

# People and Furniture Effects on the Transmitter Coverage Area

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**Abstract** — The main goal of this paper is to show the difference of the signal propagation in an environment setted in three differents ways: with people and furniture, only furniture and empty. Two measurement campaigns are accomplished to analize these environment configurations. The first one was a classroom measured at 1.82 GHz and the second one was a research laboratory measured at 2.4 GHz.

**Index Terms** — radio-channel characterization, propagation loss, mobile communications, WLAN

## I. INTRODUCTION

After the huge success of the cellular systems, with millions of users around the world, with several high quality services being offered by diverse cellular companies, the wireless networks started to occupy an important position in the communication general scenary. People began to think in local networks that could offer the same services of the network wired with mobility and implantation easiness of a wireless system. They developed, then, the wireless local area networks (WLAN). These networks present an enormous implantation advantage, once it is not necessary any change in the building structure where the service will be implemented, and they still allow mobility to the users, in other words, they do not need to be physically in their offices to develop their tasks [1].

The WLAN's use a frequency band known as unlicensed radio band, that reduces the cost and the bureaucracy in the installation of the networks; however, an interference problem can appear among the nets. For instance, if two companies in neighboring buildings (or even in the same building, however, in different floors), use the WLAN for the communication and both are in the same frequency band, a net can interfere in the signal of the other, because of this way, it is necessary to study each access point coverage area to propose a reuse frequency plan.

Therefore, an important aspect in the project of a mobile communication network (considering a cellular system or a WLAN) is to determine, or at least to estimate, the transmitter coverage area. This area depends on several factors of the propagation loss presented by the radio signal since it leaves the transmitter until it arrives to the receiver.

In the specialized literature are described several models that try to predict the signal propagation loss in indoor and outdoor

environment. These models can be deterministic or empirical [2]-[5].

A disadvantage found in several indoor empirical models studied [2]-[5] it is the no consideration of the people and furniture presences in the environment studied, in other words, they try to predict the propagation loss aim to do a better coverage area planning and, due to this, to provide good services to attend the users. However, in general, the project is made considering the empty environment and without the user's presence.

This work aim to determine the propagation loss from measurements, due to the people and furniture presences in the environment, besides to make an error analysis presented by some models when the environment is empty or when there is furniture and/or people presents.

To determine the loss due to the people and/or furniture presences in the environment, two measurement campaigns were accomplished. The first campaign was accomplished at a classroom in three configurations. In the methodology used in that campaign, described with more details in the following session, measurements were made in the same points of the classroom, with the same equipments and under the same conditions for the room firstly empty, after with furniture and later with furniture and people. The second measurement campaign was accomplished at a research laboratory, containing several computers. The possible configurations in this last case were with the presence and people's absence (it was not possible to remove the furniture). After the treatment of the acquired data, some results were obtained and they will be described in this work, that is organized like this: Section II presents the methodology used and results obtained in the campaign accomplished at the classroom; section III presents the methodology used and the results obtained in the campaign accomplished at the laboratory and the section IV presents the conclusions obtained in this work.

## II. CLASSROOM

### A. Environment and Equipments

The first measurement campaign was accomplished in a classroom with 5m of width, 5m of length and a ceiling height of 2.85m

The transmitter set was composed by sweeping generator (model HP-837620), an amplifier and a dipole antenna (with gain of 2.14dB) irradiating a signal of 28dBm at 1820 MHz.

The receiver set used is shown at Fig. 1, being constituted by a receiver TEMS (with gain of 0dB) and a notebook running a TEMS's proprietary software, which has the function of storing the power values measured in each point.



Fig. 1. Receiver System.

### B. Methodology of Measurement

The classroom was subdivided in 25 smaller areas in whose centers the measurements were accomplished (Fig. 2). The receiver was moved in circles [6]-[7] in a 1.10m mean height of the ground for the data collection, in order to obtain a measurement area. It is important to stand out that of the 25 divided areas only 24 were indeed used, because there was an area with a shelf that could not be removed of the room. In each point of measurement were stored 10,000 samples of the received power of a sweeping generator that was located in the exterior of the room at 1.45m height and at 1.20m distant of the wall that separates the corridor and the classroom.

