
PLAZA HOTEL
PLAZA HOTEL
MAIN ST.

Test systems for V2X communications

Future automated vehicles will be wirelessly networked with their environment and will therefore be able to preventively respond to dangerous situations. To ensure that the safety-related information is received even under poor transmission conditions, the transmitter and receiver must comply with minimum standards. The R&S®TS-ITS100 and R&S®TS8980 RF test systems check whether this is the case.

Automated vehicles can safely navigate the road only if they have precise knowledge of their environment and the traffic situation. A wide variety of sensors and cameras already provide some of this information. New technologies are needed to further reduce the risk of accidents. Critical traffic situations can be detected before they occur thanks to the wireless exchange of information between vehicles (V2V communications), as well as between vehicles and the traffic infrastructure and all road users (V2X communications). If, for example, all vehicles approaching an intersection exchange information about speed and direction, potential collisions can be detected, warnings can be issued, and autonomous countermeasures can be initiated early on. For this reason, the exchange of information between the vehicles must be reliable even under poor transmission conditions and without line of sight.

Distortions compromise safety

Wireless links are prone to failure due to physical effects. Fading includes shadowing and interferences due to scattering, diffraction, refraction and reflection, which cause multipath propagation of the signal. This means that multiple versions of the same signal arrive at the receiving antenna at different times and with different signal levels and distortions. This superposition can distort, attenuate or even cancel the signal.

Another complication is that road users are also continuously moving, which results in time-variant fading scenarios. If a receiver cannot handle time-variant fading, then it might not be able to detect and process the signal. This loss cannot be compensated for by strong coding or a special protocol, creating a considerable risk, especially when drivers rely on the warnings by V2X systems.

Test of physical transmission

To minimize the safety risk arising from poor transmission conditions, the RF transmitters and receivers in the onboard units (OBU) and roadside units (RSU) of the communications system must exhibit certain characteristics. Developers and users integrating V2X components into their systems can use RF tests to verify these characteristics. The two lowest layers of the OSI model (Fig. 1) are relevant to these tests because they are responsible for the physical transmission of the message:

- The physical layer handles the physical transport of the data via a transmission medium. In the case of V2X communications, this transport is wireless. This layer uses specific modulation modes, carrier frequencies and bit rates. Often the quality of the transmission channel is also taken into consideration.
- The data link layer is divided into an RF section (MAC) and a protocol section (LLC). The medium access control (MAC) layer controls the access to the transmission medium for multiple users. This is relevant to RF measurements. The logical link control (LLC) layer handles tasks such as error detection and correction at the protocol level.

In contrast to RF tests, tests at the protocol level, i.e. from the LLC layer up to the application layer, are not suitable for verifying RF characteristics. These tests check that the bitstream, which is generated in the LLC layer from the received signal, is processed correctly. Therefore, the success of all tests at the protocol level depends essentially on whether the signal can be safely received and converted into a correct bitstream that will not contain more bit errors than the channel decoder can correct.

Layer	Name	
7	Application	
6	Presentation	
5	Session	
4	Transport	
3	Network	
2	Data link	Logical link control (LLC)
		Medium access control (MAC)
1	Physical	

Fig. 1: OSI layer model.

The RF module in the OBU (i.e. the MAC layer and the physical layer) must meet certain minimum requirements, e.g. with respect to power and frequency accuracy and packet error rate (PER). In addition, the transmitted signal may not interfere with any of the transmission technologies on adjacent frequencies.

How are the requirements for the RF module checked, and how can it be ensured that a transmitted message/action is actually received? A look at the wireless communications industry shows that three different types of RF tests are used to validate and certify smartphones:

- Regulatory tests check, for example, whether the transmit signal stays within power limits defined for other frequencies. The regulatory authority of a country usually specifies these values, and compliance with them is required by law. These types of specifications are now available for V2X units.
- Conformity tests ascertain whether a smartphone meets the RF specifications of the respective wireless standard. For example, smartphones must not exceed a specified maximum packet error rate or maximum transmit power. A separate test specification often describes how to perform and evaluate these tests.
- Stricter or additional tests as required by some wireless service providers help them to differentiate themselves from the competition by providing better transmission quality and higher network reliability. Only mobile devices that meet these specific requirements are approved for the network of this provider.

