

DSRC Performance Comparison With and Without Antenna Diversity Using Different Transmission Power

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ABSTRACT

Vehicle-to-Vehicle (V2V) safety application research based on short range real-time communication has been researched for over a decade. Examples of V2V applications include Electronic Emergency Brake Light, Do Not Pass Warning, Lane Departure Warning, and Intersection Movement Assist. It is hoped that these applications, whether present as warning or intervention, will help reduce the incidence of traffic collisions, fatalities, injuries, and property damage. The safety benefits of these applications will likely depend on many factors, such as usability, market penetration, driver acceptance, and reliability. Some applications, such as DNPW and IMA, require a longer communication range to be effective. In addition, Dedicated Short Range Communications (DSRC) may be required to communicate without direct line of sight. The signal needs to overcome shadowing effects of other vehicles and buildings that are in the way. Some remedies may include increasing transmission power, using higher gain antennas, and using multiple antennas with diversity reception. This paper presents experimental results of several field trials using different configurations in transmission power, antenna diversity, and antenna gain of a DSRC receiving system.

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INTRODUCTION

Dedicated Short Range Communication (DSRC) is an enabling technology for wireless cooperative safety systems between vehicles. The wireless physical layer is defined by the IEEE 802.11p [1] amendment to 802.11 [2] standard. Upper layers are captured in IEEE 1609.3 [3] and 1609.4 [4]. Security is defined in IEEE 1609.2 [5]. Safety-related payload content is defined in SAE J2735 [6].

Broadcast beacons called Basic Safety Messages (BSMs) are being sent out periodically from the equipped vehicles. A BSM contains vehicle information such as speed, location, acceleration, brake status, and yaw rate. By exchanging this basic information, vehicles are becoming more aware of potential hazards and may be able to avoid or mitigate collisions.

This paper shows recent experimental measurements of DSRC performance on a typical suburban blind intersection using single and dual antenna setups, different transmission power levels, two antennas with different gains, and two different types of receivers. This paper analyzes the transmitted power and communication distance and how they influence cooperative safety applications.

BODY

OBJECTIVE

V2V communication without line-of-sight (LOS) truly demonstrates the advantage of wireless-based cooperative safety systems compared to stand-alone autonomous sensors such as radars and lidars. For cooperative safety systems to be effective, vehicles need to have situational awareness and communicate in non-LOS scenarios. Likewise, a vehicle hosting an Intersection Movement Assist (IMA) application needs to communicate to the vehicles coming from a blind intersection and alert the driver of a potential collision so that he can react and respond appropriately.

Increasing power or using antenna diversity overcomes communication issues in non-line-of-sight scenarios. The study can be used to support fine-tuning of network simulators. Also, the results offer some real-world experimental insights about the power needed for a required range of communication to support a wide variety of intersection-related safety applications. The presented communication performance in the intersection scenario can be used in future research to configure meaningful simulations that investigate the radio channel characteristics at intersections. The research quantifies the relative

improvements in performance due to power increase, higher antenna gain, packet switching diversity, and antenna diversity with respect to each other.

RELATED WORK

This paper shows communication performance in terms of packet success ratio and the experimental relationship between range and power for the different communication configuration for a non-line-of-sight intersection. To date, there is no documented research of a comprehensive study of a blind intersection with different configurations.

In terms of related work, Mangel [12] analyzed the characteristics of various intersections in a city area and provides the basis of the needs for researching DSRC reception at Non-Line-Of-Sight environment. Alexander [7] describes performance of two radio chip set receivers in a closed intersection scenario; however, the work looks only at a single transmitted power value. Hong [8] shows empirical results, in terms of PER, RSSI and T-window [9] analysis, of field testing using 10, 20, and 33 dBm transmission power in urban and suburban intersections. In addition to analyzing power versus range relationship, this paper examines effects of different radio chipsets, antenna diversity, and antenna gains at a suburban intersection. Mangel [11] compared the reception rate and reception power using a fixed-location transmitter at various intersection points using a single antenna. While the test provides a general performance of the specific setup, it did not consider the potential of using antenna diversity to improve the reception performance, which can be substantial in a similar environment with a strong multi-path effect.

TEST SETUP

The tests were conducted using two vehicles. One served as the receiver and the other as the transmitter. Two types of Onboard Equipments (OBEs), referred to in this paper as Type A and Type B, were used in the test vehicle. Both OBEs have internal memory for logging the over-the-air transmitted and received messages. Type A OBE uses a proprietary radio chipset while Type B uses a commercial Atheros chip.

