in a specific rural wireless at 2.4 GHz vary from 1.2 to 2.2. The path loss exponents values from 2 to 2.85 are obtained for an 802.11 WLANs outdoor environment at 2.4 GHz [2]. [10] found values of the path loss exponents from 2 to 5 for frequency from 0.5 GHz to 30 GHz. The path loss exponents measured in [11], range from 1.86 to 2.08 for a wireless sensor network at 2.4 GHz. In [12], the path loss exponents values range from 2.2 to 3.32 at 3.705 GHz.

Comparing path loss exponent values from our experiments those found in literature, we obtain a good agreement.

Conclusion et perspectives: -

In this paper we have determined the pathloss exponents for a mobile network in outdoor urban environments. Our study was based on measurements of the received powers of a mobile station in urban environments. We determined the parameters of the propagation equation from which a propagation model was developed. This propagation model is developed for mobile networks using 2.6 GHz frequencies in urban outdoor environments. We obtained the values of the following propagation exponents: 4.8, 3.53, 3.6 and 3.98 for site 1, site 2, site 3 and site 4, respectively. Our results are consistent with the scientific results from the literature and correspond to the values of the propagation exponents in urban environments.

As future work, we will extend our research to several frequencies to experiment with different mobile network technologies, especially the 5G technology. Also, we will study the impact of these propagation exponents on power control in a propagation channel. Finally, we may conduct the study in an indoor environment.

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