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Vehicle-to-Barrier Communication During Real-World Vehicle Crash Tests

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Abstract

Vehicle-to-barrier (V2B) communication is expected to facilitate wireless interactions between vehicles and roadside barriers in next-generation intelligent transportation systems. V2B systems will help mitigate single-vehicle, run-off-road crashes, which account for more than 50% of roadside crash fatalities. In this work the characteristics of the wireless channel prior to and during a crash are analyzed using orthogonal frequency division multiplexing (OFDM) techniques, which has been used in existing vehicular communication systems. More specifically, the performance of OFDM-based V2B links are measured in real-world crash tests for the first time. Three crash tests conducted at the Midwest Roadside Safety Facility, Lincoln, Nebraska, are reported: a bogie vehicle crashing into a soil-embedded post at 27 mph, a sedan crashing to a concrete curb at 15 mph, and a pickup crashing to a steel barrier at 62 mph. Metrics including signal to interference plus noise ratio received signal strength, error vector magnitude, phase error, channel coherence, and bit error rate, are used to illustrate the impacts of antenna type, antenna deployment, speed, and mobility during the crash tests. The empirical evidence shows that barrier-height (0.7-0.9m) antennas at the barrier can improve V2B signal quality compared to higher deployments ($\geq$ 1.5m) due to stronger reflection of electromagnetic waves at larger angle of incidence. Moreover, compared to omni-directional barrier antennas, directional barrier antennas can increase signal quality, connectivity, and coherence time of V2B channel because of reduced multi-path effects, however, the antenna orientation needs to be carefully determined to maintain connectivity.

Keywords: Vehicle-to-barrier communications, vehicle crash, OFDM impairments

1. Introduction

Connected vehicles of tomorrow and autonomous vehicles of the near future are slated to operate on roadside infrastructure designed decades ago. Today, more than 50% of all traffic fatalities are a result of run-off-road (RoR) crashes [1, 2, 3]. These RoR crashes include vehicular crashes caused by hitting the fixed objects, rollovers, cross-median crashes, return-to-travelway crashes etc. Specifically, 40% of the defined RoR crashes represents single-vehicle crashes [2]. Roughly 20% of all traffic fatalities are related to RoR fixed-object crashes [4]. Recent vehicles are equipped with sensory technologies, such as blind-spot detection or lane-departure warning. Yet, recent statistics released by the White House and U.S. Department of Transportation's National Highway Traffic Safety Administration show that 8.3% (2,483) more people died in traffic-related accidents in 2015 than in 2014, and this increasing trend continued in 2016 with 5.8% (1,900) more fatalities compared to 2015 [5]. This unfortunate data point breaks a recent historical trend of fewer deaths occurring per year [6].

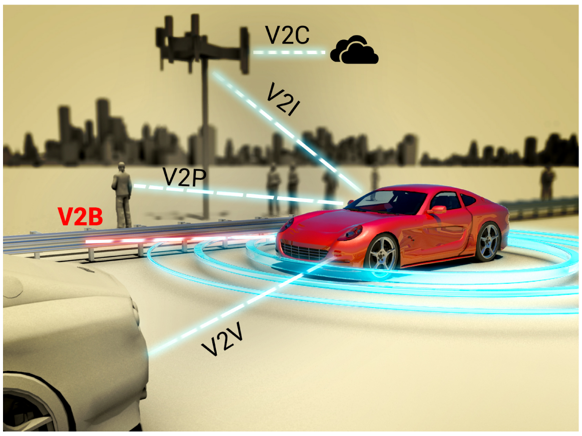

Figure 1: Vehicular Communication Technologies [7]

For nearly two decades, intelligent transportation sys-

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