

Understanding Connected Car Testing



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Executive Summary

In-car telecommunication technologies are playing an increasingly important role in the modern vehicle. In this guide we explore the range of wireless technologies and networks for automotive applications that already provide advanced entertainment systems and safety mechanisms. We also provide an insight of the enablers for the future of automotive which will provide advanced driving assistance, paving the road for autonomous driving.

Introduction

The concept of the “connected car” as an expression is relatively new, it has emerged as cars have become gradually more communicant. Science fiction has long predicted more and more communicative and self-driving vehicles, and there are now many reasons to see connectivity as the main driver of this revolution to become a reality in the coming years. We see that the complexities of the modern automobile continue to increase with more and more technology being added from communications to safety systems. In-car connectivity is likely to become ubiquitous over the next decade. Adding the numerous features required for driving assistance, and then later on, the features allowing full autonomous driving car will pose the question of the reliability. Ensuring reliability in the early development stages and throughout the vehicles life to will ensure public approbation needed for adoption of autonomous features.

This paper explores the different aspects of the telecommunication that will enable a truly connected car. Anritsu is bringing its expertise to present which aspect can be tested to ensure an optimal implementation.

The first chapter covers the **wireless connectivity** with the cellular, short range as well as broadcast. Second chapter focus **on board safety** with driver assistance such as the European eCall/ERA-Glonass system – enabling a car to respond to a crash by contacting the emergency services and wirelessly send impact sensor information, along with satellite GNSS positioning co-ordinates. Looking forward, the third chapter presents the **Intelligent Transport System (ITS)** ecosystem enabling communication between car and infrastructure (V2I) and cars to cars (C2C). The fourth chapter focus on the evolution of **In-Vehicle Networks** from traditional CAN toward Ethernet and Fiber communication. This white paper concludes on the **Electromagnetic Interference** challenges.

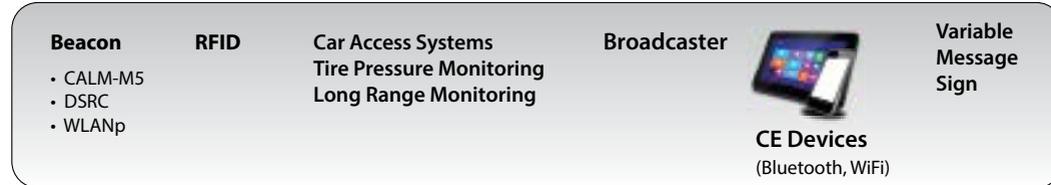
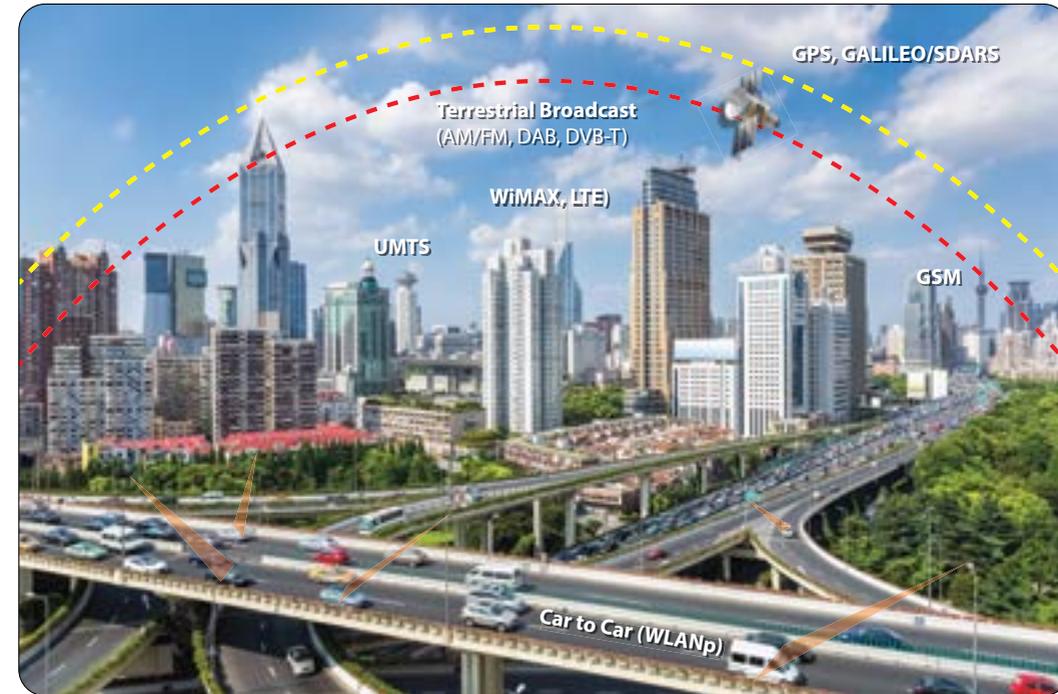


Figure 1: Overview of connected car ecosystem

This paper will mainly cover the wireless standard described in summarized in the following table.

	LTE	Wi-Fi	802.11p	Bluetooth Low Energy	Radar
Category	Telematics	Infotainment	V2V/V2X	Infotainment	V2V/V2X
Frequency	700 MHz to 2.1 GHz	< 1 GHz: 11af/ah 2.4/5 GHz: 11n 5GHz: 11ac	5.8/5.9 GHz (700 MHz)	2.4 GHz	24/26, 76, 79 GHz
Distance	Multi-100m to 1 km	Multi-10m to 100m	Multi-10m to 1km	Class 1: 100m Class 2: 10m Class 3: 1m	1 to 2000 m (laser radar: 30 to 50 m)
Gross Data Rate	9.6 kbps to 100 Mbps	600 Mbps: 11n 6.9 Gbps: 11ac	3 to 54 Mbps	1 Mbps	---
Usage	Emergency, Probe info, entertainment, etc.	WiFi-spot on car, Video receiving via IVI system / smartphone	Positioning check and collision avoidance, etc.	Hands-free, music/ information providing	AEB, FCW, ACC Accident-Avoiding Self Driving, Autonomous Car

Wireless Connectivity

(LTE/2G/3G, Bluetooth, Wi-Fi, AM/FM/DAB)

Wireless technologies have acquired increasing importance during the last decade in the automotive industry, making the experience of driving easier, safer and more comfortable. All these wireless standards, including mobile, short range wireless and navigation, help to keep the driver connected everywhere, while broadcast technologies are now utilized to keep all of the car occupants connected and entertained.

Besides FM/AM radio, today's vehicle incorporates digital radio (DAB) as well as video broadcasting, including DVB, ISDB standards and will feature cellular broadcasting with eMBMS.

In this chapter we will explore the different aspects of the wireless connectivity starting with the increasing integration of Cellular technologies, then move on short range wireless and conclude with the traditional broadcasting technologies.

Cellular Technologies (3GPP - LTE/2G/3G)

Perception of infinite internet: The 5G network should give the user the perception that The industry often refer to "cellular" the wireless communication standardized by the organization called 3GPP which publish the standard for 2G/3G/LTE. The current trend consisting to integrate cellular connectivity to cars is bringing to the market a wide ranges of new services for "connected Cars".

The technology being integrated to cars has been long being used by phones and more recently by connected devices (M2M, IoT). One of challenge facing the automakers is to combine the requirements long term and security vision of the automotive industry with the fast evolving cellular world which has not being defined on the same ground.

To understand how to perform testing and validation, it is required to distinguish the functional areas required to enable wireless connectivity. In automotive, the logical embedded electronics boards controlling systems are known under the generic term "electronic control unit (ECU)". From a high level functional perspective the connectivity is implemented in the ECU commonly called a "Telematics Control Unit" (TCU). The word telematics technically refers to any system by which a mechanical or electronic device communicates with other devices or with human users over a network. Over the years, the term has come to mean the specific use of on-board communication capabilities in automobiles. The heart (and brain) of the Telematics system is the Telematics Control

Unit (TCU). The TCU is a small computer that listens in on the communications of other electronic systems in the car, then interprets and disperses that data as necessary. It accomplishes this by piggy-backing onto the Controller Area Network (CAN-bus/Ethernet) a communication system found in all modern cars. The CAN acts as a communications bridge between all of the ECUs within the vehicle. The TCU itself is roughly the size and weight of a paperback book.



The TCU usually contains the following main functional blocks:

- Network Access Device "NAD", GSM/GPRS/WCDMA/LTE ensuring wireless connectivity.
- GNSS: GPS receiver (positioning), Gollineo, Glonass , Baidu.
- Host CPU (host for Telematics Services including eCall application),
- Antenna system interfaces (NAD and GPS),
- Vehicle interfaces (CAN, eCall trigger)
- Audio interface (for EMU microphone and speaker)

The NAD includes wireless modules (b) which brings data interface for the other ECU (for e.g : on board computer, infotainment ...).

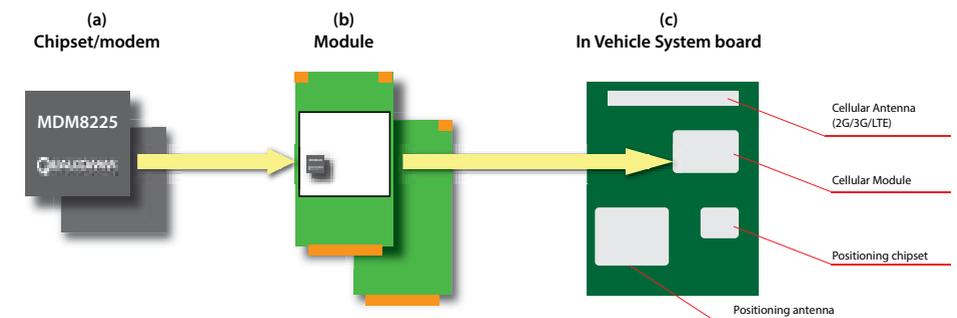


Figure 2: Integration path of modules in Telematic Control Unit (TCU)

The modules are composed of Chipset (a) assembled together with power supply circuit and communication interfaces. Modules come with an MCU (microcontroller), Memory and embedded UICC. The module controls the wireless chipset by providing the high level commands for connectivity sessions and providing the required power.

The chipset itself (a) is a piece of silicon that includes the radio modem along with a baseband processor (signal modulation, encoding, radio frequency shifting, etc.). The Chipset usually includes a network processor providing a stack up to the IP layer.

A similar implementation is also valid for short range wireless Modules (Wi-Fi/BT/NFC), Broadcast (FM/DAB) and GNSS (GPS/Galileo/GLONASS).

The TCU (Fig 3, a) is then fitted on the dashboard (b) providing antenna connection, to a variety of sensors (tire pressure, radars ...) and a user interface.

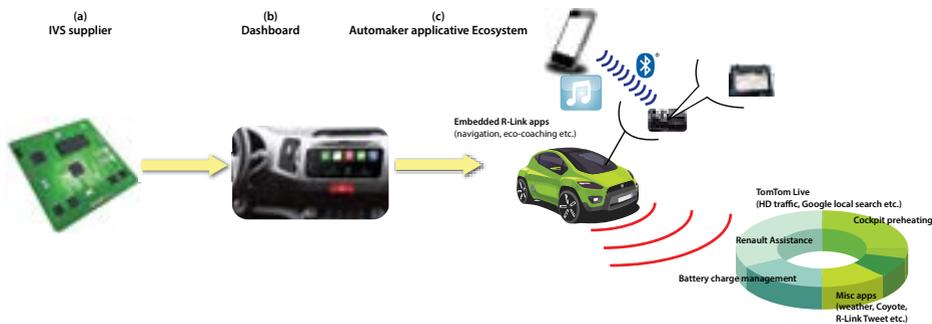


Figure 3: The on board telematics is composed of an operating system with dedicated applications which is directly connected to cloud service (Fig 3, c)."

One typical example of the telematics platform can be seen on Figure 4 where we see the interaction of the TCU with the different part of the automotive.

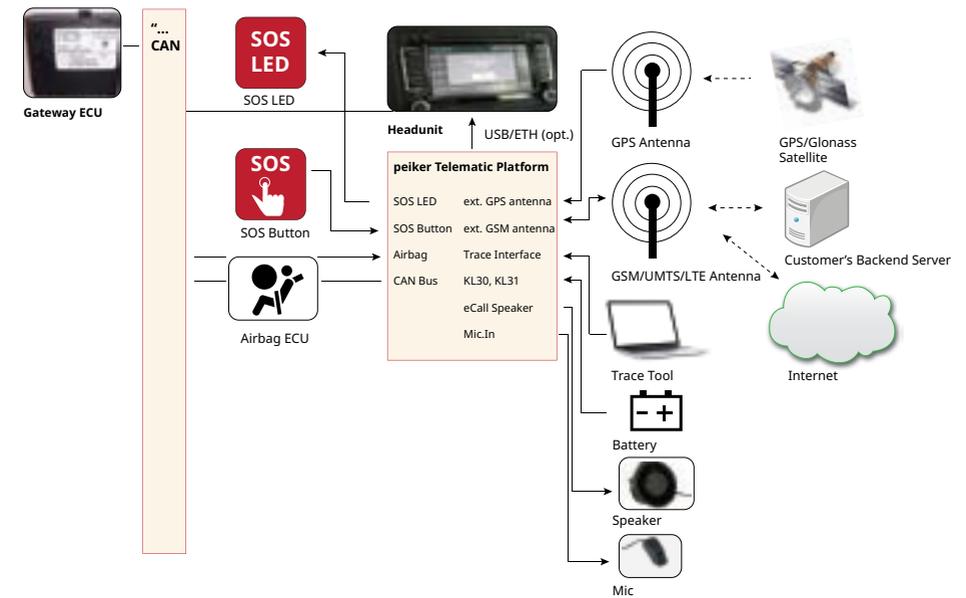


Figure 4: Example of TCU architecture

Testing Cellular Communication

The world of cellular telecommunication is fortunately driven by recognized international standards that are defining most of the architecture and testing required to operate a device on a licensed cellular network. The 3GPP is the main international organization in charge of defining standards. It defines how RF, protocols and services should be implemented and tested. Other standards are also widely recognized for specific applicative service such as GSMA or OMA.

Based on those standards, the telecom industry has seen the emergency of partnership between mobile network operators, mobile device manufacturers and the test industry to provide harmonized testing certification framework. The GCF (Global Certification Forum) and the North American (PTCRB) are the most recognised.

The cost of certification is a non-negligible aspect of the development of a cellular devices and consequently connected cars. The certification required is a key element in the integration strategy adopted by automakers and part supplier. Indeed, several integration choices are possible:

An Automaker could develop his own In Vehicle System or buy it from a part supplier.

If the TCU is developed in house it is possible to use a module that would ease the integration.

Recently some optimized Certification scheme for connected devices (M2M/IoT) which are not regular phones, are starting to provide a framework to cover specific testing required for automotive. However, those current standards often cover the requirements of mobile terminal or low cost M2M module. Future dedicated automotive certification within those organization are being considered by some Task Force in early 2015 (GCF Automotive Task Force, SG#60) or by GSMA automotive working Group. The requirement of cellular telecommunication have been often defined based on a trade-off between battery consumption and communication quality. In the context of smartphone usage it is often acceptable to not have an optimal performance as the communication is not critical.

A vision of automotive grade cellular communication is now required where some of the requirement are can be substantially different from a smartphone approach (no indoor coverage, battery consumption not so important, critical communication ...).

The testing tools and methods presented in the following sections can cover the specific needs of the connected car chain by providing functional test dedicated to automotive that are not necessarily covered by certifications.

IVS Board	Advantages	No certification costs, proven performance, short time to market
	Disadvantages	per unit cost
	Typical Deployment Range	1k to 10K
	Vendor	Peiker, Magneti Marelli, Valeo...
An integration with a module	Advantages	Lower per unit cost, flexibility i form factor, reduced operator certification (assuming the module is pre-certified by the operator)
	Disadvantages	Certification costs (PTCRB - \$20K - 40K), operator certification may be required (typically no cost)
	Typical Deployment Range	>10K
	Vendor	Peiker, Magneti Marelli, Valeo...
An integration with a chipset	Advantages	Lowest per unit cost & flexibility in form factor
	Disadvantages	Certification costs (PTCRB - \$60-80K, Operator - up to \$500K) , long time to market 12-24 months & high level of wireless expertise is required for development.
	Typical Deployment Range	1 million+
	Vendor	Qualcomm, Nvidia, Marvel, MediaTek, Texas Instruments, ST Ericsson, Freescale ...

Table 1: Comparison of integration mode

SmartStudio

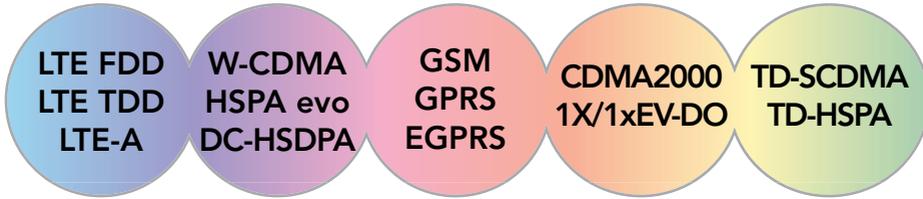


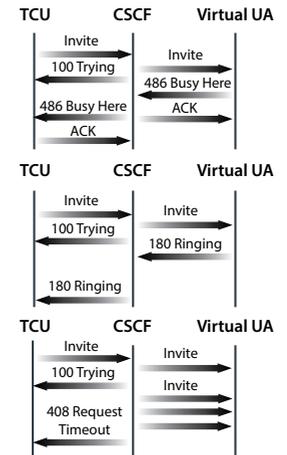
Figure 5: IMS internal server for testing VoLTE

Functional Testing with Anritsu

One of the optimal tool to do functional testing of cellular communication is the application tester MD8475A. It provides an all-in-one base station simulator supporting LTE, LTE-Advanced, W-CDMA/HSPA/HSPA-Evolution/DC-HSDPA, GSM/EGPRS, CDMA2000 1X/1xEV-DO Rev. A. and TD-CDMA/TD-HSPA.

