Application Note

TELEMATICS CONTROL UNIT: DESIGN AND TESTING CONSIDERATIONS

Products:

- ► R&S®CMX500
- ► R&S®CMW500
- ► R&S®CMW100
- ► R&S®SMBV100B

Nikhil Kumar | Rohde & Schwarz | Version 1.00 | 06.2020

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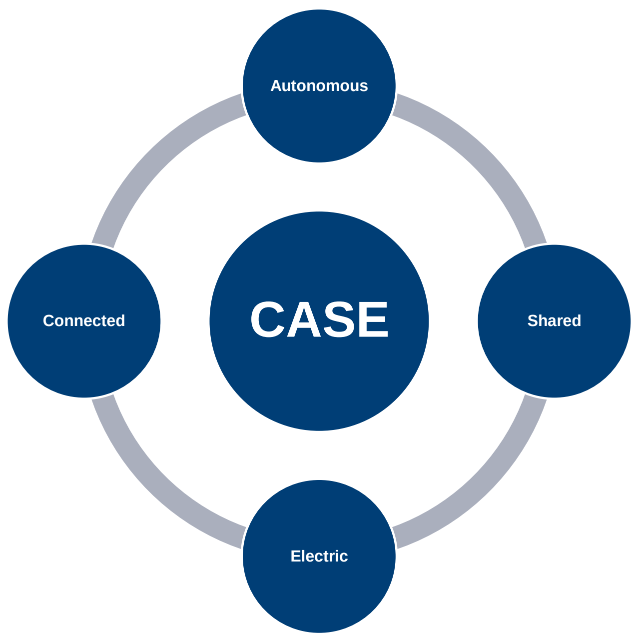
Contents

1 Overview

The wireless connectivity between the modern vehicle and the outside world is possible due to the constantly evolving component inside the vehicle called the telematics control unit (TCU). Connecting the vehicle to the cloud enables new business models for the vehicle manufacturers and promises new safety and convenience related features for the drivers and passengers. The modern use cases powered by connectivity are far more than just providing over the air software updates. Adding a TCU to the vehicle and keeping it operational comes with its own set of challenges and hence demands a focused approach towards designing and testing TCUs. In this paper we will discuss various features of the TCU, key design considerations, and also provide details on testing aspects that can help automotive OEMs and Tier-1s to ensure proper functioning of the TCU.

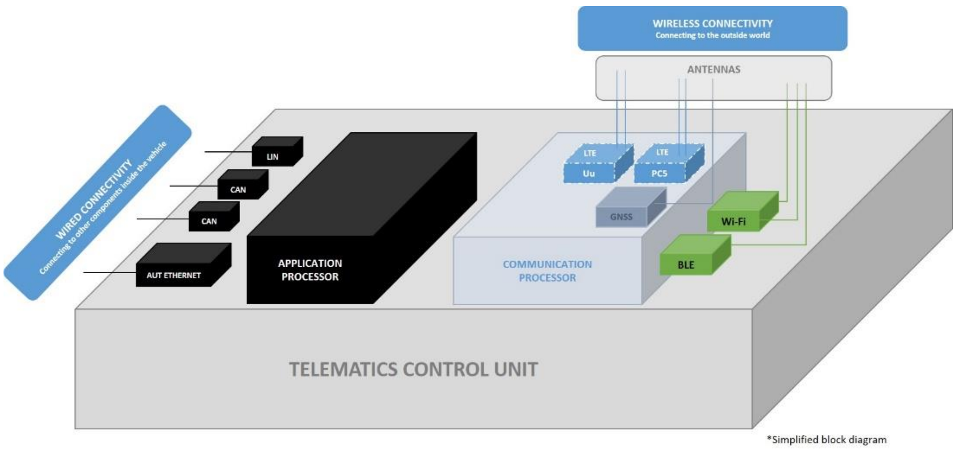
2 Introduction

Current trends in the automotive industry indicate a focus on four areas i.e. connected, autonomous, shared, and electric, often referred by the acronym CASE. In this paper we are going to dive deep into the domain of “connectivity”. Connecting the vehicle to everything around it (like cloud infrastructure, road side infrastructure, person, and other road users) enables new business models for the vehicle manufacturers and promises new safety and convenience related features for the drivers and passengers. The modern use cases powered by connectivity are far more than just providing over the air software updates. Connectivity is in fact such a core feature of the modern vehicle that it leaves imprints on the autonomous, shared, and electric domains as well. Some of these use cases will be discussed later in this document.



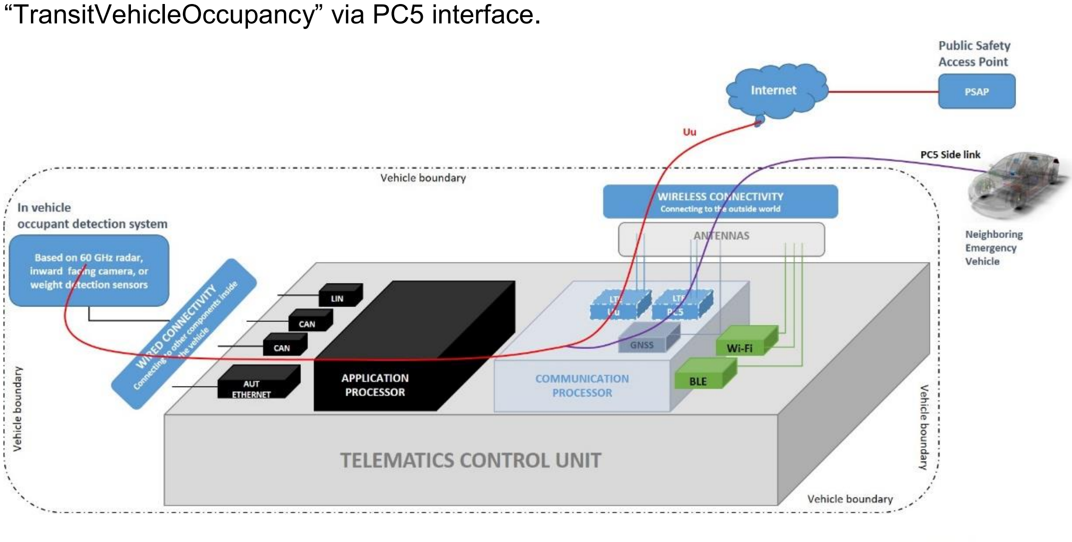
CASE: Connected, Autonomous, Shared, Electric

Connectivity related features of a vehicle are enabled by a key component called telematics control unit (TCU). A TCU is loaded with multiple wireless technologies that enable the vehicle to exchange information with the entities outside the vehicle. The TCU is also connected to multiple components inside the vehicle like other electronics control units and domain controls via wired connections using automotive Ethernet and controller area network (CAN) bus technologies.



TCU: Telematics Control Unit

The following figure shows how the TCU connects an "in-vehicle occupant detection system" to the "outside vehicle" entity like public safety access point (PSAP) for emergency call (eCall) or neighboring emergency vehicle in a V2X scenario. Knowing the number of occupants inside the vehicle is of prime importance for the PSAP and is conveyed inside minimum set of data (MSD) as "NumberOfPassengers" via Uu interface. Similarly, occupancy data can be passed on to neighboring emergency vehicle inside safety message as "TransitVehicleOccupancy" via PC5 interface.



