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Characterization of UWB Clustering Channel Model in Indoor Laboratory Environments

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1. Introduction

Recently, with the rapid growth of ultra wideband (UWB) communication systems, the accurate prediction of UWB signals propagation has been the subject of extensive research for system designers. Due to the broad variation of the multipath propagation channel, the statistical approaches are the best way to model the channel properties. As it is reported in most of the UWB measurement campaigns, the arriving multipath components (MPCs) tend to form clusters in the temporal domain [1]-[3]. An UWB channel impulse response (CIR) which account for the clustering phenomenon of MPCs has been proposed in [2] based on the conventional Saleh-Valenzuela (S-V) channel [4]. The parameters of this model have been derived in [2] using measurement data collected in the frequency band of 3-10 GHz in various types of high-rise apartment under different propagation scenarios.

In this paper, the results of UWB time domain measurement which have been performed for both line of site (LOS) and non-LOS (NLOS) scenarios in the laboratory (Lab) environments are presented to investigate the distribution function of clustering CIR parameters.

2. Time Domain Measurements

2.1 Measurement Setup

A diagram of the time-domain measurement setup is shown in Fig. 1. At the transmitter side, a pulse generator was used as an UWB signal source. The width of the transmitting pulse is less than 50 ps. This generator was connected to the transmitting antenna through a low loss wideband cable. The output signal of the receiving antenna was amplified by a low noise amplifier with a gain of 28 dB and 3 dB bandwidth of 12 GHz. A digital sampling oscilloscope was used at the receiver side which sampled the received signal at a rate of 1 sample per 12.5 ps. The pulse generator and digital sampling oscilloscope were synchronized through a reference clock signal at a frequency of 200 kHz. Measurements were performed by a pair of 1-18 GHz double-ridged waveguide horn antennas. These transmitting and receiving antennas were both placed on moving carts at a height of 135 cm above ground.

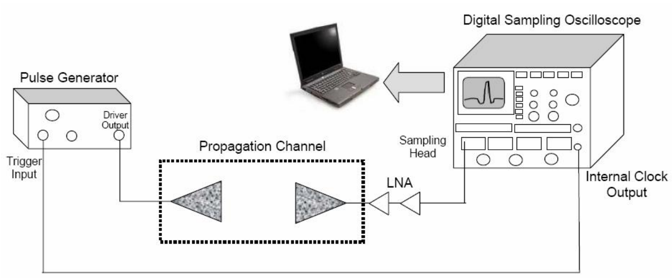

Figure 1: A diagram of the used measurement setup.

2.2 Measurement Location and Procedure

The time-domain measurement campaign was conducted for both LOS and NLOS scenarios at a basement floor with the plan shown in Fig. 2. All the main rooms of this floor are modern Labs. The building walls are made of brick with metallic stud. The partitions are aluminum frame structured with fabric, wood and glass surface. The floor of the rooms is covered with tiles. The doors are made of wood and have metallic frames. The furniture inside each room consists of many different electronic and measurement devices, metallic and wooden cupboards and cabinets, table made of wood, mid back work chairs, computers, etc.

Figure 2: Plan of the measurement environment with different Tx and Rx locations.

To perform the measurements, three different transmitter locations were considered. The receiver points were chosen at those locations where the received signal could be clearly detected. The measurements were collected at each receiver location by moving the receiver antenna over a square grid of 9 points spaced 50 cm apart as shown in Fig. 2. In order to cancel out the noise, 100 measurements were averaged at each measurement point. A system calibration was made to compensate any imperfection of the system components. Then, any dc offset that had not been taken into account by the calibration was removed.

3. Clustering Channel Model

The clustering CIR of the UWB channel can be express by S-V model as follows [2]:

$$h(t) = \sum_{l=0}^{L} \sum_{k=0}^{K_l} a_{k,l} d\,(t - T_l - t_{k,l}) \tag{1}$$

where $d(\cdot)$ is the Dirac delta function, L is the number of clusters and K_l is the number of MPCs within the l th cluster, $a_{k,l}$ is the multipath gain coefficient of the k th component in the l th cluster, T_l is the delay of the l th cluster which is defined as the time of arrival of the first arriving MPC within the l th cluster, $t_{k,l}$ is the delay of the k th MPC relative to the l th cluster arrival time, T_l. From (1), $\{L, T_l\}$ and $\{K_l, t_{k,l}, a_{k,l}\}$ are classified as inter-cluster and intra-cluster parameters, respectively [2]. The number of clusters, L, is modeled by a Poisson distribution as proposed in [5]. The presence of some objects in the environment under consideration can increase the number of clusters. It was found that the number of MPCs per cluster, K_l, can be modeled by exponential distribution. It should be noted that the number of MPCs per cluster (thus, the number of clusters) is dependent on the resolution of the parameter estimation technique, the type of the transmitting and receiving antennas, the transmitter-receiver separation distance, the physical layout of the environment and the dynamic range of the measurement system. More clusters are observed in a heavily cluttered environment.