Fig. 2: The R&S®TS8980 (left, for LTE) and R&S®TS-ITS100 (for WLAN 802.11p) RF test systems perform all required conducted tests in the development stage.

Radio signals over cable

The automotive industry tests automotive components and electronic control units not only in the lab, but also on testing grounds or on roads. For wireless communications, this is the equivalent of field tests, offering a realistic environment for RF tests. However, external influences such as the weather may unpredictably change the RF characteristics of the radio link. The test setup and test sequence also depend on the vehicles involved and the antenna locations, and often they can only be changed with considerable effort.

Transmit characteristics
- Frequency accuracy
- Modulation accuracy
- Out-of-band emissions
- Transmission power level
- Spectrum emission mask
- Spurious emissions

Receive characteristics
- Adjacent channel rejection
- Nonadjacent channel rejection
- Decentralized congestion control
- Out-of-band emissions when transmitter is off
- Performance with fading (packet error rate)
- Sensitivity

Fig. 3: Examples of RF tests for checking OBU and RSU characteristics.

This is not practicable for testing in the development stage. That is why conducted tests are performed as an alternative to field tests, where RF test systems such as the R&S®TS-ITS100 or R&S®TS8980 (Fig. 2) simulate the signals in the radio channel and transmit them to the device under test (DUT) via cable. These RF tests can be performed for each prototype and each software or hardware modification. They provide a large number of advantages:
- The tests can be performed at any time and at relatively low cost.
- The test conditions are clearly defined and can be changed time and again irrespective of outside influences.
- Defined test sequences under identical conditions lead to comparable results, making troubleshooting easier.
- Unlike field tests, parameters such as the fading profile can be easily modified.
- Several tests can be combined into series and automated, e.g. as endurance tests to check the reliability of a prototype.
- RF tests such as error vector magnitude (EVM) or RX sensitivity tests only make sense as conducted tests, since uncontrollable noise and interference from external sources falsify the measurement results in field tests.

Depending on the selected scenario, channel simulation exactly simulates the physical characteristics of the radio link. The R&S®TS-ITS100 RF test system can also simulate the special V2X fading profiles in real time.

Field tests are useful nonetheless, especially for antenna measurements, e.g. for determining the antenna pattern or for beamforming tests. Conducted tests therefore cannot completely replace the field tests.

Detecting RF problems

To be able to compare the test results for the various hardware and software versions of a V2X unit, all test sequences must be clearly defined. Some countries have therefore laid down test specifications for V2X systems that include test cases in four categories (Fig. 3):
- TX in-band: The test cases in this group test the transmitter (TX) characteristics, such as maximum and minimum transmit power, frequency accuracy and modulation accuracy.
- TX out-of-band: The unwanted transmit power outside of the allowed frequency band must not disrupt other technologies. TX out-of-band test cases measure this transmit power and compare it against the permissible limit value.
- RX in-band: This category tests the receiver (RX), for example by measuring the lowest receive power at which the received signal can still be decoded or using performance measurements with fading. Fig. 4 shows a configured V2X fading profile on the R&S®SMW200A vector signal generator.
- RX out-of-band: Specialized test cases measure whether an OBU or RSU unintentionally emits power into other frequency bands when the transmitter is switched off.

Various V2X plugtests* have shown that especially the TX out-of-band and fading tests are problematic for many DUTs (Fig. 5). The R&S®TS-ITS100 can detect such RF problems as early as the development phase.

At present, various wireless technologies are under discussion for implementing V2X communications, in particular WLAN 802.11p, LTE and 5G, which will be available in a few years. Regardless of which technology is used, Rohde & Schwarz already offers the test solutions needed for V2X measurements. LTE-based solutions can be tested using the R&S®TS8980 RF test system family. The test scope is continually being adapted to the evolution of LTE, making it also suitable for V2X measurements.