Enabling connectivity between the internal components of the vehicle to outside world

It is clear from the above example that the TCU plays a pivotal role in the vehicle architecture. There are numerous use cases like these that are made possible via the TCU. No wonder product and engineering teams put a lot of thought in designing and testing this key piece of the vehicle.

The next few sections will list down key product design questions that must be considered while developing a TCU. This will be followed by testing aspects that will focus on types of testing and explain various test setups that can be used to test telematics control unit by development and verification teams at automotive Tier-1s and automotive OEMs.

3 Design considerations

The vehicles are made for the consumers as well as for businesses. The expected behaviors of a passenger vehicle are quite different from that of a commercial vehicle. Engineering teams therefore need to design the TCUs aligned with the end customer's requirement. In addition to this, the wireless technologies as well as the automotive industry are transforming at a very fast pace. The wireless industry is moving from fourth generation (4G) to fifth generation (5G) and the automotive industry is working on autonomous vehicles.

It is a good idea to start with a few key questions while designing the new TCU. Developers and designers need to constantly revisit and keep asking themselves the following questions about the TCU to keep up with the technological advancements as well as the competition.

Why build?	How to build?	What to build?
Establish connectivity between the vehicle and its neighbors which could be far (e.g. cloud infrastructure) or near (e.g. other vehicles, person, and road side infrastructure) such that it **enhances safety** for the driver and passengers, and **enables new business models** for the OEMs.	Buy versus build: Should the telematics control unit be developed in-house or bought from a supplier.	Pick the right selection of wireless technologies along with hardware and software components that serve the long term business goals.

Key questions while developing TCU

3.1 Why build?

A wide range of features can be realized by adding TCU to the vehicle. Having a wireless link (via Wi-Fi or cellular connection) between the OEM cloud services and the vehicles enables over the air software updates, predictive maintenance, recall messages, usage based insurance, and many location based services. It also makes remote debugging and teleoperation possible in certain use cases applicable for autonomous vehicles. It is clear that these applications are difficult to be developed by the OEMs themselves and can only be realized by partnerships between telecom operators, cloud infrastructure providers, IoT solution providers, and the automotive OEM.

The impact of some of these features is significant in terms of savings for the OEMs. OTA updates alone can minimize vehicle recall related costs. OTA updates can also deliver software bug fixes and deliver new features to the end user. This method of software delivery is much more efficient than taking the vehicle to a maintenance center or expecting the user to update their vehicle using portable USB drives. OTA updates improve vehicle safety and increase customer satisfaction on a continuous basis throughout the lifetime of the vehicle. It also opens a wide range of revenue opportunities for the OEM even after the initial sale of the vehicle. Partnering with insurance providers for usage based premiums, or with telecom providers for data usage are a few examples. In-vehicle apps for entertainment related services is also something that the OEMs can explore.

Safety is another dimension that can be added to the vehicle via vehicle to everything (V2X) and other connectivity related features like emergency call (eCall).

Novel ideas like autonomous fleets can also benefit from the wireless link between the vehicle and the cloud infrastructure. Remote debugging, remote assistance, and teleoperation are a few possibilities that are possible over the cellular link. Constant monitoring of the health of an autonomous vehicle (AV) and updating HD maps in real time are a few other examples that are made possible via connectivity. These applications do come with their own set of challenges like latency, throughput, cellular network coverage, etc., but LTE and 5G cellular technologies provide adequate tools to deploy them.

Engineering teams working on training and testing autonomous fleets can benefit from adding advanced Wi-Fi versions like 802.11ax to the TCU. Engineers are constantly updating large fleets of autonomous vehicles (AVs) with newer versions of software and take these autonomous vehicles for drive tests. There is a constant challenge to bring back large amounts of data from the drive test and upload for analysis before the next version of software is installed on the AV fleet. Using a wired connection is inefficient and using an LTE connection for this use case will be very expensive.

Looking at the wide set of features, conveniences, cost savings, and possible revenue models, it is clear that having a TCU loaded with the right combination of cellular and wireless technologies is a good idea.

3.2 How to build?

Automotive OEMs have traditionally been acquiring components from Tier-1s in the supply chain and this includes TCUs. However, there can be situations where the automotive OEM might want to develop their own TCU. “Buy versus build” therefore becomes a challenging question. Teams need to carefully analyze multiple factors before they pick one strategy over the other. Some of these factors are listed in the table below.

	Buy	Build
Description	OEM lays down the requirements and TCU is manufactured by Tier-1.	OEM designs and develops a customized TCU in-house.
Wireless & SW/HW engineering expertise	Tier-1s have years of experience developing TCUs. They also have engineering talent and expertise in wireless, software, and hardware engineering.	If the OEM has expertise in wireless, hardware, and software engineering then this approach can be considered.
Customization	As the possible use cases increase, the OEM might ask for customized design and features. A TCU for an autonomous vehicle might need customized interfaces and specific performance metrics from the cellular modems (e.g. teleoperation). Number of bands in LTE and 5G NR also demands flexible hardware design. Such specific customizations will increase the cost for the OEMs.	It might be easier for the OEM to manage customizations and offer greater flexibility by developing the TCU for an AV in-house. OEMs can also hold on to the “secret” sauce used to build the TCU. This can be a major competitive advantage, especially while developing an autonomous vehicle.
Cost	As the number of features and customizations increase, the Tier-1 is bound to ask for a higher price. The value they bring with the customized TCU increases sharply as it is for specific use cases.	Building the TCU in-house can give a better control on cost over time. Vertical integration within the company also gives a better control on maintaining overall quality and make integration easier.
Testing effort	Tier-1 bears most of the testing effort including operator certification and delivers TCU as a finished product. The OEM still needs to bear the integration effort.	All testing effort is owned by the OEM.
Time to market	This approach is better for the OEM, especially if there is limited in-house engineering expertise and they want to launch the vehicle soon.	Time to market can significantly increase and can delay the launch of the vehicle if the TCU is not up to the mark or not delivered in time.
Business model	It is reasonable to assume that future business models will have multiple revenue streams in addition to just selling the vehicles. If this is the case, then there could be cases where the TCUs might need to be replaced multiple times (due to technology advancements) during the lifetime of the vehicle. Buying the TCU will increase the cost for the OEM.	A relatable example will be migration of a 4G TCU to a 5G TCU. OEMs might want to take an approach where they can update the TCU at no cost to the consumer and expect greater returns from data services. In such a case, an OEM might prefer a TCU that is developed in-house.

Feasibility matrix

3.3 What to build?

At a high level, product development teams need to decide on the hardware, accompanying software, and pick which wireless technologies need to be part of the TCU. Identifying these items is essentially the answer to “what to build”. Identifying the TCU features and then working backwards to reach to the list of wireless technologies is one possible approach. Factors like cost or engineering effort, etc. are not considered and are outside of the scope of this document.

