Radio channel characterization and modeling for vehicular communications

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Abstract – Vehicle-to-vehicle transmissions have emerged as a key component of future communication standards, whose design and testing critically depends upon the understanding of propagation mechanisms. An important and specific aspect of vehicular communication channels lies in the fact that these are essentially non-stationary. Hence, this short paper addresses two recent contributions in the field of non-stationary vehicular propagation, based on extensive measurements conducted at 5.3 GHz in suburban, urban, and underground parking areas.

Vehicular wireless channel modeling has received significant attention in the last decade in the context of Intelligent Transportation Systems (ITS). In addition to multimedia communications, ITS should further enable all vehicles to collect traffic data and road state information and share information for safety improvements thereby preventing road accidents by periodically monitoring the locations of surrounding vehicles. Naturally, this should be paired with a dependable connectivity, as such applications imply strict packet delay constraints. The system performance is ultimately fixed by the propagation channel, which must therefore be modeled accurately.

However, because both transmit and receive terminals are possibly moving, sometimes at high speeds, vehicular propagation is characterized by non-stationary conditions, making classical cellular models inadequate on this point of view. The first issue to be addressed is thus to define the so-called *quasi-stationarity* region, i.e. the finite region in time or space over which the channel statistics remain *similar enough*. Of course, appropriate similarity measures are required to substantiate what "*similar enough*" means. Once stationarity regions have been identified, the second issue is to model the wireless channel, taking into account the non-stationarity aspects, in particular the transitions between successive stationarity regions. Both issues have been addressed recently, based on numerous measurement campaigns and modeling efforts.

The measurement campaign used the Aalto MIMO channel sounder [1] at 5.3 GHz and a bandwidth of 60 MHz and a transmit power of 36 dBm. The receive terminal was equipped with a dual-polarized semi-spherical antenna array comprising 15 dual-polarized patch elements (i.e. 30 feeds). A uniform linear array with 4 vertically polarized omnidirectional antenna elements was used at the transmit side. Both antenna arrays were mounted on wooden platforms atop the roof of two cars. These cars were driven at 5 to 40 km/h into four environments: Aalto university campus (Otaniemi), the suburbs and city center of Tapiola and an underground parking lot. The inter-vehicle distance varied between 10 and 500 m, depending on the traffic conditions, which ranged from no traffic at all (in the underground parking area) to heavy (in urban and suburban areas), with frequent obstructions of the line-of-sight. A detailed overview of the full setup can be found in [2, 3].

When dealing with quasi-stationarity concepts, it is important to make a distinction between the *propagation level* and the *system level*. The former can be thought of as the inherent non-stationarity of the *physical* propagation channel, as determined by the dynamic multipath components. Naturally, it should be independent of the system configuration. The latter results from the combination of the channel with the system resolution in delay and angle. Hence, it depends on the bandwidth and on the antenna array size and reflects the characteristics that the system can "see". For a system with infinite bandwidth and perfect angular resolution, the quasi-stationarity on system-level tends to the propagation-level quasi-stationarity. This implies that the estimated degree of non-stationarity reduces when the bandwidth and array size become limited [3].

The second axis deals with channel modeling: the proposed non-stationary vehicular channel model [4] is essentially a stochastic directional tap-delay line model. The most important aspect of the model is the smooth transition from one region to the next one, which rests essentially on a birth-survival-and-death process for each multipath component (MPC).

This model has been successfully validated by experimental data in [4], as illustrated below.

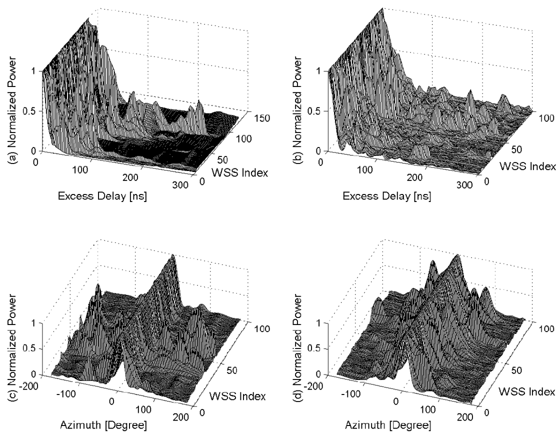

Figure 1: Comparison of measured (left) and simulated (right) power-delay and power-angular profiles in suburban environments.

References

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