Experimental Characterization of Indoor Mobile Radio Channel in 700 MHz Band

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***Abstract*—Characterization of the indoor mobile radio channel in the 700 MHz band is obtained from experiments carried out in the indoor environment of the Engineering building in Fluminense Federal University. From the processed data, the power-delay profiles obtained permitted to calculate the time dispersion parameters and the statistics of the signal variability, concluding about the use of this band in cellular systems in Brazil.**

Keywords – channel characterization; channel statistics; delay spread;power-delay profile; signal dispersion.

I. INTRODUCTION

The access to mobilenetworks has been growing notoriously throughout the world. The demand for this service was mainly due to the advance of the Internet access through mobile phones, smartphones, which made mobile network grow proportionally. The 4G (fourth generation) networks, already in operation in many countries, have been gradually installed here in Brazil. Initially, LTE (Long Term Evolution) technology started on band 7–2600 MHz. However, with the deactivation of the open TV, the 700 MHz band (named band 28) was released for cellular systems [1]. Thus, the need for studies in this band for LTE is fundamental for a better understanding of the behavior of mobile radio channel in 4G technology, so that a wireless communication system is correctly projected.This work contributes with the experimental study of time dispersion and statistics of an indoor reception signal coming from an outdoor transmission. For that, this paper is structured as follows: Section II describes the used transmission and reception systems, besides the measurement environment; Section III deals with the channel characterization and the results; and Section IV provides the conclusions of this work.

II. SOUNDING SYSTEM SPECIFICATIONS

The environment chosen for measurements was the Engineering School building of Fluminense Federal University in Niterói city, Rio de Janeiro, Brazil. Fig. 1 shows an aerial view of the outdoor environment where are highlighted the transmission point (TX) and the sounded Engineering School building, marked as RX, in red line. Black and blue lines show, respectively, the distance of the initial and the final points to the transmitter.

On the day of the measurements, the weather was clear, without wind or rain. The transmission system was fixed, placed in the rooftop of Physics Institute building. The reception system was mounted in a mobile platform, moved at a speed of 1.2 m/sapproximately, along the five floors and the hall of Engineering School building [2].

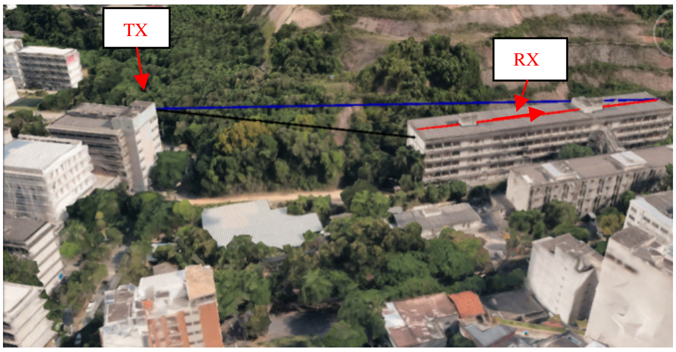

Fig. 1. Outdoor view of the measurement scenario.

A. *Transmission Setup*

The equipment and devices used in the signal transmission are listed in Table I.

TABLE I. TRANSMISSION SETUP SPECIFICATIONS

Equipment/Device	**Specification**
Vector Signal Generator	Anritsu MG-3700A
Power Amplifier	Minicircuits ZHL-16W-43+
Digital Power Supply	ICEL PS-5000
Sectorial Antenna	RFS APX75-866512-CTO Beamwidth: 65 degrees Frequency: 698-896 MHz Gain: 14 dBi
Cable RG 213	Cable 1: 1 m, with 0.2 dB loss Cable 2: 6 m, with 1.33 dB loss

In the narrowband sounding, a 768 MHz carrier was transmitted to the channel and whereas in the wideband transmission, a 20 MHz bandwidth OFDM signal, previously generated in a MATLAB programming environment, was transferred and saved in the memory of the vector signal generator at the laboratory. At the generator output, the power level was -11 dBm, taking into account the saturation curve of the power amplifier (PA). For the PA, the signal was conducted so that the power saturation did not occur. Its biasing was performed by the PS-5000 power supply. From the PA, the signal followed the sector antenna. In Fig. 2 is the block diagram of the transmission setup.

The information signal transmitted was a pseudorandom sequence with OFDM modulation. The number of carriers chosen was equal to 1024 and the number of samples of the cyclic prefix was 128, as used in [3]. Then, these values were transformed into complex symbols and converted to time domain. The cyclic prefix was inserted and the real and imaginary components were separated to form the phase and quadrature components of the OFDM signal.