It supports services such as eCall, IMS, VoLTE, off-load tests and call-processing tests for smartphones which are now present on vehicles. In addition, the time required to configure a test environment is greatly reduced by the easy-to-use GUI based SmartStudio software, as well preconfigured test sequences for automatic remote control of the GUI. Operating this network simulators does not required advanced knowledge in programing or protocol stack.

Integrated IMS test environment with GUI operation



The integrated IMS server is configured by GUI operation. This platform can realize effective troubleshooting of wireless protocol and SIP messages. It does not require advance knowledge in programing.

Multi-RAT handovers with strong C2K and TDS capabilities

The two cell simulated covers all cellular communication standards. It allows a large variety of scenario such as Intra/Inter-RAT Handover, Cell Selection & Reselection, Redirection, CSFB, SR-VCC.

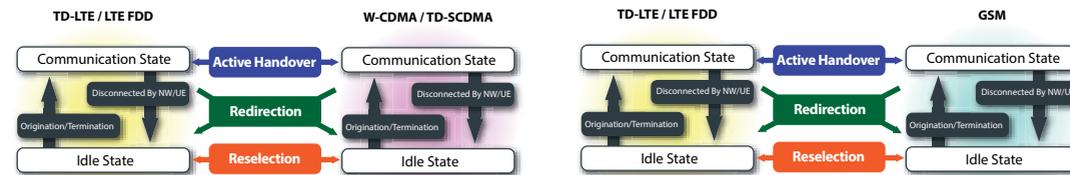


Figure 6: Mobility scenario in mobile networks

The Challenge of Application Testing

The advent of connectivity in car can be considered as one of the biggest evolution since the mass production. The majority of cars are to be fitted with operating system and an ecosystem of apps directly connected to the cloud. The key to this evolution is to ensure a consistent user experience, while maintaining safety.

Nowadays consumers are attached to their smartphones, which translates into a wish to safely access their smartphones through the dashboard. Vehicle manufacturers have capitalized on this desire by developing new solutions allowing passengers to access their smartphone Apps through the in-car HMI via a technology called MirrorLink (working on non-proprietary technologies such as IP, USB, Wi-Fi and Bluetooth) or CarPlay from Apple.

However, there is currently a strong focus in the automotive industry to develop operating systems cross-platform running locally dedicated native telematics apps. The use of a proprietary operating system allow the tight integration of a variety of automakers and partners services connected to the cloud.

Example of current proprietary interface.



The major concerns when it comes to integrate the fast evolving services in vehicles is how to make it updatable and secure. We have seen this dilemma with the of numerous telematics application for cars that could not be integrated easily in proprietary, the system had to be implemented using dedicated boxes to be compatible with a given car on board diagnostic port (OBD). Most of the time, the work required to fit the solution to each car model means that the easy alternative is nowadays to provide an external boxes (car sharing, insurance boxes, fleet management,...).



One of the direction to provide an application ecosystem that would be cross platform is to use the HTML5 or web-based Apps directly connected in the cloud that make it easier for OEMs to seamlessly enable and update their customer's favorite content and services by simply implementing a browser within the car. There is a debate about the impact of HTML5 on traditional native Apps, and whether the industry will experience a major shift towards web-based or HTML5 Apps. This is a strategy already being pursued by various OEMs and suppliers such as Telsa (figure), which also sees other developmental benefits associated with non-embedded Apps.

In reality, web-based Apps and native Apps are expected to co-exist for the foreseeable future.

Example of OS running HTML5 Apps (Linux based)



Aside from the traditional automotive industry we see a growing interest from well-established internet/smartphone players such as Google and Apple to propose their software platforms alongside with their cloud ecosystem. During CES in January 2015, a new industry group called Open Automotive Alliance helmed by Google and top-tier automakers like Audi, GM, and Honda.

Application Testing Solutions

There are several projects and groups working worldwide to define 5G needs, On top of the Hardware performance in combination with a given Operating System, connected applications are playing a major role for the customer end user experience (figure 3). The customers are judging the car infotainment system on how their favorite applications operates.

Applications are often regarded by developers from a purely core IP network perspective. In fact, IP packet transmission are strongly impacted by the physical radio layer and the media access control (MAC) layer. Understanding the behavior of mainstream applications facing different simulated radio condition can help integrators to optimize either the hardware implementation or their own applications.

Handover and Throughput Testing

One of typical optimization example is to evaluate the throughput of a given application in optimal condition, then asses its quality of service by simulating scenario when the car is moving from one cell to another by variation the power of the received power.

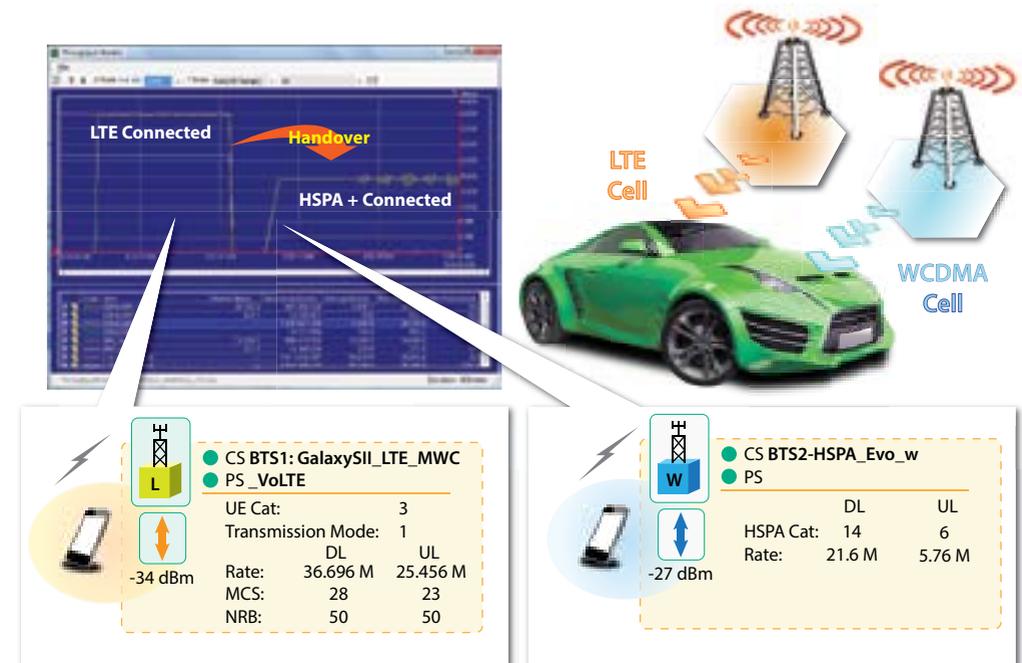


Figure 7: Handover example from LTE to 3G cell

The performance of different layer can be measured from the physical layer up to the IP layer and automated thanks to an automation framework integrating lperf functionality and reporting.

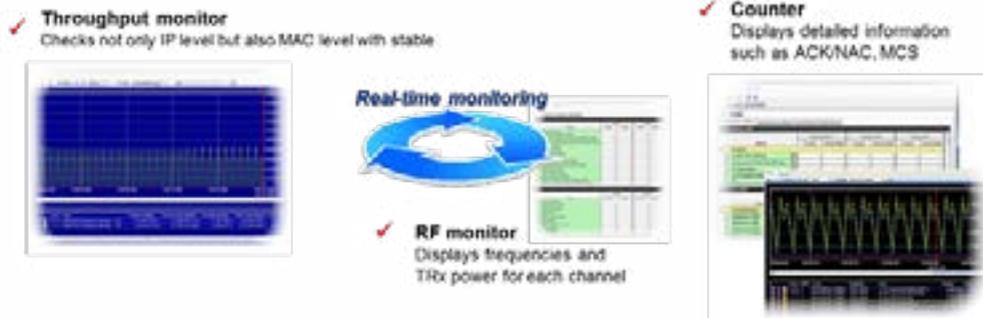


Figure 8: Different layer of monitoring throughout (IP/MAC/RF)

The stability of the Network simulator provides a reference point to ensure repeatable test in the development process. At each software upgrade or hardware modification, an automated set of test can be run against the different application server such as the Car cloud Manufacturer or the IMS server of a given operator.

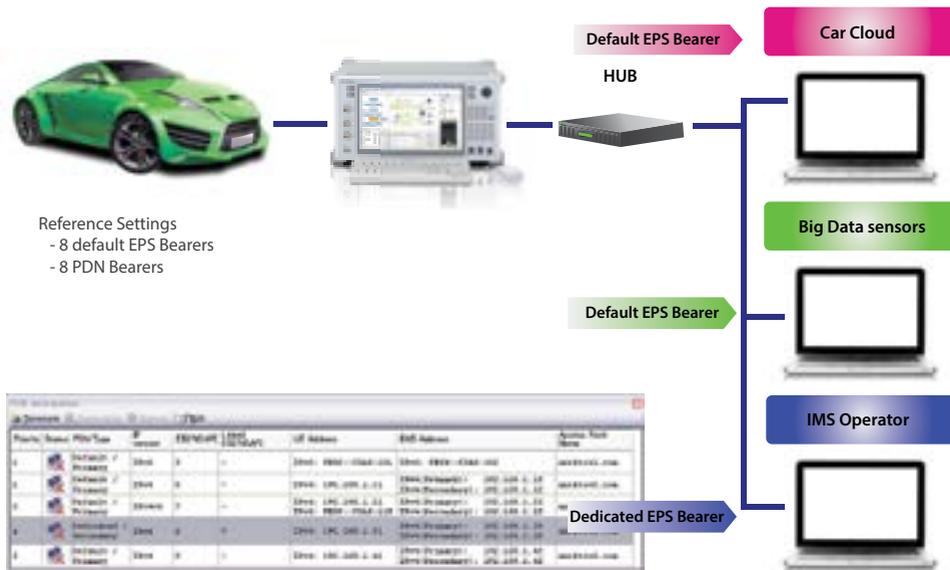


Figure 9: Connecting the simulator to external servers

On top of doing radio link impairment, it is also possible to introduce network impairment at the IP packet level by introducing for example delays, jitter, or packet loss with a traffic impairment simulator (MD1230B).

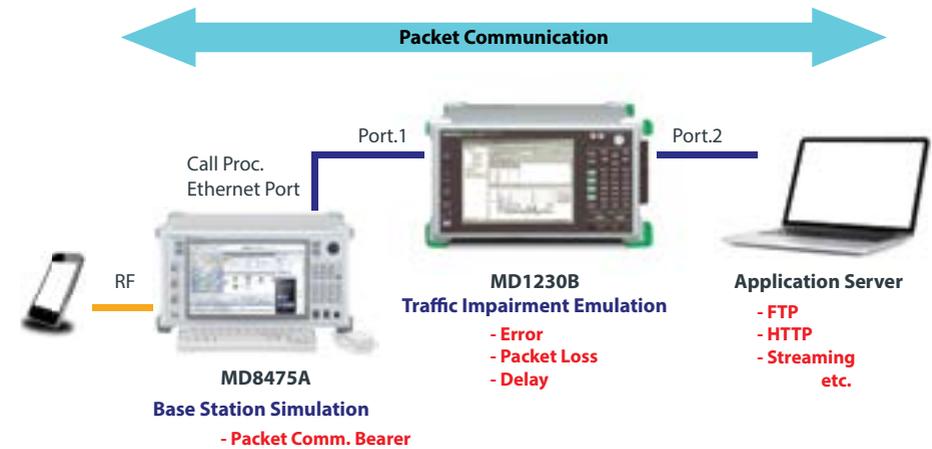


Figure 10: Example of network impairment on the IP layer

Voice Testing: IMS/VoLTE and Voice Quality

One other typical optimization when it comes to automotive functional connectivity testing is telephony. With Voice over LTE currently now deployed, some challenges are seen to integrate the VoLTE client embedded in Cars. The protocol exchange is often varying depending on which operators' core solution. The typical traffic profile is characterized by small continuous packets with short latency requirement and high tolerance to packet drop. The applications needs to optimize for the protocol and this traffic by setting specific radio bearer to cope with this traffic profile. Adapting and optimizing the higher layer protocol in combination with the lower layers is the key to ensure optimal performance and quality of service.

Anritsu provide inside its network simulator MD8475A an integrated testing IMS server. All IMS services—including VoLTE—can be tested easily from just one MD8475A using the SmartStudio user interface. SmartStudio provides simple radio bearer configuration, allowing you to quickly focus on the application layer without the need for extensive knowledge of the low level radio protocols.



Figure 11: Interface of network simulator with IMS services

Having a network simulator allow also to test abnormal scenario when the server is not responding the way it is expected. The call can be rejected at different stage for example at the Attach setup or at the APN setup, or at the IMS registration.

- Attach Reject

Setting specific messages when the terminal connects to the base station can be used to reject terminal connection requests...

- APN Reject

Setting specific messages when the terminal connects to the network server can be used to reject terminal connection requests...



Figure 12: Example of reject cause at attach and APN level

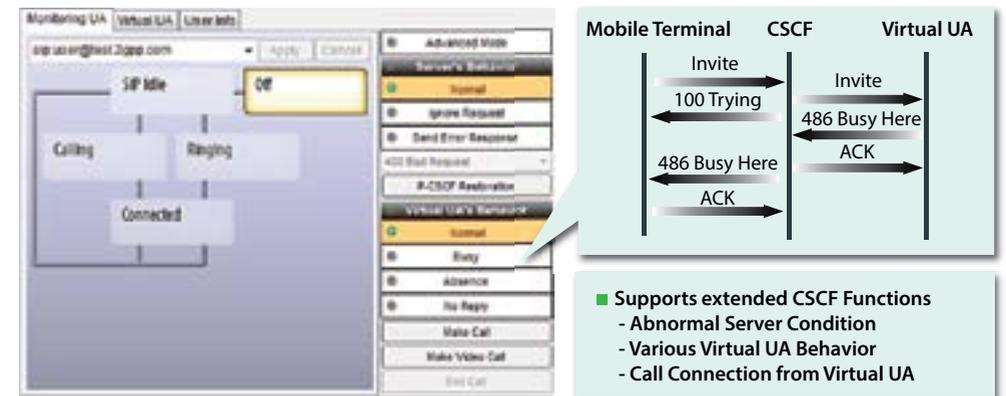


Figure 13: Example of IMS busy scenario

The IMS server can operate according to the default IMS protocol stack but can also be defined using a specific messaging and sequence order.

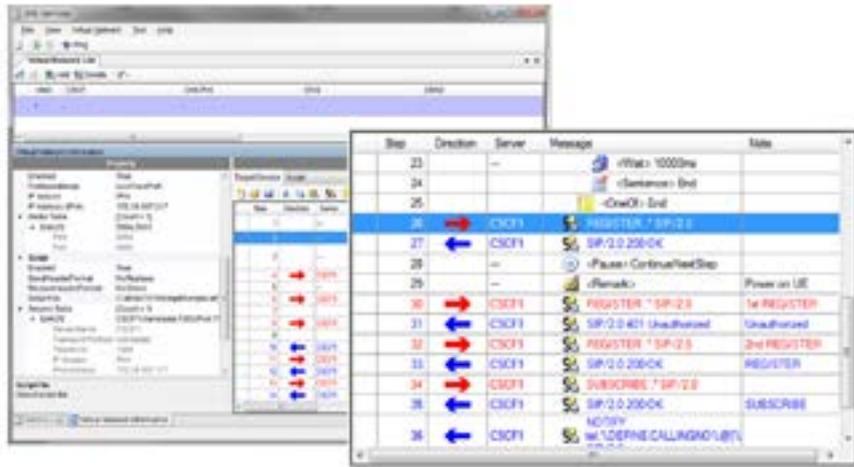


Figure 14: Example of custom script

Voice Quality Testing

Testing voice quality in cars is an important aspect as it will determine directly the user experience. To ensure a consistent testing, a network simulator is an ideal solution. The Anritsu MD8475A can be complemented with an audio tester option provided by Head Acoustics to ensure the voice quality is optimal using Circuit switch on 2G/3G or VoLTE on LTE.

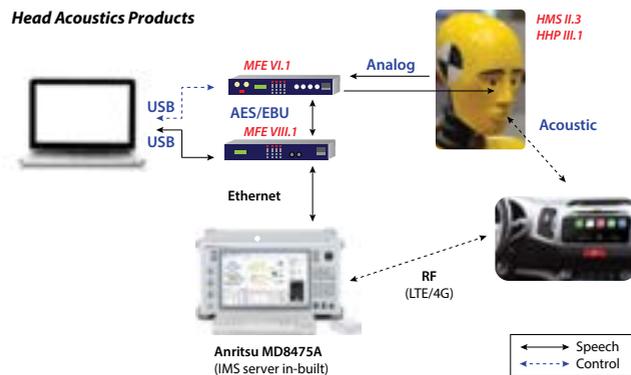


Figure 15: Audio testing with Anritsu and Headacoustics

Automation Framework

One of the main advantages of a network simulator is the repeatability of test to ensure a scientific approach when only the DUT is the changing variable. By automating the testing procedure it provides an ideal framework for the verification cycle.

Anritsu propose a software call “SmartStudio Manager” that allow to create automation Test Sequence easy based on sample pre-configured.

Expandability for external equipment control such as power supply, W-LAN AP to allows users to configure various types of automated environment easy for automotive user experience verification

It allows to Realize for example “24/7” stress test, or regression test when a new software is released to find new bugs and check if existing functions and new functions work without any problem after enhancement

The simple chart flow drag and drop automated test environment allows users to develop test case without script programing.

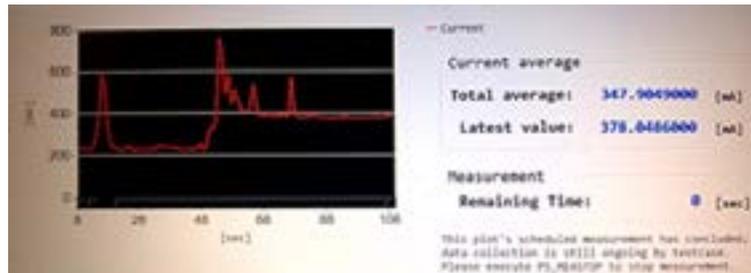
Wireless Module Consumption and Battery Testing

Even though the battery of a car is often perceived as not being a limiting factor in wireless implementation, it is important to ensure that the module being implemented does not drain battery. Indeed, with car being more communicant it is now expected, even when the car is not on the road, that some information are periodically exchanged between the car and the cloud. The periodicity of the message exchanged will determine the autonomy of the car while not used for a certain period of time.