The procedure of measuring in the 24 points above mentioned, it was repeated for three room configurations: empty, see Fig. 3(a), only with furniture, Fig. 3(b), and with people and furniture, Fig. 3(c). Emphasizing that the conditions of the equipments remain the same ones during the three configurations of the measurement.

The present furniture is typical of a classroom consisting of 25 student chairs, a teacher's table and a shelf with television. To configuration with people were present 15 students, disposed randomly.

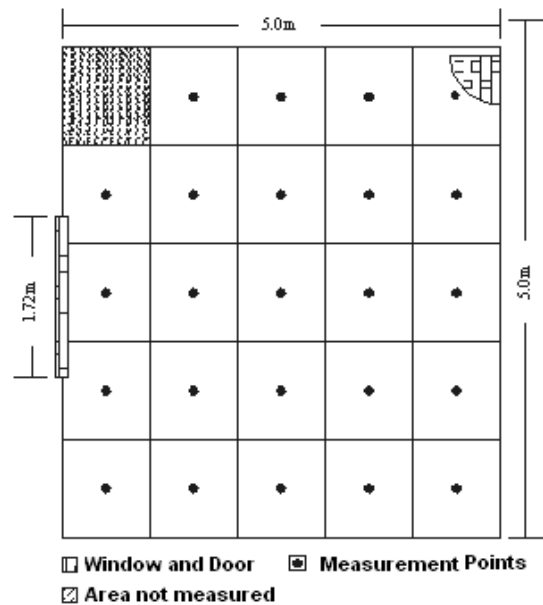
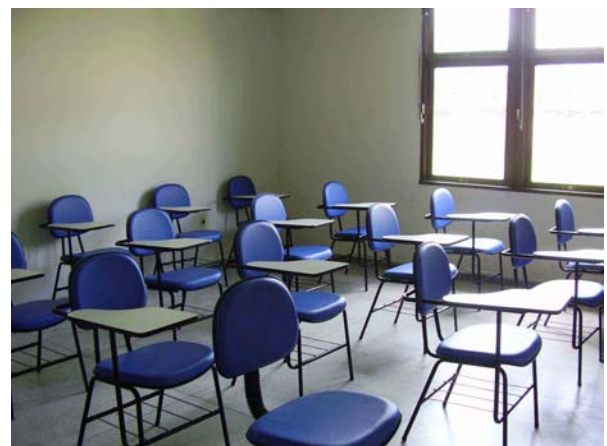


Fig. 2. Illustration of floor plan of the classroom where the measurement was accomplished.



(a)

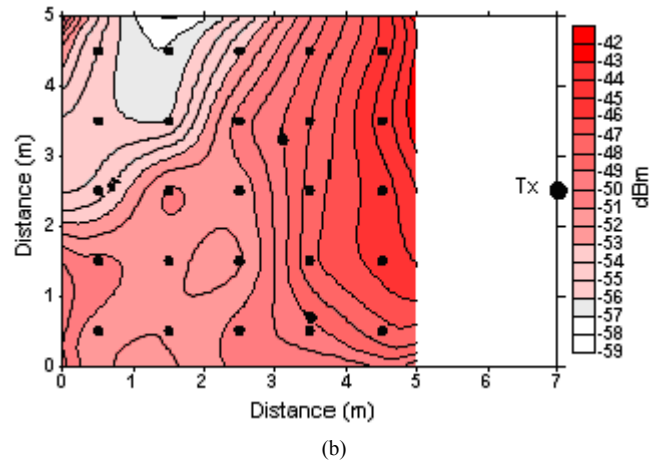


(b)

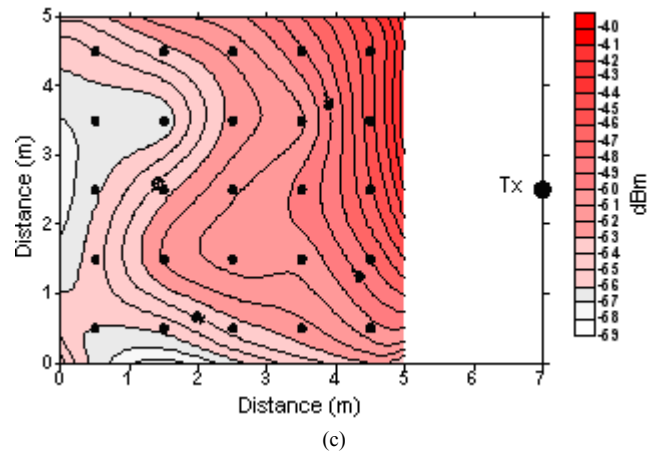


(c)

Fig. 3. Classroom at 3 configurations: (a) empty, (b) furnished, (c) furnished and with people.



