Measurement and Modeling of UWB channel in indoor corridor environments

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Abstract

This paper deals UWB channel measurements and modeling for both LOS and NLOS in indoor 5 of corridors which have different types of structures and whose walls are made up of different materials.

Keywords : UWB, Channel measurement, Channel modeling, Path loss exponent, Indoor Corridor.

1. Introduction

In narrow-band systems, most of papers deal the channel measurements and modeling in LOS (Line-of-Sight) and NLOS (Non Line-of-Sight) in office and residential, and industry environments. But some papers do in LOS, 'soft' NLOS, also known as Obstructed LOS, and 'hard' NLOS [1-3]. In contrast to narrow-band systems, UWB (Ultra-Wide-Band) systems have much wider bandwidth so dependency on frequency also should be included in the UWB channel modeling. Some papers have shown it in LOS and NLOS [4-5]. But despite of these efforts, there are less paper considering different structures and materials in same environments.

This paper deals the effect of different structures and materials in indoor corridor environments on the UWB channel parameters, especially the path loss exponent, which is a function of a distance or a function of a frequency. And the paper shows the path loss exponent modeled differently in indoor 5 of corridors and also for LOS and NLOS in each of corridors.

2. Measurement Campaign

2.1 Measurement System

In this paper, the UWB measurement system has 1.6GHz of bandwidth from 5.0GHz to 6.6GHz. Both transmitting antenna and receiving antenna are dipole antennas which have 2.1 dBi of gain and are on 1.5m of height. A PA (power amplifier) with 25 dB of gain and a LNA (low noise amplifier) with 27 dB of gain are used. And a calibration is performed to remove effects of antennas, PA, cable, and LNA in an anechoic chamber. UWB frequency channel response which has 801 tone of frequency within the bandwidth is obtained using a VNA (Vector Network Analyzer).

2.2 Measurement Scenario

In this paper, the UWB channel measurement was performed for both LOS and NLOS in indoor 5 of corridors environments which have different types of structures and whose walls are made of different materials, but the ceilings and the floors are made of the same materials in all corridors. The main different features are represented in Table 1. In LOS cases, we measured for 9 of points which space one meter apart from the transmitting antenna to the corner of corridor and in NLOS cases 6 of points from the corner of corridor. And in each of receiving points, the measurement was performed for the 4 extra of points which are distant a half wavelength.