Three factors are considered here, i.e. “Use case”, “target market”, and “lifetime of TCU”. These examples show how considering some of the key factors can help in reaching to the right feature set and eventually to the list of wireless technologies that the TCU should support. Some of the features mentioned here are based on advanced concepts like autonomous vehicles and advanced technologies like 5G New Radio (NR).

► Use case

Case 1	**TCU for a passenger vehicle**
Description	This is one of the most common use cases and also going to be the way modern cars are delivered to private consumers in near future. Telematics control unit is part of the vehicle.
Key points	► The vehicle must be able to connect to the LTE network and able to access data services like entertainment apps, IP Radio, navigation map updates, etc. Data usage over LTE can be charged. ► The OEM must be able to offer over the air software updates via LTE and Wi-Fi. Using this mechanism software, bugs can be patched and new features can be added to the vehicle throughout the lifetime of the vehicle. Data over LTE can be charged. ► OEM can monitor the health of the vehicle parts and predict maintenance before the parts damage. OEM can also send critical recall messages that require the vehicle to drive back to dealership. ► User can connect personal mobile devices to the vehicle to sync mobile calls and audio via Bluetooth. ► User can use mobile app to set cabin temperature, unlock and lock the vehicle remotely. Other operations are also possible. ► User can receive usage based insurance coverage by sharing driving habits with the insurance providers if they chose to do so. ► Vehicle can possibly receive and send V2X messages adding safety features like GLOSA (Green Light Optimized Speed Advisory), EEBL (Emergency Electronic Brake Light), etc. DSRC or C-V2X will be needed in such situations. ► Location based services along with built-in navigation maps will need GNSS.

Case 2	**TCU for a commercial vehicle that is part of an autonomous fleet**
Description	Autonomous vehicles loaded with multiple sensors like camera, radar, LIDAR, etc. can manage prediction, perception, and planning decisions, but requires TCU for connectivity.
Key points	► Autonomous machines need constant monitoring that can be managed by a remote control station. This requires constant information reporting on travelling routes, vehicle health monitors, etc. This can be achieved via LTE connection. ► In some cases LTE-M or other machine type communication can also be used for asset tracking. GNSS will also be needed for precise location tracking. ► In certain limited scenarios, the AV might need help from a remote operator. These could be inside geo fenced locations like yard

	parking, mining areas, etc. This requires ultra-reliable, low latency 5G NR connection. ► Other situations where the on board sensors and software algorithm cannot decide the best possible alternative might fall back to a safe alternative of stopping on the side of the road and wait for remote operator to decide the next steps. Teleoperation requires extensive cellular coverage and needs multiple LTE connections (possible via connecting to multiple cellular operator networks) to increase the effective in-coverage area. Having multiple modems is a possibility and adding an electronic SIM will also be needed that can store multiple profiles. ► Platooning trucks that are part of the same fleet can constantly share V2V messages. 5G NR V2X can make such use cases possible. ► AVs constantly use HD maps data to understand their surroundings. If a truck detects differences between the stored HD map and the actual surroundings, then it can update the HD map so that the remaining members of the fleet have up to data HD map. This will require LTE and 5G connections. ► Updating software for a large fleet of AVs in the yard all at the same time can be achieved via 802.11ax. This method is cheaper than updating over the LTE network.

► Target market

Case 3	**The passenger vehicle is sold in Europe**
Description	This section lists considerations that are in addition to Case 1 and are applicable due to the geographic location of the vehicle being European Union.
Key points	► Support for eCall (emergency call) is mandatory. This means 2G/3G and GNSS has to be part of the vehicle. Teams can also go for eCall modules that are prepackaged for such use case. ► Uncertainty with the choice of V2X technology makes it difficult to pick DSRC, or C-V2X, or both. Teams can also consider novel designs at the hardware level that can be flashed at a later time with an appropriate software to enable one of the two possibilities. ► Pick the LTE modem which supports LTE Bands that are supported by the regional network operators. ► Pick the 5G NR modem which supports 5G Bands that are supported by the regional network operators. ► Pick the right GNSS module that is compatible with Galileo satellite constellation.

Case 4	**The passenger vehicle is sold in the United States**
Description	This section lists considerations that are in addition to Case 1 and are applicable due to the geographic location of the vehicle being the United States.
Key points	► Uncertainty with the choice of V2X technology makes it difficult to pick DSRC, or C-V2X, or both. Teams can also consider novel designs at hardware level that can be flashed with an appropriate software at a later time to enable one of the two possibilities. ► Pick the LTE modem which supports LTE Bands that are supported by the regional network operators. ► Pick the 5G NR modem which supports 5G Bands that are supported by the regional network operators. ► Pick the right GNSS module that is compatible with GPS satellite constellation.

► Lifetime of the TCU

Case 5	Expected lifetime of the TCU is same as that of the vehicle
Description	This is the same use case as case 1. The list below considers aspects that arise due to the duration of the lifetime of the TCU.
Key points	► TCU can be developed with the understanding that it is going to be part of the vehicle for the lifetime of the vehicle. ► Software upgrades to fix bugs is possible via LTE or Wi-Fi ► Cellular networks are going to be upgraded and 5G will be rolled out soon. Teams can consider selecting hardware capabilities that support LTE bands initially but can be reused for 5G FR1 bands. Software defined radios, along with appropriate RF front end and antennas that support the frequency ranges can be used. This is assuming that the regional network operators have the appropriate frequency bands allocated to them and they plan to re farm the LTE bands for 5G FR1.

Case 6	Expected lifetime of the TCU is shorter than that of the vehicle
Description	This is the same use case as case 1. The list below considers aspects that arise due to shorter duration of the lifetime of the TCU compared to that of the vehicle.
Key points	► In certain situations, hardware upgrade might become a necessity. Once such case is the migration from a 4G LTE TCU to 5G NR TCU where a software only upgrade is not compatible to the frequency bands in the region. Teams must consider a modular design of the TCU with clearly defined interfaces with the rest of the vehicle architecture. A hardware swap is a possible strategy. ► OEMs might consider charging the end customer for this upgrade or might provide this alternative for free since they see possibilities of alternative revenue streams like data usage on 5G network. This design decision needs to align with the OEM’s overarching business strategy.

4 Testing aspects

For obvious reasons, engineering teams strive to build products that can work flawlessly in the vehicle once released. Testing these products therefore becomes one of the most important areas during the product development lifecycle. Teams can emulate scenarios like handovers, interference, and fading conveniently in the lab environment using test equipment.

Emulating multiple 5G and LTE base stations in the lab and then running handover scenarios ensures that the users are able to test complex measurements and handover situations that are bound to happen in the live network. The ability to add secondary component carriers (SCC) enables the user to test enhanced data throughput using principles of carrier aggregation. Having access to configuration parameters gives the users the ability to change data allocation, guaranteed bit rate configuration, and emulate network slicing.

Built-in faders also add the ability to make the tests more challenging for the device, which is essential to test the robustness of the implemented feature. Signal generators act as the source of interference to the technology under test and lets the user create a challenging environment for the device under test.

Engineers can also emulate vehicle motion using a satellite simulator. This gives the users the ability to model moving scenarios for different routes and trajectories conveniently in the lab environment. This makes the test environment more realistic and brings not only the cellular modem, but also the GNSS module under test.