Car makers have to ensure that a car not being used for a certain period of time will have enough power remain. A combination of a power meter giving the real time current drain combined with the network simulator helps to map the battery consumption related to specific exchange.



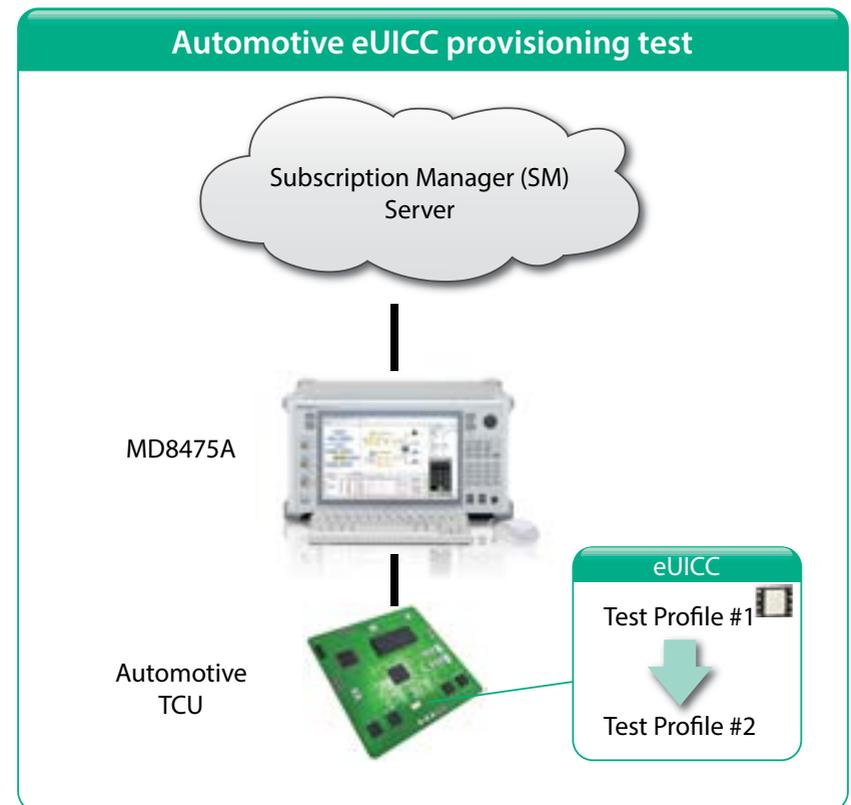
Figure 16: Typical GSM connection with data transmission



Testing Automotive with EUICC and Over-The-Air Provisioning

Automakers and mobile operators are striving to make the connected car a reality on a large scale. These efforts to make consumer services seamless, using different connectivity options, pose many challenges. One of the solution for bringing connectivity to cars has been to provide some tethering capability with the user phone contract. Recently, operators has been working closely with operators and automakers in overcoming existing barriers to embedded connectivity (built-in modem with a dedicated SIM). The operator organization GSMA has been developing specific set of standard to support embedded SIM. Following those standard brings a framework for remote provisioning of devices and easy integration of dedicated services.

With a network simulator such as the MD8475A it is possible to test the remote Over-The-Air provision directly with the provider of a live Subscription Manager server.

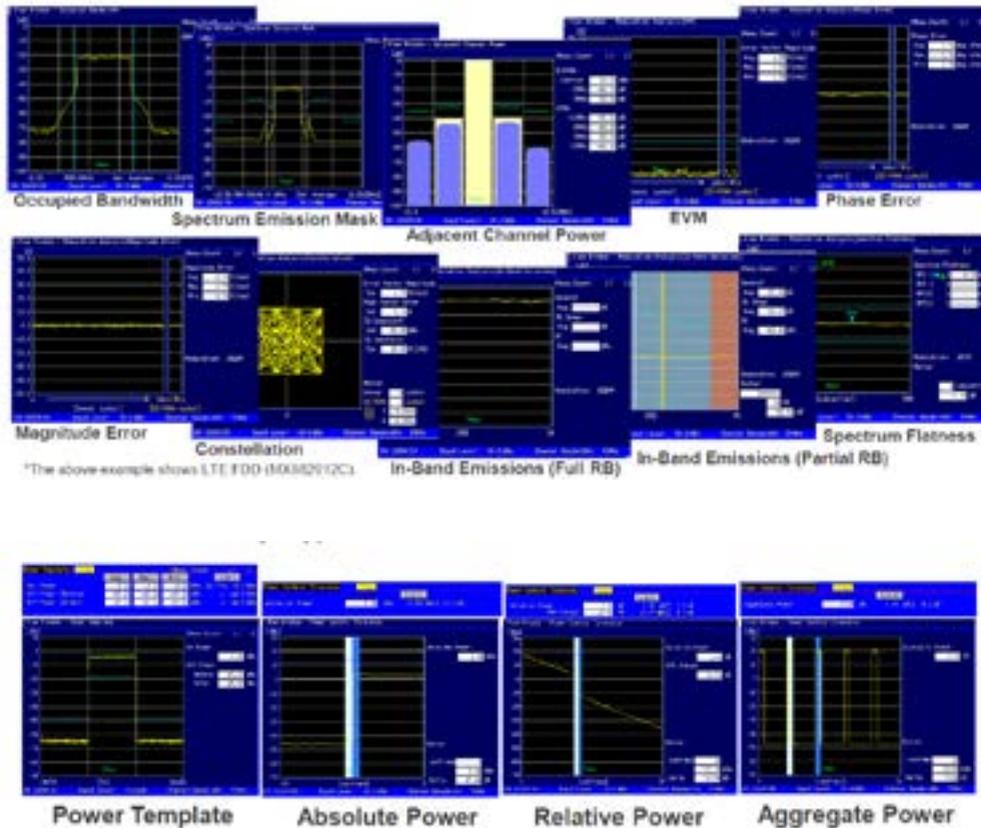


Cellular RF Parametric Testing with Anritsu

Radio Communications Analysis



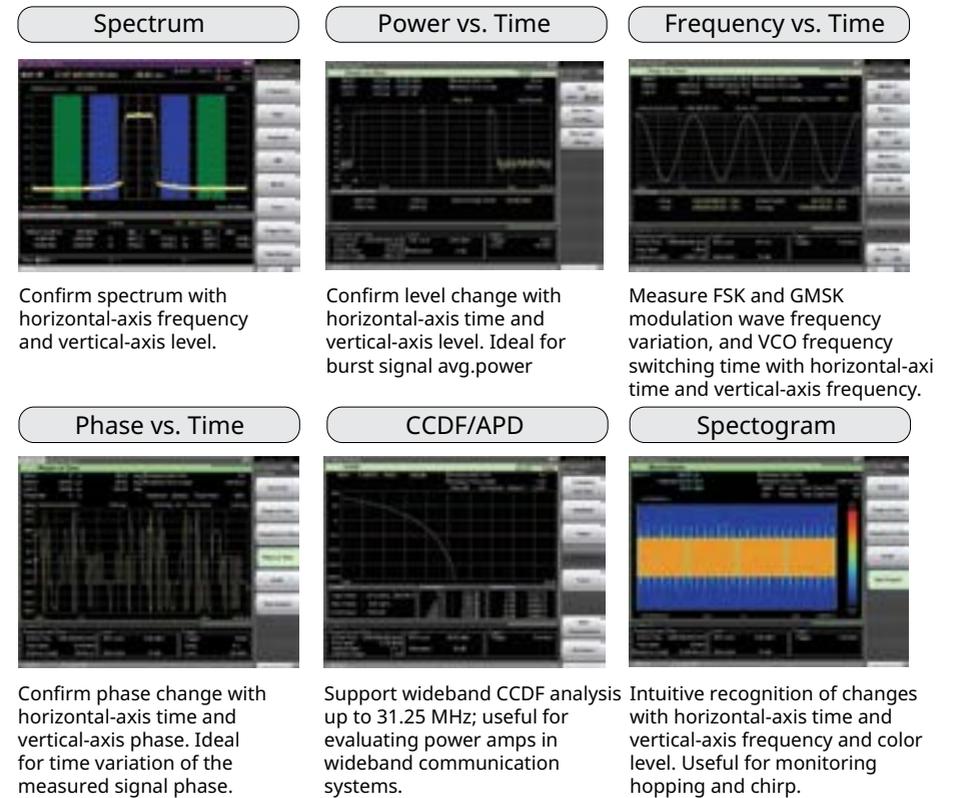
The MT8820C / MT8821C are an all-in-one solution supporting all cellular standards available on a vehicle, including LTE-A, LTE, 3G and 2G technologies. It provides basic protocol connectivity stack to attach devices and perform high-end instrument RF measurements. The versatility of this product which makes it ideal for all stages of product development and also for production. It can be used for pre-conformance verification, for validation of implementation, antenna design or for OTA measurements.



Spectrum Analysis

Anritsu's MS2830A/MS269x spectrum, signal analyzer and signal generator is a good option for in-vehicle testing of 2G, 3G, LTE and LTE-Advanced signals. It supports measurement of modulation and Tx characteristics, including adjacent channel leakage power and spectrum mask as well as spurious measurements requiring a wide dynamic range. The capture and replay function can be used to better compare real world effects with simulated designs and performance.

Six Traces Analyzing Captured Signals



Production Testing with Anritsu



One platform for Cellular, Connectivity, and Broadcast, and GNSS. More flexibility, 1-up, 2-up, 8-up testing (Multi-DUT testing)

Turnkey, chipset-specific calibration and verification software

Connect up to four 4x4 MIMO 802.11ac devices to one box 10 MHz to 6 GHz Wider Frequency Range, 160 MHz BW (VSA/VSG)

Embedded CPU for fast analysis Integrated switching and per port self-calibration

Remote SCPI API (per TRx)

All technologies in a single module:

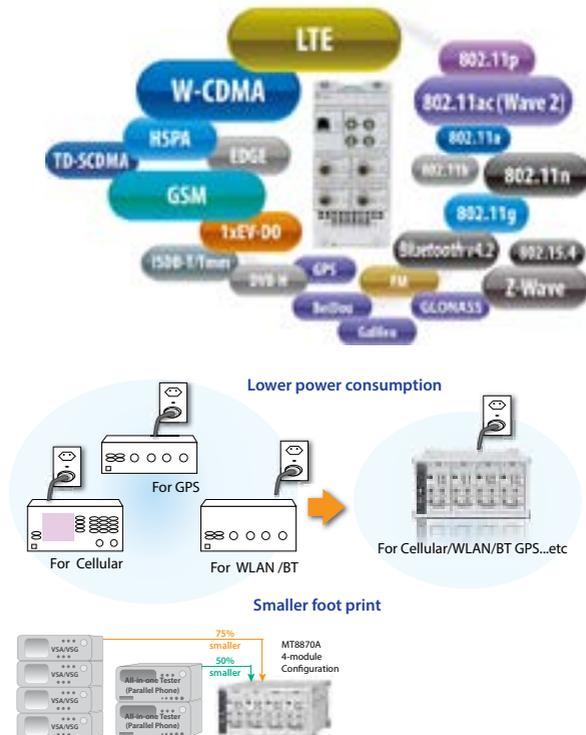


Figure 17: Advantages of MT8870A as a modular platform

Anritsu’s MT8870A Universal Wireless Test Set is a real solution for testing from R&D to production stages of all wireless standards: cellular (2G, 3G,LTE, LTE-Advanced), SRW (802.11x,Bluetooth and ZigBee), navigation (GPS, GLONASS and Beidou) and broadcast technologies (AM/FM radio, DBV and ISDB standards).

It’s ideal not only for production, where it can make fast calibration, validation and 3GPP measurements, but it also includes CombiView which is ideal for R&D and troubleshooting. And its wide frequency operating range and 160 MHz measurement bandwidth prepares it for future standards without new hardware.

Wireless Connectivity Portfolio

MD8475A e.g eCall/HO/Throughput	MT8820C RF/OTA w/signalling	MS269xA/MS2830A RF/HW w/o signalling
MT8852B BT incl. audio	MT8860C WLAN w/signalling	MT8870A Production

In Board Safety and Driver Aids

eCall/ERA-GLONASS

What is eCall/ERA-Glonass

eCall and ERA-GLONASS are a European, respectively Russian initiative to combine mobile communications and satellite positioning to provide rapid assistance to motorists in the event of a collision. When activated, the in-vehicle systems automatically initiate an emergency call carrying both voice and data (including location data) directly to the nearest Public Safety Answering Point to determine whether rescue services should be dispatched to the known position.

The core functionality of both systems is an embedded computer that continuously monitors crash sensors and satellite positioning receiver in order to initiate an automated data and full duplex voice call via a dedicated wireless modem (e.g. GSM, UMTS) in case of an emergency condition. In-band modem capability, the ability to transmit data over the voice channel, is a key requirement for both systems. The goal is to equip all cars in the EU and Russia with dedicated hardware either as first mount unit in new cars, or installed in pre-existing vehicles (after market devices).

The systems, the first based on GPS the latter on GLONASS, monitor in-vehicle sensors for such events as airbag deployment to automatically transmit location details and summon assistance via emergency cellular service. The motivation for both systems is the reduction of the consequences of road accidents in Europe and Russia.

EU, Russia have announced plans to introduce telematics-related mandates for those services (2018 in EU and 2015 in Russia).

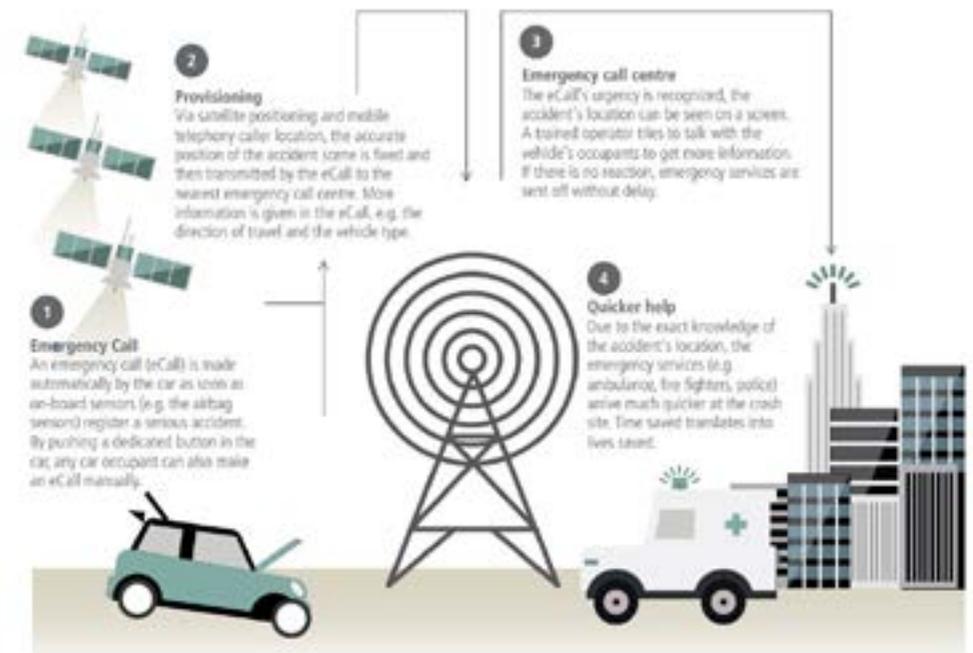
The immediate impact for the automotive industry will be painful, as OEMs are forced to absorb the additional cost of mandated TCUs and handle the on-going uncertainties relating to the evolving technical requirements. In the longer-term, however, the mandates will also enable OEMs to piggyback more connected services onto embedded TCUs and even reduce the cost of fitting embedded TCUs in markets without legislation. For this reason, the high cost of hardware may only be a short-term barrier to embedded telematics.

The voice calls placed by eCall systems in cars are required to be carried by any mobile telephone (cellular) network provider in Europe, just as 112 emergency calls are.

In order to ensure that every vehicle's eCall system can operate properly on every European cellular network, the eCall protocol is governed by standards that cover all

important aspects of the system's operation. These standards specify, for instance, the way in which information about the vehicle is packaged as a 'Minimum Set of Data' (MSD) for transmission to a PSAP, and the sequence and timing of the various steps in a vehicle-to-PSAP communication session.

In other words, the operation of eCall technology on the vehicle side (the In-Vehicle System, or IVS) as well as on the PSAP side is highly standardized and strictly regulated. Companies which design and manufacture eCall IVS modules, or components such as cellular modem chipsets, will have to ensure that their products conform to all the standards – there are more than 20 – applicable to eCall in Europe. Automobile manufacturers which deploy eCall systems in cars (by installing the module and peripheral components such as an antenna and a manual activation button) will also have to provide for a complete system following those standard.



Source: European Commission

Figure 18: eCall ecosystem

Testing eCall: Network Simulator Environment

The function of a network simulator such as the Anritsu MD8475A is to receive and transmit signals in exactly the same way as a telephone network, such as a European GSM cellular network. Such network simulators are commonly used, for instance, by mobile phone handset manufacturers when developing new handset designs in order to verify their RF (physical layer) and software (protocol layer) performance.

In the development of an IVS, the network simulator enables the engineer to test the operation of components, of a module, or of a complete system, in the laboratory. This known environment provides a framework for repeatable and comparable test which is not possible with live environment.

Anritsu propose a conformance test system for testing IVS from a High Level Application Protocol perspective (EN16062). It covers IVS HALP test cases of the end-to-end conformance document CEN/TS 16454:2012.