(b)



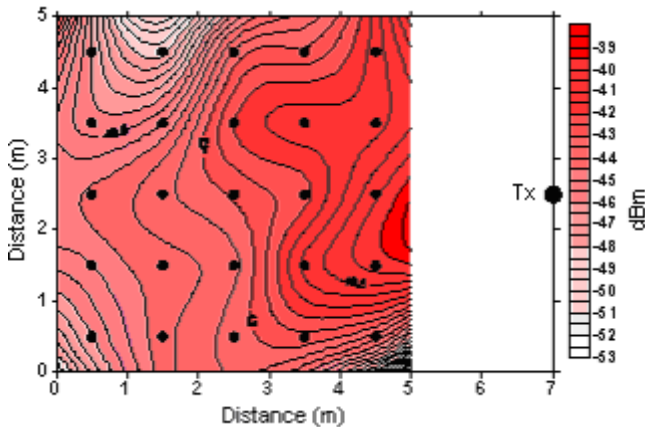
(c)

Fig. 4. Results of interpolation in the configurations: (a) empty classroom; (b) furnished classroom and (c) furnished and with people classroom.

### C. Results

After the measurement campaigns, the results were treated and in each measurement point was obtained the mean power received. Through these averages the analyses were accomplished to determine the people and furniture effects in the power received and in the propagation loss.

The Figs. 4(a)-4(c) indicate the power levels received in the empty classroom, only with furniture and with people and furniture, respectively. The blacks smaller points represent the measurement points, the larger black point (Tx) indicates the position of the transmitter that was located out of the room. Figs. 4(a)-(c) were generated by the program Surfer 8. That program makes available several interpolation methods that can be used to extrapolate and to interpolate the power received in the areas where measurements were not accomplished. The interpolation used in this work was minimum curvature, because this method emphasizes the local properties in the measurements space avoiding disturbances of distant measures. The more forts colors are concerning the highest powers, as shown the scales beside the Illustrations.



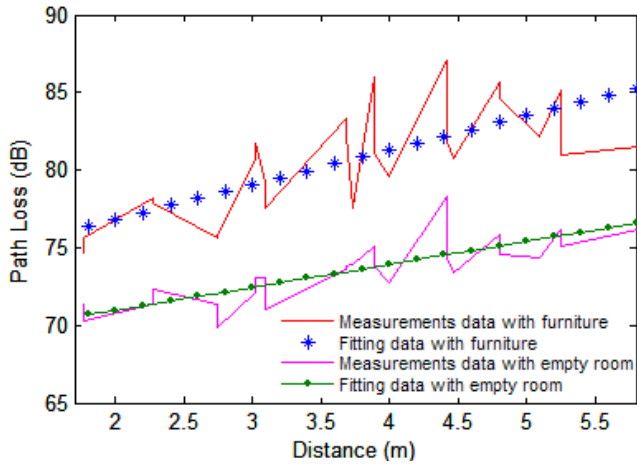
(a)

From Figs 4(a)-4(c) it is possible to verify how the furniture and the people influence in the signal power received. Another approach form is shown in Fig. 5(a)-(b), that presents the loss obtained through the power measured in each point and their linear fitting in the three configurations of the classroom. Fig. 5(a) presents the loss obtained starting from the power measured with the unfurnished and furnished classroom, through their linear fitting is possible to verify that the difference in the propagation loss between the two configurations is 6.33dB. Fig. 5(b) presents the same results for empty classroom and the classroom with furniture and people. The loss difference in these configurations is 7.64dB. The mean loss value obtained in the classroom configurations only with furniture and with people and furniture is 1.31dB that demonstrates that the loss due to furniture is very larger if compared with the loss obtained by the people's presence.

