Characterization of Doppler and Delay Spreads for Pedestrian to Pedestrian Communications

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***Abstract*—This paper exploits the Doppler and delay spreads for pedestrian-to-pedestrian (P2P) communications based on a measurement campaign carried out at 3.8 GHz. Several propagation conditions and different mobility patterns were investigated. In particular, the impact of vehicle passing in the vicinity of a P2P links was considered. It was found that the delay spread does not only depends on the propagation environment but also on the body mutual orientation whereas the presence of a moving vehicle in the vicinity of P2P links can have an impact on the Doppler spread.**

I. Introduction

Device-to-Device (D2D) communication is an emerging short-range technology envisioned for direct exchange of information between users. Many applications involve in the vicinity of human body, e.g. emergency and rescue operation services, military and defense systems, health care and medical remote sensing etc. A particular subset of these networks is pedestrian to pedestrian communications. Characterizing D2D propagation is a challenge task and this is linked to two main reasons: the propagation around human body resulting in body shadowing effects and the impact of the propagation environment [1]. Therefore, lot of research efforts were devoted in the recent years for characterizing and modeling the propagation channels. A D2D statistic channel model was proposed in [1] based on measurements carried out in indoor premises at 2.4 GHz considering three on-body antenna positions, i.e. head, belt and wrist, and multiple human mobilities. The channel parameters were then described as function of mutual body positions. In order to analyze the influence of body shadowing and mutual body orientation, different human subjects were involved in a MIMO D2D channel measurements performed in the 2-10 GHz frequency band in an anechoic chamber [2]. The effects of vehicular traffic on D2D fading channel statistics in an urban environment were studied in [3] at 2.45 GHz considering different body orientations. This paper presents preliminary results of P2P channel statistics based on measurement campaign carried out at 3.8 GHz.

II. Measurement Campaign

A P2P measurement campaign was carried out using UCLouvain-ULB channel sounder. The center frequency was 3.8 GHz and the measurement bandwidth was set to 200 MHz resulting in a delay resolution of 5 ns. The peculiarity of this frequency band is its proximity to the 3.5GHz, which is considered for 5G network. The transmit power at the antenna ports was 23 dBm. The maximum measurable excess delay was set to 20.47 μs and the channel sampling rate was set to 1062 Hz which corresponds to a maximum relative speed of 150 km/h approximately. Dipole antennas were used at transmitter (Tx) and receiver (Rx) terminals; each was placed on a cardboard tube carried by a human subject acting as pedestrian (cf. Fig. 1). The cardboard tube was used to avoid the change of antenna radiation patten resulting in the proximity of a human body. The P2P measurements were carried out in the neighborhood of UCLouvain campus, in Belgium, considering the line-of-sight (LoS) and partial LoS (cf. Fig. 1) conditions. The partial LoS condition is mainly considered when the Rx subject was walking behind vehicles parked on the road (cf. Fig. 1b). Multiple mobility patterns were considered including parallel, opposite and orthogonal directions, with or without the presence of a car traveling the road. Vehicle speed was around 30 km/h and the distance between the Tx and Rx pedestrians varied in the range of 0.5 m to 10 m depending on the measurement scenario. The recorded time was between 2 s and 10 s, approximately, depending on the measurement scenario.

(a) LoS measurement (b) Partial LoS measurement

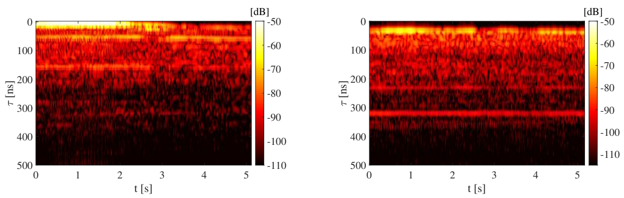
Fig. 1: Example of LoS and partial LoS Measurements

III. Measurement Results

Fig. 2 presents the power delay profile obtained in LoS and partial LoS scenarios for opposite walking direction. Due to the low antenna elevation, the power of the first path, i.e. the direct link between terminals, measured in the LoS scenarios, suffers from the body shadowing effects after the terminals intersecting each other whereas in the partial LoS scenario, the first path component is mainly shadowed by the parked vehicles resulting in time variation of the power. Moreover, different multi-path contributions were observed in