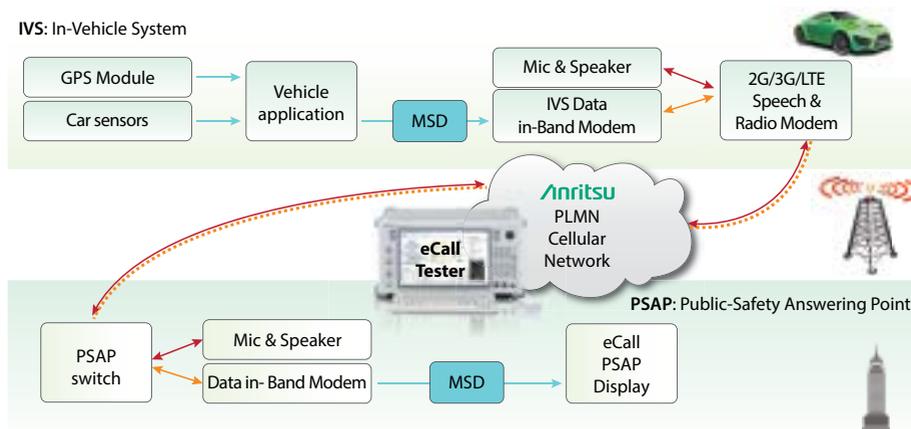
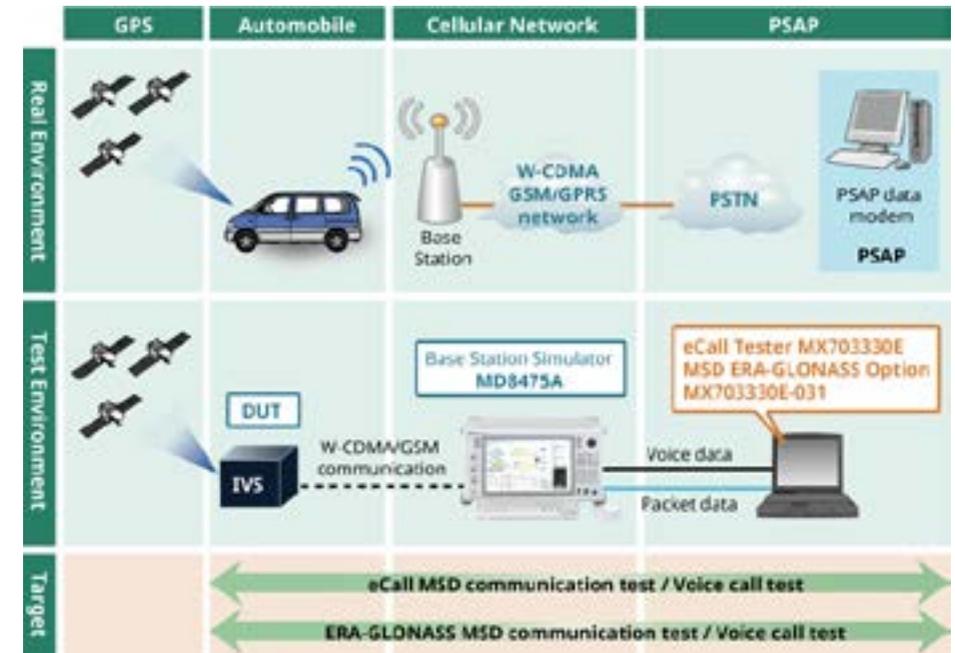


Figure 19: eCall testing with Anritsu simulators

The Anritsu eCall tester system is composed of PSAP testing interface running on a computer controlling the Network simulator MD8475A. The tester can validate the transmission of the MSD (PUSH/PULL) and also allow end-to-end voice communication. The MSD received can be compared with a reference MSD. It allows negative testing and modification of timers to challenge the eCall modules. The solution can also automate DUT (Device Under Test) if it supports AT interface.



ERA-GLONASS

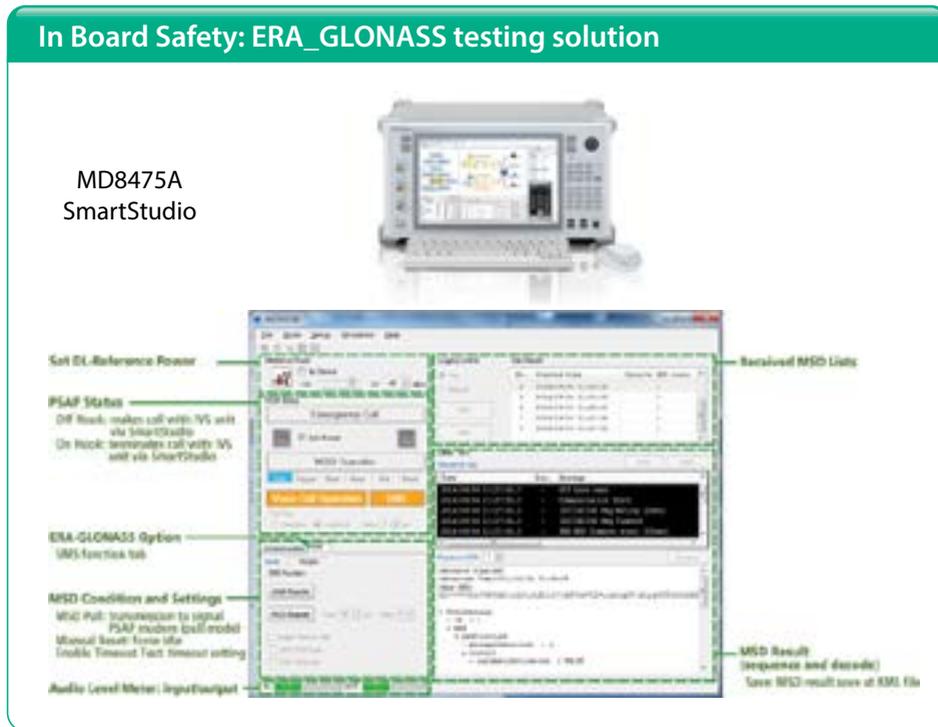
The ERA-GLONASS system is based on the Russian specification defined by the GLONASS UNION. The standard is similar to the European system. It adds some backup functionalities if the voice link is not functional by sending data over SMS. The system also used the Russian positioning GLONASS.

GOST R 54619 Global navigation satellite system. Road accident emergency response system. Protocol of Data Transmission from In-Vehicle Emergency Call System to Emergency Response System Infrastructure.

GOST R 54620 Global Navigation Satellite System ROAD ACCIDENT EMERGENCY RESPONSE SYSTEM In-Vehicle Emergency Call System General technical requirements.

GOST R 54721 Global navigation satellite system. Road accident emergency response system. Base service Description.

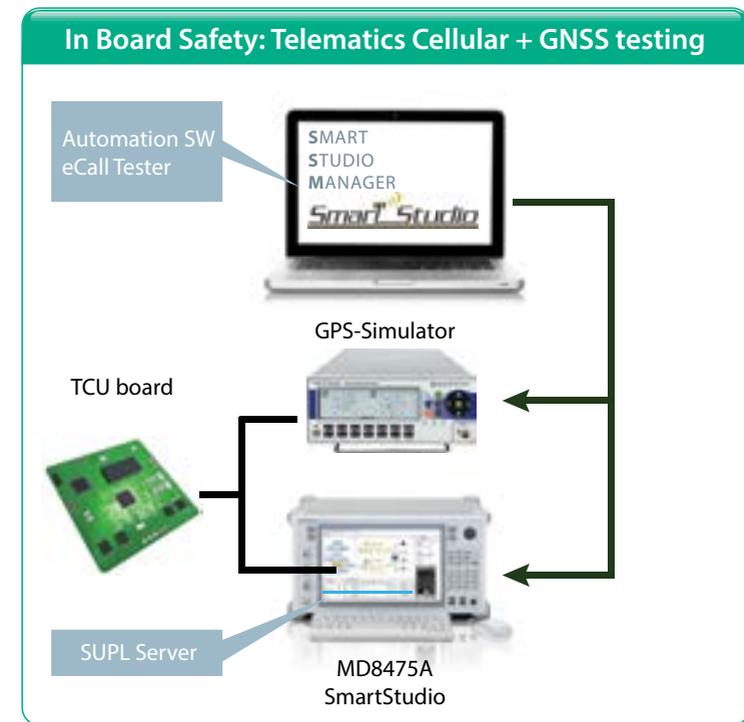
The eCall software presented earlier, can be complemented by the ERA-GLONASS option adding the SMS backup mechanism used in the case of voice failure specified in the standard.



Positioning Systems and Location based Services

Positioning in Automotive is already an essential part of the telematics services. The combination of the cellular and GNSS technologies allows a variety of services such as fleet management, car sharing, stolen vehicle service.

Using the Anritsu Automation software called Smartstudio manager it is possible to control the MD8475A network simulator, the device under test as well as a GPS simulator such as Spectracom. This can be used in to test telematics scenario that can be automated for regression testing or stress test. eCall/ERA-GLONASS testing as well as for testing Location based services can be tested directly with the Anritsu Software solution.



Standards based testing

The 3rd Generation Partnership Project (3GPP) unites telecommunications standards bodies. Its specification 3GPP TS 25.171 defines Requirements for Support of Assisted Global Positioning System Using Mobile Telephony. Spectracom GPS signal simulators includes scenarios for the following test standards:

- Course time acquisition
- Fine time acquisition
- Normal accuracy test
- Dynamic range test
- Multi-path scenario
- Moving scenario

On top of the profile defined by 3GPP the GNSS simulator flexibility allow for a variety of testing.

Testing number of GPS satellites

- Multiple channel GPS receiver testing (up 64 satellite)

Time to first fix (TTFF)

- How fast can the GPS receiver achieve a position fix
- Test GPS receivers in cold-, warm- and hot-start conditions

Reacquisition time

- How fast to reacquire signal in the case of loss of signal

Tracking sensitivity

- What signal level is required to maintain position fix
- Scenarios when and which specific satellites change signal levels

Trajectory testing

- Test motion from the bench
- Travel at speeds and make turns not easily testable otherwise
- Virtually fly objects such as aircraft and missiles

Location testing

- Test the GPS receiver anywhere on earth
- Testing in different hemisphere verifies coordinates are managed correctly

Elevation masking

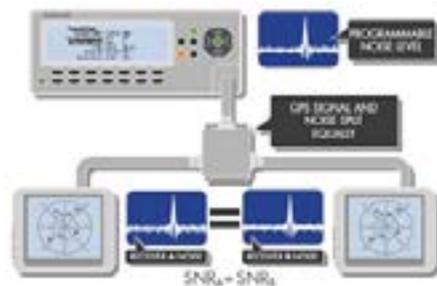
- Create masks to test dilutions of precision (DOP)

Leap second testing

- The simulator can add or subtract a leap second
- Can only occur on June 30 or December 31 at midnight
- Develop test scenario so the receiver downloads a current almanac before midnight

White noise generation / SNR testing

- Set a known signal-to-noise ratio from the simulator
- Maintain the SNR to multiple receivers through a GPS signal splitter



Satellite Based Augmentation System (SBAS)

- Test up to 3 augmentation satellites
- WAAS, EGNOS, GAGAN, MSAS (automatically selected based on simulated position)

Multipath testing

- Built-in multi-path scenarios and multi-path editor
- Build scenarios for power, frequency and time shifted signals via text files

Multi system testing

- Testing of multi-GNSS receivers: GPS + GLONASS + Galileo + BeiDou (can operate any 3 simultaneously)

Multi frequency testing (6 series only)

- L1 | L2C | L5 | E1 | E5 | E6 | B1 | B2 | B3
- Codeless receiver L1 and L2 testing / carrier phase receivers
- Keyless testing of SAASM receivers

ADAS Systems: Radar FMCW

In the context of In-board safety equipment and drivers aid's, the Advanced Driver Assistance Systems (ADAS) are developed for preventing the crash. Among others, Adaptive Control Cruise (ACC) technology is leading the way to the autonomous car.

Radar technology is becoming the centre-piece of these ADAS systems, both for safety or adaptive cruise control purposes. Operating as if they were the car's eyes, radars can manage blind spot and side-impact detection by quickly and precisely measuring the speed and distance of multiple objects. Thus, not only working as collision-warning systems, but also leading to robotically controlled vehicles, i.e. speeding down heavy vehicles separated by meters just before crashing as the autonomous emergency braking system (AEBS) for trucks.

Radar sensors have been essentially developed around two frequency bands:

- **77 GHz sensors:** initially developed for ACC systems, these E band - waveguides in the range from 60 GHz to 90 GHz - sensors can provide the necessary range for ACC applications within a small system footprint, i.e. the antenna size at those frequencies can be perfectly small for installing it within the automobile's grill. This band was regulated already in the 90's followed by the ITS standardization in Europe (ETSI EN 301 091).

TR 101 983 | Radio equipment to be used in the 76 GHz to 77 GHz band; System Reference Document for Short-Range Radar to be fitted on road infrastructure

EN 301 091 parts 1-2 | Short Range Devices; Road Transport and Traffic Telematics (RTTT); Radar equipment operating in the 76 G

TR 102 263 | Road Transport and Traffic Telematics (RTTT); Radio equipment to be used in the 77 GHz to 81 GHz band; System Reference Document for automotive collision warning Short Range Radar

- **24 GHz sensors:** initially thought for collision-avoidance assistance at low speeds (i.e. for parking or backing up), these K band radars improve the distance resolution up to centimeters and have the capability of detecting obstacles hidden in drivers' blind spots (called Blind Spot Detection, BSD). On January 2005 the range of 21.65 – 26.65 GHz for ultra-wide band (UWB) short range radar (SRR) was officially allocated in Europe. On the contrary to 77 GHz sensors, 24 and 26 GHz systems must coexist with the coupled use of this band for weather sensing, as 24 GHz is the mechanically resonant frequency of water vapour.

At this time, medium range radar (MRR) systems in the 24/26 GHz range are beginning to appear. On the other hand, the EU commission's Information and Communication Technology (ICT) for Transport is also encouraging the development of 158 GHz sensors for ACC or 122 GHz sensors for near-range parking. Already commonly commercialized BSD sensors are also being adjusted for new applications such as the rear cross traffic alert (RCTA), which simply uses the same radar architecture and can help to avoid accidents and personal injuries when exiting from a parking slot.

FMCW Radar Technology

Frequency Modulated Continuous Wave (FMCW) Radar is becoming the most popular option for automotive applications. FMCW radars, also called chirp radars, are cheaper than pulsed radars as they can use less power. A chirp waveform on the 77 GHz band is capable of differentiating objects and their size, speed and direction over a distance up to 200 meters at speeds even around 160 km/h.

As opposed to pulsed radar systems, continuous wave (CW) radar systems are continuously transmitting. Taking into account that the basic pulse radar systems use the time interval between transmission and reception to determine the target's range, a CW radar could not work in that way.

On the contrary, CW radars can directly measure the instantaneous Doppler shift of the returned signal, which leads to an instantaneous rate-of-change in the target's range. In a few words, CW systems measure the instantaneous range rate/variation, maintaining also continuous contact with the target. This range rate is actually a fraction of the real speed of the target, being equal to it only when the radar's line-of-sight (LOS) is focusing at exactly the object's direction of motion.

FMCW technology, by adding a frequency modulation to a CW system, aims to measure range instead of range rate. This is possible because our signal form becomes time-dependent.

In simple words, an FMCW system stamps the time on the transmitted frequency at every instant and, by measuring the frequency of the return signal, it can obtain the time delay between transmission and reception and therefore the range determined as with the equation 1. Of course, for precise results the bandwidth of the modulation (difference between f_2 and f_1) must be significantly greater than the expected Doppler shift.

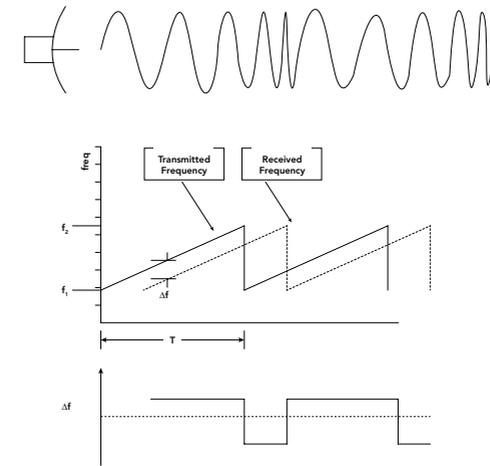


Figure 20: Representation of FMCW signal

Normally, FMCW systems can be considered as homodyne receivers, in which the local oscillator's frequency is identical or very close to the carrier frequency of the wanted signal. Indeed, the transmitter frequency is used as local oscillator in the receiver so that the received signals are down-converted directly into the baseband. Then, after filtering and amplifying them, signal processing through FFT follows and algorithms are used for identifying distance, speed and angular position.

Bandwidth-independent signal analysis of FMCW transmitters

It is extremely important to measure the transmitter performance in FMCW radars, because its frequency accuracy determines also the accuracy of the signal received. In any FMCW system, one important source of inaccuracy in the results is the frequency fluctuation around the chirps' ideal lines.

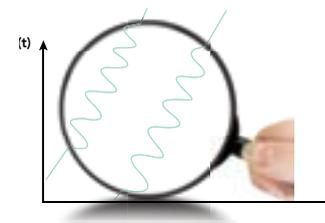


Figure 21: Typical small frequency fluctuations around the ideal ramp of a conventional FMCW signal

The bigger the fluctuation, the bigger error in the obtained beat frequency, then the bigger error in the range calculated and in the radial velocity exhibited by the system.

Radar sensors integrated into car's bumpers may be electrically affected, thus causing attenuation, reflection or bending of the radar signal, between others. Radar's transmitter performance must be checked before and after mounting the module on the car's front panel, so electrical optimization of the complete system can be performed. . In this sense, Anritsu offers knowledge and tools for evaluating FMCW transmitter performance (linearity, fluctuation, etc.) and calibrating them.

Anritsu MS2830A Spectrum Analyzer/Signal Analyzer is capable of analyzing bandwidth-independent FMCW signals thanks to its flexible Frequency vs. Time analysis and easy automation capabilities.

Signal Analysis through Fast Fourier Transform (FFT) allows to represent the signal differently depending on the magnitudes desired to view. For example, the signal can be plotted as Power vs. Frequency, Power vs. Time, Frequency vs. Time or, even, Power vs. Time vs. Frequency, called Spectrogram.

In this sense, the reader can understand that the analysis of FMCW signals can be performed via the Frequency vs. Time mode of a Signal Analyzer. Nevertheless, there are some important limitations we should be aware of:

- **Maximum Span or frequency analysis window:** this is the maximum bandwidth of the signal that can be analyzed. In terms of FMCW signals, the bandwidth will be the difference between the maximum and minimum frequencies of the chirps.
- **Analysis time:** the minimum and maximum analysis time permitted by the Signal Analyzer will limit the time length of the signals under analysis.