TRANSMITTER SETUP

As shown in Fig. 1, the transmitter vehicle was equipped with the Type A DSRC OBE, NovaTel Global Positioning System, and MobileMark omni-directional antenna. This transmitter setup was kept the same during the tests. The transmitter sent periodic DSRC BSMs every 100 ms. Transmission power was changed from test to test, but it remained a constant during execution of a particular test.

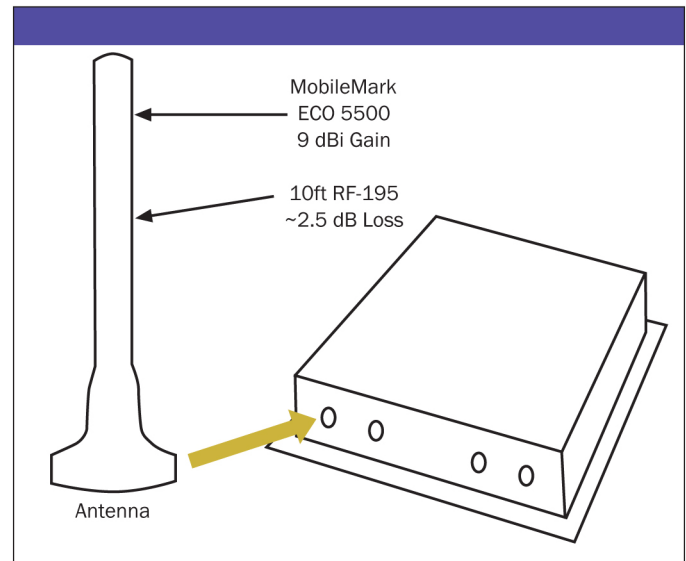


Figure 1. Transmitter vehicle setup: Type A DSRC radio module and MobileMark omni-directional antenna. This configuration was used as transmitter vehicle setup for all tests.

RECEIVER CONFIGURATION

The receiver vehicle setup configuration was changed per different testing needs. The receiver vehicle was instrumented with several configurations consisting of different combination of the DSRC radio types and antennas. In the first setup configuration the receiver vehicle had two omni-directional high gain (9 dBi on horizon) antennas mounted on the roof rack. These antennas do not require a dedicated ground plane and therefore being on the rack mounting fixture did not impact performance. Signal routed via RF-195 cable to the trunk of the vehicle where the rest of the equipment resided. Due to the cable loss signal was attenuated by about 2.5 dB.

Furthermore, the signal from each antenna was split into two feeds via signal dividers. Again the signal was attenuated by an additional 3 dB. Finally, a low loss cable LMR-400 feed the signals to the OBEs. The receiver vehicle Configuration 1 is shown in Fig. 2. This configuration is intended to capture over-the-air messages received in Type A OBE with antenna diversity functionality. Also this configuration simultaneously captures messages in the type B OBEs without diversity. As shown in Fig. 3, Configuration 2 is very similar to Configuration 1 except the antennas are now Nippon omni-directional antennas with lower gain (0 dBi on horizon). The Nippon antenna requires a ground plane, so it was magnetically mounted on the vehicle's roof. Configuration 3 consists of two pairs of Type A and Type B OBEs, that is, one Nippon antenna and one MobileMark antenna.

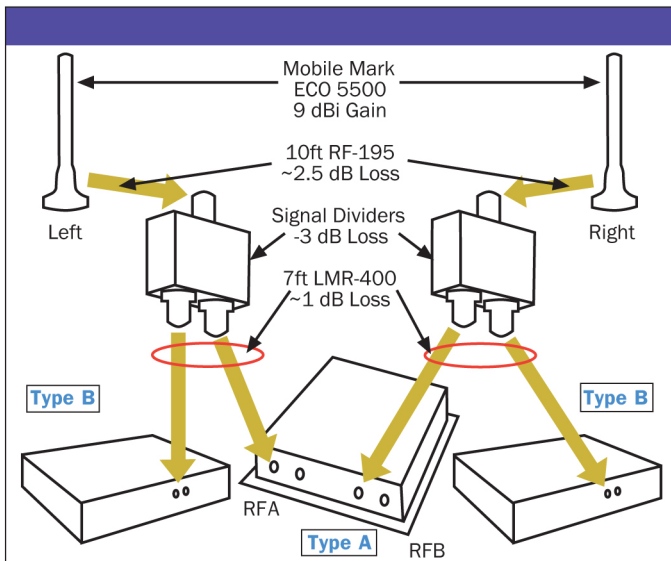


Figure 2. Receiver vehicle Configuration 1 consisting of two MobileMark antennas, two Type B OBEs, and one Type A OBE.

