

Communication in Future Vehicle Cooperative Safety Systems: 5.9 GHz DSRC Non-Line-of-Sight Field Testing

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ABSTRACT

Dedicated Short Range Communication (DSRC) is increasingly being recognized as the protocol of choice for vehicle safety applications by Original Equipment Manufacturers (OEMs) and road operators. DSRC offers the ability to communicate effectively from vehicle-to-vehicle and from vehicle to infrastructure with low latency and high reliability. A wide range of applications have been conceptualized to support safety, mobility and convenience, including: cooperative collision avoidance, travel information, and electronic payment. To be effective, infrastructure-based applications require an installed-vehicle base along with infrastructure deployment, while vehicle-to-vehicle applications require significant DSRC market penetration along with some degree of infrastructure support systems. Some vehicles currently include safety applications involving forward looking radar. The radar supplies information about objects, their distances and relative speed ahead of the host vehicle. When LIDAR (Light Detection and Ranging) becomes feasible for automotive usage, it may also offer an alternative digital vision of the objects in front of the host vehicle. Camera vision is another option for sensing surrounding vehicles. Radar, LIDAR, and camera have advantages and limitations in terms of range and directionality. OEMs are investigating DSRC as a means to enhance visibility of the oncoming and surrounding traffic, particularly in places where line-of-sight is obstructed by other vehicles, buildings, corners, etc. Future cooperative vehicle safety applications are expected to be mainly communication-based. A significant challenge lies ahead in combining and processing enormous amounts of information from the

host, surrounding vehicles and infrastructure in real time fashion. This paper will focus on the expected potential of such visibility enhancement through the use of DSRC communication.

INTRODUCTION

In the last ten years, many automotive OEMs, their tier 1 suppliers, research universities and wireless radio manufacturers, have been investigating use of DSRC for vehicle-to-vehicle and vehicle-to-infrastructure applications [1] [2] [3] [4] [5] [6]. The major U.S. Department of Transportation (USDOT) initiative called "Vehicle Infrastructure Integration" (VII) [7] has included a number of technical projects, including: VII Proof-of-Concept (POC) testing, which established the feasibility of the VII system using 5.9 GHz DSRC technology for improving transportation safety and efficiency; Cooperative Intersection Collision Avoidance Systems (CICAS) [8]; and Vehicle Safety Communications - Applications [9], both of which address automotive collision avoidance applications enabled or enhanced by the deployment of DSRC. Actual testing and equipment used for the research described in this paper were supported in part by the VII proof-of-concept testing activity – a cooperative project by the USDOT and the VII Consortium. The following is the content description of this paper. In the Background Section, we present related work and three typical non-line-of-sight crashes. In the main Section, we describe test settings; vehicle setup, testing locations, and measurement results and discussion, respectively. Finally, we conclude our findings in the Summary Section.

BACKGROUND

Current vehicles are equipped with active safety features such as an anti-lock brake system, vehicle stability assist and track control, and adaptive cruise control with forward looking radar. According to Jiang et al. [1], the next logical step in vehicle safety will be incorporating communication based cooperative systems to enhance active safety systems that are already onboard the vehicle. Benefits of communication based safety systems are the ability to warn the driver and to influence vehicle control systems in limited visibility situations.

Crashes occur for a number of different reasons. Some crashes are due to road and weather conditions especially when these conditions contribute to low visibility. Others occur as a direct, or indirect, result of human errors such as traffic law violation. DSRC technology can be used to reduce crashes by addressing some of the causes, for example: driver inattention, low visibility, and traffic signal violation. By convention, we refer to the offending vehicle as “Host Vehicle” (HV) and other participating vehicles as “Remote Vehicles” (RV). In this paper, we examine communication range and reception rate for three typical crash scenarios: Left Turn Across Path (LTAP), Do Not Pass (DNP) and Intersection Collision Avoidance (ICA).

The Left Turn Across Path crash scenario occurs in the four-way intersection environment. Two vehicles are approaching the intersection from opposite directions. A large truck is in front of the HV. The truck obstructs the line-of-sight of the two vehicles. The truck and HV are turning left. The truck safely completes its left turn. However, the HV, due to lack of visibility, fails to see the RV. A typical LTAP scenario is represented in Figure 1.

Do Not Pass accidents typically happen on the open road. Two vehicles are approaching each other on an open road, driving in opposite directions. The HV is trying to make a passing maneuver around a large truck that is driving in front of the vehicle. The truck obstructs the line-of-sight between the HV and the RV. Due to the truck obstruction, the HV fails to see the RV. Figure 2 shows a typical DNP-type crash.

Common types of Intersection Collision crashes typically occur on four-way intersections. An ICA-type crash is depicted in Figure 3. In this illustration, two vehicles are approaching the intersection. The southwest corner building obstructs line-of-sight.

NON-LINE-OF-SIGHT RELIABILITY MEASUREMENT AND ANALYSIS OF DSRC

EXPERIMENT SETTINGS - We have used two vehicles set up with VII POC hardware and software as shown in Figure 4. Each of the two experimental vehicles is equipped with an On Board Equipment (OBE) with 802.11p-based DSRC radio integrated, an integrated omni-directional roof-mounted DSRC and Global Positioning System (GPS) antenna, a GPS receiver (internal and external to OBE) and a software application in a processor allowing exchange of information via vehicle-to-vehicle communication. Two vehicles are sending the Basic Safety Message (BSM) in wireless short message type, as defined in the Institute of Electrical and Electronics Engineers (IEEE) 802.1p draft standard [10]. Each vehicle sends messages periodically every 100 ms.

The data content of the BSM is defined in Society of Automotive Engineers (SAE) J2735 [11]. The over-the-air packet size includes 45 bytes of overhead, and 39 bytes of data, for a total of 84 bytes.

Messages are sent at 15 dBm with ~4 dB cable loss yielding ~11 dBm. Data rate is 6 Mbps. We have slightly modified the temporary ID field of the BSM to include a sequence number.

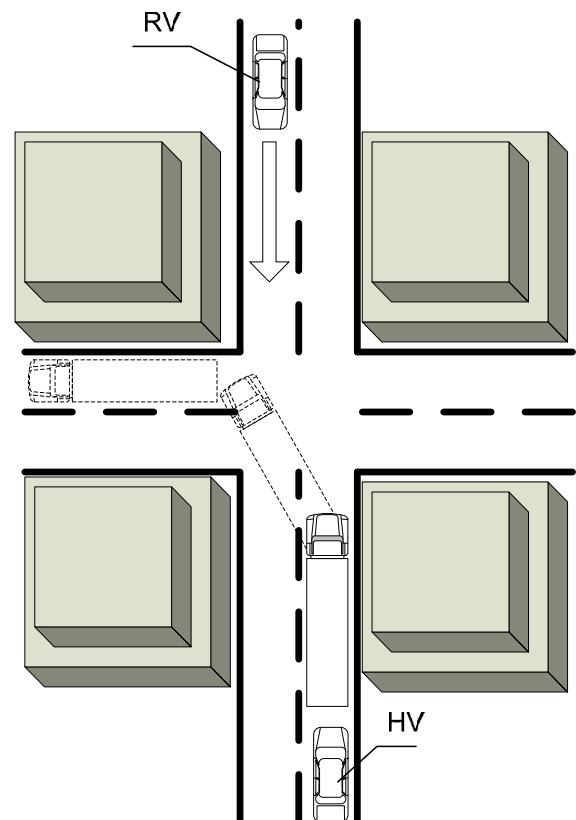


Figure 1 : Visualization of Left Turn Across Path scenario.