To sum up, benchmarking individual components and testing the TCU as a whole are essential steps before testing the vehicle on the roads.

4.1 Scope

The scope of testing a TCU is vast. It can vary from benchmarking the RF components to product verification and validation. There are other areas to focus on like non-signaling tests, signaling tests, conducted tests, over the air tests, lab tests, field tests, production tests, etc. Some of these will be covered in the following sections.

There is a wide variety of testing that will depend on the target market where the vehicle will be launched and driven. Cellular operator certification, local regulator mandated features (like eCall, ERA-GLONASS), or uncertainties about the preferred V2X technology (C-V2X, or DSRC, or both) are some of the points that play a role in deciding the scope of testing. It is required that product development and verification teams carefully look into these topics and decide the scope of testing accordingly. Teams can contact network operators to identify the scope of operator certification testing.

4.2 Test Setups

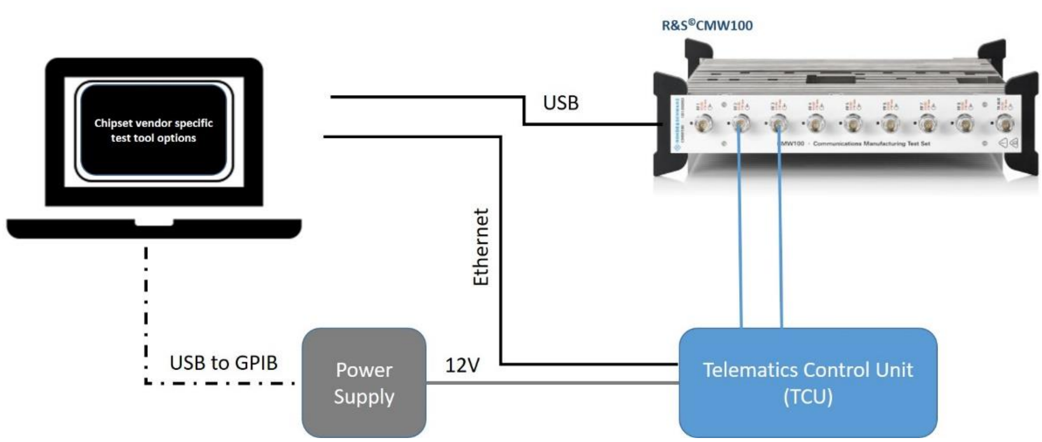
As mentioned in the previous section, there is a wide scope of testing that can vary depending upon the desired features, target market, local regulators, local telecom operators, and more. This section lists just a few examples of the test setups that are useful to test the TCU in a lab environment.

4.2.1 Benchmarking RF characteristics

Once the TCU design is in place and the suppliers of individual cellular and wireless technologies modem are decided, it is time to benchmark the RF characteristics of the modems. This type of testing can be done in non-signaling mode. At this stage, the point of interest is to verify if the individual components perform at the RF level as advertised by the suppliers. Non-signaling mode is used to verify the transmitter and receiver properties of the wireless device. At this stage, the application software is still not integrated on the TCU and hence feature testing is not possible.

4.2.1.1 Tx and Rx measurements

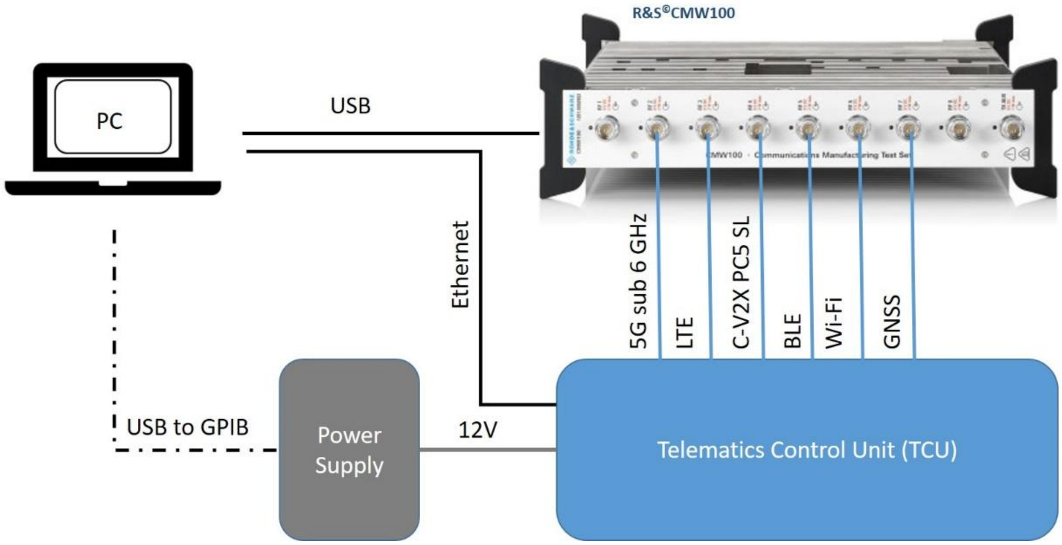
Key radio frequency (RF) parameters like spectrum emission mask (SEM), adjacent channel leakage ratio (ACLR), transmit power, error vector magnitude (EVM), etc. are some of the key parameters that must be measured. Chipset manufacturers provide customized interface that can put the device in test mode and users can trigger the individual modules using APIs. Well established chipset makers often provide software tools that can control their chips. Users of these chips should take advantage of those tools. These software tools can easily be integrated with the RF testers (like the R&S®CMW100), which are designed to make transmitter (TX) and receiver (RX) measurements.



RF measurements

4.2.1.2 Simultaneous verification of multiple technologies

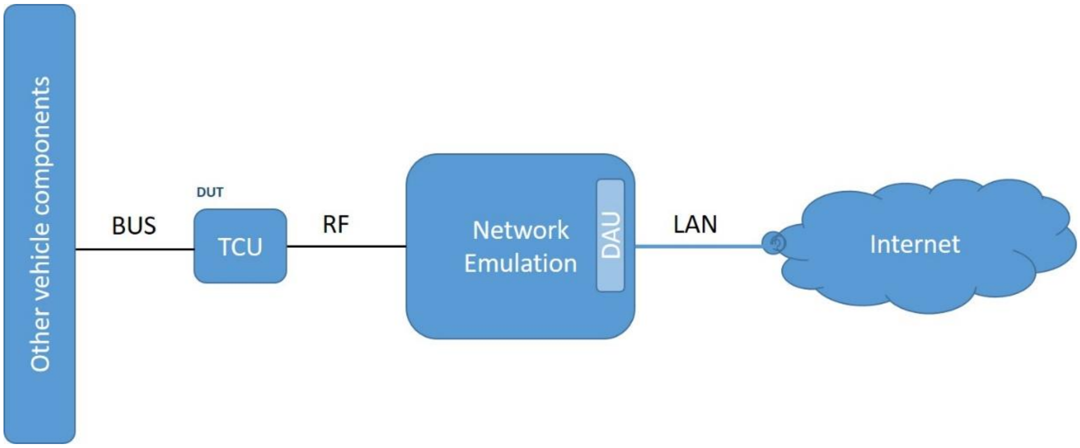
Since the TCU hosts multiple modems supporting multiple technologies, validation teams need to measure RF characteristics of all modems that are part of the TCU design. An efficient way to do this job is to simultaneously verify multiple technologies once early design prototypes of the TCU are available. The R&S®CMW100 is a versatile RF tester that supports multiple technologies and can be used for this type of testing in a non-signaling environment.



