Measurement and Modeling of Broadband Millimeter-Wave Signal Propagation Between Intelligent Vehicles

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Project Objective

Data communication links are essential components of the ecosystem of intelligent vehicles, enabling autonomous and semi-autonomous driving. Maintaining a reliable, low latency communication link has been a topic of interest in research and product development. The driving force of these developments is a better awareness of the wider surroundings of a car, based on sharing of raw sensing data across vehicles. This calls for very high data rates for such applications, in addition to very low latency for such safety critical applications, and thus calls the need for a sufficiently large available bandwidth, which is the reason why mm-wave frequency bands are of interest.

A prerequisite for the development of mm-wave V2V (Vehicle-to-Vehicle) communication systems is the measurement and the modeling of the corresponding propagation channel, i.e. what should the system envision the effect of the signal propagation to be, and to exploit desired, or mitigate detrimental, effects by the channel. Such effects can be the superposition (addition) of multiple signal components, each after following a separate path between the transmitter and the receiver. Such paths can be due to reflections on nearby objects, diffraction along edges, etc. Knowing the delay of such components, in addition to the direction of their departure/arrival, is vital to any product development in this field.

The goal from this project is to perform measurement campaigns in a variety of environments that form the basis of channel models that are in agreement with the physical reality, providing such information that are important and required for system development.

Problem Statement

Channel modeling for mm-wave V2V communications has been a hot topic recently; however, at the current time, a lot of the needed information is still unknown. This deficiency is due to fact that the measurement campaigns performed so far were done with measurement setups that do not allow the extraction of all the relevant information. In particular, it is well known that mm-wave communication suffer from large pathloss, which means the attenuation of the signal when propagating through a certain environment for a certain distance. Because of this problem, mm-wave systems require the use of adaptive arrays, which are smart antennas able to guide their beam and receive the signal from the direction of maximum power. However, existing measurements do not allow to extract the channel properties determining the applicability of such arrays (also known as “directional channel properties”). This is due to limitations in the existing channel measurement equipment, not allowing the extraction of any angular information about the received signals when vehicles are in motion. In addition, the existing measurements only cover a small subset of interesting environments that intelligent vehicles might be experiencing while in commute.

The proposed project aimed to alleviate some of these problems. The main output being a set of measurements and a channel model derived from them. The models will be made available to other US researchers, in particular to designers of V2V communication systems, an area that is of vital interest for the intelligent vehicle community.

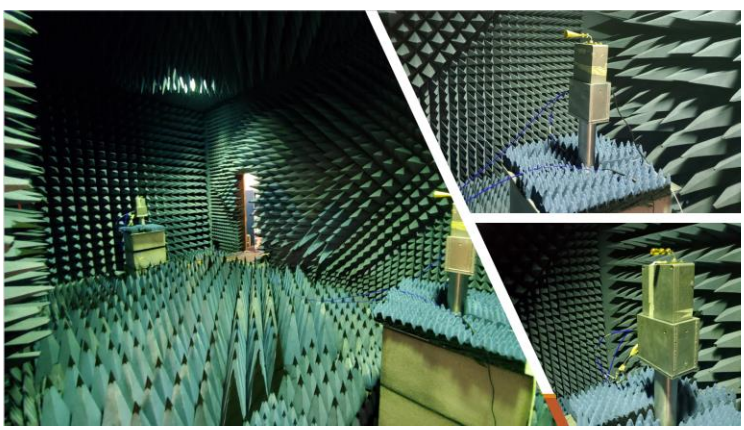
Research Methodology

The first essential step of the work is the construction of a suitable channel measurement equipment, also called "Channel Sounder". As outlined in the problem statement, channel sounders that allow real-time measurements that provide directional information are extremely difficult to build at mm-wave frequency. The sounder is based on the principle of rotating horn antennas. In other words, while previous mm-wave V2V sounders used a fixed horn orientation, we will use rotating horns, thus gathering information of the multi-path components propagating from all directions. The rotation speed of the horn antennas is very fast, allowing the measurement of the channel and the environment within its stationarity duration, i.e. the duration during which the environment stays relatively constant. Measurements were conducted on university campus at USC for sanity checks; results were compared with the environmental map and video recordings to identify the presence of scatterers and reflectors, and verify the validity of the measurement data.

Results

Due to COVID-19 pandemic and the resulting restrictions on laboratory work and in particular measurements campaigns that require close interactions of multiple people, fewer than the originally envisioned measurements were performed. We extracted directional power delay profiles and corresponding directional RMS delay spread, information is critical for the design of V2V communication systems parameters. An especially significant result was that even in a Non-Line-of-Sight scenario, i.e., where we have a truck for example blocking the Line-of-Sight link between the transmitter and the receiver, reflections via other objects in the vicinity can carry the most significant energy and allow the vehicles to maintain communications.

The next stage of our work is to perform more extensive measurement campaigns with longer trajectories and stronger variations of the distance between the transmitter and the receiver. This work will be done and the measurements results published as soon as the COVID-19 situation is resolved.



1 Antenna Calibration