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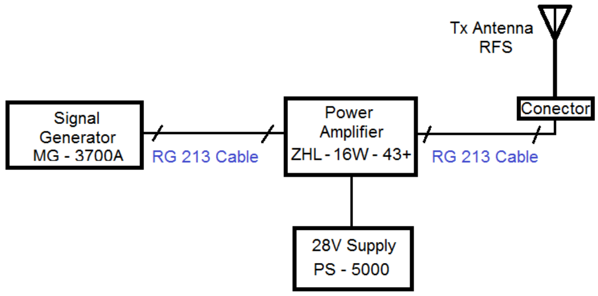

Fig. 2.Block diagram of the transmission setup.

B. Reception Setup

The antenna was installed on a mobile stand and a RG213 cable led the received signal to the input of the low noise amplifier (LNA), polarized by the 5 V source. The LNA was connected to the MS2692A, which was used as a spectrum analyzer acquiring samples of the received carrier, for the narrowband sounding, and as a signal analyzer capturing "I" (phase) and "Q" (quadrature) samples of the OFDM signal, at a rate of 50 MSamples/s. The data were transferred to the laptop via the network cable. To measure the location of the points, a GPS (Global Positioning System) device was connected to the laptop via USB (Universal Serial Bus) cable. The reception setup block diagram is described in Fig. 3. Table II provides the setup specifications.

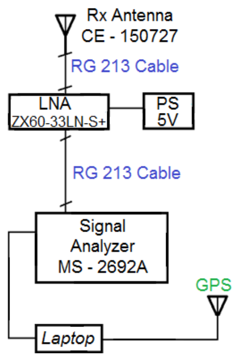

Fig. 3.Block diagram of the reception setup.

TABLE II. RECEPTION SETUP SPECIFICATIONS

Equipment/Device	Specification
Omnidirectional Antenna	CE-150727 Gain: 2 dBi for 760 MHz
GPS Device	GPS GarminMap 64S
Low Noise Amplifier (LNA)	Minicircuits ZX60-33LN-S+ Gain: 19.6 dB for 760 MHz
DC Power Supply MPL-1303 M	5 V
Signal Analyzer	Anritsu MS-2692A
Laptop	*Dell Inspiron* 15
4-cable RG 213	6 m, with 1.5 dB loss
2-cable RG 213	1 m, with 0.2 dB loss

III. CHANNEL CHARACTERIZATION AND RESULTS

A. Wideband characterization

The wideband characterization starts from the received signal after a matching filter, by software. Then, this output $h(\tau)$ is correlated to the transmitted signal in order to result in $P_h(t;\tau)$, the power delay profile (PDP),as proved in [4]. For small time intervals or small distances the channel can be taken as a WSSUS (Wide Sense Stationary Uncorrelated Scattering) channel. Fig. 4 presents the channel correlation function in four different domains: time-delay (t;τ), frequency-time (f;t), frequency-Doppler (f;μ) and delay-Doppler (τ;μ) [4] and they can be obtained simply by DFFT.

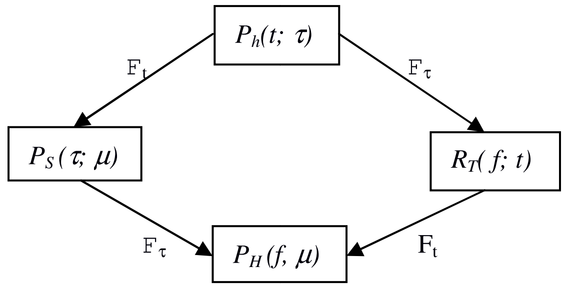

Fig. 4.Relation between the correlation functions of WSSUS channels.

The calculated time dispersion parameters were the average delay and the delay spread, calculated directly from PDPs samples.

Such profiles have the channel noise added to them. To mitigate the present noise and thus to find the valid multipath in the PDPs, the CFAR (Constant False Alarm Rate) technique [5] was used. After its application, the average delay and delay spread [4] were calculated for these cleaned PDPs and the results are in Table III.