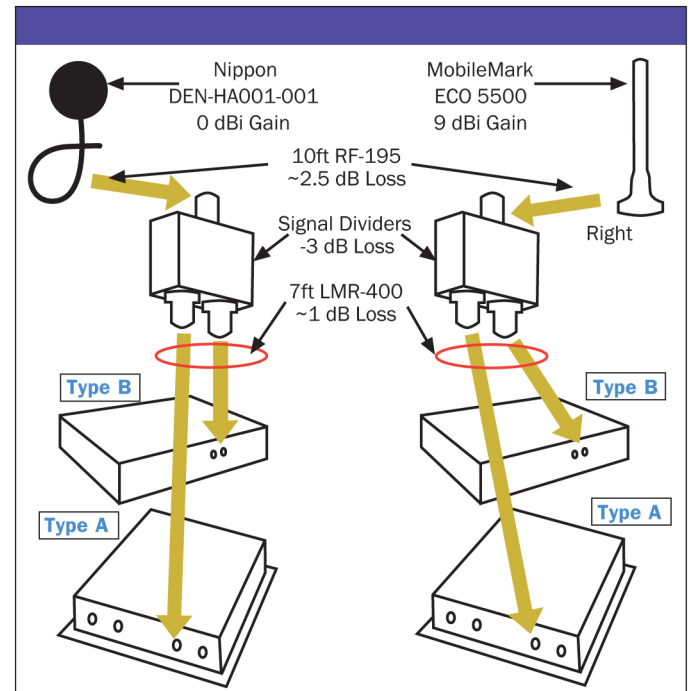


Figure 4. Receiver vehicle Configuration 3 consisting of one Nippon antenna, one MobileMark antenna, two type B OBEs, and two Type A OBEs.

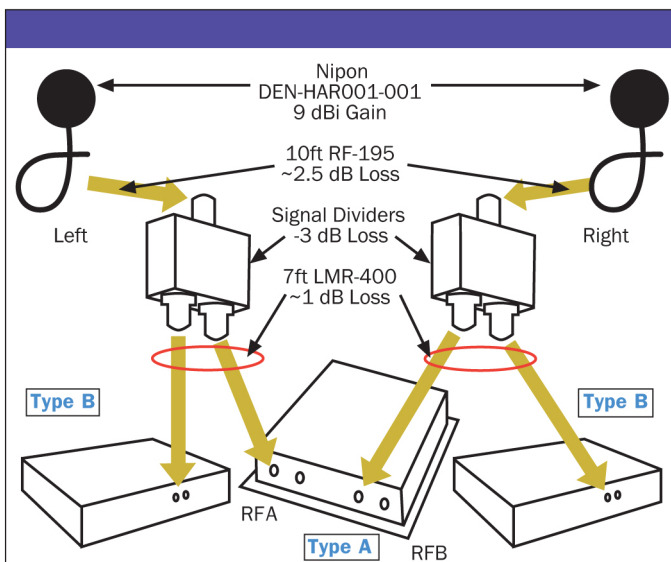


Figure 3. Receiver vehicle Configuration 2 consisting of two Nippon antennas, two type B OBEs, and one Type A OBE.

TEST SCENARIO

As shown in Fig. 5, a typical suburban street was chosen to represent a closed intersection environment. A receiver or application host vehicle (HV) was static and positioned 35 m from the intersection while the transmitter or remote vehicle (RV) was traversing.

Three experiments were conducted for each of the receiver vehicle configurations. The power of the transmitter was varied from 8 to 25 dBm at increments of 2 dBm with exception of the test with 25 dBm (maximum power type A OBE could produce). Each of the power levels was tested with 5 laps. Overall, the transmitter vehicle traveled 150 laps over several days of testing. The vehicle traveled up to 25 mph.

DATA RESULTS AND ANALYSIS

Data was logged on the internal OBE memory and was off-loaded to a test laptop after each test. Based on difficulties in obtaining data from related research [10], redundant UDP packet data collection was used in addition to the data written to the flash memory. As a risk management measure, special software was written to output UDP messages from each OBE every time a DSRC message is sent or received. The OBEs were assigned a static IP address and connected via a LAN router to the test laptop. The UDP traffic was then logged to the test laptop. While driving in areas of heavy foliage from trees, the GPS often did not provide a solution as evidenced by missing positioning points