* Events where products from different manufacturers are tested for compatibility based on a specific standard

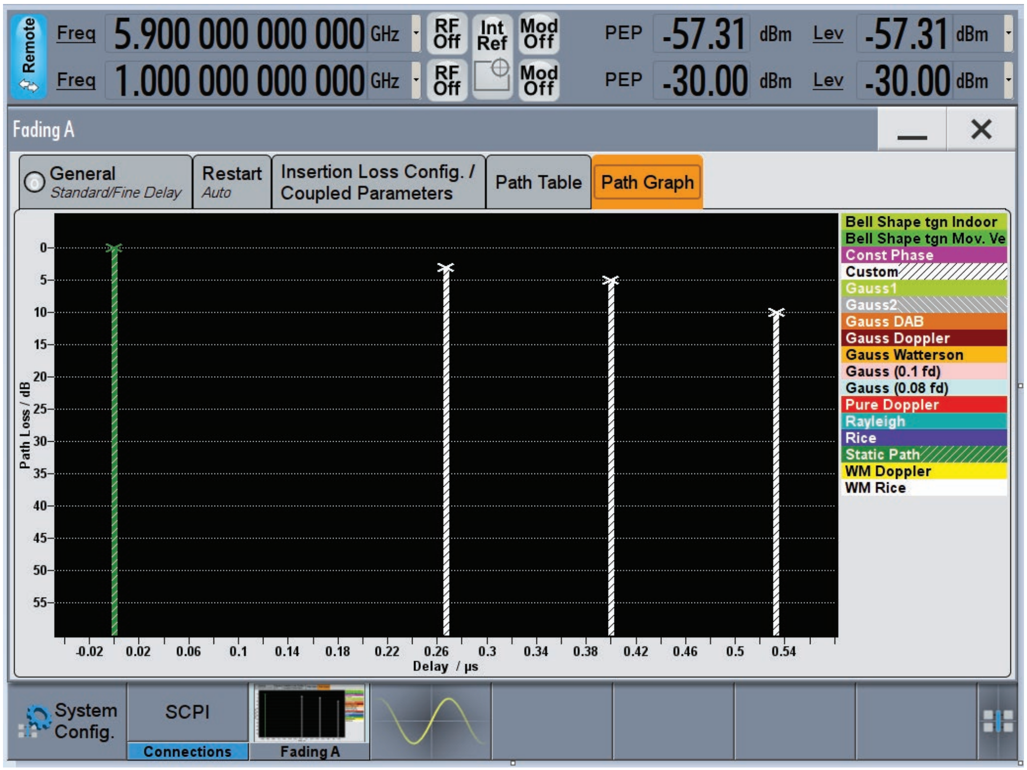


Fig. 4: Fading profile for V2X at 5.9 GHz on the R&S®SMW200A vector signal generator.