TABLE III. TIME DISPERSION PARAMETERS

Local	Mean delay (µs)	Delay spread (µs)	No. PDPs
hall (1st floor)	0.11 - 6.11	0 - 6.52	22
1st floor corridor	0.06 - 0.37	0 - 0.19	26
2nd floor corridor	0.08 - 0.46	0 - 0.16	30
3rd floor corridor	0.08 - 4.42	0 - 6.19	22
4th floor corridor	0.17 - 0.41	0 - 0.19	26
5th floor corridor	0.13 - 0.37	0.05 - 0.18	10

B. Narrowband characterization

The statistics of the signal small-scale variability was calculated in 40 λ-sectors in each corridor. The metric used for the error between the experimental (*f(x)*) and the theoretical (*g(x)*) probability density function (pdf) is L^1,defined as:

$$L^1 = \sum_{i=1}^{i=n} D(i) \qquad (1)$$

$$D = \int |f(x) - g(x)| dx \qquad (2)$$

The smaller values of L^1 predominated for Rice probability density function for all the sectors, with K parameter varying between 21 and 36, leading to good fitting to gaussian pdf too, although with a slightly greater error. Although the signal suffers attenuation due to the output environment between TX-RX, the vegetation and the building wall, itsindoor behavior shows the confinement of the signal in the corridors, since it decays slowly along them as it is observed in Fig. 5. The Rice pdf confirms the good level of the signal received with a direct signal between TX_RX. This is observed in Fig 6, where it can be seen that the signal penetrates through the windows besides crossing the walls. It is worth to say that the level increased as long as the floor was higher, reaching -52 dBm in the fifth floor. The smaller distance between TX-RX and the amount of vegetation crossed by the signal contribute for these results. In Fig. 6, the hall position and the limits of the sounded building are highlighted. The transmitting signal crosses the vegetation, but this is more intense for the path arriving in the third floor.

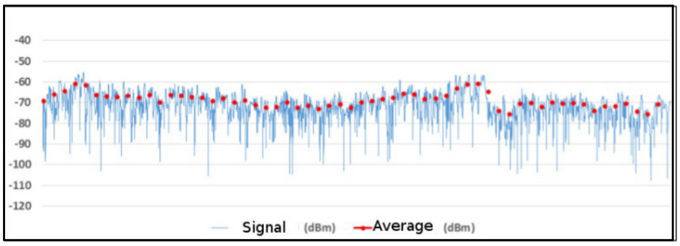

Fig. 5. Small-scale variability of the received signal (blue) and the local mean (red) on the 2nd floor corridor.

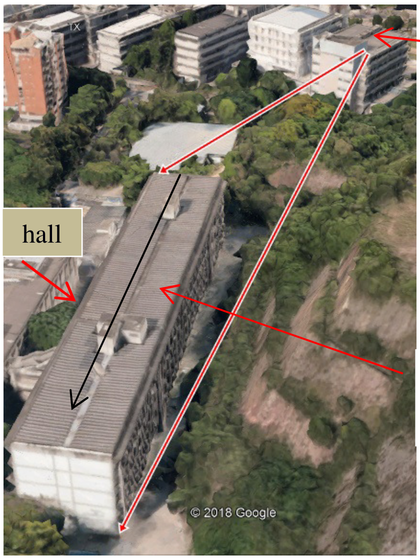

Fig. 6. Aerial view of the sounded environment.

IV. CONCLUSIONS

The main goal of this paper was to characterize the indoor channel for the 700 MHz frequency band. This range has already been auctioned for mobile communication in Brazil using LTE-4G technology, which has flexibility for scheduling frequency bands ranging from 1.4 MHz to 20 MHz, and it is has been gradually implemented in the country.

The carrier of 768 MHz was used for narrowband sounding whereas an OFDM signal composed of 1024 carriers and 20 MHz band was chosen for the wideband transmission. The signals were transmitted from the top of a building and collected by an antenna in a reception module moving along the floors and the hall of another building.

After processing, the calculated dispersion parameters presented values smaller than 190 nanoseconds in general, but in the hall and in the third floor of the building they reached some high values such as 6.52 and 6.19 microseconds, respectively. In the third floor, a lot of multipath arrived at the receiver coming from the canopy of the trees, as it is observed in Fig. 6. It must be remembered that the propagation signal in 700 MHz band suffers less attenuation than signals in 2600 MHz band. In the hall, the signal propagated in a wider area, with less confinement, and different multipath are generated.

As the small signal variability statistic of the signal, Rice was the best fitted pdf, confirming that there was a stronger direct ray coming through the windows.

Through this work, it was possible to have a view of the behavior of the channel in an indoor environment for the 700 MHz frequency band, which is being implanted in Brazil. More results will be obtained for the complete channel characterization and more measurements in this band will be carried out in other environments.

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