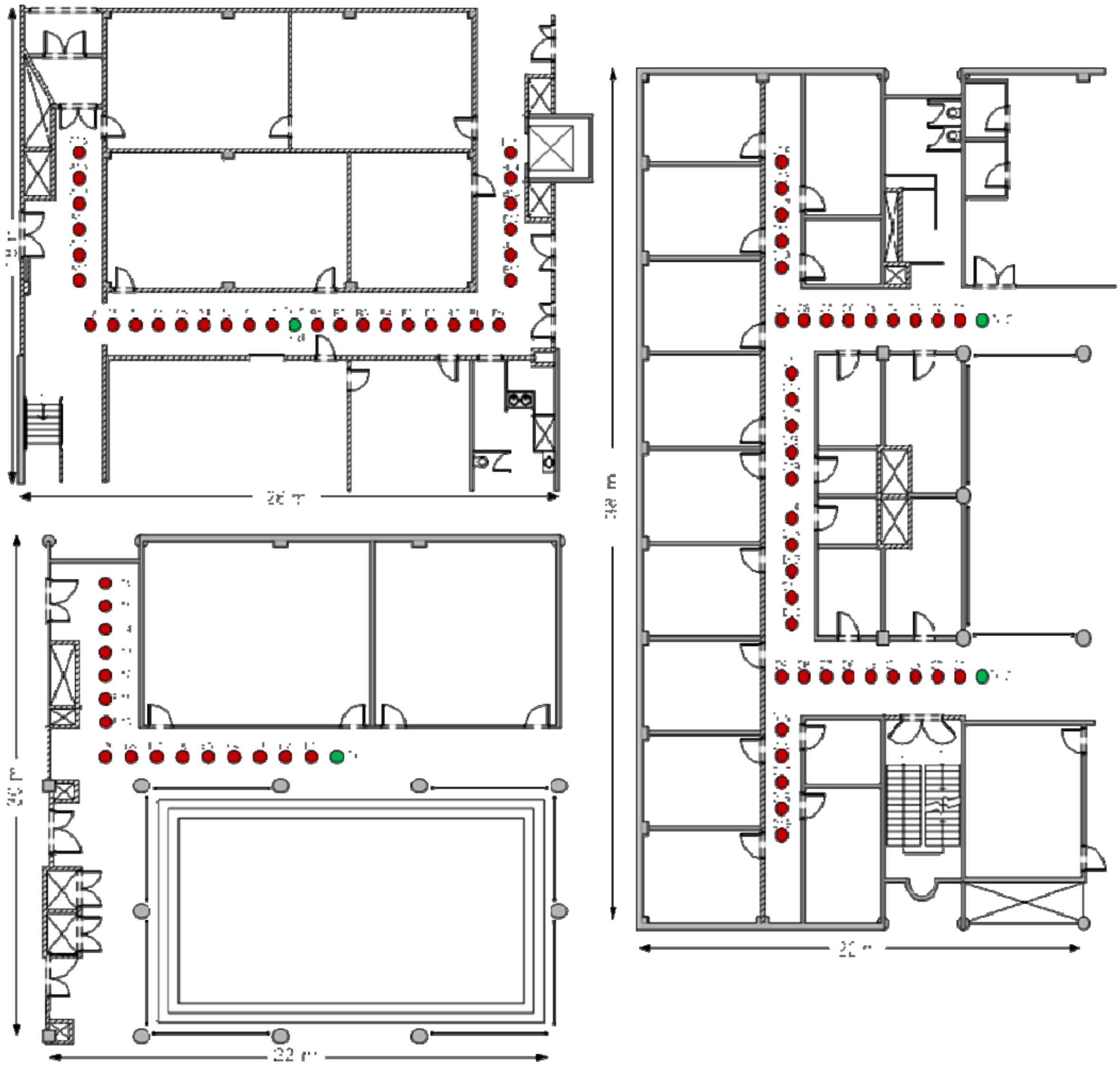

Figure 1. Indoor 5 of corridors

Table 1. Main different features for 5 corridors

	Main different features
A	· Concrete walls · 2 windows and 1 metal door on LOS-path
B	· Concrete walls · 4 metal doors on LOS-path
C	· Gypsum board walls · 3 metal doors on LOS-path
D	· Concrete walls · 3 metal doors on LOS-path
E	· Concrete walls · No left wall on LOS-path

3. Path Loss Exponent

The path loss can be written as a product of a function of the distance and frequency [1],

$$PL(d, f) = PL(d)PL(f) \qquad (1)$$

3.1 A function of the distance for the path loss

In (1), the path loss expressing the dependence on distance in dB is usually described by

$$PL_{dB}(d) = PL_{dB}(d_0) + 10n\log_{10}(d / d_0) + \varepsilon_d \quad (2)$$

where $PL_{dB}(d_0)$ is the path loss at the reference distance d_0 (which is 1m in this paper), d is the separation between the transmitter and the receiver, n is the path loss exponent expressing the dependence on distance, and ε_d is related to a large-scale fading with a zero-mean Gaussian distributed random variable (in dB) with a standard deviation σ_d (also in decibels) [6]. $PL_{dB}(d)$, $PL_{dB}(d_0)$, and ε_d in (2) are averaged over a 1.6GHz bandwidth, and n is computed using the minimum mean square error algorithm. These parameters are summarized in Table 2.

Table 2. Empirical Path Loss Parameters about a function of the distance in (2)

	Parameters	A	B	C	D	E
LOS	$PL_{dB}(d_0)$	31.49	31.80	33.90	34.35	32.06
	n	1.42	1.30	1.15	1.36	1.89
	ε_d	1.18	1.53	0.86	0.72	1.03
NLOS	$PL_{dB}(d_0)$	31.49	31.80	33.90	34.35	32.06
	n	2.55	2.39	2.42	2.63	3.23
	ε_d	1.74	3.67	2.09	1.55	1.06

In the corridor E, the path loss exponents for both LOS and NLOS are much larger than those in the other corridors. This is because no left wall exists in the corridor E. The path loss exponent for the corridor C whose walls are made of gypsum boards is smaller than one for the corridor D whose walls are made of concrete. And the path loss exponent for the corridor A which has less metal doors is larger than one for the corridor B which has more metal doors. The path loss exponent for the corridor whose walls facing the transmitting antenna include metal door is smaller than one for the corridor whose walls facing the transmitting antenna include no metal door.