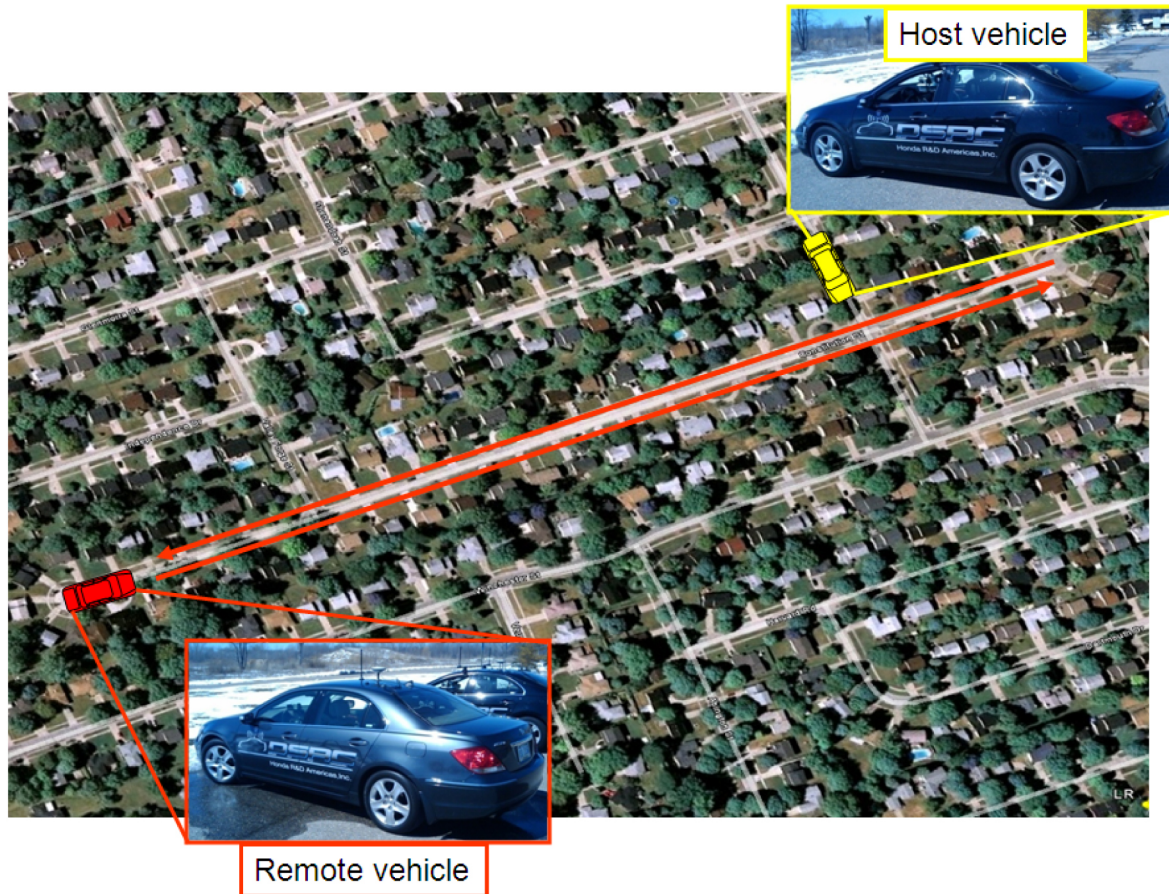


Figure 5. Aerial view of the testing site.

in the log. Therefore, during post processing, the missing points were added to the log by interpolating known previous and future position points. Some error was introduced, but the amount was insignificant for this study.

PERFORMANCE METRIC

Performance was measured in terms of packet success ratio (PSR), which measures a receiver's ability to successfully receive a packet sent from the transmitter. Rolling sequence numbers are part of the BSM. The PSR is calculated by comparing sequence numbers of the transmitted packets to the sequence numbers of the received packets. Results are divided into 5 m distance-bins and plotted on a graph as PSR (%) versus distance (m). Since the transmitter vehicle traveled no more than 25 mph, there are 10 data points on average per bin per lap. So for one test, given a particular receiver configuration and power level, there are on average 50 data points per bin. Furthermore, results are categorized as incoming if the transmitter was approaching the receiver and outgoing if the transmitter was moving away from the receiver. This was done to see if there was any significant bias due to the direction of the vehicles.

Test 1 and Test 2

The Type A receiver uses maximal-ratio combining diversity to add the two signals at the receiver and encode the packet. The incoming and outgoing results are shown in Fig. 6. In this research, the Type B receiver was not enabled for antenna diversity reception.

However, in the Configuration 1 and Configuration 2 setups, there are two Type B receivers. Each receiver was connected to a single antenna and received a signal from a single feed. In post processing, logs were combined from both receivers. A successful packet reception is declared when a particular packet is received in either or both receivers. This method is referred to as packet switching diversity.

Figure 7 shows PSR performance for Type B OBE reception.

Table 1 shows that combining the maximum ratios improves the communication range from 3 m up to 75 m compared to packet switching diversity. The mean improvement is 23.78 m with standard deviation of 17.4 m. There are no significant differences between incoming and outgoing results. Figures 8 and 9 show the communication range and improvements. The setups in Configurations 1 and 2 split the power of the antennas into two feeds. The power