Measuring RF characteristics of multiple technologies

4.2.2 End-to-end testing

End-to-end testing is often a very effective way to ensure that individual hardware and software components are working properly when brought together. In many situations this is a key step of integration testing. There are a few key areas that can be considered as sub parts of integration testing. The details are listed below.



End to end testing

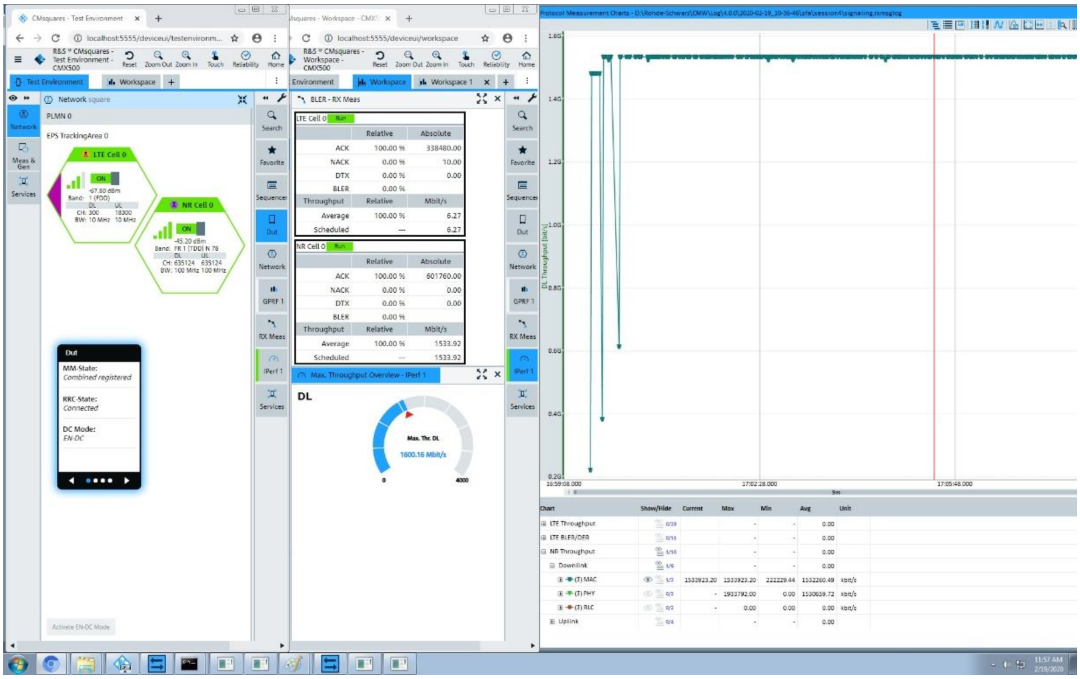
The R&S®CMW500 is a radio tester designed to emulate cellular networks and access points. The data application unit (DAU) within the R&S®CMW500 can connect to the external network and provides the IP connection to the applications running on a remote location (either in cloud or external machine in the lab). There are also built-in services like IPERF, HTTP, ping, etc., within DAU. This setup enables end-to-end connectivity. This end-to-end test setup addresses many testing aspects and can be easily extended to increase the scope of testing.

In addition to protocol stack verification for each technology (like 5G, LTE, Wi-Fi, and BLE), concerns about coexistence and interference are always present. Careful design and robust testing practices can address these topics. Network emulation and access point emulation helps engineers test and address these concerns.

Some other aspects of end to end testing are listed below.

4.2.2.1 Data throughput verification

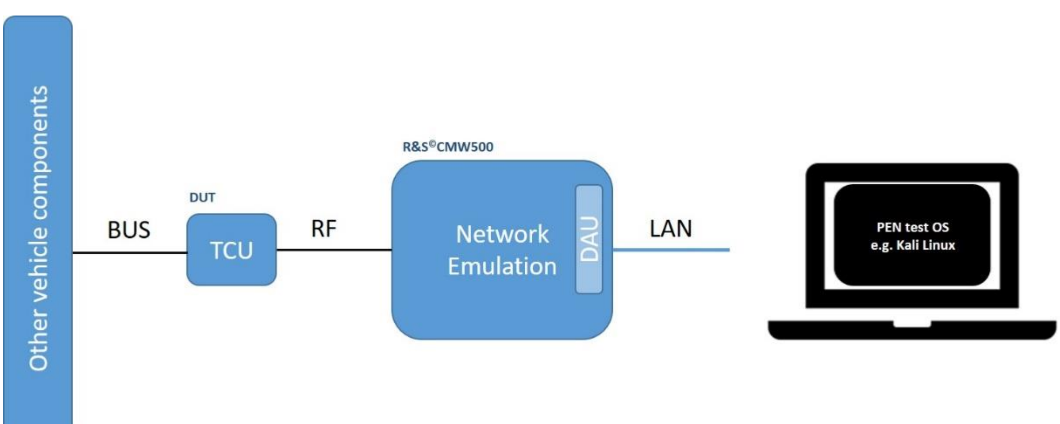
The R&S®CMX500 and R&S®CMW500 can emulate 5G NR cells and LTE cells in a lab environment, and give users the tools to test multiple scheduling configurations to test high throughput in a lab environment. The R&S®CMW500 also supports multiple flavors of Wi-Fi including 802.11ax.



5G network emulation and throughput measurement.

4.2.2.2 PEN testing

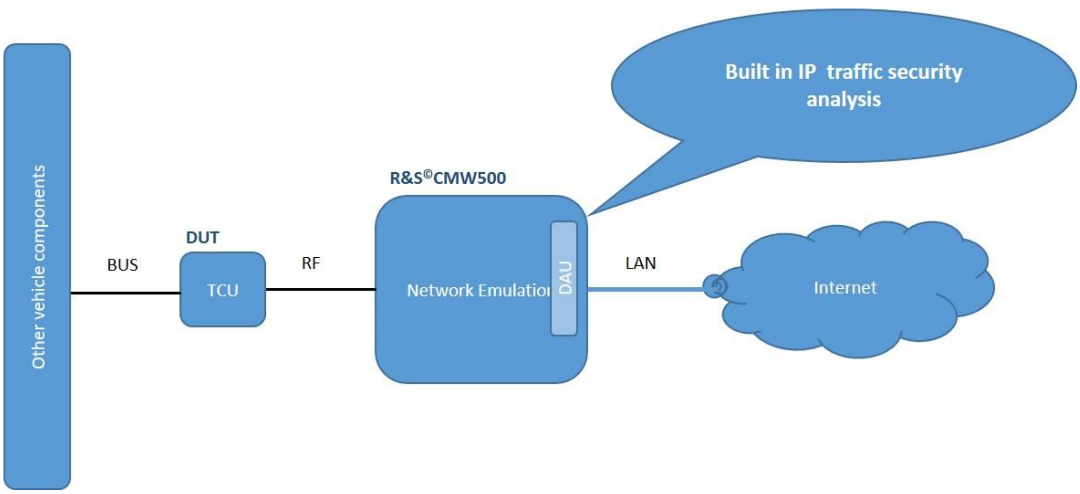
While the TCU provides the much needed connectivity to the vehicle, it can also be the prime target for an external security attack. PEN, or penetration testing, is often used to stress test connected systems to look for possible security breaches and expose the points that are vulnerable to cybersecurity attack. This is critical for connected as well as autonomous vehicles. The R&S®CMW500's flexible design allows engineers to extend the end-to-end setup and add an external PC via DAU. The PEN testing OS (e.g. Kali Linux) running on this external machine can be added to the end-to-end test setup.



