The Challenges of 5G C-V2X Testing

Vehicle-to-everything (V2X) is an emerging technology that will improve traffic safety and efficiency. V2X enables vehicles to communicate with other vehicles and other parts of the traffic system, including roadside infrastructure, bicyclists, and pedestrians. According to the U.S. Department of Transportation, applying V2X technology across the board can eliminate or reduce the severity of up to 80% of auto accidents. This technology will also dramatically reduce highway travel time and fuel consumption.

Two wireless communications technologies currently enable V2X — dedicated short-range communications (DSRC) and cellular V2X (C-V2X). While V2X has used DSRC for more than 20 years, C-V2X is now available and likely to become the dominant technology for V2X. C-V2X became available with the 3rd Generation Partnership Project (3GPP) Release 14.

The first commercial deployments of the initial 4G version of C-V2X, known as long term evolution V2X (LTE-V2X), will occur in 2020. The rollout of 5G technology will further enhance C-V2X due to its lower latency, wider bandwidths, and greater pervasiveness in the roadside infrastructure.

3GPP Release 16, scheduled for completion in 2020, and Release 17, scheduled for delivery in 2021, will bring additional capabilities. These updates will further strengthen C-V2X, specifically for ultra-reliable low-latency communications (URLLC).

This white paper provides an overview of:

- considerations for deploying cellular vehicle-to-everything technology
- 5G C-V2X capability enhancements
- importance of coexistence / interference testing
- mmWave signal quality measurement for C-V2X

KEYSIGHT TECHNOLOGIES

Releases 16 and 17 will facilitate real-time sharing of sensor data between vehicles and the roadside infrastructure. These capabilities enable vehicles to understand traffic and road conditions, access non-line of sight data sensing to see around corners, and warn each other of driving hazards. These releases will also support more complex use cases for C-V2X, including autonomous driving, sub-meter military-level 3D mapping, augmented reality, and cloud-based service.

This white paper highlights the new capabilities for C-V2X offered by 5G and provides an overview of the testing challenges 5G creates for developers of C-V2X modules and communications systems.

Considerations for Implementing C-V2X

The first C-V2X standard was part of 3GPP's Release 14 in 2017, and the first chipsets to support C-V2X became available in 2019. As a result, many aspects of C-V2X commercial deployment are still under consideration.

The primary considerations for implementing C-V2X technology are:

- **Safety** — Physical layer testing is critical to ensure that the C-V2X module meets current RF and protocol standards from the physical layer through the application layer.
- **Security** — Wireless communications of all types in automobiles introduce the potential for vulnerabilities. Cybersecurity testing is essential for C-V2X technology, but there is currently no standard for automotive cybersecurity. Major original equipment manufacturers (OEMs) each use their own standards and requirements for cybersecurity.
- **Interoperability** — C-V2X is in the early stages of adoption. Validation of C-V2X technology does not exist to ensure that devices will work together and provide the functionalities specified in the standards. Plugfest events organized by the OmniAir Consortium in the U.S. and the 5G Automotive Association, in conjunction with the European Telecommunications Standards Institute (ETSI) in Europe, promote interoperability between chipsets, software stacks, and modules created by multiple vendors.
- **Frequency** — In 2019, the U.S. Federal Communications Commission (FCC) proposed reducing the amount of frequency allocated for V2X communications from 75 megahertz (MHz) to 30 MHz The proposed spectrum reallocation would significantly reduce the amount of frequency available to V2X technologies at a time when C-V2X is just beginning broad-based adoption.

C-V2X Capability Enhancements With 5G

While the primary benefit of LTE C-V2X is the reduction in traffic collisions through safety message broadcasting, 5G technology brings a significant increase in C-V2X capability. 5G enables several new C-V2X features, including support for vehicle platooning, coordinated driving, sensor data sharing for collective situational awareness and collision avoidance, and real-time traffic and infrastructure updates.

The unique requirements of 5G technology impose specific hurdles to successful 5G testing. The 3GPP has assigned two different frequency ranges to 5G, each with particular testing challenges.

Importance of Coexistence/Interference Testing

Frequency Range 1 (FR1) includes the frequency bands from 410 MHz to 7.125 GHz. FR1 contains spectrum used by or adjacent to that of existing wireless communications systems, including LTE, Wi-Fi, and *Bluetooth*®. V2X systems that use 5G New Radio (NR) technology will need to operate in these spectrum ranges without causing interference. This is a serious concern considering the mission-critical status of V2X communications for automotive safety.

Interference testing involves testing in-band and out-of-band emissions and testing the impact of the C-V2X emissions on other radio signals. This is necessary to ensure that the 5G radio signal does not cause interference with other radios in the same vehicle or other radio signals in the channel. Interference testing also ensures that the C-V2X signal does not interfere with other signals in the adjacent spectrum.