Based on the S-V channel model, the cluster inter-arrival times and the ray intra-arrival times are described by two independent exponential probability density functions as follows [4]:

$$p\left(T_l \mid T_{l-1}\right) = L \exp\left[-L\left(T_l - T_{l-1}\right)\right], \quad l > 0 \tag{2}$$

$$p\left(t_{k,l} \mid t_{(k-1),l}\right) = l \exp\left[-l\left(t_{k,l} - t_{(k-1),l}\right)\right], \quad k > 0 \tag{3}$$

where L is the mean cluster arrival rate and l is the mean ray arrival rate.
The average power of both clusters and rays within the clusters are assumed to decay exponentially:

$$\overline{a_{k,l}^2} = \overline{a_{0,0}^2}.e^{-T_k/G}.e^{-t_{k,l}/g} \quad (4)$$

where $\overline{a_{0,0}^2}$ is the expected value of the power of the first arriving MPC, G is the decay exponent of the clusters and g is the decay exponent of the rays within the clusters.

4. Measurement Results Analysis

Cluster identification is the first task for CIR parameter extraction. However, general cluster identification algorithms are not appropriate for this application. In [2], cluster regions were selected manually by visual inspection. This kind of cluster identification is subjective and time consuming and leads to dramatically different results even from the same data analyzed by different analysts. To overcome these limitations, an automatic algorithm has been proposed in [6] for identification of clusters in UWB CIRs. We use a similar approach for cluster identification. From analysis of recorded measurements in the Lab environment, the average number of clusters, $\overline{L}$, is obtained equal to 9.1 and 9.5 for LOS and NLOS scenarios, respectively. The resulted cumulative distribution functions (CDFs) of the number of MPCs per cluster, K_l, are shown in Fig. 3 for both scenarios. As can be seen in this figure, the CDFs can be closely modelled by theoretical exponential distribution functions with the mean value of m_{K_l}, which is equal to 21.8 and 33.6 for LOS and NLOS scenarios, respectively. It can be seen that the mean value of the number of MPCs per cluster is increased from LOS to NLOS scenarios.

In order to extract the mean cluster arrival rate, L, the arrival time of the first MPC in each cluster was consider to be the cluster arrival time, regardless of weather or not it had the largest amplitude. The arrival time of each cluster was subtracted from its successor. The conditional probability distribution given in (2) could be estimated by applying the least mean square fit of the cluster inter-arrival time to an exponential distribution. The resulted $1/L$ values are 2.33 ns and 3.85 ns for LOS and NLOS scenarios, respectively. A similar method should be carried out to estimate l which is the average ray arrival rate within a cluster. The estimated $1/l$ values are 0.1565 ns and 0.1582 ns in LOS and NLOS conditions, respectively.

The cluster and ray decay exponents, G and g, can be estimated by considering clusters and rays with normalized amplitudes and time delays and selecting their mean decay rates. In order to estimate G, amplitude of the first cluster arrival in each data set is set to one and its time delay is set to zero. Then, all other clusters arrivals in the same data set are express relative to this amplitude and time. The estimates for G which obtained by least mean square fit are 37.4 ns and 109.9 ns for LOS and NLOS scenarios, respectively. The normalized cluster relative power versus the cluster relative delay is shown in Fig. 4 for both scenarios. Applying a similar approach to estimate g results in values of 5.1 ns and 6.4 ns for LOS and NLOS scenarios, respectively. Figure 5 shows the normalized ray relative power versus the ray relative delay for both scenarios.

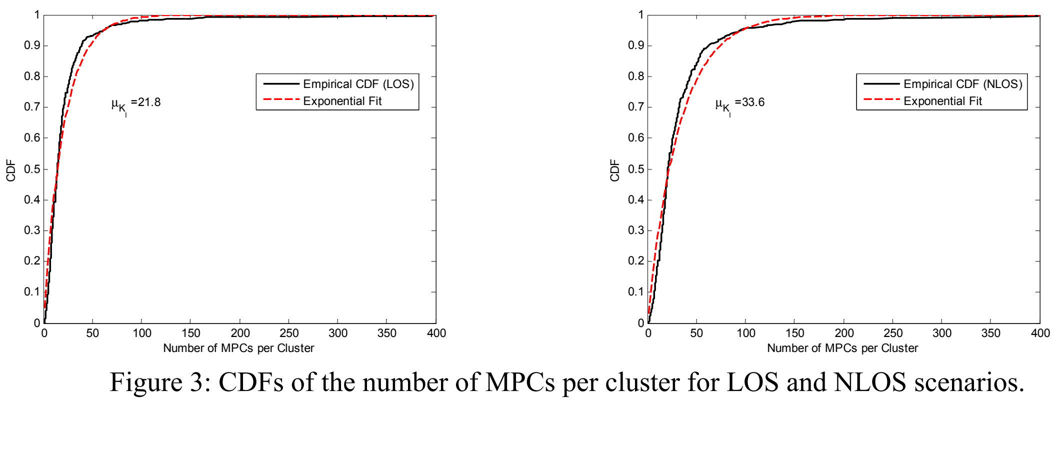

Figure 3: CDFs of the number of MPCs per cluster for LOS and NLOS scenarios.