PEN testing

4.2.2.3 User application testing

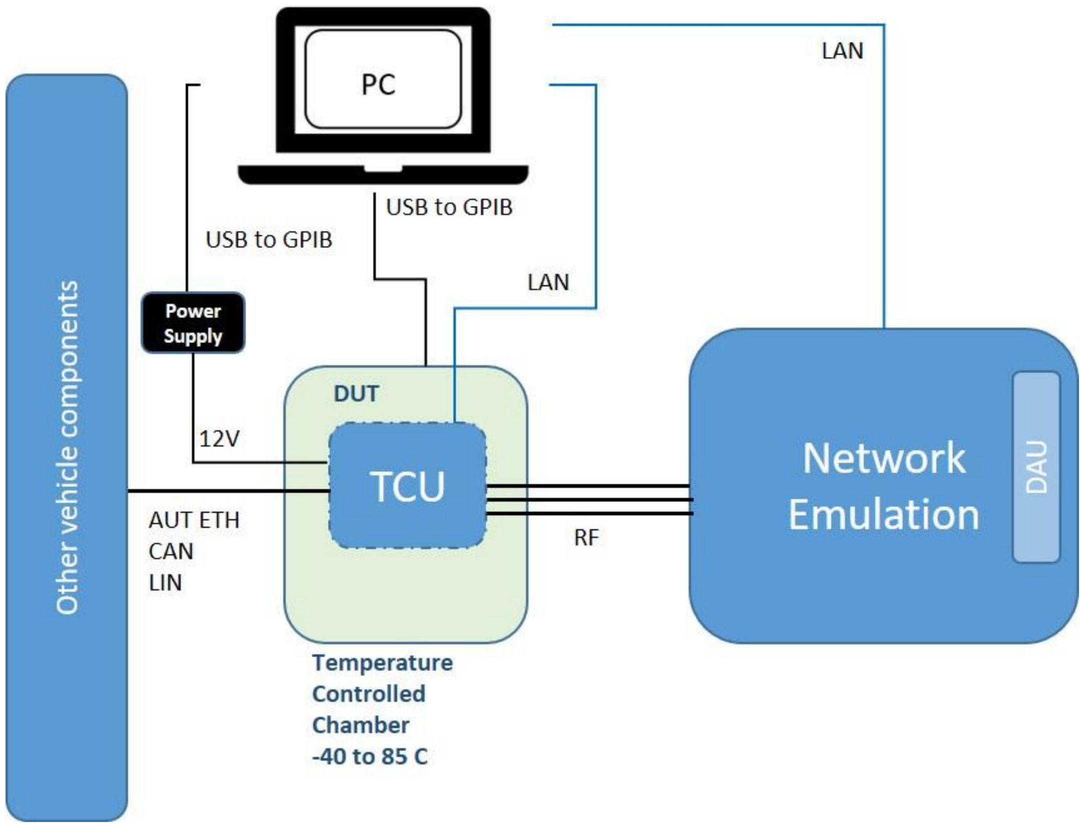
Infotainment apps running on the head unit also use the connectivity path provided by the TCU to the cloud services. In addition to user experience testing, security analysis is also a key area that must be addressed during the testing phase. Validation engineers can analyze the IP connection using the R&S®CMW500. IP security analysis software is placed inside the data application unit and this placement gives the user the flexibility to analyze IP traffic irrespective of the radio access technology used by the TCU for communication between the infotainment app and the internet. Endpoint geolocation, domain name lookup, traffic analysis of encrypted and unencrypted data, digital certificate analysis, keyword search, and port scanning are test personalities built in the R&S®CMW500 software.



IP connection security analysis

4.2.2.4 Temperature range

The vehicle can drive in various weather environments subjecting the TCU to extreme temperature swings. It is not uncommon to see test engineers considering temperature range of -40 C to 85 C in order to test automotive parts. A sample test setup is shown below that brings temperature range into the testing landscape.



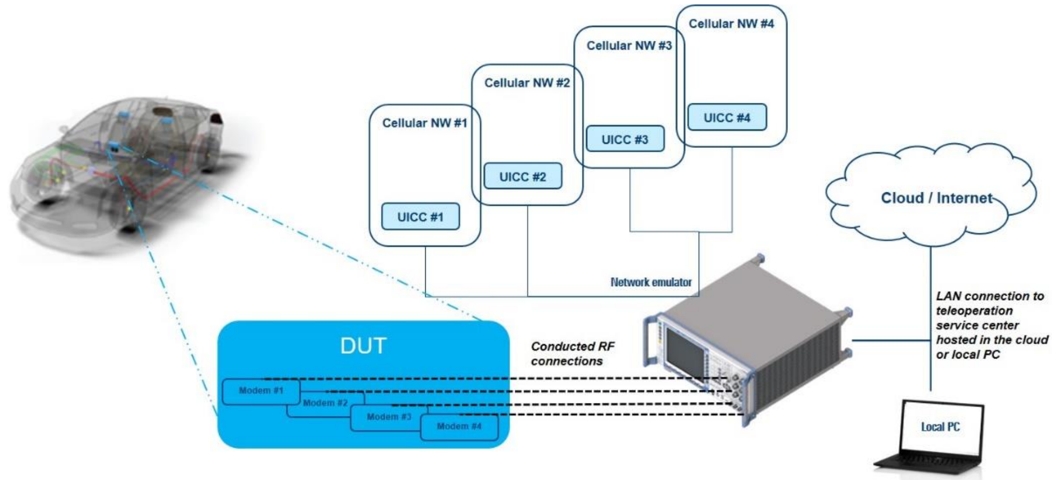
Interference test across temperature range

4.2.2.5 Use case verification

There are certain novel use cases that must be tested in the lab environment by creating an environment that is close to real world conditions. Teleoperation and cellular vehicle to everything (C-V2X) are two such examples.

4.2.2.5.1 Example 1: Teleoperation

Having multiple cellular modems included in the vehicle is a necessary design decision for use cases like teleoperation, since this enables redundancy of the cellular link and increases the effective good cellular coverage area. Such an approach ensures the remote operator can reach the remote vehicle via multiple cellular network providers. The R&S®CMW500 can emulate multiple cellular networks simultaneously. The data application unit (DAU) within the R&S®CMW500 can connect to the external network and provides the IP connection to the teleoperation application running in a remote location (either in cloud or external machine in the lab).