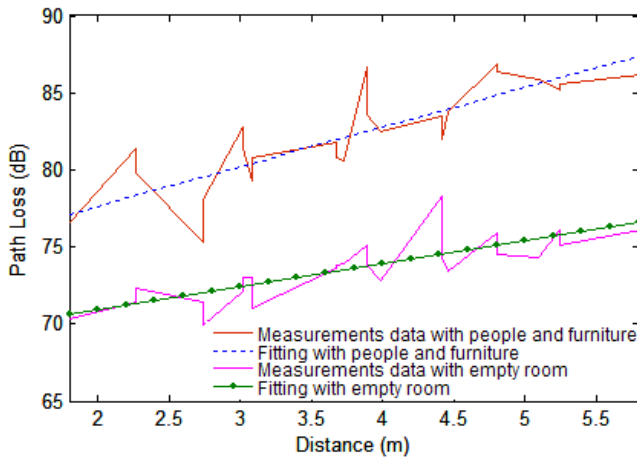
The path loss versus distance was computed using [8]:

$$L(dB) = \alpha(dB) + 10n \log(d) \quad (1)$$

Where  $\alpha$  is a constant,  $d$  is the distance between the transmitter and receiver (in meters) and  $n$  the path loss exponent that indicates the path loss with the distance.



(a)



(b)

Fig. 5. Path loss versus radio distance: (a) empty and furnished classroom; (b) empty and furnished and with people classroom.

The Table I presents the values of  $n$  and the mean path loss for each configurations measured.

TABELA I  
PATH LOSS EXPONENT AND THE MEAN PATH LOSS FOR EACH ROOM CONFIGURATIONS

	Empty	Furnished	Furnished and with people's presence
$n$	1.14	1.8	2.01
$L(\text{dB})$	73.05	79.38	80.69

It is evident, therefore, that the people and furniture presences in an indoor environment influence, significantly, in the propagation loss of the signal measured. So it is very important that an empiric model of good accuracy presents, at least, a term that incorporates the presence of people and furniture in the environment.

To validate the previous affirmative, the prediction errors obtained through two models very known in the literature were analyzed. This analysis was accomplished comparing the mean error obtained between the measured loss and the predicted

loss for three configurations of classroom environment. To follow will be presented the models used and their prediction results.

#### D. ITU-R Model

In this model, the attenuation due to obstacles in the same floor (walls, columns, etc) is included implicitly in the attenuation factor with the distance, and the floor loss is accounted for explicitly, how shown in the follow equation:

$$L = 20 \log(f) + 10n \log(d) + L_f(n_f) - 28 \quad (2)$$

Where  $f$  is the transmission frequency,  $n$  is the path loss exponent,  $d$  is the distance between transmitter and receiver and  $L_f(n_f)$  is the floor penetration loss, which varies with the number of penetrated floors  $n_f$  [3].

#### E. Wall and Floor Factor Models (WLL)

This model considers the signal attenuation when it cross obstacles in the same floor (walls and columns) and different floors [3].

$$L = L_l + 20 \log(d) + n_f a_f + n_w a_w \quad (3)$$

Where  $a_f$  and  $a_w$  are the attenuation factors (in decibels) per floor and per wall, respectively;  $L_l$  is the loss in  $d=1\text{m}$ ;  $n_f$  and  $n_w$  are the number of floors and walls crossed, respectively.

#### F. Results of Comparisons

The Table II presents the prediction errors obtained for the three classroom configurations. Observe that, in relation to the error obtained when the environment is empty, the error increases when the environment is furnished, and it continues increasing when there are furniture and people in the environment. That happens because in the equations of these models no have any parameter that considers the presence of those obstacles.

TABELA II  
MEAN ERROR FOR EACH ENVIROMENT COFIGURATION

Model	Empty	Furnished	Furnished and with people's presence
ITU-R	28.763 (dB)	35.938 (dB)	37.345 (dB)
WLL	22.687 (dB)	29.861 (dB)	31.268 (dB)

### III. LABORATORY

In the building of the Electric and Computation Engineering Laboratory of the Federal University of Pará (UFPA) a wireless network (WLAN) is installed for to serve the local demand. For so much, it is installed at the Laboratory of Applied Electromagnetism (LEA) (located in the second floor of the mentioned building) an access point (AP) that was used as transmitter in the measurement campaign accomplished in LEA. This access point operates at 2.4 GHz, with 15 dBm of power transmitter. This laboratory presents 4 environments, but

only 3 were used. A plan illustrating the configuration into the laboratory is shown in Fig. 6.