3.2 **A function of the frequency for the path loss**

And in (1), the path loss expressing the dependence on frequency in dB is represented by

$$PL_{dB}(f) = PL_{dB}(f_r) + 20k\log_{10}(f / f_r) + \varepsilon_f \quad (3)$$

where f_r is the reference frequency which is 6.14GHz in this paper, k is the path loss exponent expressing the dependence on frequency, ε_f is a Gaussian random variable (in dB) and standard deviation σ_f also in dB. $PL_{dB}(f_r)$, k and ε_f are summarized in Table 3.

Table 3. Empirical Path loss Parameters about a function of the Frequency in (3)

	Parameters	A	B	C	D	E
LOS	$PL_{dB}(f_r)$	40.61	41.35	41.95	42.24	41.08
	k	0.54	1.02	1.79	0.30	−2.72
	ε_f	3.27	2.62	3.70	4.63	3.72
NLOS	$PL_{dB}(f_r)$	56.92	55.44	57.41	58.46	61.86
	k	1.71	0.41	1.91	−0.31	−3.47
	ε_f	3.51	3.29	4.06	4.95	3.42

Here, the outstanding feature for these parameters is that there are no similar patterns between LOS and NLOS in all environments. Instead, like the result of Table 1, for the corridor E the path loss exponent expressing the dependence on frequency, k are negative values for LOS and NLOS. This result represents that in the environment without one side wall the path loss decrease as the frequency increase. The path loss exponents, k for the corridor B and D whose walls are made of concrete are less than one for the corridor C whose walls are made of gypsum board. This result shows that the path loss expressing the dependence on frequency in the environment with concrete wall is less than that in the environment with gypsum board wall. In the corridor A and C, k for NLOS is larger than one for LOS, but not in the corridor B and D. In the whole bandwidth, 1.6GHz, the variation of path loss in corridor D is the smallest among all corridors and that in corridor E is the largest.

4. Conclusions

We present the measurements and the modeling of UWB channel in indoor 5 of corridors. The corridors have different structures and different materials each other. And among 5 of corridors, there is a corridor which has no left wall. In indoor 5 of corridors, the UWB measurements are performed in LOS and NLOS. When the path loss can be written as a product of a function of the distance and frequency, the distance dependence of the path loss is not only different in LOS and NLOS but also in each of corridors. And the frequency dependence of the path loss is also depend on whether LOS or NLOS and is different in each of corridors. From the result of the path loss parameters, especially, the path loss exponents of UWB in all corridors are not only differently modeled according to whether LOS or NLOS, but also in each of corridors which has different structures and materials.

The main results for this paper are summarized as follow.

1. The corridor which has not at least one side wall has larger path loss as the distance increase and smaller path loss as the frequency increase.
2. While the path loss with respect to the distance for the corridor with gypsum board walls is smaller than that for the corridor with concrete walls, the path loss with respect to the frequency is larger in the corridor with gypsum board walls.
3. In the corridor which has less metal doors, the path loss with respect to the distance is larger than that in the corridor which has more metal doors.

References

[1] F. Molisch ," Ultrawideband Propagation Channels-theory, Measurement, and Modeling," IEEE Trans. Veh. Tech., Vol.54, Sept. 2005.

[2] J. Karedal, S. Wyne, P. Almers, F. Tufvesson, and A. F. Molisch, “"Statistical analysis of the UWB channel in an industrial environment,”" in Proc. VTC Fall 2004, 2004, pp. 81–-85.

[3] B. Kannan et al., "UWB Channel Charac- terization in Office Environments,” "IEEE, Tech. Rep. Document IEEE 802.15-04-0439-00-004a, 2004.

[4] V. Erceg et al., “"An empirically based path loss model for wireless channels in suburban environments,”" IEEE. J. Sel. Areas Commun., vol. 17, pp. 1205–-1211, 1999.

[5] S. S. Ghassemzadeh, R. Jana, C.W. Rice,W. Turin, and V. Tarokh, “"Measurement and modeling of an ultra-wide bandwidth indoor channel,”" IEEE Tran. Commun., vol. 52, pp. 1786–-1796, 2004.

[6] T.S. Rappaport, "Mobile radio propagation: Large-scale pathloss," in Wireless Communications: Principles and Practice, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, 2002..

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