Indoor Path Loss Variations with Frequency and Visibility Conditions at 3.5 GHz Band

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***Abstract*— Studying the radio wave propagation within indoor environment is needed previously to deploy wireless networks. Thus, and next to deploy 5G systems at 3.5 GHz band, some insights on the behavior of the channel are required. This contribution describes the results of a measurement campaign in three different indoor scenarios, which are representative for a collection of similar environments. A simple path loss exponential decay model, adjusted by the measurement outcomes, indicates the evolution of radio waves as a function of the distance to a transmitter. In line of sight conditions, path loss seems to be just a bit stronger than in open space situations (the exponent is between 2 and 2.5, depending on the frequency, compared to the standard value 2 of open spaces). However, obstructed line of sight conditions strengthen this decay rhythm, being over 4.**

Keywords—5G, indoor, measurement, propagation

I. INTRODUCTION

Deploying next generation wireless communication networks requires a good knowledge on radio wave behavior. This means that we need highly precise simulation tools, but also that we would appreciate general information providing previous insight on radio channel performance. This contribution falls within this last group of requirements, focusing on narrowband behavior of radio channels in a 300 MHz wide frequency band around 3.5 GHz.

The interest of this band lies in its use for fifth generation (5G) cellular systems [1], recently manifested in public auctions in different countries [2-4]. As planners will massively manage this band in the next months, a general knowledge on how radio waves will attenuate in different indoor conditions results of interest to network designers. Thus, the aim of this contribution is to analyze the path loss exponent in three environments: a wide and large auditorium and a long corridor (in this case, in both line of sight –LoS– and obstructed LoS –OLoS– conditions).

After this brief introduction, section II gives the measurement details: setup, procedure and environments, required to interpret the results developed along section III. This section also analyses the parameters obtained after fitting a path loss exponent decay law to the measured results at all frequency spots. Finally, section IV contains the conclusions we extracted from those results.

II. MEASUREMENTS

A. Setup

We performed measurements after tailoring an automated system for positioning the receiving antenna and for controlling the measurement instrument. A vector network analyzer (VNA) Keysight Fieldfox N9913A was the instrument intended to gather the channel response within the different considered environments.

A pair of vertical polarized biconical dipole antennas headed both transmitter and receiver ends. Their patterns are very adequate for multipath analysis: they do not filter any component in the horizontal plane, providing a wide beamwidth.

The transmitting antenna emitted from a fixed location at each environment, placed at 20 cm below the room ceiling. The receiving antenna travelled along straight-line paths, mounted on a linear positioner controlled from a computer that also controlled the VNA. The positioner consists of a 2.5-meter long screw, powered by a step-by-step motor. Its height related to the floor was 1.1 m.

B. Procedure

The measurement procedure consisted of repeating the sequence measure-move-stop in a continuous loop. At each static point, an average of 10 frequency swepts, from 3.35 to 3.65 GHz, constituted the gathered complex frequency response around 3.5 GHz, which is a very popular frequency for 5G experiments [5]. Adjacent measurement points are 21 mm apart, meaning a quarter of wavelength of the central frequency.

The length covered by receiver at each environment, 8.80 m in total, results from concatenating four times the single linear positioner. As a result, we gathered data at 816 measurement points, being each swept conformed by 1001 frequency spots. The total amount of frequency complex responses are 2.54 million, considering the three scenarios.

C. Environments

Two large rooms within the School of Telecommunication Engineering at the University of Vigo served as scene for the measurement campaign: a 20.30 m by 12.30 m auditorium, with seats for 240 students and open space, and a 2.24 m wide by 14.5 m long corridor where we measured with both LoS and OLoS conditions.

