



RMS Delay Spread Models for UWB Off-Body Channels in Crowded Indoor Scenarios

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Abstract

A polarized average root mean square delay spread model for UWB off-body channels, for both line-of-sight and non-line-of-sight, is presented. The model is based on measurements performed in a crowded indoor office environment at 5.8 GHz with 500 MHz bandwidth. The root mean square delay spread in the line-of-sight case is higher for vertical transmitting antenna, and is the highest for non-line-of-sight, regardless of polarization, achieving even 12.2 ns. A strong correlation between root mean square delay spread and system loss is observed for line-of-sight.

1. Introduction

A Body Area Network (BAN), which concept was first proposed in [1] and defined in [2], is a short range, small-scaled wireless network, that may operate in the vicinity of, or inside, a human body [3, 4]. The communication channel's characterization in BANs is not only nontrivial but also crucial to optimize overall communication performance [5]. Knowledge about radio signal attenuation, as well as time dispersion parameters, is of great interest when designing a wideband network. However, typically, BANs do not operate in an empty propagation environment, therefore, there is the need to consider other people's presence in the surrounding of BANs on the radio channel characteristics.

This paper addresses the situation in which the user wearing a UWB BAN device is in an office environment with other people behaving in various ways, e.g., standing still, gesturing or walking. Such scenarios were empirically investigated in order to characterize the wideband off-body radio channel, i.e., the average root mean square (RMS) delay spread, in realistic BAN situations.

2. Measurements and Scenarios

The measurements campaign has been already described in [6] and [7], therefore, this section provides only a brief description of the considered environment, equipment and scenarios.

Measurements were performed in an office meeting room ($7 \times 5 \times 3$ m³), with the user walking at a constant velocity (≈ 1.3 m/s). A coplanar-fed UWB monopole was used as an off-body transmitting (Tx) antenna, while a dual-polarised on-body UWB antenna, composed of two ring monopoles on a common substrate plate, was used as the receiving (Rx) one. Only one on-body Rx antenna placement was considered, i.e., front side of the torso, at a height of 1.3 m, while the off-body Tx antenna was attached to the wall on one side of the room at a height of 2.0 m. A 4-port Vector Network Analyser Agilent E5071C was used to capture channel impulse responses for a 500 MHz wide channel at 5.8 GHz.

Initially, measurements were taken with just the user in the room (NP - No People), and then they performed with six additional people inside the room in three other situations: static, i.e., preserving a fixed posture and position (6PS); moving, i.e., changing postures at fixed positions (6PM); and walking, i.e., walking across the room (6PW). Measurements were repeated for each of these scenarios for the user walking towards (Line-of-Sight - LoS) and away (Non-Line-of-Sight - NLoS) from the wall with the Tx antenna.

3. RMS Delay Spread Models

Based on the measured instantaneous values of RMS delay spread, S , the average values were estimated using a running average with the averaging window width of 0.2 m (4 wavelengths). These average values have been used for the fitting of models using a linear regression with the least square method. The quality of the prediction model has been positively evaluated with the use of the RMS error, of the coefficient of determination, and of the F-statistics.

The preliminary analysis has shown that there is a small (i.e., not significant) effect on the RMS delay spread coming from the presence of people inside the room. Therefore, the proposed models do not distinguish between these situations. On the other hand, for LoS a strong influence of the Tx antenna polarization is observed, so two alternatives are considered, i.e., vertically (Tx_V) and horizontally (Tx_H) polarized cases.

Under these assumptions, one can formulate the following model for the average RMS delay spread for LoS:

$$\overline{S}_{\text{LoS[ns]}} = \begin{cases} 6.2 + 0.4(d_{[m]}/d_{0[m]}) & \text{for Tx_V,} \\ 3.6 + 0.5(d_{[m]}/d_{0[m]}) & \text{for Tx_H,} \end{cases} \quad (1)$$

where d_0 is a reference distance of 0.5 m. It may be seen that the average RMS delay spread for LoS increases with distance with comparable slopes for Tx_V and Tx_H, but the intercept is lower for the latter. Thus, the value of S seems to be lower for the case of Tx_H. For NLoS, one can model the average RMS delay spread as follows:

$$\overline{S}_{\text{NLoS[ns]}} = 12.2 - 0.1(d_{[m]}/d_{0[m]}), \quad (2)$$

which shows that S is much higher than in the LoS case, being almost independent of distance - a small negative slope may be applied to present the general observation that S slightly decreases with distance.

The preliminary analysis has shown that there is a strong correlation between S and system loss, L , for the LoS case, Fig. 1, but no strict linear relationship for the NLoS one.

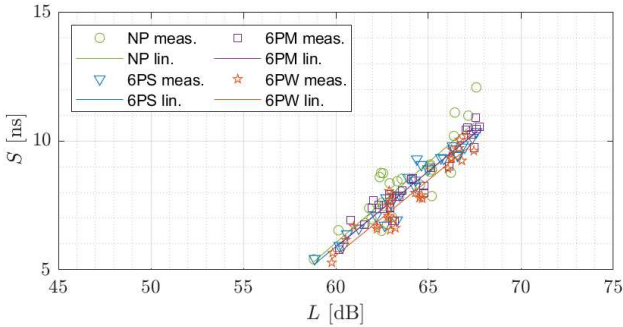


Figure 1. Delay spread vs. system loss for LoS and Tx_V.

Therefore, in a situation when there is no information on distance, but the system loss level is known, one can use this model to estimate the average S as a function of L , represented by:

$$\overline{S}_{\text{LoS[ns]}} = \begin{cases} 0.6L_{[\text{dB}]} - 22.8 & \text{for Tx_V,} \\ 0.3L_{[\text{dB}]} - 13.5 & \text{for Tx_H.} \end{cases} \quad (3)$$

One can see that the increase of S with L is two times more significant for the Tx_V case. In order to avoid negative values of S , this model can be applied only for $L > 45$ dB. All presented models may be applied for BANs operating at 5.8 GHz with a 500 MHz bandwidth in indoor office environments, similar to the one described in Section 2, where the maximum distance between the user and the off-body antenna does not exceed 6 m, and people density is in the range [0.03, 0.2] persons/m².

4. Conclusions

Models for the average RMS delay spread for UWB off-body channels for crowded indoor scenarios, for both LoS and NLoS, are presented. The RMS delay spread for LoS increases with distance by 0.8 ns/m and 1 ns/m, for Tx_V and Tx_H, respectively. Nevertheless, it is higher for the former case, since the intercept of the model is higher by 2.6 ns. On the other hand, for the NLoS case, the RMS delay spread seems to be almost constant with distance, being at the level of 12.2 ns with a small decay of 0.2 ns/m.

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