Interference from out-of-band emissions can degrade the reliability of C-V2X communications, directly impacting transportation safety. The U.S. Department of Transportation (DOT) conducted a technical assessment on the out-of-band interference impact of DSRC, Wi-Fi, and LTE C-V2X operating in adjacent channels. The DOT assessment concluded that signals from all three technologies leaked into the adjacent spectrum. This caused interference and raised the question of the reliability of C-V2X communications under the proposed spectrum reallocation.

C-V2X modules must operate in a shared spectrum environment without negatively impacting bandwidth. Sharing airwaves increases the responsibility of semiconductor manufacturers, automakers, and OEMs to ensure that the C-V2X system will coexist with the existing commercial wireless infrastructure. C-V2X systems require complex algorithms to monitor and detect other users in the spectrum. This technology enables a vehicle to sense its location and other transmitters in range and adjust the way it transmits and receives signals accordingly.

mmWave Signal Quality Measurement

Frequency Range 2 (FR2) includes the mmWave frequencies from 24.25 GHz to 52.6 GHz. Extending to mmWave frequencies enables 5G NR to offer access to a larger contiguous bandwidth. This access can relay much more data related to traffic and road hazards to and from the cloud or directly to other nearby vehicles. The smaller wavelength of the signal introduces challenges to signal quality and link budget.

Many factors impact signal quality, including baseband signal processing, modulation, filtering, and up-conversion. Also, C-V2X modules will face signal impairments that become more problematic at the higher frequencies and wider channel bandwidths of mmWave.

Orthogonal properties inherent in orthogonal frequency-division multiplexing (OFDM) systems prevent interference between overlapping subcarriers. However, issues such as in-phase/quadrature (I/Q) impairments, phase noise, linear (AM to AM) and nonlinear (AM to PM) compression, and frequency error cause distortion in the modulated signal. Phase noise is one of the most challenging factors in mmWave OFDM systems. Too much phase noise in a system results in an error vector magnitude that is too high, leading to impaired demodulation performance. Too much phase noise also causes subcarrier interference, further impairing demodulation performance.

Operating at mmWave frequencies increases bandwidth but introduces new challenges in path loss, blockage, and signal propagation. Because of the shorter wavelength of mmWave transmissions, physical obstacles in the channel — including other vehicles — will block the signal. The use of vehicle-mounted antennas in C-V2X exacerbates these issues.

Beamforming is a method of applying relative phase and amplitude shifts to each antenna element to shape and provide discrete directional control of a transmitted beam. It is a key technology used to overcome the propagation issues that afflict mmWave transmissions. As a result, FR2 transmissions are highly directional, requiring higher gain active antennas with electrically steerable direction. In automotive systems, where the body of the vehicle acts as a large ground plane located in close proximity to the antenna, FR2 transmissions create a host of additional antenna testing challenges and link budget management complexities.

5G C-V2X module designs need to overcome the physical challenges associated with mmWave signals. You need test solutions to measure and characterize signal quality accurately without introducing new issues. It is also critical to validate the C-V2X quality of service (QoS) and performance on the network.

New Strategies Required

Like everything else it touches, 5G brings enormous enhancements to C-V2X technology. Those enhancements also introduce many new design and test challenges. C-V2X designers and developers must ensure the performance of their C-V2X systems meet safety requirements even as the standards continue to evolve. They must also achieve conformance with many global and regional standards to ensure their products meet interoperability, interference, and security requirements.

Design and test are the starting point of innovation, and C-V2X is no exception. Bringing reliable C-V2X modules to the real world involves many test cases that span latency, reliability, range, congestion control, data throughput, antenna operation, dynamic channel impairments, and many more aspects.

As technologies evolve and get more complicated, traditional test solutions and methodologies must evolve. C-V2X requires new end-to-end testing solutions that include RF, protocol, functional, and Intelligent Transportation System (ITS) stack tests.

C-V2X utilizes two transmission modes. One mode is for communications with the conventional mobile network. The other is for direct communications with vehicles, infrastructure, and vulnerable road users such as bicyclists and pedestrians. Global Navigation Satellite System (GNSS) emulation is required for time and localization synchronization between the two transmission modes.

To learn more about 5G in C-V2X and other automotive applications, please read the following resources:

- Test Challenges and Solutions for C-V2X – Webinar
- Making 5G Work – eBook
- Vehicle-to-Everything (V2X): Shaping the Future of Smart Mobility – White Paper
- Winning in 5G with Rapid Characterization of Evolving Antenna Designs – White Paper
- Keysight 5G Solutions – Online

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