At first sight, the Span would obviously limit the kind of signals that can be analyzed in terms of bandwidth, i.e. only signals that can be captured within the frequency analysis window will be analyzed. Some instruments will strictly follow this limitation and will not allow the analysis of signals with wider bandwidths.

Regarding the second parameter, the minimum analysis time would limit the resolution of the analysis. For example, if the chirp is much shorter than the minimum analysis time, there may not be enough points for represent accurately one of the chirps inside the analysis time window.

Anritsu can show expertise in analyzing FMCW signals of any bandwidth independently of the signal analyzer maximum Span. The method developed is based on the dithered sampling concept.

Dithering is a common term within the Signal Processing field that also applies in Image Processing applications. For example, there are astronomical cameras that can operate in dithered mode, building the final image from multiple exposures with very small shifts between them. This is particularly favorable when the original detector pixels are too large to adequately sample the image being focused.

When a signal is perfectly or almost perfectly periodic, the capture of that signal can be performed more accurately if a combination of different periods are processed adequately. This idea can be applied in signal analyzers when there exists the need of analyzing signals with wider bandwidth than the instrumentation is capable of. The most important requirement is that these signals must be periodic.

Normally, dithered sampling methods are applied for reconstructing the signal's amplitude over time. Nevertheless, for capturing a FMCW signal regardless its bandwidth, we can apply this concept in the frequency axis. The following figure is aiming to explain this method:

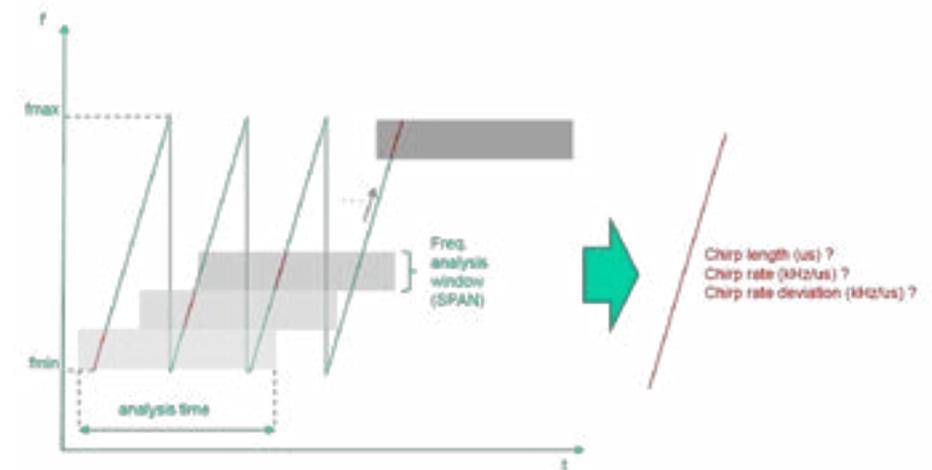


Figure 22: Dithered sampling method for bandwidth-independent analysis of FMCW signals.

Figure 22 shows how it is possible to reconstruct a full periodic chirp with narrower SPAN values than the actual chirp's bandwidth. Basically, the whole bandwidth of the signal can be analyzed by a natural number of frequency analysis windows, which must be the result of dividing the signal's bandwidth by the SPAN applied to the Signal Analyzer.

Not only simple Up- or Down-chirps can be analyzed with this methodology. The analysis of a more complex FMCW signal is possible. In the following case, the signal under consideration holds both an up-chirp and down-chirp, as represented in the following picture:

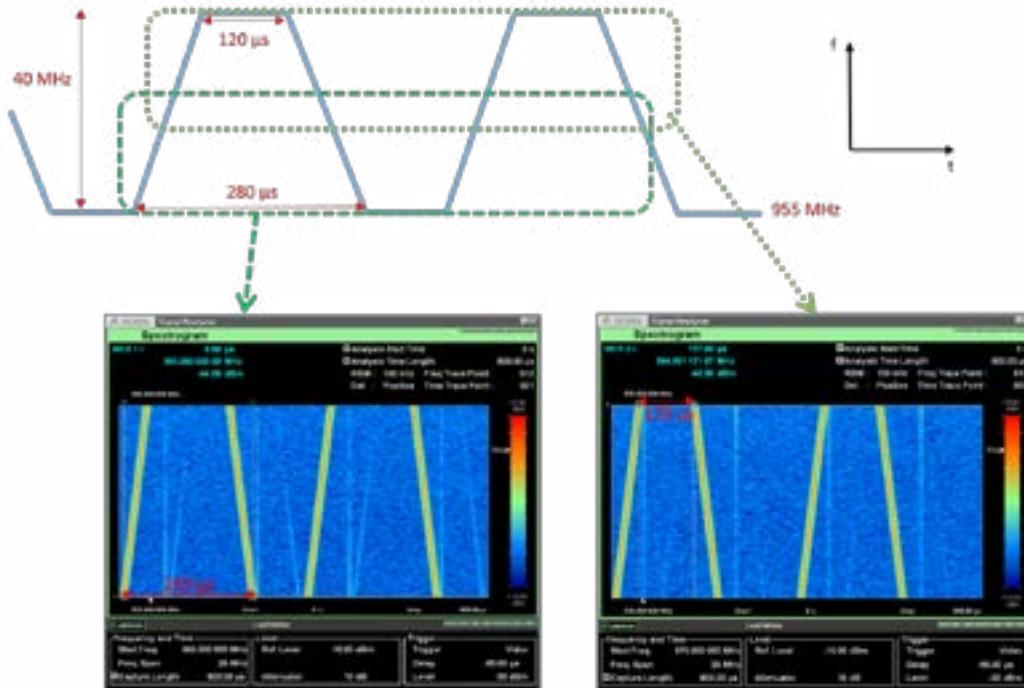


Figure 23: Double chirp signal representation and real capture with MS2830A Spectrogram mode

In this case, the period of the signal is 400 µs and it is formed by an up-chirp and a down-chirp of 80 µs each. The bandwidth is 40 MHz and we analyze it using frequency windows of 10 MHz, i.e. in 4 steps. The automated tool developed can reconstruct both chirps and return the complete analysis for each of them independently.

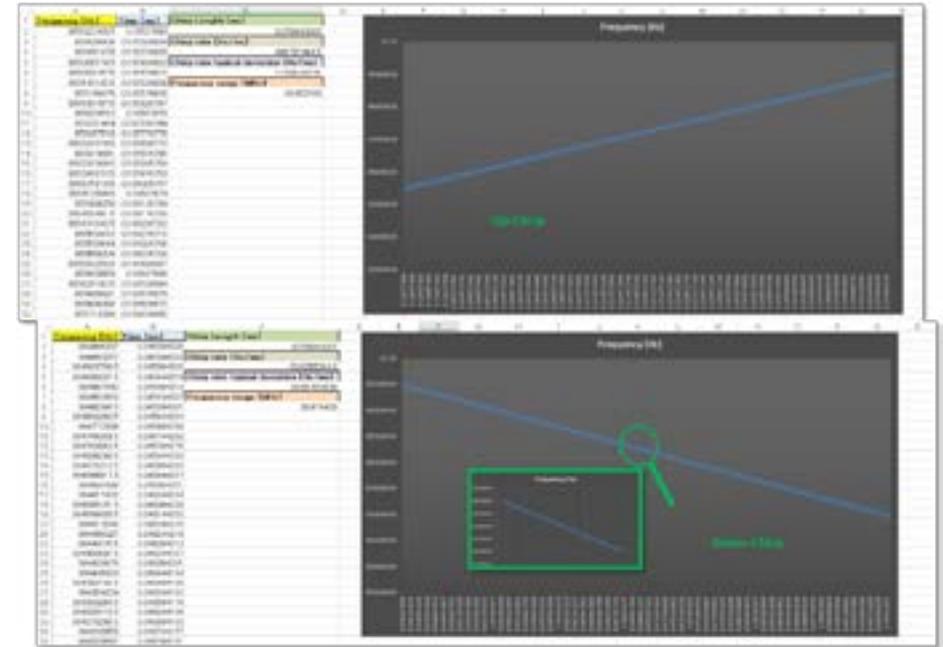


Figure 24: Double chirp analysis results from the MS2830A automation tool

Anritsu MS2830A 43GHz Signal Analyzer in combination with external mixers can be used for analyzing any FMCW Radar transmitter in Dithered Sampling mode.

TPMS and RKE

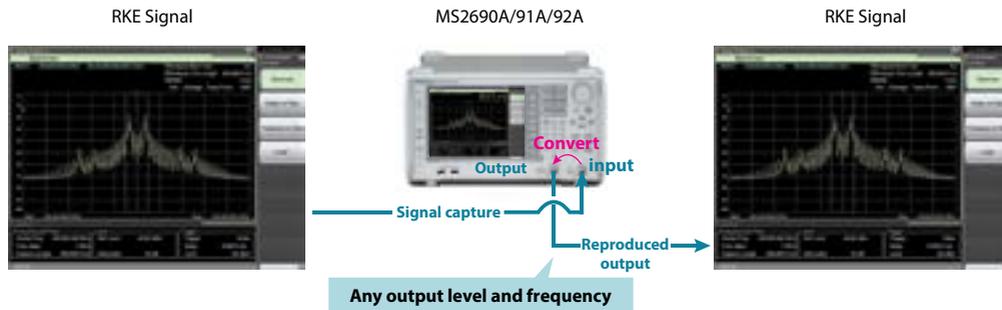
A tire pressure monitoring system (TPMS) is an electronic system designed to monitor the pressure inside the pneumatic tires on various types of vehicles. TPMS report real-time tire-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light.

Target

- Avoiding traffic accidents due to under-inflated tires by early recognition of the malfunction of tires
- Reducing rolling resistance thus increasing overall fuel efficiency

Testing with easy Capture and Reproduction of Actual RKE and TPM Signals

The following test system based on MS269xA/MS2830A uses a built-in vector signal generator to reproduce captured actual signals, including Remote Keyless Entry (RKE) and Tire-Pressure Monitoring System (TPMS). This is good for troubleshooting faults because waveform-converted signals can be reproduced repeatedly. In addition, the DUT Rx characteristics are easily verified because reproduced signals can be output at any level and frequency.



Flexible Signal Analysis using VSA Function

Captured pulse signals and noise are analyzed using the flexible VSA function supporting Spectrum, Power vs. Time, and Frequency vs. Time displays. In addition, spectrum performance can be checked intuitively using the Spectrogram display showing frequency, time, and power on one screen to troubleshoot and develop car wireless equipment, such as RKE and TPMS, using FSK signals.

MS2690A/91A/92A



Remote Keyless Entry (RKE)

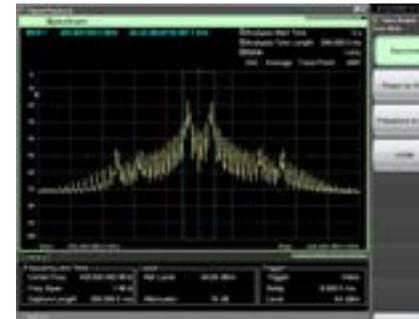
MS2690A/91A/92A



Tire-Pressure Monitoring System (TPMS)

RKE Measurements using VSA Function

Spectrum



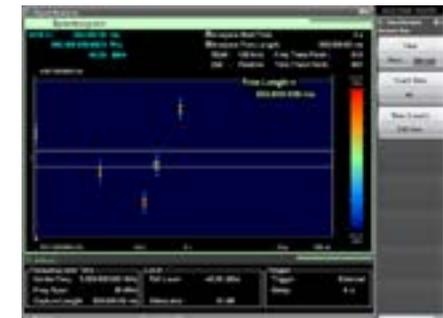
Power vs. Time



Frequency vs. Time



Spectrogram

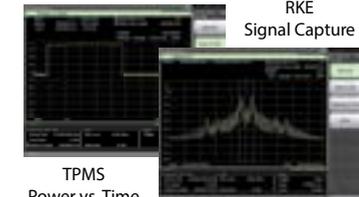


Safety and Driver Aids

MS269xA/MS2830A
RF/HW w/o signalling



RKE
Signal Capture

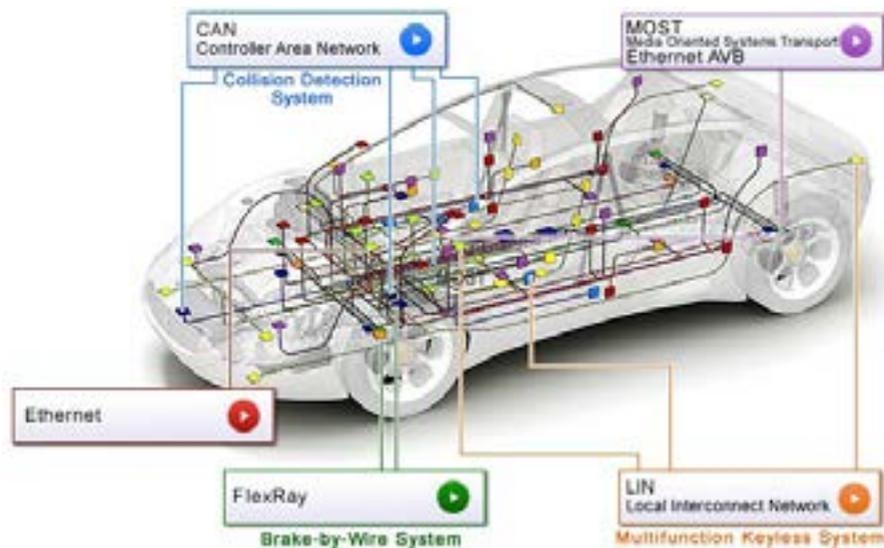


TPMS
Power vs. Time

In-Vehicle Networks

(Ethernet, CAN, Optical Fibers, RF cables & connectors)

With the increase of complexity seen in vehicle several communication standard and physical medium have been developed specifically for automotive applications. Vehicles are now composed of hybrids networks optimized for specific functions. The CAN (Controller Area Network) buses remain the base for low level communication in vehicles. CAN usage remains particularly widespread, despite its speed below 1Mbps and load limitations.



LIN (Local Interconnect Network) developed in the 90' by European car manufacturer is a serial network that provides a low-cost solution vehicle body applications with low throughput below 20 kbit/s. Its application area could be mirror switch, window lift, seat control switch, door lock ...

FlexRay, also an automotive bus standard, though faster than CAN, is intended for timing critical applications such as drive by wire rather than media. FlexRay offers determinism, which can be important in safety. It enables for example "x-by-wire" capabilities, such as brake-by-wire, along with other functions where speed and reliability are paramount.

MOST (Media Oriented Systems Transport) is a high-speed multimedia network technology optimized for the multimedia transmissions. Its ring topology and synchronous data communication transport audio, video, voice and data signals via either plastic optical fiber (POF) electrical conductor or on Unshielded Twisted Pair (UTP).

The latest version MOST150 introduced in October 2007 allow a maximum throughput of 150 Mbps. Used with plastic optical fiber MOST proves to be lighter and more flexible compared to shielded electric data lines meeting strict EMC requirements as it does not cause any interference radiation and insensitive to electromagnetic interference irradiation.

Despite its relatively good throughput that covers most of the current multimedia application needs, MOST on POF due to its current medium and architectural limitation is not a candidate to cope with the ever increase demands of connected cars. On top of data throughput increasing for multimedia infotainment, we see security sensors such as camera and radar demanding a substantial amount of data.

One of the keys moving forward for autonomous driving is to network the systems so you can build a picture of the environment around the vehicle, showing anything in the full 360°.



Figure 25: Sensors and infotainment requiring high throughput

Looking at the typical demand in term of throughput for multimedia and safety applications the data demand is critical.

Application	Hres	Vres	Bit depth	FPS	Bandwidth (Mb/s)	100 Mbps	1000 Mbps
Camera	1280	720	12	30	331.78	Medium Compression	Uncompressed
Camera	1920	1080	12	30	746.50	Strong Compression	Uncompressed
Video	800	600	18	30	259.20	Strong Compression	Uncompressed
Video	1280	720	24	60	1327.10	Strong Compression	Lite Compression
Video	1920	1080	24	60	2985.98	Strong Compression	Lite Compression

Table 2: Typical video throughput demands (source: Peiker)

The introduction of Ethernet 802.3 on twisted Pair Cable is seen as one of solution to be added to the current hybrid network to achieve higher-speed scalable to Gbits/second. The Ethernet is one of the most successful standard in history with a 40 year of existence. The massive adoption that have driven the cost down. Currently, the Ethernet is used mostly as a diagnostic as it has not specifically design for automotive requirements such as reliability or latency with guaranteed KPI. As it was originally conceived, Ethernet moves packets through networks on a best-effort, non-deterministic basis.

This makes it poorly-suited for use in mission-critical real-time systems used to control drivetrain or braking systems or support driver-assist functions. But later developments have added mechanisms like the IEEE 802.1tsn (time-sensitive networking) protocol which provides assured, non-conflicting delivery of data and command packets within strict time parameters which makes it allow a "Deterministic Ethernet".

Additional standards for specific timing-critical applications are also available, including the IEEE 802.1AS/802.1Q/802.1Qca protocols which support the transport, switching and management of latency-sensitive connections used in high-speed real-time control applications.

The next generation of infotainment systems will also benefit from IEEE 802.1AVB which enables the aggregation and distribution of audio/video streams.

All these capabilities rely on the IEEE 1588 precision timing protocol to provide the timing information required by each node to keep its clock synchronized with the network's master clock.

All the extensions to the original IEEE 802.1/802.3 standards now define practical solutions for providing security, deterministic performance, traffic shaping and many of other application-specific functions, features and specifications. As a result, Ethernet already has many of the capabilities it needs to meet the unique demands of in-vehicle networking. Nevertheless, there were several technical challenges which had to be addressed before Ethernet could win acceptance as the bus of choice for tomorrow's connected vehicles.