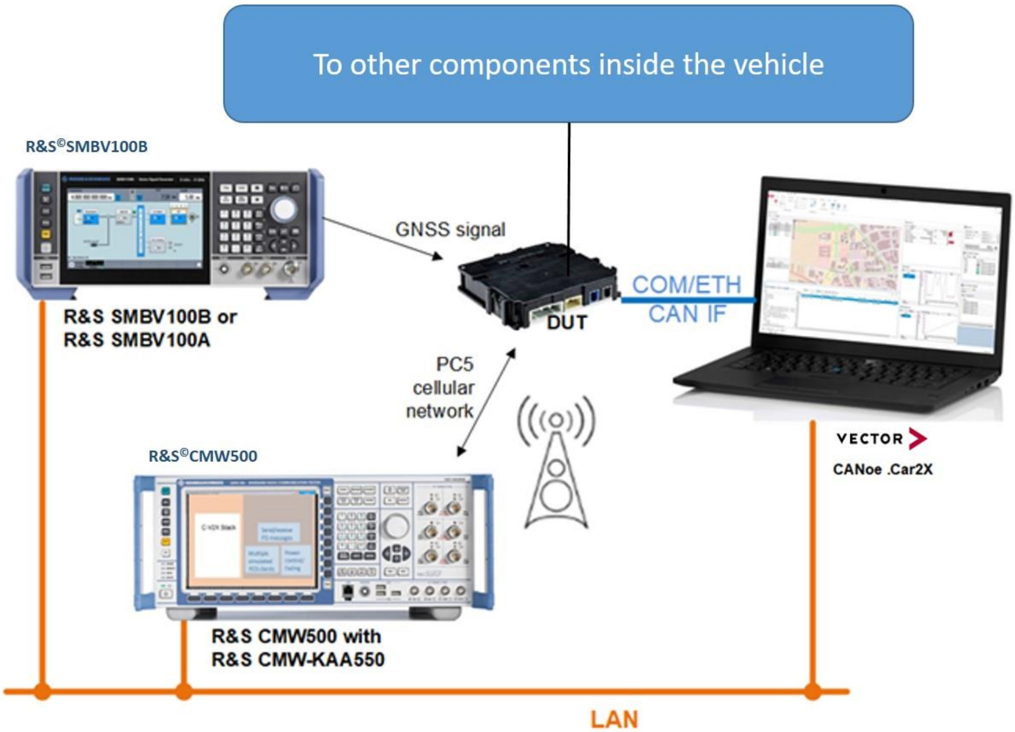
Test setup with end-to-end data connectivity

The number of R&S®CMW500 boxes required will depend on the number of distinct cellular networks the a user may want to emulate. This will also depend on the LTE cell frequency, modulation scheme, fading scheme, and MIMO configuration that the user desires to use on their test setup.

4.2.2.5.2 Example 2: C-V2X use cases using sidelink

The PC5 sidelink enables direct communication between vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P). In order to test end-to-end use cases like emergency electronic brake light (EEBL), left turn assist (LTA), and forward collision warning (FCW), it is essential to emulate multiple vehicles around the device under test. Sophisticated tools are also required to design various traffic scenarios. GPS is also necessary for providing the location and timing information to all C-V2X stations active in the test scenario.

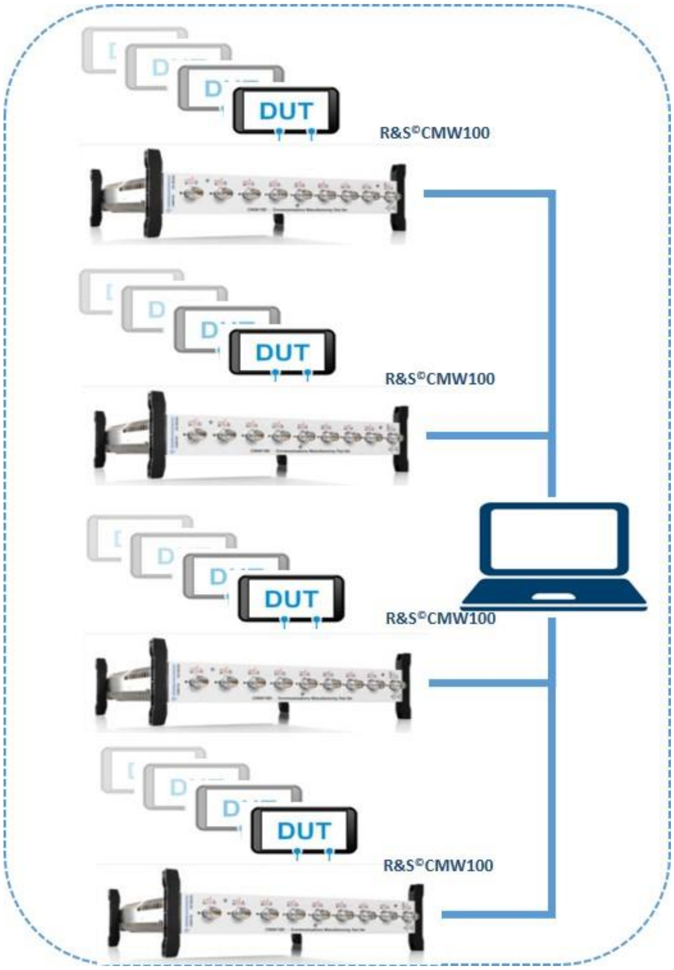
The R&S®CMW500, R&S®SMBV100B, along with Vector®CANoe car2x software provides the necessary tools to develop use cases and verify end-to-end C-V2X functionality on the sidelink. The tool set supports the Chinese, U.S., and European intelligent transportation stack (ITS) versions, making it easier for teams who are working on TCUs that will end up inside vehicles in all three regions.



C-V2X Application Testing

4.2.3 Production testing

The focus in production environment are quite different than that of feature verification and integration testing. Automated production line testing is essential and the goal is to achieve close to zero down time. Testing both multiple devices and multiple technologies simultaneously is desirable. The devices are set in factory test mode (FTM) and testing is geared towards improving the efficiency on the production line. Multiple R&S®CMW100 production testers can be controlled using a central computer in order to automate production tests. Rohde & Schwarz also offers automation software that can be very useful for automated production testing.