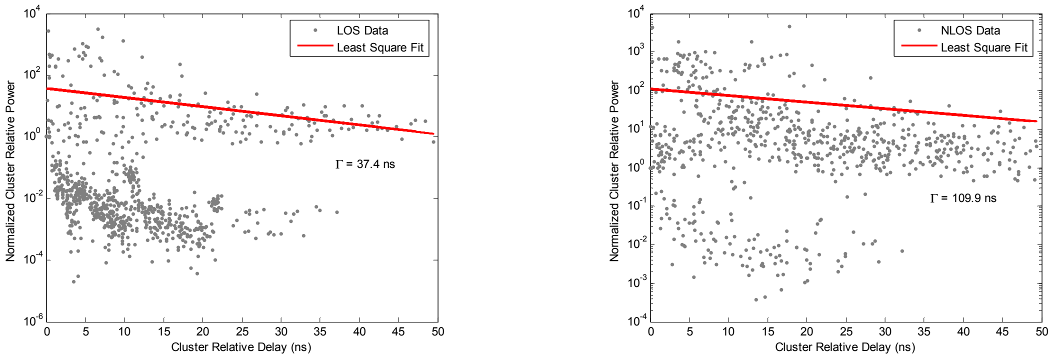

Figure 4: Normalized cluster relative power versus cluster relative delay for LOS and NLOS scenarios.

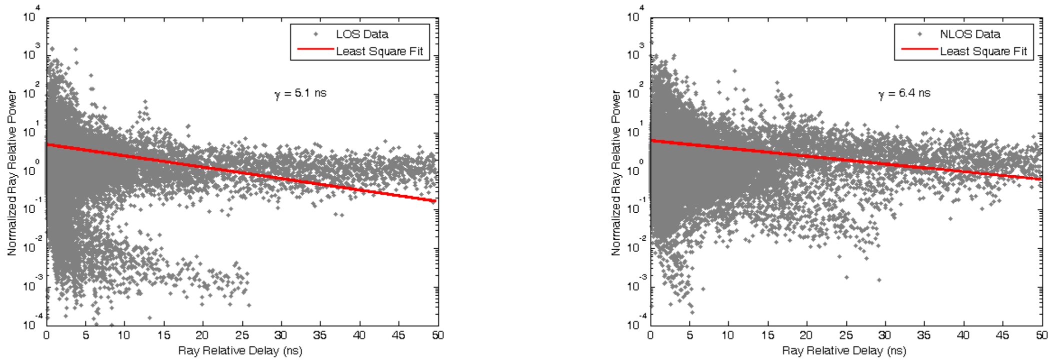

Figure 5: Normalized ray relative power versus ray relative delay for LOS and NLOS scenarios.

4. Conclusion

The results of time-domain UWB channel measurement in the Lab environment were presented. The clustering CIR parameters were obtained for both LOS and NLOS scenarios.

Acknowledgments

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References

[1] J. R. Foerster and Q. Li, "UWB Channel Modeling Contribution from Intel," Intel Corporation, Hillsboro, OR, USA, Technical Report P802.15 02/279 SG3a, IEEE P802.15 SG3a contribution, June 2002.
[2] C.-C. Chong and S. K. Yong, "A generic statistical based UWB channel model for high-rise apartments," IEEE Transactions on Antennas and Propagation, vol. 53, no. 8, pp. 2389–2399, August 2005.
[3] H. Arslan, Z. N. Chen, and M.-G. Di Benedetto, *Ultra Wideband Wireless Communication,* John Wiley & Sons, 2006.
[4] A. A. M. Saleh and R. A. Valenzuela, "A statistical model for indoor multipath propagation," IEEE Journal on Selected Areas in Communications, vol. 5, no. 2, pp. 128–137, February 1987.
[5] A. F. Molisch, B. Kannan, C.-C. Chong, S. Emami, A. Fort, J. Karedal, J. Kunisch, H. Schantz, U. Schuster and K. Siwiak, "IEEE 802.15.4a channel model—final report," IEEE 802.15-04-0662-00-004a, November 2004.
[6] J. Chuang, S. Bashir, D. G. Michelson, "Automated Identification of Clusters in UWB Channel Impulse Responses," in Proc. 20th Canadian Conference on Electrical and Computer Engineering, pp. 761-764, April 2007.