Testing the physical Layer Ethernet

One of the biggest challenges in creating automotive-grade Ethernet was finding an alternative to the multi-pair unshielded twisted-pair (UTP) cabling commonly used by 100BASE-T and 1000BASE-T networks. While well-suited for use in today's LANs, Category-5/6 cabling is simply too bulky and expensive to be practical in the tight confines and tight budgets of high-production automobiles. Moreover the connectors do not handle vibrations encountered in Automotive. In order to meet the unique cost and manufacturability requirements of automotive applications, the OPEN Alliance (One-Pair Ether-Net) Special Interest Group has developed a new PHY technology (Figure 26).

Referred to as 100BASE-T1 or 1 Twisted Pair 100Mbps Ethernet (1TPCE), it uses digital echo cancellation and Decision Feedback Equalization (DFE) techniques borrowed from 1000BASE-T Gigabit Ethernet to support full-duplex Ethernet at 100Mbps over a single pair of unshielded twisted wires (UTP).

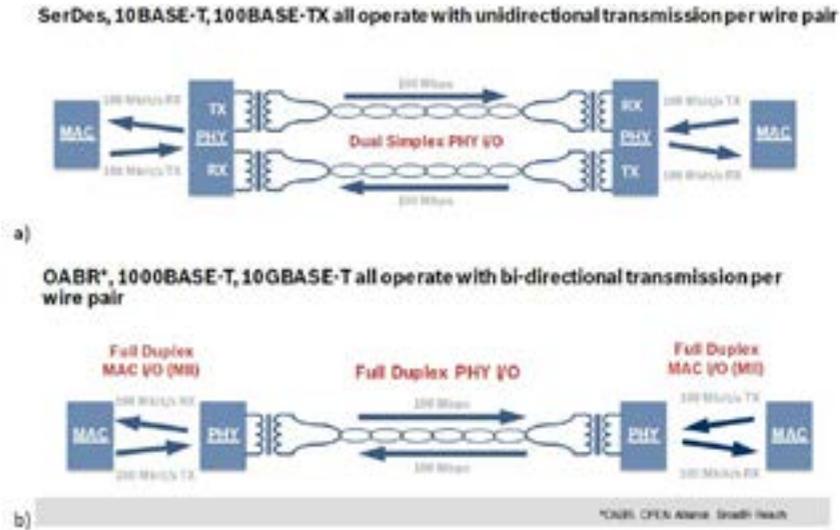


Figure 26: (a) Conventional 10/100BASE-TX Ethernet. (b) The single-pair full-duplex PHY developed by the OPEN Alliance. (Source: the OPEN Alliance)

Analogous efforts for 1000BASE-T1/RTPGE are also ongoing. This is a single-pair version of Gigabit Ethernet intended as a high-speed aggregation backbone. It could also serve as a direct connection for network backbone and diagnostics, ADAS cameras, infotainment video and other applications with data requirements above 100 Mbps.

Ethernet Testing

Despite all its advantages, Ethernet won't displace legacy vehicle networks overnight. Since FlexRay, MOST, and other more capable bus technologies are still fairly adequate for some applications, manufacturers will be able to upgrade existing products in a gradual manner by using the automotive-grade switch silicon as part of a low-cost bridging solution.

Bridging allows Ethernet to peacefully co-exist with legacy sub-systems which can be upgraded as necessary, enabling an orderly, punctuated transition to a unified all-Ethernet vehicle network (Figure 27).

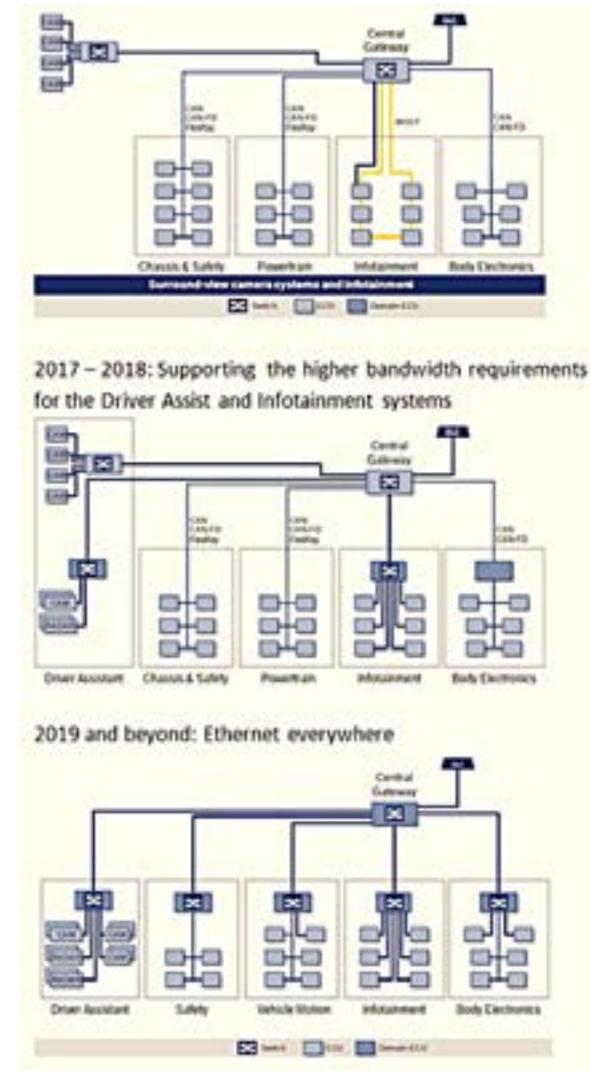


Figure 27: Ethernet is expected to gradually replace legacy vehicle bus technologies in most applications over the next five years. (Source: Bosch)



MT1000A Network Master Pro

- All-in-one field transport tester – supports testing from 1.5 Mbps to 10 Gbps.
- Traffic generation up to full line rate
- Ethernet Service Activation Test (Y.1564)
- Automated RFC 2544 tests of Throughput, Frame Loss, Latency or Packet Jitter, Burstability
- BER tests – include Frame Loss and Sequence Error tests
- Simultaneous monitoring in both line directions
- IP Channel Statistics to identify error streams, top talkers, network attacks
- Frame capture for protocol analysis with Wireshark
- Electrical cable tests and optical signal level displays
- Easy and intuitive GUI.
- Dual port at all rates.
- WLAN/Bluetooth/LAN connectivity.
- PDF and XML report generation for documentation of test results.
- Remote operation and remote control (scripting).



Today's in-vehicle communication networks are becoming more and more sophisticated as new technologies like Ethernet is being fully deployed alongside the entire car. The MT1000A redefines the direction of future test platforms by bringing network test requirements to a portable device, making it the ideal tool for field testing.

MT9090A Gigabit Ethernet Analyzer

- Versatile, purpose-built solution for Gigabit Ethernet field testing.
- Comprehensive Ethernet testing for installation, maintenance and troubleshooting.
- Ping test, traceroute test and Electrical cable diagnostics.
- Two ports simultaneously work for shortening multiple ports installation, including pass through test and in-line monitoring test.
- Option for automated ITU-TY.1564 testing, simultaneously testing of multiple traffic streams emulating real world networks.
- Option for automated RFC 2544 testing.
- Test Automator simplifies operation and ensure proper set-up.
- Channel Stats option identifies error streams, top talkers and network attack.
- Service disruption time measurement to test the performance of real-time applications.



For installation, commissioning and quality verification the Network Master Gigabit Ethernet tester provides powerful and flexible traffic generation capabilities, allowing you to easily test the in-vehicle network under various conditions, including generation of VLAN traffic.

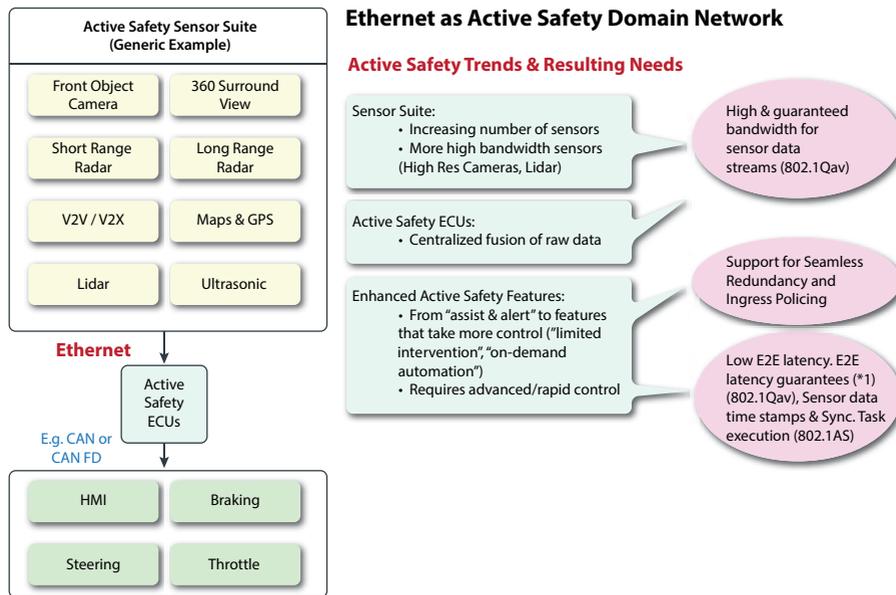
The instrument also provides facilities for BER testing of the lines, performance statistics and quality evaluation.

Sensor suite:

- Increasing number of sensor
- More high bandwidth sensors (HD Camera, Lidar) -> High & Guaranteed Bandwidth for sensor data stream (802.1Qav)

Active Safety ECUs

- Centralized fusion of raw data



Cable Testing

Cable testing is an essential part to ensure the quality of the transmission within a car. Anritsu propose a large variety of instruments from handheld spectrum analyzer and Vector Network Analyzers that can easily check the proper continuity of cables and connectors.

The handheld spectrum analyzer allow a quick verification of cables dedicated to cellular communication

S331E Handheld Spectrum Analyzer

- Cable and Antenna Analyzer: 2 MHz – 4 GHz
- Return Loss, VSWR, Cable Loss, Distance-To-Fault, Smith Chart, 1-Port Phase
- Field-proven design: Four-hour battery life, rugged, compact, lightweight, daylight viewable display
- USB connectivity, built-in touch screen keyboard



Anritsu S331E SiteMaster Compact Handheld Cable and Antenna Analyzer can complete sweeps quickly, perform calibrations instantly, and implement fast trace naming while in the field. Ideal product for Cable & Antenna Installation and Maintenance in the automotive industry.

Insertion Loss , 2-port measurements of Amplifiers, duplexers, diplexers or filters , Phase Matching Cables and Antenna Tuning are relevant applications fitting into the upcoming in-vehicle networks.

- Intuitive menu-driven touch screen user interface



The vector analyzer provides a higher coverage of high frequency allowing to check radar applications.

MS46122A USB Vector Network Analyzer

- World's first series of compact VNAs from 1MHz to 40 GHz for cost-effective measurements.
- PC control takes advantage of external computer processing power and functionality.
- Compact 1U high package for efficient use of bench and rack space.
- Time domain with time gating option grants easier and faster fault identification.



Anritsu Shockline Compact VNA MS46122A is the smallest, most advanced 2-port VNA in the world.

The series benefits from patented shock line VNA-on-chip technology, which simplifies the internal VNA architecture at high frequencies, reduces instrument cost, and enhances accuracy and measurement repeatability. All the members of the MS46122A series are low cost full-reversing 2-port VNAs aimed at RF and microwave applications in manufacturing, engineering and education. With 220 microseconds per point sweep speed and better than 100 dB dynamic range they are extremely suitable for a wide variety of device test applications in the Automotive Industry, such as cable, connectors (including FAKRA), antenna or radar.



Intelligent Transport Systems

(V2V/C2C, V2X/C2X, C2I/V2I, 802.11p, DSRC/WAVE)

Until recently, most communication was exclusively one-way: from the infrastructure to the vehicle, otherwise known as X2Car. Global navigation satellite systems (GNSS) and other positioning signals would provide navigation and telematics; Bluetooth would enable hands-free telephone use and media; traffic information would arrive over radio frequencies, via RDS.

Now, however, such channels are increasingly being complemented by Car2X, where the car communicates with its environment, and indeed by two-way exchanges of information with other vehicles (Car2Car). Some work is currently done to bring more intelligence to those network using what is referred as ITS.

What is ITS

ITS is a term used by different standard organization around the world to define the Intelligent Transport Systems framework which aim to provide innovative services relating to different modes of transport and traffic management . This enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. ITS are not restricted to Road Transport - they also include the use of information and communication technologies (ICT) for rail, water and air transport, including navigation systems. In the case of Automotive, ITS refers mainly to telematics systems and all types of communications in vehicles, between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure). The various types of ITS rely on wireless services for communication.

The ITS Standards are to enable interoperability by specifying who communicate with whom (vehicle, pedestrian, road-side infrastructure, central servers). They also define what type of message is transmitted on which media (wireless frequency band) and which protocol (MAC/IP/..) for which application.

The ITS standard are developed around the world by different regional organizations. Most of the technological approach are very similar and some cooperative work is aiming at some sort of worldwide compatibility or convergence. However, some technological difference are seen mainly due to regularity constraints, such as radio frequency which are different depending on the country/region.

Standardization activities

- USA: IEEE, SAE (Society of Automotive Engineers)
- Japan: ITS Info-Communications Forum, ARIB (Association for radio industry and business), ISO
- Europe: CEN (European committee for standardization), ETSI (European telecommunications standards Institute),
- World: ISO



Radio Spectrum Dedicated to ITS Communications

US and Europe are considering mainly the 5.8 GHz band whereas Japan would operate at lower frequencies around 700 MHz.

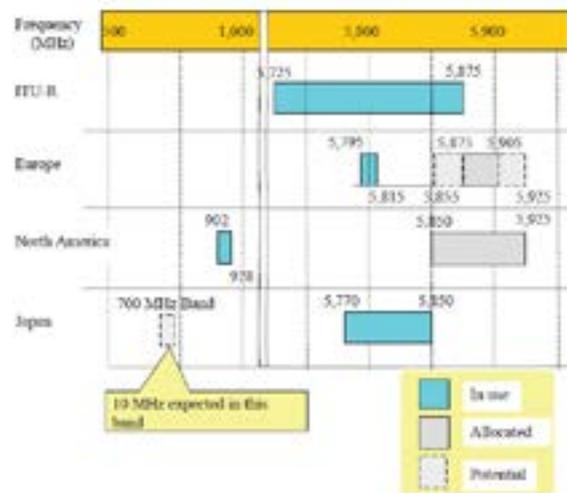


Figure 28: Frequency allocation dedicated to ITS communications

Source: <http://www.imobilitysupport.eu/library/imobility-forum/plenary-meetings/2015-1/5th-plenary-meeting-28-jan-2015-1/presentations/2737-18-paul-spaanderman-tno/file>

The New Standards behind ITS for Vehicular System

ITS system rely on the telematics systems already in place such as wireless cellular connectivity (2G/3G/LTE), GNSS positioning, Radar , ... However, those standard do not allow the reactivity required to enable fast and reliable communication for Car to Car (C2C/V2V), or Car to Infrastructure (C2X/V2I). Hence, an additional wireless technology had to be defined to meet those requirements. A new physical layer as well as a protocol stack have been defined by each organization.

For the physical layer and MAC layer the European and the US organizations use the standard 802.11p based on the one of the variation of the IEEE WLAN using OFDM. The intention is that compatibility with the USA (DSRC/WAVE) and Europe (ITS-G5) should be ensured even if the allocation is not exactly the same; frequencies will be sufficiently close to enable the use of the same antenna and radio transmitter/receiver. Japan is also considering a compatibility with 802.11p on 5.8GHz but it also developing its own standard operating on another band on 700 MHz (ARIB STD-T75) based on Time division access which is said to be more suitable for intersections scenarios.

For the upper layer each region has developed its own standard. USA upper layer is based on DSRC/WAVE (IEEE 1609), the European on ETSI EN 302 665, while japan relies on its DSRC (ARIB STD-T75).

In the following section we will describe the different regional approach for the upper layer, then we will do an overview of the common physical layer 802.11p and how to test it.

ITS in USA

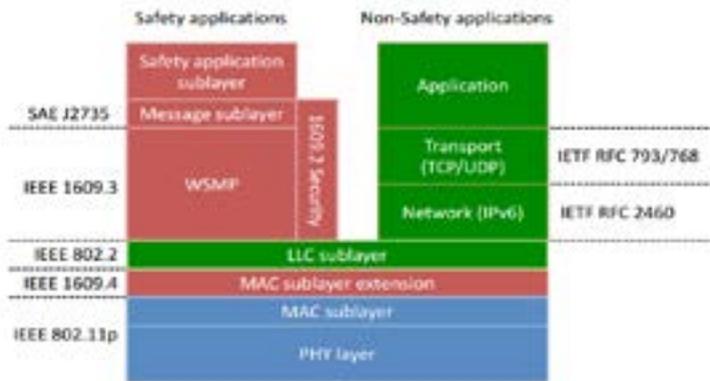
The ITS standardization in the US is an evolution of the legacy DSRC systems now called WAVE (wireless access in vehicular environments). This upper layer is divided into two separate entity: one dedicated for “non-safety Application” based on traditional IP and the other one dedicated to “Safety application” which is not based on IP aiming to reduce overhead. Indeed using IP is not optimal for safety as it has a substantial amount of overhead bits to deal with routing which can slow down transmission and lead to congestion. The Reduced overhead of the IEEE 1609.3 WSMP (WAVE short message protocol) has 11 bytes of overhead allowing applications to directly control lower-layer parameters.

WSM Version (1 Octet)	Security Type (1 Octet)	Channel Number (1 Octet)	Data Rate (1 Octet)	TX Power (1 Octet)	PSID (4 Octet)	Length (2 Octet)	WSM Data (Variable)

Figure 29: Typical message WSMP

The Sublayer SAE J2735 defines message sets, message formats for especially safety applications.