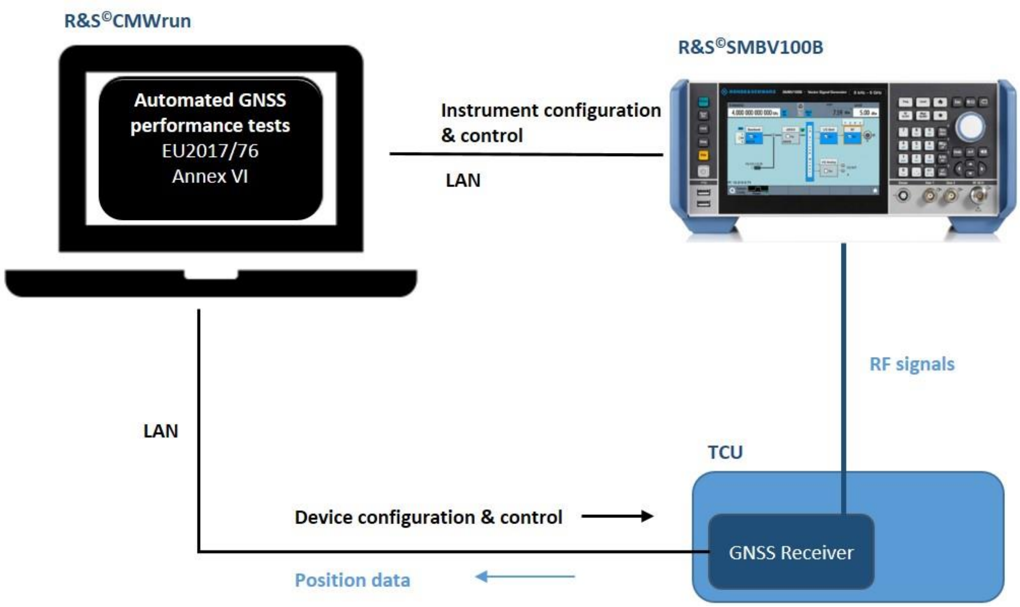


Production testing

4.2.4 GNSS testing

4.2.4.1 Performance test

eCall (emergency call) is one example where regional regulations help in deciding the scope of testing. GNSS performance and conformance tests must be performed before the vehicle is launched for public use. An automated framework as shown below can save time and costs for development teams, as well as help them validate the performance of the eCall module inside the TCU. Tracking sensitivity, acquisition sensitivity, time to first fix, and location accuracy are required performance tests for the GNSS receiver.

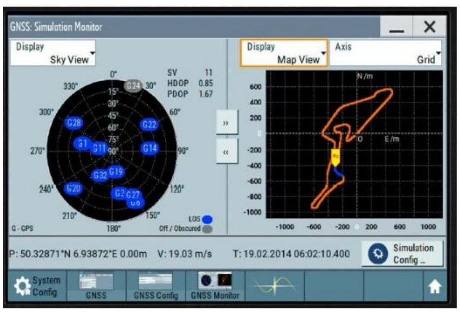


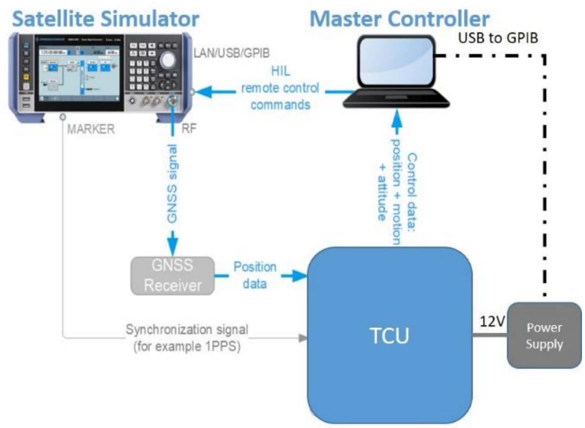
GNSS receiver performance test

4.2.4.2 Feature verification

The TCU has a GNSS module that provides the location coordinates to the vehicle. A GNSS simulator is required to emulate a constellation of satellites. Users can use predefined or user-defined waypoint files to simulate moving scenarios using the R&S®SMBV100B. Latitude, longitude, and altitude are set according to the starting simulated position defined in the input file. The input file also has data for the trajectory in the form of a sequence of positions. *.txt *.nmea, *.kml or *xtd file extensions are supported by the R&S®SMBV100B.

Navigation data can be fed to the test instrument via files as well as via remote commands in real-time. Remote command APIs allow greater flexibility and makes integration of R&S®SMBV100B easier in larger hardware in loop (HIL) setups.





Real time GNSS data feed

4.3 Test equipment

	R&S®CMX500	R&S®CMW500	R&S®CMW100	R&S®SMBV100B
Non signaling	X	X	X	
Signaling	X	X		
GNSS				X
Data throughput	X	X		
IP security analysis	X	X		
R14/15 C-V2X Application		X		X
eCall		X		X
Possible extension for PEN (penetration)	X	X		
Possible extension for temperature range	X	X		
Production			X	

Test equipment and testing aspects mapping

Rohde & Schwarz offers a repertoire of test equipment in order to address the needs of the development and testing teams working on telematics control unit. These provide the necessary tool kit to emulate complex scenarios in a lab environment, thereby decreasing the total cost of testing and feature development. This test equipment ensures complex and evolving TCU designs work as expected in the lab environment. It also gives the engineering teams the confidence to take their product into the next phase of field-testing.

Having the correct test equipment also ensures tests are repeatable on a consistent basis giving the teams confidence in their set of test scenarios that become part of the regression test suites. Automation framework enables the users to control the test equipment remotely and create repeatable test scenarios. This shortens the time to verify incremental versions of the device under test during regression testing phase.

5 Concluding Remarks

Connectivity will remain one of the prime features of all future vehicles. It provides information, entertainment, and safety for drivers and passengers as well as cost savings and new revenue models for OEMs. The TCU is at the epicenter of all connectivity related use cases and hence it is essential that it works flawlessly inside the vehicle.

There are other topics like over the air tests (OTA), electromagnetic compatibility (EMC), electromagnetic interference (EMI), and automotive Ethernet that are closely associated with the TCU but are beyond the scope of this document. Readers are encouraged to contact Rohde & Schwarz to learn more about these topics.

Rohde & Schwarz is a global leader in wireless and automotive test equipment solutions. Our T&M equipment is currently in use by all major OEMs, Tier1s, handset manufacturers, and MNOs worldwide.

6 Product Information

R&S®CMX500 is the radio communication tester that supports 5G NR signaling test in FR1 and FR2 frequency bands. It supports standalone (SA) and non-standalone (NSA) modes. It has a modern web-based user interface for RF, Functional, Application and Protocol test

R&S®CMW500 functional radio communication tester that provides signaling test solutions for multiple technologies like LTE, WCDMA, GSM, WLAN, Bluetooth etc. It provides high quality, customized, automated test environment for functional tests. It enables developers and test teams to simulate radio access networks and includes a fully integrated end-to-end data solution. R&S®CMW500's RF hardware supports all 3GPP-defined bandwidths up to 6 GHz

R&S®CMW100 communications manufacturing test set is a new trendsetting product for calibrating and verifying wireless devices. It is ideal for use in fully automated robotic production lines. It supports parallel testing of up to eight antennas, has close connection to test fixture, less attenuation loss and involved cross talking. It has minimum space requirements, footprint and energy consumption. It has silent operation, and highest reliability due to fan less operation and dustproof housing.

R&S®SMBV100B is the vector signal generator with the frequency range from 8 kHz to 3 GHz or 6 GHz. It supports signal generation for all major digital communication standards including 5G NR, LTE, and WLAN. It also supports GNSS simulation with support for GPS, Glonass, Galileo, BeiDou and QZSS/SBAS

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The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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Application Note | Telematics Control Unit: Design and Testing Considerations