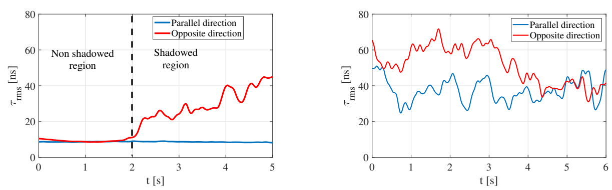
TABLE I: Delay and Doppler spread of P2P measurements

		LoS scenarios				**Partial LoS scenarios**			
		Parallel direction		*Opposite direction*		*Parallel direction*		*Opposite direction*	
		-	Vehicle in motion	-	Vehicle in motion	-	Vehicle in motion	-	Vehicle in motion
Delay spread [ns]	$\min(\tau_{rms})$	7	6.6	7	7	11	10	14.2	12.41
	$\max(\tau_{rms})$	16.3	16.7	74.2	79	84.7	124.2	100	114.5
Doppler spread ($\nu_r ms$) [Hz]	$\min(\nu_{rms})$	5.4	5.4	14	14	6.7	7.4	7.3	9.8
	$\max(\nu_{rms})$	5.6	6.2	14.8	16.5	6.7	8.3	11.4	13.1



(a) LoS scenario (b) Partial LoS scenario

Fig. 2: P2P Power delay profile measured in opposite walking scenario.



(a) LoS scenario (b) Partial LoS scenario

Fig. 3: Delay spread: parallel direction vs. opposite direction in LoS and Partial LoS.

both scenarios. This can be related to the change of pedestrian locations in the measurement environment. Note that the first path component and second mutli-path component are almost sketched in the form of lines due to the short relative distance between terminals and the low spatial resolution (1.5m). The delay spread was calculated as a function of time in order to analyze the impact of body shadowing and propagation conditions. Fig. 3 presents the time-varying delay spread measured in LoS and partial LoS conditions for parallel and opposite walking directions. As seen, the delay spread in LoS scenario, where there is no body shadowing, is equal to 10 ns on average while it increases linearly with a slop of 8 in the shadowed region with the increasing of relative Tx-Rx distance. For the partial LoS scenario, the delay spread takes value between 20 ns and 70 ns, approximately. This increase of value can be mainly linked to the presence of parked vehicles masking the transmitted signal. Table I presents the minimum and maximum values of delay and Doppler spreads obtained from different mobility patterns and propagation conditions. Fig. 4 compares the Doppler spectrum of the first path component obtained in opposite walking direction under the partial LoS condition to that given by the same scenario when a vehicle passes the road between terminals in the same

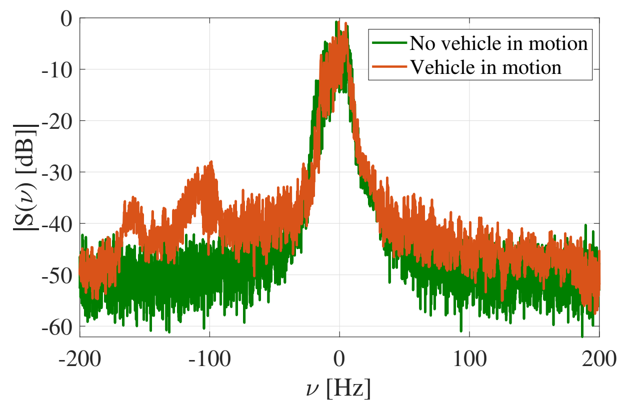


Fig. 4: Impact of moving vehicle on Doppler spectra measured in partial LoS scenario for opposite direction.

direction of Rx. A spreading spectrum is shown around the Doppler frequency -100 Hz which corresponds to a velocity of 30 km/h, approximately. Note that the negative value can be due to the fact that the vehicle moves far away from the receiver with a velocity greater than the receiver velocity. Moreover, this spreading can reasonably explain the dilation of the Doppler spread in the case of the presence of moving vehicle as shown in table I.

IV. Conclusion

P2P measurements were performed in order to characterize the delay and Doppler properties of the channel. It was shown that the delay spread must be characterized as function of the propagation environment and the mutual body orientation while the presence of moving vehicle around the P2P links can impact the Doppler spread. In a following step, we plan to study the statistics of non-stationary fading channel.

Acknowledgement

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