IEEE and SAE standards (USA)



Protocol Stack

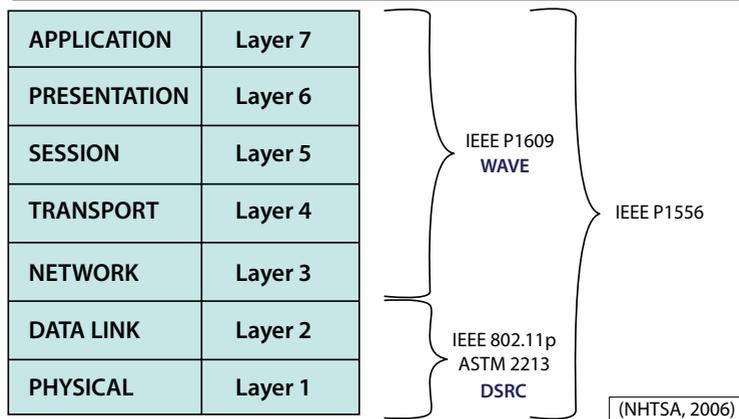


Figure 30: IEEE/SAE standard protocol stacks

ITS in Europe

In Europe, the standard body developing ITS for the European Commission Mandate M/453 are the ETSI, CEN and CENELEC. The two main specifications for ITS are the ETSI EN 302 665 defining the communication architecture, and the ETSI EN 302 663 defining the PHY and MAC using IEEE 802.11p known as ITS-G5.

The architecture of the protocol layer in the European framework follows the ISO/OSI protocol. Similarly to US specification the "Network and Transport" layer is divided into two main component: one traditional "IP networking" and a new dedicated safety feature called "Geonetworking".

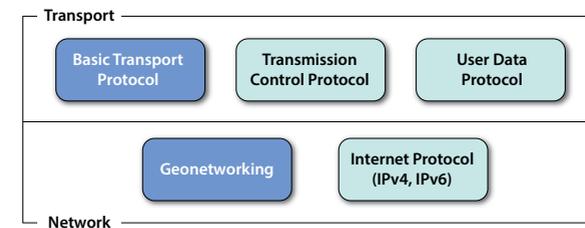


Figure 31: ETSI/CEN Transport/Network layer : Separation between safety (Geonetworking) and IP

The Geonetworking layer is optimized for delivery to particular geographical destination area. It has reduced headers (UDP like) enabling broadcast, unicast, multicast or any cast.

As seen on Figure [xx], the Access Layer is not only using the newly developed ITS-G5 but can also support a variety of medium (Wi-Fi/GPS/Bluetooth, Cellular, and Ethernet).

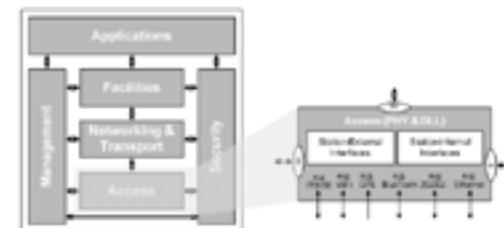


Figure 32: Protocol stack from ITS Europe; ITS access layer as part of the ITS station reference architecture

Listing of ITS ETSI and CEN documents: <http://webapp.etsi.org/WorkProgram>

ITS in Japan

The ITS Forum is the organization in charge of the coordination of ITS activities in Japan. It promotes the Japanese standard produced by ARIB. The main focus of Japanese standardization is to support intersection scenario where 80% of traffic accidents occur in Japan. This was one of the reasons to put a special focus on developing a technology on the 700 MHz, on top of the worldwide 5.8 GHz band. This lower frequency fits better to intersection scenarios due to a better coverage to reflect wave around street corners (Figure 33). It used Time division access to provide better control over interferences.

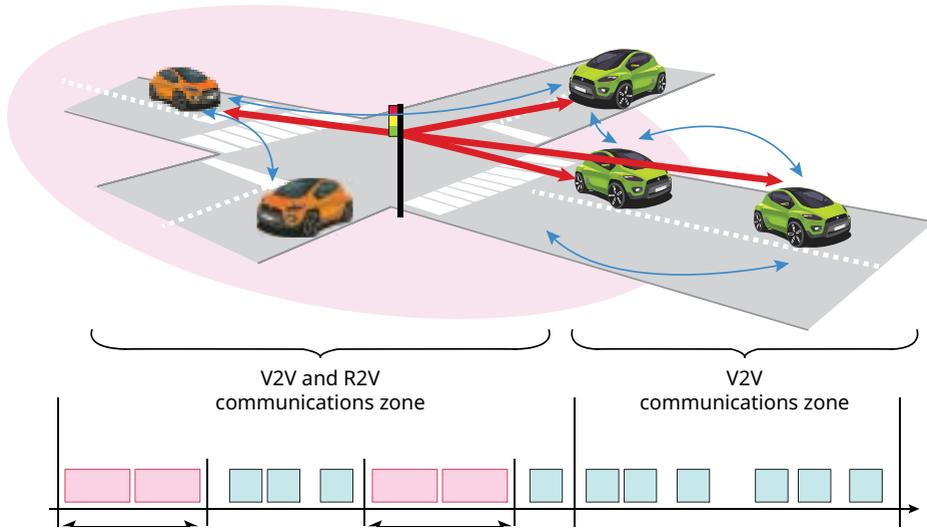
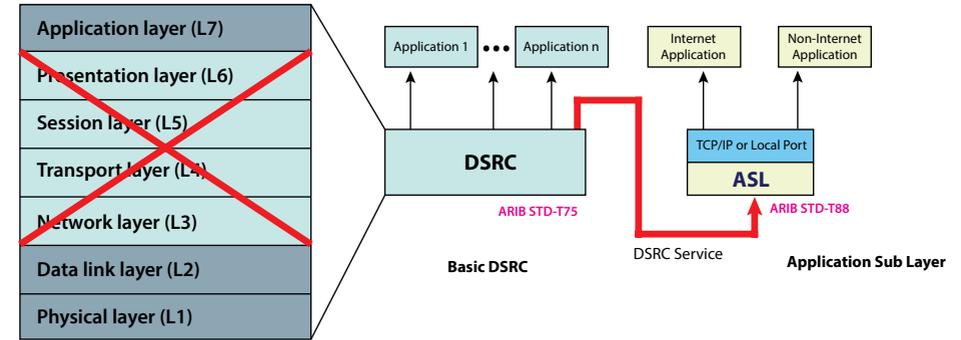


Figure 33: Japanese ITS Forum vision on Intersection scenario time division between Radio to Vehicle (R2V) and Vehicle to Vehicle (V2V)

The standard ARIB STD-109 “700 MHz Band Intelligent Transport Systems” defines the architecture for vehicle to infrastructure communication and for vehicle to vehicle communication. It is based on DSRC protocol stack with no presentation/session/transport/network layers (figure[xx]). This allows a fast (single/multi hop) message dissemination. This also supports an application Sub Layer (ASL) for various types of, IP-based, Non-IP-based applications.

ARIB STD- 109 includes general system overview, general and technical requirements for radio equipment, communication control system, and measurement methods for the transmitter, receiver, and controller.



The Physical Layer: 802.11p (OFDM)

In WAVE (Wireless Access in Vehicular Environments) applications, vehicles or the road infrastructure cannot tolerate long connection establishment times before they

ITS forum also provides guidelines recommendation for ITS: <http://www.itsforum.gr.jp/Public/guideline/index.html>

can communicate with other elements present on the road. Similarly, non-safety applications also demand efficient connection establishment and data transfers with roadside stations (e.g. traffic updates) because of the short time it takes for a fast vehicle to drive through the very small coverage areas. Additionally, the rapidly moving vehicles and complex roadway environments present challenges. One of these challenges are crossings, where propagation characteristics, number of nodes and short start to finish times create a big problem that the 802.11 protocol stack has to deal with.

The 802.11 was the physical and MAC layers chosen by various ITS standards. One of the main reasons for ITS organizations to choose this technology was the cost. The reduced cost being achieved due to the minor modification required to the current standard of a well-established 802.11 set of standards.

The 802.11 OFDM physical layer fits many of the technical vehicular requirements. It is a well-established technology already present in cellular systems, audio and video broadcast technologies and WLAN. In addition, OFDM technology is highly suited for mobile communication with its robustness to fading effects. Moreover, the ad-hoc capability of 802.11 is a perfect fit for vehicle-to-vehicle or vehicle-to-infrastructure communication.

The IEEE 802.11 working group proposed a standard for the physical and medium access control layers of vehicular networks called 802.11p based on the 2007 standard, which was officially approved in July 2010.

Amendments to the Physical Layer

At a physical layer level, the philosophy of IEEE 802.11p design was “make it simple”, with the minimum necessary changes to IEEE 802.11 PHY so that WAVE devices can communicate effectively among fast moving vehicles in the roadway environment. This approach is possible because IEEE 802.11a radios already operate at 5 GHz and major changes are not required to accommodate radios to operate in the 5.8 GHz band for European regulation. Accordingly, three changes are made and are described in the following paragraphs.

The 802.11a IEEE 802.11 OFDM physical layer standards defines three different PHY layer options for the signal bandwidth: 20 MHz, 10 MHz, and 5 MHz. The different modes can be achieved by using reduced clock/sampling rates. 802.11a Existing 802.11 standards use the full-clocked mode with a 20-MHz bandwidth, while 802.11p operates by default at half-clocked sampling rate and uses a lower signal bandwidth of 10 MHz. Half the bandwidth double the transmission time for a specific data symbol. This allows a larger symbol duration and guard interval making the receiver more robust combating the characteristics of the radio channel in vehicular communications environments, e.g. the signal echoes reflected from other cars or houses.

While there are a number of channels available globally for IEEE 802.11p deployment and usage, the nature of closely distributed vehicles on the road creates increased concern for cross channel interferences. The experiments presented in V. Rai, F. Bai, J. Kenney and K. Laberteaux, “CrossChannel Interference Test Results: A report from the VSCA project”, IEEE 802.11 Task Group p report, July 2007 demonstrate the potential for immediate neighboring vehicles (i.e., next to each other in adjacent lanes) to interfere each other if they are operating in two adjacent channels.

For that reason, receiver performance requirements in this amendment have been enhanced with stricter channel rejection for both adjacent and non-adjacent channels in order to improve the immunity of the communication system to out-of-channel interferences. Also a much stricter spectrum emission mask (SEM) is defined to prevent interference.

Table 3 provides a comparison of the Adjacent and Non Adjacent channel rejection requirements for 802.11p compared to the previous standards for the combinations of modulation and coding ratio available in the amendment.

Modulation	Coding Rate	Adjacent Channel Rejection	Non-adjacent Channel Rejection
		802.11p (db)	802.11agn (db)
BPSK	1/2	28	42
BPSK	3/4	27	41
QPSK	1/2	25	39
QPSK	3/4	23	37
16QAM	1/2	20	34
16QAM	3/4	16	30
64QAM	2/3	12	26
64QAM	3/4	11	25

Table 3: Comparison of the adjacent and non-adjacent channel rejection requirements for 802.11p

Figure 34 shows the new spectrum emission mask requirements for 802.11p amendment. Limits and frequency offsets depend of the devices transmit power class and are also dependent on the certification body for each region.

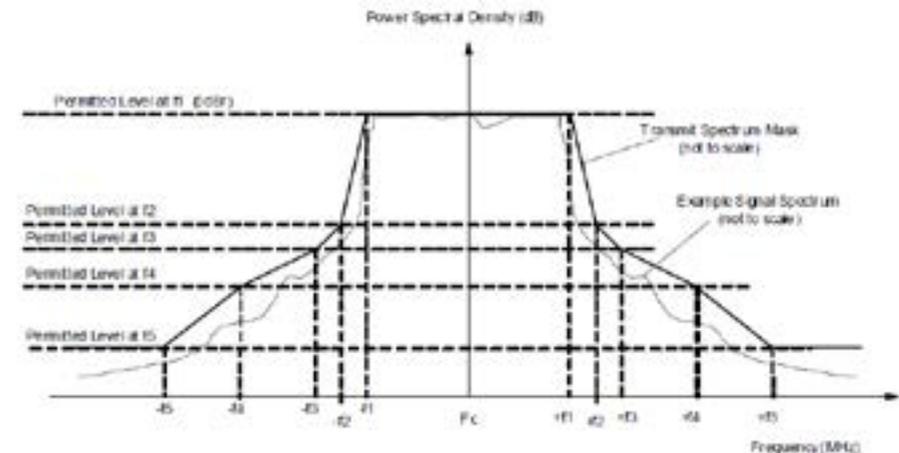


Figure 34: Spectrum emission mask. (Source: IEEE Std 802.11p -2010)

Amendments to the MAC Layer

In a simplified manner, the purpose of the IEEE 802.11 MAC is to manage a set of radios in order to establish and maintain a connection. Radios can freely communicate among themselves within the group but all transmissions from outside are filtered out. Such a group is a Basic Service Set (BSS) and there are many protocol mechanisms designed to provide secure and robust communications within a BSS. The key purpose of the IEEE 802.11p amendment at the MAC level is to enable very efficient communication group setup without much of the overhead typically needed in the current IEEE 802.11 MAC. In other words, the focus is on simplifying the BSS operations in a truly ad hoc manner for vehicular usage, in order to being able to provide faster connections and transactions.

The following sections describe how to test 802.11p with Anritsu signal analyzer and signal generator. We also present the solution for Production testing.

Testing 802.11p with Spectrum Analyzer and Signal Generator

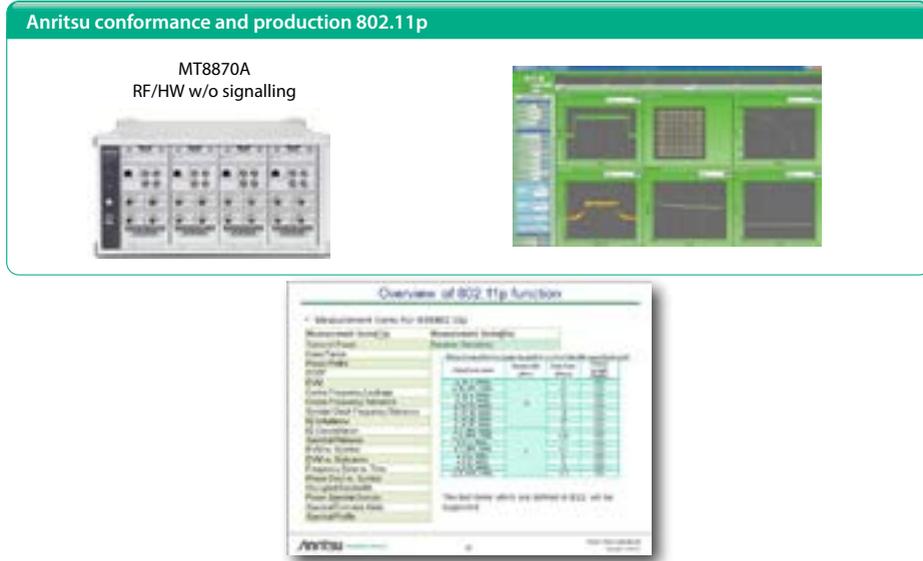
The testing of 802.11p requires the same functionalities as other WLAN functionalities. Our tester support different profile from TELECOM T405, ETSI and FCC.



Item		11n/n/a/j 11g (ERP-OFDM) 11g (DSSS-OFDM)
Numeric Result Display		
Frequency Error		√
Symbol Clock Error/Chip Clock Error		√
Transmit Power		√
Time Offset		√
EVM (rms)		√
Data EVM		√
SIG EVM (rms)		√ ¹¹
L-SIG EVM (rms)		√ ¹²
HT-SIG EVM (rms)		√ ¹³
VHT-SIG-A EVM (rms), VHT-SIG-B EVM (rms)		—
EVM (Peak)		√
Symbol Number, Subcarrier Number/Chip Number		√
Quadrature Error		√
IQ Gain Imbalance		√
Center Frequency Leakage		√
Spectral Flatness (Amplitude/Phase/Group Delay)		√
Outside Subcarrier Amplitude Max and Min Value		√
Inside Subcarrier Amplitude Max and Min Value		√
Phase Error		—
Magnitude Error		—
IQ Origin Offset		—
Detect Parameter		√
Data Rate, Modulation Method, Symbol Length/Chip Length		√ ¹⁴
Preamble		√ ¹⁵
MCS, Stream ID, Symbol Length, Guard Interval		√ ¹²
Graph Display		
Constellation		√
EVM vs. Subcarrier		√
EVM vs. Symbol/EVM vs. Chip		√
Spectral Flatness (Amplitude/Phase/Group Delay)		√
Phase Error vs. Chip		—
Eye diagram		—
Numerical Result Display		
Transmit Power		√
Power Flatness Max		√
Carrier Off Power		√
On/Off ratio		√
Peak Power Spectrum Density (PSD)		√
Transient Time (power-on ramp, power-off ramp)		—
Graph Display		
Burst		√
Transient		√

Testing 802.11p with Conformance Tester and Production Tester

Anritsu provides the MT8870A universal tester solution which provides a non-signaling mode for a fast testing on production chain.



Useful Long-term Capture

Up to 4 hours of RF signals at 20 MHz can be captured by installing the optional MS2690A/91A/92A-050 HDD Digitizing Interface. The characteristics of time-shifted signals, such as DSRC and IEEE802.11p used for car-to-car and road-to-car communications, can be measured using analysis tools like MATLAB.

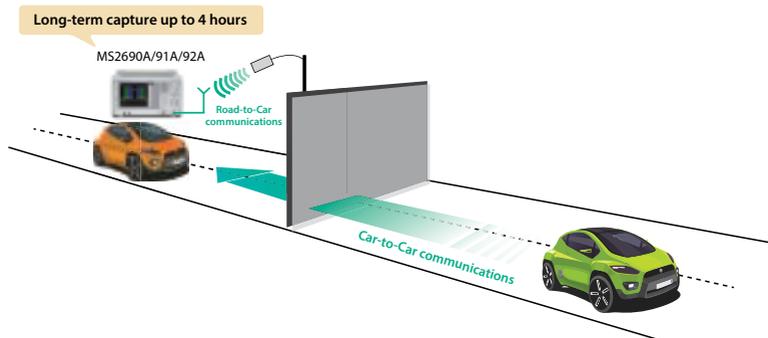


Figure 35: Correct schematic: Road to Car should be Vehicle to infrastructure (V2I)

Testing the Japanese DSRC standard ARIB STD T75:



The Anritsu ETC/DSRC software is designed for measuring the RF Tx characteristics of wireless equipment in compliance with ARIB STD T75 narrowband communication standards. MS2690/MS2830A Signal Analyzer main frame supports ETC/DSRC eye pattern and modulation analysis.