In this laboratory 20 points of measurement were selected along the environment, the blue points of Fig. 6. In each point were collected, during approximately one minute, power samples of the signal received by a notebook equipped with a wireless network board. The reception and storage of the signal level were accomplished through the NetWork Stumbler software.

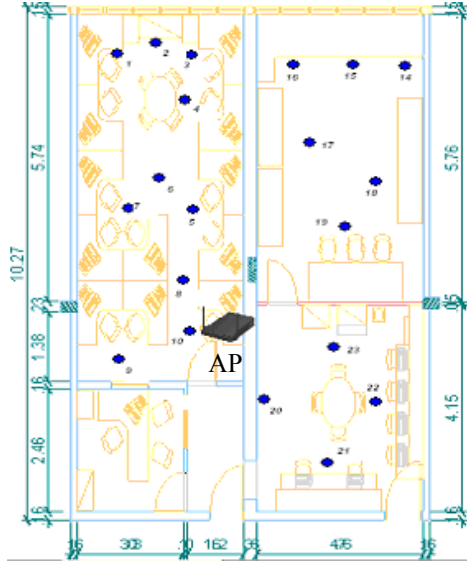


Fig. 6. Location of the points of measurement in the laboratory floor plan.

In this measurement campaign the environment was evaluated in two situations: with and without people. After the treatment of the obtained data, it was possible to generate the Fig. 7, that presents the propagation loss with the distance obtained starting from the power measured and the linear fitting corresponding for the two configurations of the environment studied. Again it is evident the difference in the propagation loss when the environment is with or without people.

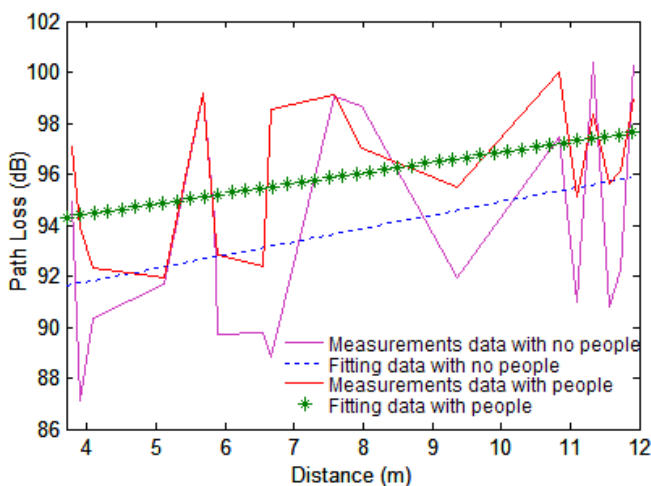


Fig. 7. Measured power versus radio distance.

The mean power received at the laboratory when it is only with the furniture is  $-72.03\text{dBm}$  with a propagation loss of  $92.03\text{dB}$ . For the configuration with people and furniture the mean power received was  $-75.24\text{dBm}$  with a corresponding loss of  $95.24\text{dB}$ . Therefore, there is a difference of  $3.21\text{dB}$  in the propagation loss in relation to the two tested configurations.

#### IV. CONCLUSION

In the cellular systems and in the WLAN's the determination of the coverage area of the transmitter is a critical factor for the good performance of the system. There are several propagation loss models in the literature that try to make a prediction of the coverage area of the transmitter. Most of these models, however, don't consider the people and furniture presence in the environment, which elevates the prediction errors of such models.

In this work two measurement campaigns were accomplished in the  $1.8\text{GHz}$  and  $2.4\text{GHz}$  bands, demonstrating that the people and furniture presence in the environment cause attenuation in the signal propagation. Tests accomplished with two known models demonstrate that the prediction error increases when it is introduced furniture and people in the environment, proving the need to insert a term that considers these obstacles. In this way, it would be possible to determine with good accuracy the coverage area of a radio base station or an access point, consequently, the quality of the offered service and the good performance of the networks would get better because the frequency reuse distance could be determine with better accuracy and, this way, the interferences would decrease.

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