III. RESULTS

In order to analyze the narrowband behavior of the considered radio channels, we used an exponential decay path loss model. We extracted the path losses at each frequency spot along all receiving locations within each scenario, constructing a path loss vector. Then, we fitted such a vector to a law as:

$$PL_{total}(d) = PL_0\, d^{\,n} \quad (1)$$

where PL_{total} is the path loss as a function of d (meter), the distance to transmitter, and n and PL_0 are the path loss exponent and the path loss reference at 1 m, respectively. We computed both values by minimizing the root mean squared error related to measured data. Converting into logarithmic units, equation (1) would be:

$$PL(d) = PL_0 + 10\, n \cdot \log d \quad \text{[dB]} \quad (2)$$

which shape describes a linear regression of the variation of the path losses (in logarithmic units) with distance. The n-parameter, i.e. the path loss exponent, represents the rhythm of decay of the channel response with distance. So, it is a good indicator of the narrowband behavior of the radio channel in each environment.

We can observe some variations of n-parameter as a function of the frequency at the auditorium, and their values fall within 2 (as the open space behavior) and 2.5. The 1001 frequency spots provide a mean value for n-parameter of 2.2. Although the auditorium is a very open room, it seems that the presence of furniture (student desks) and structure elements (walls, ceiling, floor) speeds up the decay rhythm as receiver moves away, compared to the open space behavior.

Figures 1 and 2 provide an interesting comparison between LoS and OLoS conditions within corridor. In LoS conditions, the evolution of the n-parameter shows variations similar to the auditorium: they are all the time above 2, and most of the time they are below 2.5. However, when a brick wall corner blocks the direct link between transmitter and receiver, the variation of the n-parameter changes completely, being between 3.7 and 4.4 for all frequencies. This represents an increment of almost 2 in respect to results in LoS conditions.

In the corridor, the mean values for n-parameter resulted to be 2.2 and 4.1 for LoS and OLoS conditions, respectively.

IV. CONCLUSIONS

This contribution contains the results of an intense measurement campaign developed within a 300 MHz bandwidth around 3.5 GHz in three different scenarios. Narrowband analysis on measured outcomes provided the path loss exponent in the three scenarios and at all swept frequency spots.

Although the considered auditorium and corridor presented strong structural and design differences, the narrowband behaviors of their radio channels were similar, being both in LoS conditions: path loss exponents are between 2 and 2.5 (2.2 in mean), meaning a bit larger than in open space conditions.

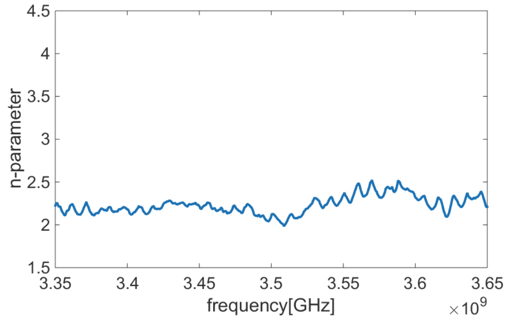

Fig. 1. Path loss exponent in corridor, LoS conditions

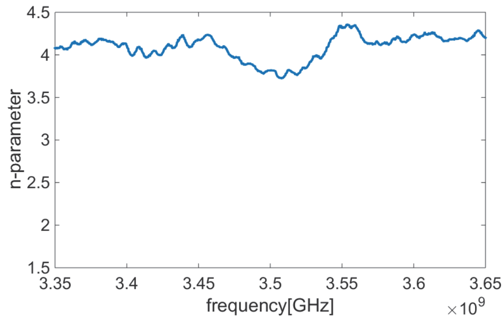

Fig. 2. Path loss exponent in corridor, OLoS conditions

However, OLoS led to path loss exponents around 4.1, clearly larger than in LoS environments. More interesting is that we gathered OLoS data in the same room of one of the LoS scenarios, only moving the transmitting antenna to a location where a wall corner blocked the direct link towards the receiving path. This means that the main difference between this pair of gathered data is the obstruction of the line of sight. This insight on the effect of an obstruction in the line of sight, which enhances the path loss exponent, must be taken into account in preliminary designs of wireless indoor deployment of 5G systems.

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