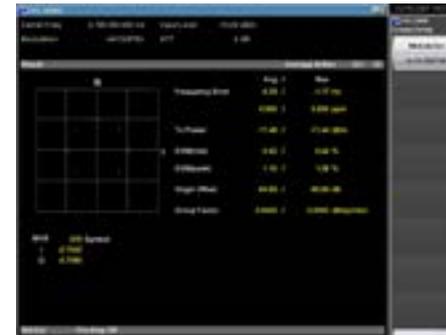
Modulation Analysis (π/4DQPSK)

- Frequency Error
- Tx Power
- Peak/RMS EVM
- Origin Offset
- Droop Factor
- Constellation

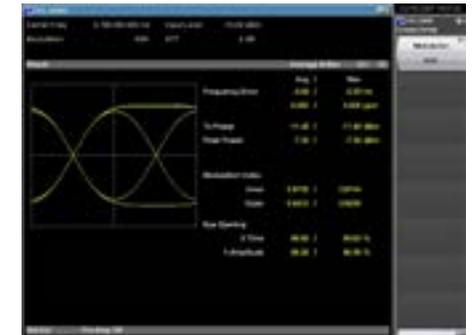
Modulation Analysis (ASK)

- Frequency Error
- Tx Power
- Peak Power
- Modulation Index
- Eye Opening
- Eye Diagram
- Adjacent Channel Leakage Power (ACLR)

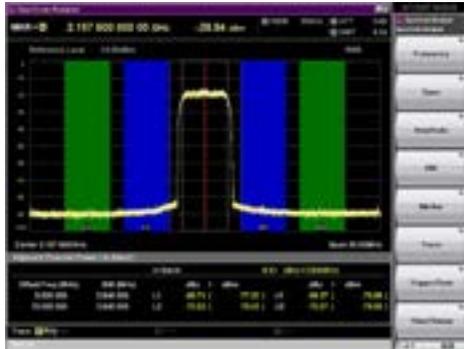
Modulation Analysis (π/4DQPSK)



Modulation Analysis (ASK)



ACLR



OBW



EMC/EMI Testing

Combining anechoic chamber with network RF and protocol simulator allow to provide a controlled environment for testing form factor cars.



Figure 36: Testing bus in chamber with Anritsu measurement solution

Interference Hunting

As wireless services grow, interference, once uncommon, becomes a fact of life for wireless and broadcast services. A metropolitan area of a million people may have 1000 licensed two way radios, 600 cell sites, and 100 broadcasters.

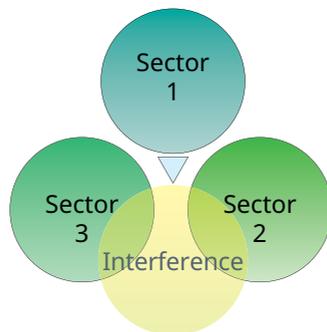
To this mix, add military, aeronautical, emergency services and, from now on, automotive. Apart from these there are all the lower powered unlicensed signals such as Wi-Fi or wireless video cameras. If you consider that many of these services are expanding, being modified, aging, or failing, it becomes evident that interference will be an issue.

The first indicators of interference for analog systems are noisy links. Legacy AM and FM systems indicate interference problems by various noises. Hiss, hum, or even voices from other transmissions can be heard. For digital transmissions, such as HDTV, cellular, or P25, interference shows up as limited range, dropped calls, or low data rate. That familiar waterfall sound on your cellular phone indicates poor reception and a high bit error rate, which might be caused by interference.

A second indicator of interference is a high noise floor in the receive channel. Interference naturally affects reception first, where the signal levels are normally small. Some radio systems, cellular systems in particular, monitor the receive noise floor level specifically to detect poor reception conditions. Broadcasters, who don't receive, rely on customer complaints and field measurements instead.

A high receive noise floor is the diagnostic for interference. This warrants an interference hunt and identifies the geographic starting point.

In cellular systems, when we come across a high Rx RSSI we should locate where in the sector is the interference source. If this affect multiple sectors or cells, it can be used for giving a first pass location estimate by looking at sector coverage are and considering relative powers.



Causes of Interference

- **On-Channel Interference:**

This can happen to broadcasters due to channel assignments that are close in frequency while also being geographically close. It can also happen due to variations in the ionosphere, which will cause signals to travel further. The classic example of this is how distant AM radio stations can be received easily at night, but not during the day.

Cellular providers have a wider variety of issues. Often, they use a tiling pattern for the cells, assigning frequency or codes in this pattern, which helps control cell overlaps. Factors that can cause excessive overlap include:

- Antenna tilt
- Valleys
- Antennas mounted on high buildings
- Better than expected signal propagation over water
- Errors in frequency settings
- And for CDMA systems, excessive multi-path.

Antenna tilt, valleys, and antennas mounted on high buildings all have a common cause. The antenna is transmitting further than intended because it is aimed too high. Water, oddly enough, allows radio waves to propagate better than over land. It is similar to how sound travels better over water than land. A cellular operator in a medium size metropolitan area might have 500 cell sites. If each cell has 9 radios (typical for a GSM site), there are $9 * 500$, or 4,500 radios. All of these radios need to be set to the right frequency at all times. Finally, CMDA systems are quite tolerant of multi-path. However, when the possible multi-paths exceed the capability of the phone's rake receiver to delay signals, the resulting "extra" paths are seen as interference. Typically, phones can handle 4 or 5 signal paths and still get signal gain. If there are more paths, they are seen as interference.

- **In-band interference:**

Signals can be off channel, but in-band. Interference, as we have said before, is a receive issue. This means that you need to be looking for interference on receive frequencies. If you are working a cellular issue, and the base station has a high noise floor, you need to be looking on the uplink channels, not the downlink. If the issue is, instead, cell phone reception in a given area, then you would look on the downlink frequencies, since that is what the cell phone receives. Two Way Radio and other Push-to-Talk systems

often use the same frequency for both the uplink and the downlink so this distinction becomes less important for them. A key point is that an interfering signal does not need to be on the receive channel to cause interference. It only needs to be within the receiver bandwidth, which normally means that it only needs to get past the receiver prefilter. Once an interfering signal is present at the input of a receiver, it affects the receiver's front end, causing a reduction in sensitivity. This will cause the effective carrier-to-interference ratio (C/I) to be lower and result in all the symptoms of a weak signal (noisy, waterfall effect, low data rate), except that the received signal strength measurements will be strong due to the high noise floor. This interference mechanism is called Receiver De-Sensitization, or Receiver Desense. In extreme cases, it can even result in Receiver Blocking.

• Impulse noise:

Impulse noise is created whenever a flow of electricity is abruptly started or stopped. A surprising variety of items can create impulse noise: Lighting suppression devices at a site: These arc suppressors work by allowing excess voltage to arc to a ground. Over time, as they age, the breakdown voltage tends to lower, to the point where the higher power legitimate RF transmissions can cause arcing, which can create receive interference.

- Electrical motors from elevators, floor buffers or even FAX machines: Many types of electric motors have brushes, which can create quite a bit of arcing and sparking.
- Bakery ovens: Bakery ovens have high wattage heating elements, over 2,000 watts. The ovens are typically regulated by turning the heating element on and off as needed to maintain the desired temperature. This switching action generates impulse noise.
- Welding: This is an electric arc that starts and stops every time the welder draws a bead.
- Electric fences: Electric fences generate a short pulse of high voltage then turn it off for a second or two. This allows shocked animals time to move away from the fence before it shocks them again.
- Power lines, which may arc and spark.
- Light dimmers: Light dimmers operate by suddenly turning the AC power off part way through the power cycle of the sine wave. This creates impulse noise.

- Micro-arcing, or fritting: Micro-arcing, or fritting, is created when RF connectors do not make firm contact. Fritting first shows up at peak RF power levels as wideband, intermittent, jumps in the noise floor. This can be a 5 to 20 dB jump. Most of these impulse noise sources affect the lower frequencies. It is typically very broad-band, over a GHz wide. Micro-arcing or fritting can be caused by cable mis-handling issues like over-torquing.

• Harmonics:

Harmonics are multiples of an RF carrier. For instance, if we had a transmitter at 100 MHz, it might have harmonics at 200 MHz, 300 MHz, 400 MHz, 500 MHz, and so on. Typically, the odd numbered harmonics (300 MHz, 500 MHz, etc.) are stronger than the even harmonics. Governing bodies normally regulate the power level of harmonics. However equipment does fail or go out of specification. Many of those failure mechanisms create high harmonic levels. Also, if the original broadcast is at a high power level, even legal harmonics can be powerful enough to cause problems. For instance, if you have a 1 mega-Watt transmitter in your area, it may be required to have a third harmonic 60 dB lower than its effective radiated power. However, 60 dB down from 1,000,000 watts is 1 Watt. You can see how a 1 Watt harmonic could be a serious problem if its frequency is within the pass band of your receive filter.

• Passive Intermodulation (PIM):

This is also called the Rusty Bolt Effect. It is caused when two or more strong RF signals combine in some sort of non-linear device, such as a transistor, diode, or even the crystals found in corrosion or rust. This corrosion may even be outside the radio system. It can be caused by a rusty fence, rusty bolts, corroded rooftop air conditioners, or even a rusty barn roof. Of course, it is also possible that the cause comes from loose connectors in an antenna feed line or poorly configured transmitters.

• Near-Far problem:

The Near-Far problem is the RF equivalent of two people trying to talk across the room at a loud party. The surrounding noise tends to make conversation difficult or impossible. In the case where a wide area RF coverage is overlaid with a smaller area coverage, and the two operating frequencies are close enough to give receivers a problem, the nearby, in-band-but-off-frequency signal can overload a receiver trying to listen to the weaker signal. The near-far problem can also happen between cell towers, as long as the cell phone cannot make a handover. This may be the case near the edge of a metropolitan market where a cell phone of carrier "A" is broadcasting a strong signal to reach the distant cell tower of carrier "A." If there is then a cell tower operated by carrier "B" near that phone, the "B" carrier receiver may be temporarily desensed by the loud Phone "A."

• Intentional Interference:

Some sources of interference are intentional. A quick search of the internet using terms like “Cell Phone Jammer” will find dozens of companies specializing in jamming. Jammers can be found in shopping malls, where employers want to ensure employee productivity, in cars, or even in military bases. Generally, civilian use of jammers is illegal. In the United States, the Federal Communications Commission has concentrated legal action on companies selling cell phone jammers, citing potential harm from interfering with emergency communications.

Spotting Interference

• Spotting Interference in the Field

Once a high receive noise floor has been identified and located, it is time to use a spectrum analyzer. The first and best place to start looking at is the input to the receiver. If the receiver has a pre-filter, it is best to measure the signal after the pre-filter. This will allow you to see what the receiver, and the receiver’s antenna, sees. The methodology would be:

- Measure the receiver’s noise floor,
- To look for any obvious interference that might be present at the input to the receiver. It is important to get a “visual ID” on the signal at this point so you can be sure you are on the same signal later.

• Spotting the Signal at Ground Level

From a base station point of view, once an interfering signal has been spotted and characterized using the tower’s antenna, the next task is to find the same signal using a ground level antenna. This will allow you to search for the signal, either by direction finding or seeking areas of higher signal strength. The issue is that signals that may be strong at the altitude of the tower’s antenna may be weak at ground level. There may be hills or buildings between your ground level location and the source of the signal. The first thing to try is to see if the signal is visible near the base of the tower. If it is, the signal has been spotted at ground level and it’s time to move to the next task, locating the source. If not, there are several things to try:

- Check other sectors for the interfering signal. This will give you a general idea of the signal direction.
- Try looking for the interfering signal from a nearby rooftop or top floor. In an urban area, this may be the best way to direction find. You are up above all the buildings that cause RF reflections with, hopefully, a clear line of sight to the source.

- Try moving to a hill of some sort. This can also give you a clear (or clearer) line of sight to the RF source.
- Investigate nearby valleys, swales, or other low spots. If a RF interference source is in a valley, the radiation pattern will be only visible when you have a direct line-of-sight inside the low spot.
- Use in-instrument mapping techniques to plot signal strength versus location. This can be a “brute force” way to find the interfering signal, eventually. A magnetic mount Omni-directional antenna placed on a car’s rooftop is useful for this sort of search.

Characterizing Interference

Once the interfering signal is spotted, it is important to characterize the signal before disconnecting from the receiver’s signal. To characterize the signal, we should adjust the spectrum analyzer to get the best view of the signal by using the pre-amplifier, adjusting the reference level, the span, and the resolution bandwidth values. Observe the signals’ shape, bandwidth, and behavior. Look for frequency drift, amplitude changes, and frequency hopping. If the signal is intermittent, or turns on and off, use Max-Hold to create an envelope. If you have spectrogram capability, this can be used to check for periodicity. For signals that are intermittent with a long time between appearances, it can be helpful to use a “Save on Event” capability. This capability uses a mask automatically generated from the “normal” signal and only saves a trace when something unusual appears. Once saved, the traces can be examined for time-of-appearance, and signal characteristic.

Identifying Signals

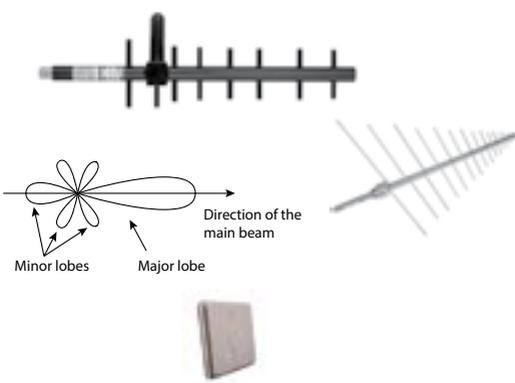
A receive filter is essential if you have an interference problem. While you are looking for signals that do not belong to the input of your receiver, it is important to know what signals are typically present in your bands. It is also important to know what other signals may be present, legitimately. This can save a lot of time when hunting signals. For instance, it is quite possible that a strong signal from a nearby transmitter in an adjacent band is getting through your pre-filter. This is common near band edges. It helps to know just who might be putting out interfering signals, and this knowledge can be an excellent short cut when hunting interference.

Sometimes, it is possible to identify a signal by its frequency and location using government data bases. For instance, in the United States, the Federal Communications Commission maintains a data base of signals and locations, linking them to owners, with contact information. Unfortunately, some of these data bases suffer from being

out-of-date. Some signals may be intermittent. Hopefully, they are periodic, or at least repeat with some discernible pattern.

When they are short term intermittent, or bursty, signals, it can be helpful to use Max-Hold on Trace B of the spectrum analyzer, while keeping the Trace A in the normal view. This allows you to see the shape of a bursty signal and may help with visual identification.

Antennas for Interference Hunting



Yagi

- Good directivity
- Good front-to-back ratio
- Side lobes
- Frequency Specific

Log Periodic

- Broad frequency range
- Less directivity
- More side lobes

Log Periodic

- Broad beam
 - 60 degrees or more
- Excellent front-to-back ratio

Interference Hunting

MS2720T Spectrum Master



Handheld Interference Hunter MA2700



Interference Hunting in Automotive

A car can be a perfect complement for Interference Hunting with Successive Approximation method. If we equip the car with a Mobile Interference Hunting System, we can automatically identify and locate sources of interference thanks to the provisioning of maps on tablets or laptops.



Anritsu Mobile Interference Hunting System is fitted with a Spectrum Analyzer, an Off-the-shelf omnidirectional magnet mount RF antenna with GPS and a tablet or PC with some software. It can find multiple type of interferers:

- Low power
- Narrowband, wideband
- Modulated
- Pulsed signals (similar to radar)
- Signals hidden in LTE uplink channels
- “Black” TV/radio stations & BTS cellular equipment operating illegally

It uses Channel Power Measurements that track signals drifting in frequency and track both wideband and narrowband interference. A Geo-referenced map has GPS latitude and longitude information embedded in the map. This allows a GPS enabled spectrum analyzer to locate your current position when plotting signals on the map. The antenna handle with compass and GPS report position and direction to the spectrum analyzer, making taking directional bearings easy.



Figure 37: Example of displayed results from Anritsu Interference Hunting solution

If we use a directional antenna, we can adapt our system to the Triangulation method, which is better for longer distances (over a half-mile) and is mainly done by a map and a compass.



Direction finding in the presence of multipath

When hunting for interference multipath can be a big issue. If you are in a city with tall buildings you may not get a direct signal from an interferer until you are very close. One method to hunt under those circumstances is to simply follow the largest signal. In a busy city this is easiest to do on foot. At an intersection aim your directional antenna down each of the streets while watching the signal level. Go down the street with the strongest signal. Repeat at each intersection. When you get a radical change in direction you know that you are close, especially if the signal level has been rising with successive measurements. Once you are close, you can use traditional direction finding techniques to locate the interferer.

Locating the Source

Once you are close to the RF interference source, you can use non-mapped techniques to find the source

It is helpful to look around for possible sources of the interference. If you are chasing an intermodulation signal, look for rust or poor metallic connections. If this is in a residential neighborhood, look for consumer grade RF devices. Intentional jammers are also a possibility.

Nearby radio transmitters are always a possible source of RF interference. They have the signal strength, and only need the right (or wrong) frequency, to become a problem. Antennas that are shared by multiple carriers are a great place for passive intermodulation (PIM). Finally, leaky cable TV lines or security cameras with an RF link can be an issue. The RF linked video cameras seem to be a particular problem as they seem to be freely exported/imported without regard to local RF spectrum assignments.

Summary

With more and more car manufacturers announcing their plan for autonomous automotive, it is becoming clear that telecommunication in car will play a major role in the future. They will revolutionize the transport as we know it, and will allow the emergence of new life style. The adoption of various driver assistance features by the public will be driven by the trust they have in technology. In this paper we have explored the range of wireless technologies and networks in cars that provide advanced entertaining systems and safety mechanism. Integrating those technology coming from various field in automotive pose major challenges. Testing is playing an essential part in automotive were life is at risk. To ensure quality, Anritsu's portfolio allows testing those technologies at all stages of product development, from R&D to production.

Anritsu's portfolio allows testing of these technologies at all stages of product development, from R&D to production, providing dedicated solutions and universal wireless testers that will ensure your products comply with the latest specification.

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