Power spectrum

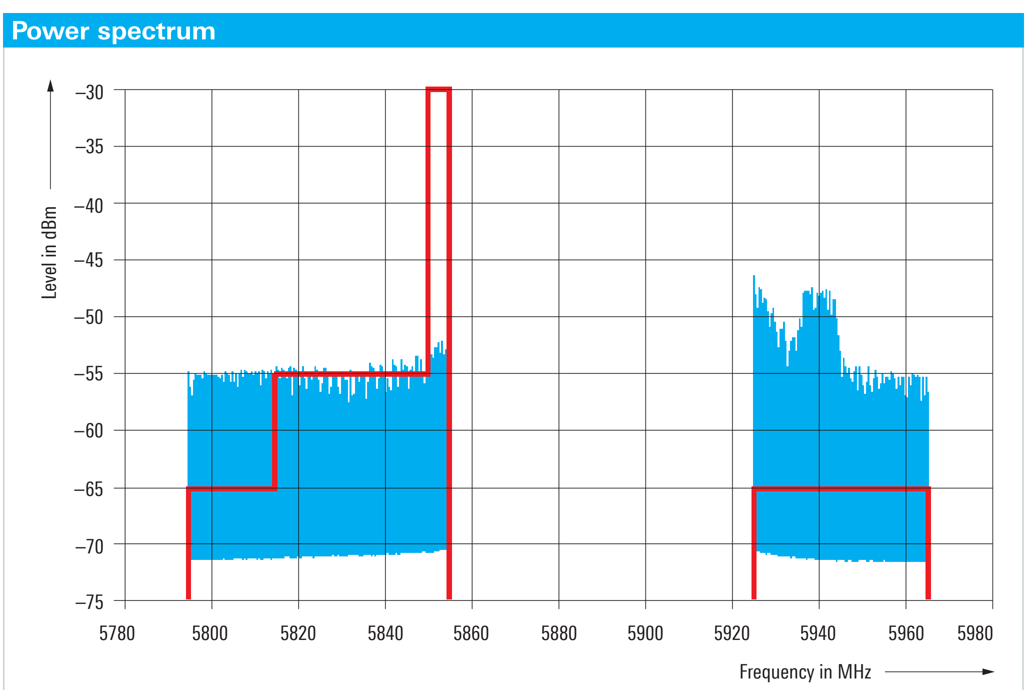
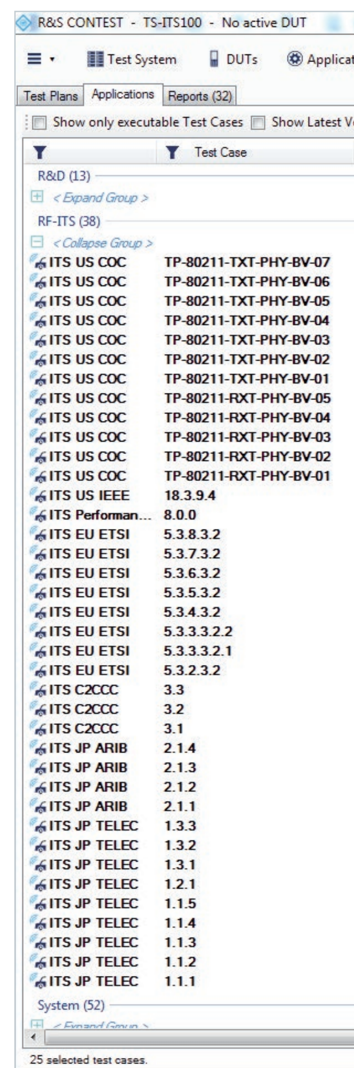


Fig. 5: TX out-of-band test: The transmit power (blue) of a WLAN 802.11p unit exceeds the permissible limit at multiple points (red line). The frequency range between 5855 MHz and 5925 MHz is reserved for V2X in Europe and in the US.

Fig. 6: R&S®Contest software for the R&S®TS-ITS100 and R&S®TS8980 RF test systems. The small window on the right shows some of the parameter settings that users can configure themselves.



For WLAN 802.11p, the R&S®TS-ITS100 RF test system contains the complete package of test cases for

- Europe at 5.9 GHz (ETSI EN 302 571),
- USA at 5.9 GHz (IEEE 802.11-2012) and
- Japan at 760 MHz (TELEC T257 and ARIB STD-T109).

For out-of-band tests, the test system permits measurements up to 18 GHz and can use a variety of filters as needed for various regions. The system hardware is already set up to handle diversity and multiple input multiple output (MIMO). WLAN 802.11p tests pose a special challenge because there is no defined uniform interface to 802.11p units. In order to configure a unit for a test case, the test software must address the unit with individual commands. For this reason, the test system already contains ready-made plug-ins for many units to make fully automated testing possible.

Both test systems are controlled fully automatically using the R&S®Contest software (Fig. 6). It provides a graphical interface for selecting the RF tests, as well as for compiling the test plans and evaluating the results. This software, which has been widely used in the wireless communications industry for many years, can also test WLAN 802.11p test cases. The R&S®Contest reports can be used for validation and certification.

Summary

In order to improve road safety, vehicles will be wirelessly connected to each other and to the traffic infrastructure in the future. The safety-related information exchanged must be reliably received under all external conditions. Only RF tests, such as those offered by the R&S®TS-ITS100 test system for 802.11p and the R&S®TS8980 test system for LTE, can ensure that the OBUs and RSUs meet minimum physical requirements, so that lives can be saved in case of emergency.

Dr. Thomas Brüggen